Abstract book

# The 39th International Conference of Polymer Processing Society

# PPS - 39

May 19 - 23, 2024
Hilton Cartagena Hotel
Cartagena de Indias, Colombia

Universidad de los Andes
Colombia

ICIPC®
INSTITUTO DE CAPACITACIÓN E INVESTIGACIÓN DEL PLÁSTICO Y DEL CAUCHO

Polymer Processing Society

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# *PPS – 39 Organizing Committees*

**Conference Chair:** Jorge Alberto Medina, Universidad de los Andes, Colombia

**Conference Co-Chair:** María del Pilar Noriega, Daabon Group, Colombia

**Secretariat:** Jairo Ernesto Perilla, Universidad Nacional de Colombia, Colombia

**Institutional Organization:**

- Laura Florez, Instituto de Capacitación e Investigación del Plástico y del Caucho (ICIPC), Colombia
- Felipe Salcedo, Universidad de los Andes, Colombia

**Regional Support:**

- Humberto Arturo Gómez, Universidad del Norte, Colombia
- Edgardo Arrieta, Universidad Tecnológica de Bolívar, Colombia

**General Organization:**

- Polymer Processing Society
- Universidad de los Andes
- Instituto de Capacitación e Investigación del Plástico y del Caucho (ICIPC)

# *Welcoming Remarks by the PPS – 39 Chairman*

Dear Colleagues,

On behalf of the Polymer Processing Society, the Universidad de los Andes and Instituto de Capacitación e Investigación del Plástico y del Caucho, I would like to welcome you all to the 39th International Conference of the Polymer Processing Society (PPS – 39) held from May 19 to 23, 2024 in Cartagena de Indias, Colombia. As one of the highly acclaimed meetings in the field of polymer processing, the PPS Conference takes place annually in different countries all over the world, with the most recent ones being held in Fukuoka, Japan (2022) and St. Gallen, Switzerland (2023). It is an honor for Colombia to host the PPS – 39 for the first time in 40 years since the founding conference in Akron, OH, USA (1985).

Regarding the Conference activities, we are proud to present 18 General Symposia and 4 Special Symposia. For the first time, we include the Machine Learning in Polymer Processing General Symposium. On this occasion, all the Special Symposia are related to the sustainability and circularity of polymers. In summary, there are 8 plenary lectures, 7 distinguished keynotes, 7 industrial keynotes, 49 keynotes lectures, all of them given by distinguished researchers and industry representatives in the field of polymer science and processing. We are also delighted to announce the number of participants to the PPS – 39 to be over 415 from 42 different countries around the world. The Organizing Committee is putting its best effort into organizing this event and making it a memorable one.

The academic and social spaces planned for the event will be appropriate for strengthening existing relationships and surely, for the development of new possibilities of interaction. The professional and human quality that characterizes this society will continue to be an example that, added to other areas of knowledge, will represent hope for peace and global equity.

Lastly, I would like to thank all the sponsors of the PPS – 39, without whom it would be difficult to organize a successful International Conference. Their contributions are greatly appreciated.

Yours sincerely,

**JORGE ALBERTO MEDINA**
Chairman of PPS – 39

# Polymer Processing Society

The Polymer Processing Society was founded in March 1985 at the University of Akron, Ohio, USA; the intent was to provide a mechanism and format for interaction and presentation of research results in the international polymer processing community; the goals are to foster scientific understanding and technical innovation in polymer processing by providing a discussion forum for the worldwide community of Engineers and Scientists in the field. The thematic range encompasses all formulations, conversion and shaping operations applied to polymeric systems in the transformation from their monomeric forms to commercial products.

Membership for the PPS is open to all researchers in the field and to all persons who feel the activities of the society advance their professional development.

PPS website: www.tpps.org

## Executive and International Representatives

### Executive Officers

**President:** Sadhan Jana (USA)
**Past President:** Anup K. Ghosh (India)
**President Elect:** Volker Altstädt (Germany)
**Secretary:** Evan Mitsoulis (Greece)
**Treasurer:** Tim A. Osswald (USA)
**Member-at-Large:** Ica Manas – Zloczower (USA)
**Member-at-Large:** Paula Moldenaers (Belgium)
**Member-at-Large:** Hiroshi Ito (Japan)
**IPP Editor-in-Chief:** Jose Covas (Portugal)
**PPP Editor-in-Chief:** Sati Bhattacharya (Australia)

### International Representatives

Franco Costa (Australia)
Clemens Holzer (Austria)
Gerald Berger-Weber (Austria)
Anton Ginzburg (Belgium)
Sebastião Canevarolo (Brazil)
Luiz Pessan (Brazil)
U. T. Sundararaj (Canada)
Chul B. Park (Canada)
Abdellah Ajji (Canada)
Hesheng Xia (China)
Jorge Medina (Colombia)
Petr Saha (Czech Republic)
Martin Eder (Denmark)
Abderrahim Maazouz (France)
Cyrille Sollogoub (France)
Christian Hopmann (Germany)
Iner Kuehnert (Germany)
Holger Ruckdäschel (Germany)
Suryasarathi Bose (India)
Hossein Nazockdast (Iran)
Samuel Kenig (Israel)
Roberto Pantani (Italy)
Masahiro Ohshima (Japan)
Kentaro Taki (Japan)
Shin-ichi Kihara (Japan)
Joung Sook Hong (Korea)
Keun Park (Korea)
Octavio Manero (Mexico)
Mosto Bousmina (Morocco)
Patrick Anderson (Netherlands)
Johan Verbeek (New Zealand)
Ana Vera Machado (Portugal)
Suprakas S. Ray (South Africa)
Ana Isabel Ares Pernas (Spain)
Rudolf Hufenus (Switzerland)
Shih-Jung Liu (Taiwan)
Hathaikarn Manuspiya(Thailand)
Yusuf Menceloglu (Turkey)
Phil D. Coates (UK)
Tony McNally (UK
Margaret Sobkowicz Kline (USA)
Lih-Sheng Turng (USA)
Fardin Khabaz (USA)
Pablo Raimonda (Uruguay)
Phan Trung Nghia (Vietnam)

### Membership Chair

John Vlachopoulos (Canada)

### Webmaster

Miko Cakmak (USA)

# *General and Special Symposia*

| General Symposia | Symposium Organizers |
|---|---|
| Additive Manufacturing (3D Printing) | D. Drummer (Germany), H. Xia (China), J-Y. Jeng (Taiwan), K. Taki (Japan), J. Soulestin (France), J. C. Cruz (Colombia) |
| Extrusion | C. Rauwendaal (USA), C. Hopmann (Germany), C. Tzoganakis (Canada), J. A. Covas (Portugal), K. Wilczynski (Poland) |
| Functional Additives and Reactive Processing | M. Kontopoulou (Canada), S. S. Ray (South Africa) |
| Injection Molding | A. van Bael (Belgium), A. Guevara (Mexico), G-J. Zhong (China), AN. Hrymak (Canada), J. Vlachopoulos (Canada), L-S. Turng (USA), R. Pantani (Italy) |
| Polymerization and Synthesis | C. A. Sierra (Colombia), Dr. D'hooge (Belgium), T. McNally (United Kingdom), Y. Menceloglu (Türkiye) |
| Polymer Blends and Alloys | I. Manas-Zloczower (USA), J. Verbeek (New Zealand), C. Altan (USA), K. Lamnawar (France), M. L. Alvarez (Colombia), T. Ougizawa (Japan), C. Sollogoub (France) |
| Polymer Composites | C. Rosales (Venezuela), C. R. Bernal (Argentina), E. Ozden-Yenigun (UK), J. A. Acosta (Peru), J. Gu (China), S. Kenig (Israel), M. Yazici (Turkey), O. Manero Brito (Mexico), R. Dahlmann (Germany), B. Vergnes (France), P. Raimonda (Uruguay) |
| Polymer Foams and Membranes | V. Altstädt (Germany), C. B. Park (Canada), E. Di Maio (Italy) J. I. Velasco (Spain), R. Nofar (Turkey), J. Perilla (Colombia) |
| Fibers and Films | A. Ajji (Canada), R. Hufenus (Switzerland), K. Kornev (USA), Y. Yan (China), T. Kikutani (Japan), M. Cakmak (USA) |
| Nanotechnology and Nanocomposites | F. Salcedo (Colombia), L. Sun (USA), A. Vera (Portugal), M. L. Arnal (Venezuela) |
| Mechanical Properties and Fracture | L. A. Pessan (Brazil), G. Regnier (France), T. A. Osswald (USA), P. M. Frontini (Argentina) |
| Modeling and Simulation | E. Mitsoulis (Greece), F. Khabaz (USA), F. Costa (Australia), J-F. Agassant (France), P. D. Anderson (Netherlands), T. Kajiwara (Japan) |
| Rheology and Characterization | N. Grizzuti (Italy), P. Moldenaers (Belgium), S. V. Canevarolo (Brazil), S. Ospina (Colombia), S. Dagreou (France) |
| Morphology and Structural Development | A. J. Muller (Spain), M. Yamaguchi (Japan), P. C. Lee (Canada), I. Kühnert (Germany), U. Sundararaj (Canada) |
| Rubber and Elastomers | R. Eberlein (Switzerland), S. C. Jana (USA), S. Wießner (Germany) |
| Machine Learning in Polymer Processing | A. J. Román (USA), J. Zhang (UK), J. S. León (Colombia), C. Cruz (Germany), R. Albuquerque (Germany) |

| Special Symposia | Symposium Organizers |
|---|---|
| Biopolymers, Biocomposites and Bioprocessing | C. Schauer (USA), J-M. Raquez (Belgium),<br>P. Saha (Czechia), J. S. Hong (Korea), L. Averous (France),<br>M. A. Villar (Argentina) |
| Circular Economy of Polymer | A. Rigail (Ecuador), B. van Hoof (Colombia),<br>K. Ragaert (Netherland), J-M. Lee (Singapore) |
| Degradation, Biodegradation and Composting | C. Díaz-Acosta (USA),<br>H. A. Gómez (Colombia), B. Fayolle (France) |
| Polymers in the Sustainable Development Goals of the United Nations | M. A. de Paoli (Brazil), P. Ortiz (Colombia),<br>N. Tarazona (Germany) |

# *General information*

## *Registration*

The conference registration desk is located on the upper floor, in the mezzanine, at the Hilton Hotel. The service hours are:

| | |
|---|---|
| Sunday, May 19th | From 13:30 to 17:00 |
| Monday, May 20th | From 8:15 to 18:00 |
| Tuesday, May 21st | From 8:15 to 16:00 |
| Wednesday, May 22nd | From 8:15 to 18:00 |
| Thursday, May 23rd | From 8:15 to 12:00 |

## *Oral Presentation Guideline*

1. **Presentation time**
    - Oral Presentation Time: 20 min. (Including 5 min of Q&A)
    - Distinguished, Industrial and Keynote Presentation Time: 30 min. (Including 5 min of Q&A)
    - Plenary Presentation Time: 40 min. (Including 5 min of Q&A)

2. **Presentation Equipment**
    - Each presentation room will be equipped with a computer connected to an LCD projector, laser pointer and microphones. If you require other audio-visual equipment, please let the registration table know.
    - The use of personal computers to show the oral presentation slides is not allowed.

3. **Submitting the Presentation File**

    Presenters are requested to directly submit the final presentation files stored in a standard media (USB) or by email to the PPS – 39 staff in the conference reception desk one day before your schedule timeframe. Our staff will review the presentation with you to make sure that everything is in order and that it can be displayed correctly; also, our staff will load your file on the conference computer.

## *Poster Presentation Guideline*

1. **Poster Guideline**

    The poster title, author(s)'s name(s) and affiliation(s) should be placed at the top of the poster, as it is shown in the provided template on the webpage of the conference (www.pps39.uniandes.edu.co). All illustrations, charts and pictures should be visible from 1.5 m. The poster dimensions are 80 cm (~ 32 inches) width 120 cm (~ 48 inches) height.

2. **Poster Area**
   Poster session will be held in two places: **Hilton's Mezzanine** (Monday, May 20th) and **Universidad de los Andes Caribe** (Tuesday, May 21st). Each display board will be identified by a poster number assigned to each presentation according to the conference program. Each presenter must hand over their poster on the registration timeframes before their assigned poster session. After receiving it, PPS – 39 staff will locate the poster in its assigned space.

3. **Presentation Time**
   Poster viewing will take place on Monday, May 20th from 18:20 – 19:20 and on Tuesday, May 21st from 18:30 – 19:20. Posters presenters are asked to be available for discussion at their posters during the poster viewing session. All delegates are encouraged to attend.

## *Instruction to the Session Chairs*

1. The Chair of the Session will obtain a short CV of the keynotes and plenary speakers before the session starts from the conference staff at the session room or from the secretariat.
2. Introduce yourself (name and affiliation) and then introduce <u>shortly</u> the speaker.
3. Time of the presentations are as follows:

   - Oral Presentation Time: 20 min. (Including 5 min of Q&A)
   - Distinguished, Industrial and Keynote Presentation Time: 30 min. (Including 5 min of Q&A)
   - Plenary Presentation Time: 40 min. (Including 5 min of Q&A)

4. Members of the support team and of the PPS – 39 staff will be in the room to help the Chair with all the tasks and possible requirements.
5. Each presentation room will be equipped with a computer connected to LCD projector, laser pointer and microphones.
6. All presentations will be uploaded by the supportive team and PPS – 39 staff before the sessions.

**IMPORTANT!!**

- Please respect strictly the timing as indicated on the program.
- If a speaker is not present to give his/her lecture, please <u>do not change the time order</u> of the next presentation. Do strictly keep the schedule as printed on the program.

# Summary of Events

| Date | Time | Event | Location |
|---|---|---|---|
| Sunday, May 19 | 9:00 – 16:00 | Open Foam Course | Room Magistral<br>Universidad de los Andes Caribe |
| | 13:30 – 15:40 | Executive Committee Meeting | Room Hemiciclo<br>Universidad de los Andes Caribe |
| | 15:40 – 17:00 | International Representatives Meeting | Room Hemiciclo<br>Universidad de los Andes Caribe |
| | 13:30 – 17:00 | Registration | Mezzanine, Upper Floor<br>Hilton's Hotel – Second Floor |
| | 17:00 – 19:00 | Welcoming Reception | External Gardens<br>Hilton's Hotel |
| Monday, May 20 | 8:15 – 9:00 | Registration | Mezzanine, Upper Floor<br>Hilton's Hotel – Second Floor |
| | 9:00 – 9:30 | Opening Ceremony | Room Bolivar - Esenttia<br>Hilton's Hotel |
| | 9:30 – 10:10 | Plenary Lecture | Room Bolivar - Esenttia<br>Hilton's Hotel |
| | 10:10 – 10:40 | Industrial Keynote | Room Bolivar - Esenttia<br>Hilton's Hotel |
| | 10:40 – 11:00 | Coffee Break | Designated Coffee Break Areas<br>Hilton's Hotel |
| | 11:00 – 12:50 | Scientific Program | Various Conference Rooms<br>Hilton's Hotel |
| | 12:50 – 14:20 | Lunch | Designated Lunch Spaces<br>Hilton's Hotel |
| | 14:20 – 15:00 | Plenary Lecture | Room Bolivar - Esenttia<br>Hilton's Hotel |
| | 15:10 – 16:40 | Scientific Program | Various Conference Rooms<br>Hilton's Hotel |
| | 16:40 – 17:00 | Coffee Break | Designated Coffee Break Areas<br>Hilton's Hotel |
| | 17:00 – 18:20 | Scientific Program | Various Conference Rooms<br>Hilton's Hotel |
| | 18:20 – 19:20 | Poster Session | Mezzanine, Upper Floor<br>Hilton's Hotel – Second Floor |
| Tuesday, May 21 | 8:15 – 8:30 | Registration | Mezzanine, Upper Floor<br>Hilton's Hotel – Second Floor |
| | 8:30 – 9:10 | Plenary Lecture | Room Bolivar - Orbia<br>Hilton's Hotel |
| | 9:10 – 9:40 | Industrial Keynote | Room Bolivar - Orbia<br>Hilton's Hotel |
| | 9:50 – 10:40 | Scientific Program | Various Conference Rooms<br>Hilton's Hotel |

| Date | Time | Event | Location |
|---|---|---|---|
| Tuesday, May 21 | 10:40 – 11:00 | Coffee Break | Designated Coffee Break Areas<br>Hilton's Hotel |
| | 11:00 – 12:40 | Scientific Program | Various Conference Rooms<br>Hilton's Hotel |
| | 12:40 – 14:20 | Lunch | Designated Lunch Spaces<br>Hilton's Hotel |
| | 14:20 – 15:00 | Plenary Lecture | Room Bolivar - Orbia<br>Hilton's Hotel |
| | 15:10 – 16:20 | Scientific Program | Various Conference Rooms<br>Hilton's Hotel |
| | 16:20 – 18:10 | Site Visits | San Felipe Castle |
| | 18:20 – 19:20 | Poster Session | Universidad de los Andes<br>Caribe |
| | 19:20 – 19:40 | Dinner | Universidad de los Andes<br>Caribe |
| Wednesday, May 22 | 8:15 – 8:30 | Registration | Mezzanine, Upper Floor<br>Hilton's Hotel – Second Floor |
| | 8:30 – 9:10 | Plenary Lecture | Room Bolivar – Taghleef Industries<br>Hilton's Hotel |
| | 9:10 – 9:40 | Industrial Keynote | Room Bolivar – Taghleef Industries<br>Hilton's Hotel |
| | 9:50 – 10:40 | Scientific Program | Various Conference Rooms<br>Hilton's Hotel |
| | 10:40 – 11:00 | Coffee Break | Designated Coffee Break Areas<br>Hilton's Hotel |
| | 11:00 – 12:40 | Scientific Program | Various Conference Rooms<br>Hilton's Hotel |
| | 12:40 – 14:20 | Lunch | Designated Lunch Spaces<br>Hilton's Hotel |
| | 14:20 – 15:00 | Plenary Lecture | Room Bolivar – Taghleef Industries<br>Hilton's Hotel |
| | 15:10 – 16:40 | Scientific Program | Various Conference Rooms<br>Hilton's Hotel |
| | 16:40 – 17:00 | Coffee Break | Designated Coffee Break Areas<br>Hilton's Hotel |
| | 17:00 – 18:40 | Scientific Program | Various Conference Rooms<br>Hilton's Hotel |
| | 20:00 – 23:00 | Dinner Banquet | Iguanas Terrace<br>Club Naval of Cartagena |
| Thursday, May 23 | 8:15 – 8:30 | Registration | Mezzanine, Upper Floor<br>Hilton's Hotel – Second Floor |
| | 8:30 – 9:10 | Plenary Lecture | Room Bolivar – BASF I<br>Hilton's Hotel |
| | 9:10 – 9:40 | Industrial Keynote | Room – BASF I<br>Hilton's Hotel |

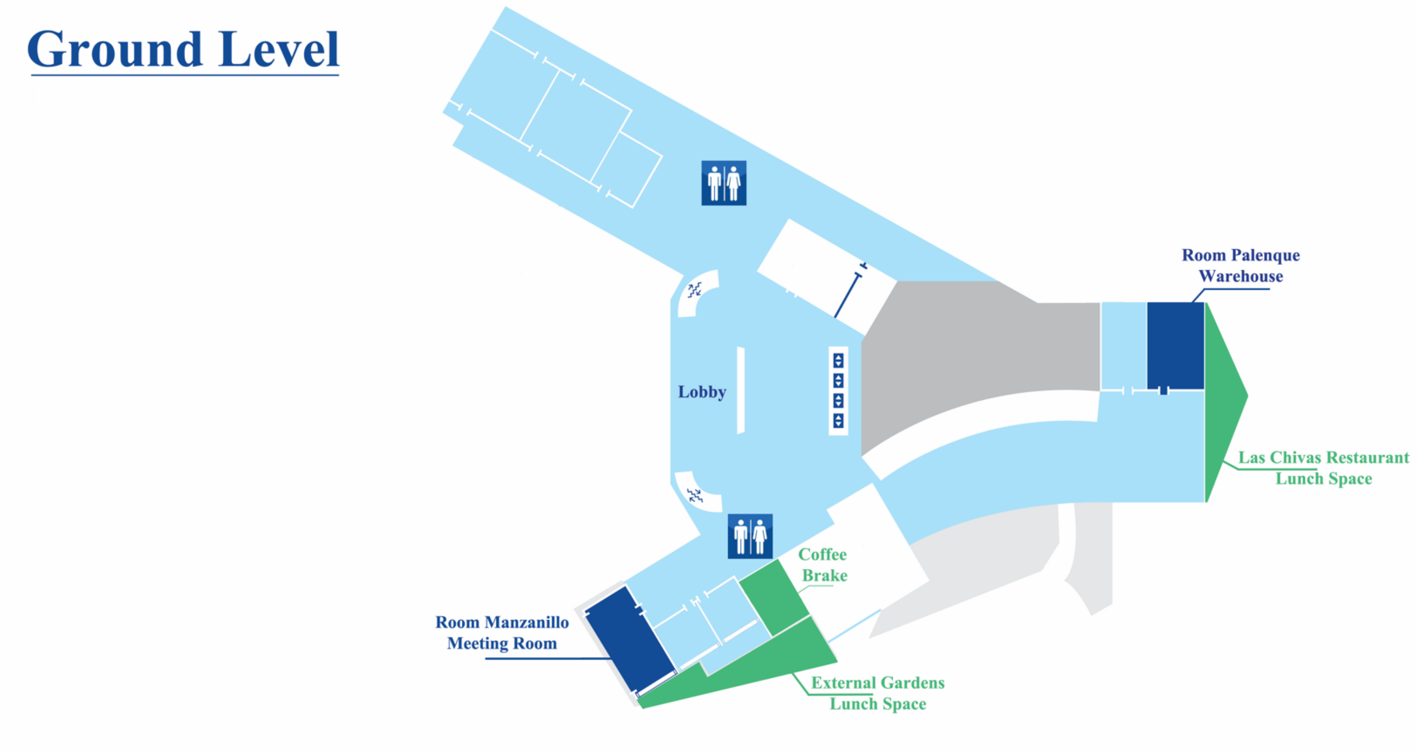
| Date | Time | Event | Location |
|---|---|---|---|
| Thursday,<br>May 23 | 9:40 – 10:20 | Plenary Lecture | Room Bolivar – BASF I<br>Hilton's Hotel |
| | 10:20 – 10:40 | Coffee Break | Designated Coffee Break Areas<br>Hilton's Hotel |
| | 10:40 – 12:50 | Scientific Program | Various Conference Rooms<br>Hilton's Hotel |
| | 12:50 – 13:10 | Closing Ceremony | Room Bolivar – BASF I<br>Hilton's Hotel |
| | 13:10 – 14:50 | Farewell Lunch | Las Chivas Restaurant<br>Hilton's Hotel |

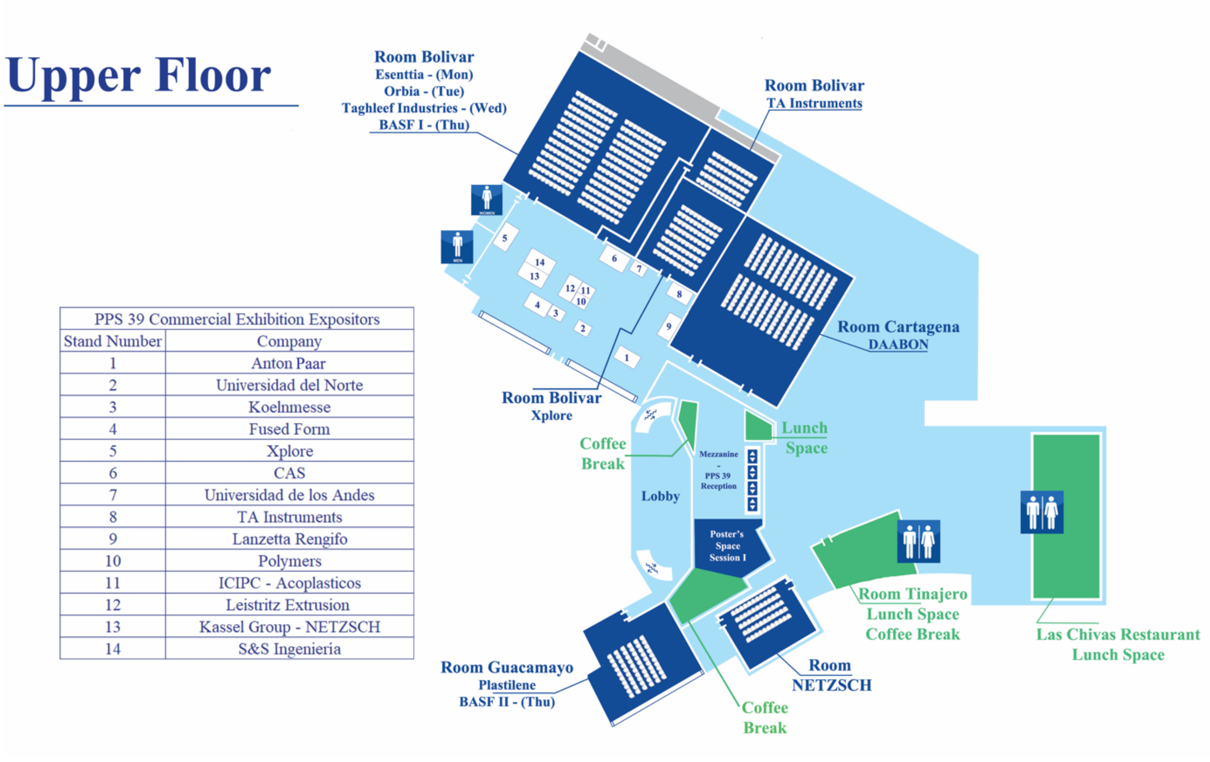
# *Parallel Sessions*

| Room | Symposia | Day |
|---|---|---|
| Bolívar<br>***Esenttia*** | S19 – Biopolymers, Biocomposites and Bioprocessing | Monday |
| Bolívar<br>***Orbia*** | S19 – Biopolymers, Biocomposites and Bioprocessing | Tuesday |
| Bolívar<br>***TA Instruments*** | S05 – Polymerization and Synthesis<br>S10 – Fibers and Films<br>S15 – Rheology and Characterization<br>S18 – Machine Learning in Polymer Processing<br>S21 – Degradation, Biodegradation and Composting | Wednesday<br>Tuesday<br>Monday<br>Thursday<br>Wednesday |
| Bolívar<br>***Xplore*** | S03 – Functional Additives and Reactive Processing<br>S06 – Polymer Blends and Alloys<br>S11 – Nanotechnology and Nanocomposites<br>S17 – Rubber and Elastomers | Monday<br>Monday<br>Tuesday, Wednesday, Thursday<br>Tuesday |
| Bolívar<br>***Taghleef Industries*** | S02 – Extrusion<br>S19 – Biopolymers, Biocomposites and Bioprocessing | Wednesday<br>Wednesday |
| Bolívar<br>***BASF I*** | S02 – Extrusion | Thursday |
| Guacamayo<br>***BASF II*** | S04 – Injection Molding | Thursday |
| Cartagena<br>***Daabon*** | S14 – Modeling and Simulation<br>S20 – Circular Economy of Polymers | Monday, Tuesday<br>Tuesday, Wednesday, Thursday |
| Guacamayo<br>***Plastilene*** | S22 – Polymer in the Sust. Development Goals of the UN<br>S01 – Additive Manufacturing (3D printing)<br>S04 – Injection Molding | Monday<br>Monday, Tuesday, Wednesday<br>Wednesday |
| ***NETZSCH*** | S12 – Mechanical Properties and Fracture<br>S08 – Polymer Foams and Membranes<br>S07 – Polymer Composites<br>S16 – Morphology and Structural Development | Monday<br>Monday, Tuesday<br>Tuesday, Wednesday<br>Wednesday, Thursday |

# *The PPS – 39 Venue*

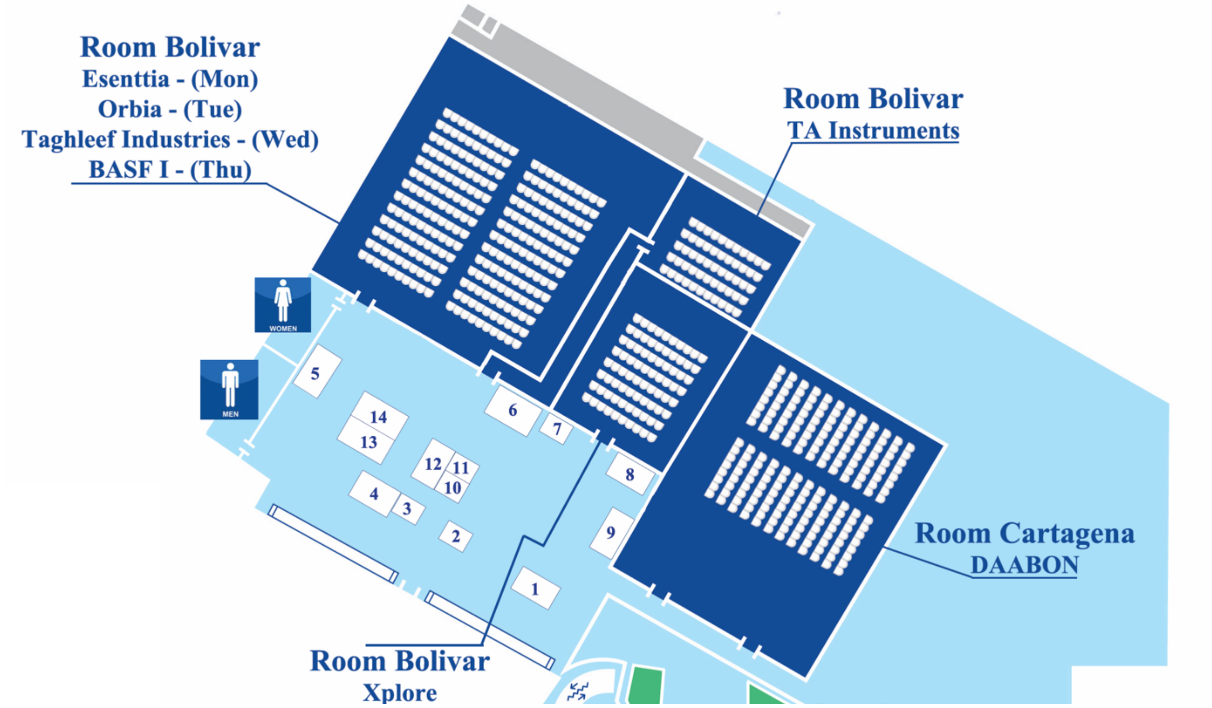
## Hilton's Hotel





| PPS 39 Commercial Exhibition Expositors | |
|---|---|
| Stand Number | Company |
| 1 | Anton Paar |
| 2 | Universidad del Norte |
| 3 | Koelnmesse |
| 4 | Fused Form |
| 5 | Xplore |
| 6 | CAS |
| 7 | Universidad de los Andes |
| 8 | TA Instruments |
| 9 | Lanzetta Rengifo |
| 10 | Polymers |
| 11 | ICIPC - Acoplasticos |
| 12 | Leistritz Extrusion |
| 13 | Kassel Group - NETZSCH |
| 14 | S&S Ingeniería |

# *Exhibitor Link*



| Booth Number | Company Name |
|---|---|
| 1 | Anton Paar |
| 2 | Universidad del Norte |
| 3 | Koelnmesse |
| 4 | Fused Form |
| 5 | Xplore |
| 6 | CAS |
| 7 | Universidad de los Andes |
| 8 | TA Instruments |
| 9 | Lanzetta Rengifo |
| 10 | Polymers |
| 11 | ICIPC – Acoplasticos |
| 12 | Leistritz Extrusion |
| 13 | Kassel Group – NETZSCH |
| 14 | S&S Ingeniería |

# *Honoring María del Pilar Noriega*

Colombia has a very traditional society and for this reason, the fact that a woman is a leader and stands out, is highly significant. María del Pilar Noriega represents an upright professional who, sailing against the current on many occasions, has been able to represent our country internationally in academic settings, but most importantly, has contributed to the technological development of the region due to her extensive expertise in the field of polymer extrusion. She is rigorous with her profession, with refined tastes and detail oriented. She is professionally, at the forefront, in the use of our agro-resources in a bioeconomy framework.

Her trajectory in research and teaching was developed in the Instituto de Capacitación e Investigación del Plástico y del Caucho (ICIPC), where she served in different important roles since its inception in 1993. She was the General Director from June 2012 to June 2019, and was an adviser from June 2019 to June 2020. Currently, she is the Investigation, Development and Innovation Director of Daabon Group focused on green chemistry and biorefineries.

She obtained her PhD in Mechanical Engineering of the University of Wisconsin-Madison, United States, 2001. Specialized in Polymer Chemistry from the Technical University of Dresden, Germany and obtained another specialization in Extrusion Technology from the Plastic Technology Institute of the Stuttgart University, Germany. She graduated as a Chemical Engineer from the Pontifical Bolivarian University, Medellin, Colombia.

She is certified in Intellectual Property, Advanced level, from the World Intellectual Property Organization -WIPO. She has coauthored 5 technical books and a significant number of publications in international journals. She was a coinventor in 4 invention patents granted in Colombia, 2 invention patents in the United States, 4 international patent requests and 1 national patent request.

She is a scientific ambassador from the German Academic Exchange Service (DAAD), since 2017, and co-chair of the Asociación Antioqueña de Profesionales con Estudios en Alemania (ASPA) since 2013. She is a Fellow member of the Society of Plastics Engineers (SPE) of the United States, as well as the extrusion division board of directors member. She was named member of the Sage Mission -which is an expert group of different fields, which help define the necessary route to advance science, technology, and innovation in Colombia- and she was the coordinator in charge of the convergent technologies and 4.0 industries focus.

For the institutions regarded with 39th International Conference of the Polymer Processing Society organization, it is an honor to recognize the importance of Maria del Pilar Noriega as an agent who favors, with her professional and personal actions, the construction of a better society.

# *James L. White Innovation Award*

The Polymer Processing Society invites nomination for the James L. White Innovation Award to honor outstanding researcher(s) or inventor(s) from both academia and industry, either as individuals or as a group, in polymer processing and related fields. The award is for an innovative development in the field of polymer processing technologies with recent commercial impact. It aims to recognize originality, innovation and creativity among researcher(s) or inventor(s) in the science and technology of processing polymer and polymeric products.

Candidates may come from any part of the world but must either be PPS members or should have participated in recent activities of the PPS. They may currently be working in industry, governmental or academic institutions or have retired from such. Nominations are invited from PPS members and the polymer processing community at large, and the nomination forms are available on the PPS website. The award consists of a recognition plaque and a $3000 check.

## *The 2024 Recipient of the James L. White Innovation Award*

### Prof. Chul B. Park

Professor Chul B. Park is recognized with this prestigious James L White Innovation Award for his innovation in supercritical foaming technologies for which he was the major inventor. His innovative research has led to commercialization of numerous practiced technologies such as the MuCell® injection molding technology licensed and practiced by Trexel, the MuCell extrusion foaming technology licensed and practiced by MuCell Extrusion/Zote Foam, the roto molding PP foam technology licensed and practiced by Ingenia, the supercritical GNP exfoliation technology licensed and practiced by NanoXplore, and so on. He has also contributed to the Crocs shoe technology by removing the crocodile surface. In addition, He has contributed significantly to the replacement of the environmentally hazardous HCFC-based blowing agents with supercritical-fluid blowing agents in PS insulation foam processing. He also invented the two-peak expanded PLA bead-foam technology with his team to replace the EPS, and this technology was exclusively licensed to Synbra and now Bewi.

Professor Park holds the post of Distinguished Professor of Microcellular Engineered Plastics at University of Toronto. Professor Park is also the Director of the Microcellular Plastics Manufacturing Laboratory, which is highly regarded as one of the world’s pioneering research institutions in the refining of plastics foaming technology.

Professor Park is an accomplished scientist with an outstanding track record in the field of polymer foam processing, for which he has garnered international recognition. He has identified the fundamental mechanisms in the mysterious foam technologies, elucidated the effects of gas on the thermodynamic and rheological properties of various plastics and composites, and invented numerous foam processing technologies. His research has had a major impact in his research field, and he is one of the most cited researchers in polymer processing and foaming. He is the author or co-author of over 2500 professional publications, including four books, 550 journal papers, 500 conference papers, and 30 patents. His publications have earned him a Scopus H-Index of 94 and Scopus Citations of 32000.

Because his inventions are internationally recognized, Professor Park has attracted numerous industrial companies to work with his research group at University of Toronto through contracts or Consortium. More than 50% of his research funds (~ US$45M) came from industry. Most of his research funds have been used to hire and train research staff (i.e., postdocs and students). All the research staff are trained to work on both technology and relevant science. More than 300 people have been engaged and trained in his lab: 75 (72 completed + 3 current) postdocs, 110 (83 completed + 27 current) PhD students, and 138 (completed) Master students. 44 amongst these trainees became professors. He models the importance of working in collaborative teams with industrial companies while focusing on industrially relevant, innovative technology development based on the fundamental scientific findings. His approach has been very successful, and he became a trend setter for plastic foaming research.

In recognition of his distinguished research achievements, he received over 100 awards and honors in his career. He has been inducted into 6 national academies: the Academy of Sciences of the Royal Society of Canada, the Canadian Academy of Engineering, the Korean Academy of Science and Technology, the National Academy of Engineering of Korea, the European Academy of Science, and the Chinese Academy of Engineering. He is also recognized as a Fellow of 6 professional organizations including the Society of Plastics Engineers.

# *Morand Lambla Award*

The Morand Lambla Award honors and outstanding young researcher in the field of polymer processing and related fields such as polymer chemistry, polymer characterization and processing of polymeric-based products at an international level. The award aims at stimulating and recognizing originality, high achievement, and potential for continuing creativity among young researchers in the science and technology of preparing polymers and polymeric products.

Candidates can come from any part of the world and need not be PPS member. Further, they may currently be working in industrial, governmental, or academic positions. To be eligible, nominees must not yet reach their 45th birthday by Dec. 31 of the current year. The nomination forms are available on the PPS website. The award consists of a recognition plaque and a $3000 check.

## *The 2024 Recipient of Morand Lambla Award*

### Prof. Junwei Gu

Professor Junwei Gu, Ph.D. Supervisor, Chinese National-Level Leading Talent, Shaanxi Provincial Outstanding Young Researcher, and Leader of the Shaanxi Provincial Science and Technology Innovation Team for “Thermally Conductive Polymer Composites”. He has been elected as Fellow of the Royal Society of Chemistry, Fellow of the Royal Aeronautical Society, and Fellow of the Institute of Materials, Minerals and Mining. He has been selected as a Highly Cited Researcher by Clarivate Analytics and a Most Cited Chinese Researcher by Elsevier. He is currently the Dean of the School of Chemistry and Chemical Engineering of Northwestern Polytechnical University, Deputy Secretary-General/Director of the Chinese Society for Composite Materials, Executive Deputy Director of the Thermally Conductive Composite Materials Professional Committee, and Deputy director of the Shaanxi Key Laboratory of Macromolecular Science and Technology.

He is mainly engaged in research on the design, preparation and molding processing of functional polymer composites and fiber-reinforced advanced resin matrix composites. As the first/second completer, he has won 4 provincial and ministerial scientific research awards including the second prize of Shaanxi Provincial Natural Science Award and the second prize of Ministry of Education Technology Invention Award. He has also won the Young Scientist Award of the Chinese Society for Composite Materials, the Polymer Innovation Paper Award of the Chinese Chemical Society (2 times), and the “New Innovation Award” for polymer molding and processing and its industrial development.

He has presided over more than 20 projects at the provincial and ministerial level and above, including key projects of the Natural Science Foundation of China. He has published more than 160 academic papers as the first and/or corresponding author in journals such as *Angew Chem Int Ed*, *Adv Mater* and *Macromolecules*, with more than 29000 citations and an H-factor of 102. He serves as the chief/co-editor of 4 monographs. 34 national invention patents have been authorized. He serves as associate editors and editorial board members of several journals such as *Compos Sci Technol*, *Nano-Micro Lett*, etc. He has also won the second prize of the National Teaching Achievement Award and the second prize of the Shaanxi Provincial Teaching Achievement Award.

# *Plenary and Keynote Lectures*

The PPS – 39 conference program includes 8 plenary lectures, 61 keynotes and 260 oral and poster presentations. Apart from established general symposia of the PPS meetings, the PPS – 39 program includes also especial symposia dedicated to the emerging interest in the field of polymer processing. These special symposia are biopolymers, biocomposites & bioprocessing, circular economy of polymers, degradation, biodegradation & composting, and polymer in the sustainable development goals of the United Nations.

## *Plenary Lectures*

| Title / Plenary Speaker | Date/Time | Room |
|---|---|---|
| ***S01 – 437***<br>Nanostructure Control in 3D Printing through Polymerization Self-Assembly Process<br>**Cyrille Boyer (University of New South Wales, Australia)** | Monday, May 20<br>9:30 – 10:10 | Bolivar<br>Essentia |
| ***S20 – 435***<br>Towards a Circular Economy: Recycling Thermoset Waste via Dynamic Chemistry<br>**Ica Manas Zloczower (Case Western Reserve University, USA)** | Monday, May 20<br>14:20 – 15:00 | Bolivar<br>Essentia |
| ***S19 – 438***<br>Environmentally Safe Preservation, Stabilization and Processing of Natural Rubber Latex in an Acid Environment<br>**Tim A. Osswald (University of Wisconsin Madison, USA)** | Tuesday, May 21<br>8:30 – 9:10 | Bolivar<br>Orbia |
| ***S16 – 436***<br>Tailoring the Structure and Properties of Isodimorphic Random Copolymers by Varying Chemical Structure and Composition<br>**Alejandro J. Müller (Faculty of Chemistry, UPV/EHU, Spain)** | Tuesday, May 21<br>14:20 – 15:00 | Bolivar<br>Orbia |
| ***S20-460***<br>Plastics - the invisible heroes of the hydrogen revolution<br>**Christian Hopmann (RWTH Aachen University, Germany)** | Wednesday, May 22<br>8:30 – 9:10 | Bolivar<br>Taghleef<br>Industries |
| ***S20 – 434***<br>Sustainable Polymer for a Circular Economy<br>**Manjusri Misra (University of Guelph, Canada)** | Wednesday, May 22<br>14:20 – 15:00 | Bolivar<br>Taghleef<br>Industries |
| ***S08 – 431***<br>Morand Lambla Award: Thermally Conductive Polymers and Their Composites<br>**Junwei Gu (Northwestern Polytechnical University, China)** | Thursday, May 23<br>8:30 – 9:10 | Bolivar<br>BASF I |
| ***S08 – 433***<br>James L. White Innovation Award: Innovative Processing, Structures and Properties of Porous Material and Foam Applications.<br>**Chul B. Park (University of Toronto, Canada)** | Thursday, May 23<br>9:40 – 10:20 | Bolivar<br>BASF I |

# Distinguished Keynote Lectures

| Title / Distinguished Keynote Speaker | Date/Time | Room |
|---|---|---|
| ***S19 – 443***<br>Bioplastics, Biocomposites, Bioprocessing and Biodegradability: Current Scenario and Future Vision<br>**Amar K. Mohanty (University of Guelph, Canada)** | Monday, May 20<br>11:00 – 11:30 | Bolivar<br>Essentia |
| ***S08 – 452***<br>Processing of polymer bead foams - state of the art, perspectives, and trends<br>**Thomas Neumeyer (Leibniz-Institut für Verbundwerkstoffe, Germany)** | Monday, May 20<br>17:00 – 17:30 | NETZSCH |
| ***S20 – 461***<br>Circular Economy and the Single Use Plastic Discourse<br>**Bart Van Hoof (Universidad de los Andes, Colombia)** | Tuesday, May 21<br>15:10 – 15:40 | Cartagena<br>Daabon |
| ***S21 – 447***<br>State of the Art and the Vision of the Future of Polymer Degradation<br>**Bruno Fayolle (ENSAM, France)** | Wednesday, May 22<br>15:10 – 15:40 | Bolivar<br>TA Instruments |
| ***S02 – 440***<br>Extrusion Theory Today and Challenges for Tomorrow<br>**Chris Rauwendaal (Rauwendaal Extrusion Engineering, USA)** | Wednesday, May 22<br>17:00 – 17:30 | Bolivar<br>Taghleef<br>Industries |
| ***S18 – 442***<br>The challenges of artificial intelligence and surrogate modelling for polymer processing<br>**Amine Ammar (ENSAM, France)** | Thursday, May 23<br>10:40 – 11:10 | Bolivar<br>TA Instruments |

# Industrial Keynote Lectures

| Title / Industrial Keynote Speaker | Date/Time | Room |
|---|---|---|
| ***S03 – 445***<br>Chemical recycling, Driver to achieve the sustainability in the plastic industry<br>**Enrique Mogollón Rincón (Esenttia S.A., Colombia)** | Monday, May 20<br>10:10 – 10:40 | Bolivar<br>Essentia |
| ***S20 – 454***<br>A review of how PVC contributes to sustainability<br>**Cleinest Cabrera (Orbia, Colombia)** | Tuesday, May 21<br>9:10 – 9:40 | Bolivar<br>Orbia |
| ***S20 – 451***<br>Sustainability Path at Taghleef Industries<br>**Carlos Rodríguez Giraldo (Taghleef Industries, Colombia)** | Wednesday, May 22<br>9:10 – 9:40 | Bolivar<br>Taghleef<br>Industries |
| ***S20 – 453***<br>Development of flexible packaging with PCR resins - Ciclolene® as a contribution to the circular economy of plastics in the region<br>**Yohana García (Grupo Plastilene, Colombia)** | Wednesday, May 22<br>9:50 – 10:20 | Cartagena<br>Daabon |
| ***S05 – 444***<br>Integrated Rheometer-Raman Monitoring: Unraveling Crystallization and Polymerization Dynamics of Polymers<br>**Viktor Zagorec (Anton Paar, Germany)** | Wednesday, May 22<br>9:50 – 10:20 | Bolivar<br>TA Instruments |

| Title / Industrial Keynote Speaker | Date/Time | Room |
|---|---|---|
| ***S11 – 302***<br>Towards versatility of POSS nanoparticles in thermoplastic compounds<br>**Ozkoc Guralp (Xplore Instruments BV, Netherlands)** | Wednesday, May 22<br>15:10 – 15:40 | Bolivar<br>Xplore |
| ***S20 – 11***<br>New Opportunities for Polyamides<br>**Philippe Desbois (BASF, Germany)** | Thursday, May 23<br>9:10 – 9:40 | Bolivar<br>BASF I |
| ***S20 – 456***<br>Microplastics: Tackling the Invisible Enemy<br>**Alfonso González Monntiel (CAS, USA)** | Thursday, May 23<br>10:40 – 11:10 | Cartagena<br>Daabon |

# *Keynote Lectures*

| Title / Keynote Speaker | Date/Time | Room |
|---|---|---|
| **S03 – 347**<br>Thin films from modified polyglycolic acid with excellent water vapor barrier<br>**Marieke Hilhorst (Wageningen Food & Biobased Research, Netherlands)** | Monday, May 20<br>11:00 – 11:30 | Bolivar<br>Xplore |
| **S12 – 427**<br>Non-Linear Fracture Mechanical Response of Polymers<br>**Patricia Frontini (University of Mar del Plata, Argentina)** | Monday, May 20<br>11:00 – 11:30 | NETZSCH |
| **S14 – 448**<br>Digital Twin or Distant Cousin? The practical realities of modeling polymer material behavior in complex manufacturing processes<br>**Franco Costa (Autodesk, Australia)** | Monday, May 20<br>11:00 – 11:30 | Cartagena<br>Daabon |
| **S15 – 314**<br>The interplay of shear-induced uncoil and disentanglement of polymer chains<br>**Sebastião Vicente Canevarolo (Federal University of São Carlos, Brazil)** | Monday, May 20<br>11:00 – 11:30 | Bolivar<br>TA Instruments |
| **S22 – 70**<br>Virgin and degraded polyamide microplastics as vectors of contaminants in aquatic systems<br>**Marco Aurelio De Paoli (Unicamp, Brazil)** | Monday, May 20<br>11:00 – 11:30 | Guacamayo<br>Plastilene |
| **S22 – 43**<br>Meeting the Challenge of Microplastics Pollution: Formation Pathways and Impact on Living Organisms<br>**Dimitrios N. Bikiaris (Aristotle University of Thessaloniki, Greece)** | Monday, May 20<br>12:30 – 13:00 | Guacamayo<br>Plastilene |
| **S06 – 428**<br>Compatibilization Polymer Blends by Electron Beam Irradiation<br>**Shmuel Kenig (Shenkar College of Engineering, Design and Art, Israel)** | Monday, May 20<br>15:10 – 15:40 | Bolivar<br>Xplore |
| **S14 – 67**<br>Film Blowing Simulations with Integral Constitutive Equations<br>**Evan Mitsoulis (National Technical University of Athens, Greece)** | Monday, May 20<br>15:10 – 15:40 | Cartagena<br>Daabon |
| **S19 – 127**<br>Evaluation of Polyhydroxyalkanoates machine learning- generated compounds for medical devices applications<br>**Yohann Delaunay (NovoNordisk & Technical University of Denmark, Denmark)** | Monday, May 20<br>15:10 – 15:40 | Bolivar<br>Essentia |

| Title / Keynote Speaker | Date/Time | Room |
|---|---|---|
| **S12 – 123**<br>Sustainable Manufacturing: Enhancing Mechanical Behavior of Common Polymers Through Deformation Processing<br>**Gary Wnek (Case Western Reserve University, USA)** | Monday, May 20<br>15:50 – 16:20 | NETZSCH |
| **S01 – 48**<br>How polymer-based pharmaceutical additive manufacturing can heal millions of patients via personalized medicine<br>**Martin Spoerk (Research Center Pharmaceutical Engineering GmbH, Austria)** | Monday, May 20<br>17:00 – 17:30 | Guacamayo<br>Plastilene |
| **S15 – 122**<br>Exploring Fluids' Behavior: Lab-Scale Capillary Breakup Extensional Rheometer and Its Applications in Polymer Processing<br>**Étienne Beaudoin (école de technologie supérieure, Canada)** | Monday, May 20<br>17:00 – 17:30 | Bolivar<br>TA Instruments |
| **S06 – 399**<br>Impact of stratification on mechanical properties of SAN/PC and ABS/PC multilayered films<br>**Cyrille Sollogoub (Ecole Nationale Superieure d'arts et Metiers, France)** | Monday, May 20<br>17:40 – 18:10 | Bolivar<br>Xplore |
| **S01 – 286**<br>Printable Advanced Composites with Energy and Biomedical Applications<br>**Kenan Song (UGA, USA)** | Tuesday, May 21<br>9:50 – 10:20 | Guacamayo<br>Plastilene |
| **S08 – 42**<br>Understanding the Foamability and Mechanical Properties of Foamed Polypropylene Blends by Shear and Extensional Rheology<br>**Paula Moldenaers (KU Leuven, Belgium)** | Tuesday, May 21<br>9:50 – 10:20 | NETZSCH |
| **S10 – 441**<br>Interdiffusion of PLLA and PDLA to form fibers consisting of highly oriented stereocomplex crystals<br>**Takleshi Kikutani (Tokyo Institute of Technology, Japan)** | Tuesday, May 21<br>9:50 – 10:20 | Bolivar<br>TA Instruments |
| **S14 – 32**<br>Global Process Modeling. Extrusion vs Injection Molding<br>**Krzysztof Wilczyński (Warsaw University of Technology, Poland)** | Tuesday, May 21<br>9:50 – 10:20 | Cartagena<br>Daabon |
| **S17 – 299**<br>Conductive elastomers nanocomposites for IP$^2$C soft sensors<br>**Rafael Barbosa (Federal University of Sao Carlos, Brazil)** | Tuesday, May 21<br>9:50 – 10:20 | Bolivar<br>Xplore |
| **S19 – 231**<br>On the Cryo-Molding process and subsequent forming processes of biopolymers with low glass transition temperature<br>**Julius Petrausch (Leibniz-Institut für Polymerforschung Dresden, Germany)** | Tuesday, May 21<br>9:50 – 10:20 | Bolivar<br>Orbia |
| **S10 – 14**<br>Melt-spun liquid-core filaments for microhydraulic applications<br>**Rudolf Hufenus (Empa, Switzerland)** | Tuesday, May 21<br>12:20 – 12:50 | Bolivar<br>TA Instruments |
| **S17 – 138**<br>Correlation between Manufacturing Conditions, Crosslink Density and Fatigue Behavior in Nitrile Butadiene Rubber<br>**Tobias Gehling (Polymer Competence Center Leoben, Austria)** | Tuesday, May 21<br>12:20 – 12:50 | Bolivar<br>Xplore |

| Title / Keynote Speaker | Date/Time | Room |
|---|---|---|
| **S01 – 379**<br>A study of the use of dry natural rubber in 3D printing<br>**Jairo E. Perilla (Universidad Nacional de Colombia, Colombia)** | Tuesday, May 21<br>15:10 – 15:40 | Guacamayo<br>Plastilene |
| **S07 – 98**<br>Formulation of highly electro-conductive thermoplastic composites using PEDOT based fillers with controlled shape factor<br>**Thibault Parpaite (Charles Sadron Institut ICS, France)** | Tuesday, May 21<br>15:10 – 15:40 | NETZSCH |
| **S10 – 402**<br>Layer Multiplying Co-extrusion of Filled Polymer Composites<br>**Joao Maia (Case Western Reserve University, USA)** | Tuesday, May 21<br>15:10 – 15:40 | Bolivar<br>TA Instruments |
| **S11 – 329**<br>Recipe Development and Cast Film Extrusion of PVDF/Carbon Nanotube/Carbon Black Composites for the Application in Bipolar Batteries<br>**Petra Pötschke (Leibniz-Institut für Polymerforschung Dresden, Germany)** | Tuesday, May 21<br>15:10 – 15:40 | Bolivar<br>Xplore |
| **S19 – 29**<br>Multiscale Structural Characterization of Biocompatible Poly(trimethylene carbonate) Photoreticulated Networks – From Conception to Mechanical Behavior<br>**Agustin Rios de Anda (Université Paris Est Créteil, France)** | Tuesday, May 21<br>15:10 – 15:40 | Bolivar<br>Orbia |
| **S01 – 4**<br>Eliminating non-negativity constraint from Tomographic Volumetric 3D Printing by a novel a binary photoinhibitory system<br>**Aminul Islam (Technical University of Denmark, Denmark)** | Wednesday, May 22<br>9:50 – 10:20 | Guacamayo<br>Plastilene |
| **S07 – 146**<br>Braided Composite System with Haptic Feedback for Teleoperation<br>**Nathalia Diaz Armas (University of Massachusetts Lowell, USA)** | Wednesday, May 22<br>9:50 – 10:20 | NETZSCH |
| **S11 – 203**<br>Tailoring the Hierarchical Self-Assembly in Bioinspired Halloysite Nanotubes/Glass Fiber Hybrid Composites<br>**Rafaela Aguiar (University of Toronto, Canada)** | Wednesday, May 22<br>9:50 – 10:20 | Bolivar<br>Xplore |
| **S19 – 33**<br>A Novel Foaming Technique to Develop Solvent-Free Functional open-cell PLA Scaffolds for Bone Tissue Regeneration<br>**Frej Mighri (Laval University, Canada)** | Wednesday, May 22<br>9:50 – 10:20 | Bolivar<br>Taghleef<br>Industries |
| **S11 – 307**<br>Graphitized GNP: A New Carbon Material with Excellent Electrical Conductivity and Outstanding EMI Shielding<br>**Sakrit Hait (University of Calgary, Canada)** | Wednesday, May 22<br>12:20 – 12:50 | Bolivar<br>Xplore |
| **S19 – 40**<br>Fabrication and characterization of Biobased Polyurethanes, from Cradle to Cradle<br>**Luc Averous (University of Strasbourg, France)** | Wednesday, May 22<br>12:20 – 12:50 | Bolivar<br>Taghleef<br>Industries |
| **S20 – 421**<br>What LCA can tell us about the impacts of microplastics<br>**Elena Corella (Dayrize BV, Netherlands)** | Wednesday, May 22<br>12:20 – 12:50 | Cartagena<br>Daabon |

| Title / Keynote Speaker | Date/Time | Room |
|---|---|---|
| **S01 – 64**<br>Multifunctional 3D-Printed Cellulosic Constructs via a Sequential Cold Chemical Vapor Polymerization Technique<br>**Majed Amini (University of British Columbia, Canada)** | Wednesday, May 22<br>15:10 – 15:40 | Guacamayo<br>Plastilene |
| **S07 – 401**<br>Functionally Graded Materials: Innovative Multilayer composites based on Poly(D,L lactide)/Bioactive Fillers fabricated by 3D Direct Pellet Printing Multi-Extrusion process<br>**Khalid Lamnawar (INSA Lyon, France)** | Wednesday, May 22<br>15:10 – 15:40 | NETZSCH |
| **S19 – 403**<br>Biochar, production, and use: a detailed review of the Art<br>**Farid Chejne Janna (Universidad Nacional de Colombia; Colombia)** | Wednesday, May 22<br>15:10 – 15:40 | Bolivar<br>Taghleef<br>Industries |
| **S20 – 450**<br>How much virgin fuel displacement can a complimentary recycling cascade achieve?<br>**Kim Ragaert (Maastricht University, Netherlands)** | Wednesday, May 22<br>15:10 – 15:40 | Cartagena<br>Daabon |
| **S04 – 446**<br>Co-injection and foam injection molding as enablers for sustainability<br>**Holger Ruckdäschel (Neue Materialien Bayreuth GmbH, Germany)** | Wednesday, May 22<br>17:00 – 17:30 | Guacamayo<br>Plastilene |
| **S11 – 273**<br>Smart Hybrids with Multi-scale Architecture and Surface Engineering Enabled by Nanocoatings<br>**Luyi Sun (University of Connecticut, USA)** | Wednesday, May 22<br>17:00 – 17:30 | Bolivar<br>Xplore |
| **S16 – 310**<br>Study on the regulation of porous structure of ultra-thin ultra- high molecule weight polyethylene separation membranes through biaxial stretching<br>**Hong Wu (Sichuan university, China)** | Wednesday, May 22<br>17:00 – 17:30 | NETZSCH |
| **S20 – 15**<br>Unlocking the Potential of Recycled Polypropylene in Food Packaging<br>**Nina Krempl (Montanuniversitaet Leoben, Austria)** | Wednesday, May 22<br>17:00 – 17:30 | Cartagena<br>Daabon |
| **S21 – 155**<br>Crystallization temperature as a proxy for fundamental degradation behavior of PBAT based plastic films in composting environments<br>**Yvan David Hernandez-Charpak (Rochester Institute of Technology, USA)** | Wednesday, May 22<br>17:00 – 17:30 | Bolivar<br>TA Instruments |
| **S02 – 294**<br>Improving the thickness gradient in thermoformed parts by using sheets with non-uniform thickness<br>**Jose Antonio Covas (University of Minho, Portugal)** | Thursday, May 23<br>10:40 – 11:10 | Bolivar<br>BASF I |
| **S04 – 18**<br>Modeling of polymer processing of thermoplastic polymers: application to the injection molding process<br>**Roberto Pantani (University of Salerno, Italy)** | Thursday, May 23<br>10:40 – 11:10 | Guacamayo<br>BASF II |
| **S11 – 425**<br>Field Assisted "Z" orientation of Nanophases to Produce Thickness Functionalized Films for Flexible Electronics using a New Roll to Roll manufacturing Platform<br>**Miko Cakmak (Purdue University, USA)** | Thursday, May 23<br>10:40 – 11:10 | Bolivar<br>Xplore |

| Title / Keynote Speaker | Date/Time | Room |
|---|---|---|
| **S16 – 349**<br>Correlative studies of temperature-controlled structures and morphologies in polylactic acid<br>**Regine Boldt (Leibniz-Institut für Polymerforschung Dresden, Germany)** | Thursday, May 23<br>10:40 – 11:10 | NETZSCH |
| **S20 – 100**<br>Recyclates for sustainable food contact-method development for the validation of plasma-induced barriers<br>**Ali Cetin (Institute for plastics processing ikv in industry and craft at RWTH Aachen, Germany)** | Thursday, May 23<br>12:10 – 12:40 | Cartagena<br>Daabon |

# Abstracts of PPS – 39

## Abstracts of Plenary Lectures

## Plenary Lecture

### S01 - 437

# Nanostructure Control in 3D Printing through Polymerization Self-Assembly Process

**Boyer Cyrille**[(1)]*
(1) School of Chemical Engineering, University of New South Wales - New South Wales - Australia

Reversible addition-fragmentation chain-transfer (RAFT) polymerization is a powerful tool for synthesizing macromolecules with controlled topologies and diverse chemical functionalities. In 2014, we reported an efficient activation of RAFT polymerization by the introduction of photocatalysts, named photoinduced electron/energy transfer – reversible addition fragmentation chain transfer (PET-RAFT) polymerization,1 allowing to activate these RAFT polymerizations under low energy and intensity visible light and without prior deoxygenation.2-3 In this talk, we will provide an overview of their potential applications in additive manufacturing (3D printing) and in nanomedicine. The application of RAFT polymerization to additive-manufacturing processes has been hindered due to their slow polymerization rates and sensitivity to oxygen.4-5 We reported a rapid visible light mediated RAFT polymerization process and applied it to a 3D printing system.6 The photosensitive resins contained a photocatalyst and a trithiocarbonate RAFT agent to afford polymerization without prior deoxygenation. Following the optimization of the resin formulation by varying the ratio of photocatalyst, a variety of 3D printing conditions were investigated to prepare functional materials.7 The mechanical properties of these 3D printed materials were investigated under different conditions, showing that the addition of RAFT affect the performance of these materials.8 Furthermore, the trithiocarbonate species incorporated in the polymer networks were able to be reactivated after the initial 3D printing process, which allowed the post functionalization of the printed materials via secondary photopolymerization processes.9 Finally, the incorporation of polymers terminated by RAFT agent was employed for the preparation of 3D printed multimaterials with a precise control of the nanostructure of these materials.10 We will discuss the effect of nanostructure of 3D printed materials on their mechanical properties and present their potential applications as energy devices. In a second part of this talk, taking advantages of the oxygen tolerance conferred by PET-RAFT technique, multiple parallel polymerizations were achieved enabling the synthetic optimization of functional polymers. More specifically, we prepared a library of antimicrobial/fungal polymers and test their antimicrobial activities against different bacteria.11-12 Interestingly, we demonstrated that their antimicrobial and antifungal activity is affected by the monomer sequence in the polymer chain as well as by the monomer structure and polymer composition.13-14

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# Plenary Lecture

## S20 - 435

## Towards a Circular Economy: Recycling Thermoset Waste via Dynamic Chemistry

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Vitrimerization is a newly developed concept to convert permanent crosslinked thermoset networks into covalent adaptable networks: vitrimers. Vitrimerization relies on designing a strategy to induce re-formability and healing in permanent chemically crosslinked polymer networks by using exchangeable chemical bonds that will lead to dynamic crosslinked networks. Thermosets can be transformed into vitrimers through a mechanochemical process, which enables the formation of exchangeable linkages precursors via ball milling the permanent crosslinked network with an appropriate catalyst and in some cases a feedstock of external hydroxyl groups. These vitrimerized materials undergo topology rearrangement at elevated temperatures through associative mechanisms, preserving the density of crosslinks. In this presentation, we illustrate the use of vitrimerization for recycling different thermoset systems with potential applications in various manufacturing sectors. The vitrimerization approach is a low-cost, eco-friendly, and scalable method that can be effectively implemented to address current challenges in recycling thermoset waste.

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# Plenary Lecture

## S19 - 438

## Environmentally Safe Preservation, Stabilization and Processing of Natural Rubber Latex in an Acid Environment

**Osswald Tim A.**(1)*
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Natural rubber tree latex is the raw material that supplies about half of the rubber production worldwide. Latex is a fragile liquid which quickly decomposes in air shortly after its extraction from trees. Current means to avoid decomposition involve the use of additives, including ammonia, that are harmful to the environment and the people handling the material. This talk introduces a new technology to preserves and stabilizes natural rubber liquid latex, in a counter-intuitive acidic environment, without the need of harmful chemicals. Rubber and products that are manufactured using this new green technology have superior mechanical properties and have been shown to be hypoallergenic. This new green latex has been used in the creation of adhesives that outperform high-performance industrial adhesives currently in the market, as well as membranes that are manufactured using the dip molding processing technique, using environmentally friendly formulations.

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## Plenary Lecture

## S16 - 436

# Tailoring the Structure and Properties of Isodimorphic Random Copolymers by Varying Chemical Structure and Composition

**Müller Alejandro Jesus**[(1)]*

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Combining the properties of parent homopolymers can, in principle, be achieved by random copolymerization. However, when the materials are semi-crystalline, a complex behavior can result. The structure and properties of semi-crystalline random copolymers (i.e., PA-ran-PB) will be a function of their chemical structure. Three general cases have been described in the literature: (a) Isomorphism is obtained when the chemical structures of PA and PB are very similar, and total inclusion of both comonomers in the crystal lattice or miscibility in the crystalline state is obtained. (b) On the other extreme, when the chemical structures are very different, the behavior is dominated by the exclusion of comonomer PB from the crystal lattice of PA and vice-versa, i.e., total exclusion behavior. (c) Isodimorphic copolymers represent the most exciting cases, that exhibit an intermediate behavior, where partial inclusion of comonomers is allowed, and crystallization can occur in the entire composition range. Isodimorphic copolymers are characterized by displaying a pseudo-eutectic point when the melting point is plotted as a function of composition. A crystal structure characteristic of PA forms to the left of this point, and a PB-type crystal structure to the right of this point. The existence of this pseudo-eutectic point implies that the melting temperature can be tailored by the composition of the copolymers, as well as their crystallinity, crystal structure, and mechanical properties. Such versatility makes isodimorphic copolymers ideal materials for a wide range of applications, from biodegradable films (in the case of copolyesters), thermoplastic elastomers, hot-melt adhesives, or tough semi-crystalline polymers. This plenary lecture will present the effects of chemical structure, molecular weight, and composition on the structure, morphology, nucleation, and crystallization for a wide range of biodegradable isodimorphic copolyesters and copolycarbonates.

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# Plenary Lecture

## S20 - 460

## Plastics - the Invisible Heroes of the Hydrogen Revolution

**Christian Hopmann**(1)*

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Sustainability is a major concern in today's economies and in the plastics sector, and universities, institutes and companies research for more sustainable production, usage and end-of-life-scenarios of plastics materials aiming for a fully circular plastics economy. Related approaches include the (re-)design of products to enable circularity, the use of bio-based materials as well as possibly materials based on CO2 captured from the air, but in particular a massive increase of both, mechanical and chemical recycling capacities. All these efforts are specifically necessary due to the expected growth in the use of material in general and of plastics in particular, which is closely linked to the growing global population and the growth of the middle class in more mature economies.

There is no doubt that these developments require significant support from R&D-work. However, it is also clear, that all these developments lead to a huge demand of energy, i.e. in terms of electricity and steam, which needs to be generated carbon neutral – preferably renewable – whenever possible. As the availability of those energy sources like water, wind and solar power is quite volatile, the demand-to-supply ratio is frequently out of equilibrium. To increase the productivity and the efficiency of the installed capacity a compensation strategy is required, which will be based on batteries and on hydrogen to a significant extent. In both technologies plastics play a vital role. Though plastics applications in batteries are already developed, little attention has been paid to the contribution of plastics in a hydrogen economy.

Within this plenary talk, an analysis of the potential of the hydrogen market and of plastics in this market is presented. It will be shown that many opportunities for plastics come along with the market development, but research needs to be done on the materials, the design of the parts and on the processes taking into account the specific technological and economical requirements of the hydrogen market. Several examples from own research of the Institute for Plastics Processing at RWTH Aachen University will be presented to highlight these requirements and possible solutions.

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## Plenary Lecture

## S20 - 434

# Sustainable Polymers for a Circular Economy

**Misra Manjusri**(1)*
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Building a more resilient, circular, and low-carbon economy is at the core of world's target in reducing greenhouse gas emissions. At the same time, we are facing harmful environmental effects created by accumulation of plastics. While plastics found many applications that benefit food preservation and lowered the transportation costs, the lack of plastic waste management is creating a pervasive environmental pollution. Today, micro-plastics (<5 mm in size) is found in our water and as well as in human blood! The questions are, can we harness the benefits that plastic brings to the society, without harmful waste? We urgently need a "Second Age of Plastics" with new materials that can answer the needs of today and not jeopardize tomorrow's generations. My group has been developing plastics and their composites that we call "Sustainable Polymers" that are environmentally friendly and have lower carbon footprint. Our sustainable materials support Circular Economy and include biopolymers and their composites from bio-renewables, wastes, recycled materials, and their combinations. Four key initiatives that can promote better use of sustainable materials in the markets include (i) Regulatory framework to support bioplastics and sustainable materials; (ii). Carbon tax credits that incentivize industry to lower their carbon footprint; (iii). Consumer education with clear, simple, and certified labels that prevent confusion and promote consistency at the consumer level; (iv) Understanding the harm created by not using bioplastics and sustainable materials, in regard to the carbon footprint.

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# Plenary Lecture

## S07 - 431

## Thermally Conductive Polymers and Their Composites

**Gu Junwie**(1)*
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Thermally conductive polymers and their composites have been showing the advantages of lightweight, high specific strength, electrical insulation, ease of processing, and low preparation cost. The multiscale design of thermal conduction pathways ordered design of molecular microstructures, optimization, and regulation of interfaces, as well as the exploration of thermal conduction models, equations, and mechanisms have been focused on by our research team in recent years. Firstly, addressing the technical challenges of low intrinsic thermal conductivity, we have developed a novel strategy based on liquid crystal mesogens and topological structure design to synthesize polymers with high intrinsic thermal conductivity. This approach leads to the preparation of intrinsically highly thermally conductive polymers such as liquid crystalline epoxy resins and polyimides. Secondly, tackling the technical issue of balancing high thermal conductivity and excellent mechanical properties in polymer composites, we have employed innovative approaches such as constructing hetero-structured fillers, and have utilized the "in-situ polymerization-electrospinning-high-temperature compression molding" method as well as 3D printing techniques. These methods enable the simultaneous achievement of high thermal conductivity and outstanding mechanical properties in polymer composites. Thirdly, addressing the scientific problem of the imperfect understanding of the thermal conduction mechanisms in existing thermally conductive polymer composites, we have proposed and established thermal conduction models and empirical equations for thermally conductive polymer composites. Additionally, we have developed qualitative analysis of the heat transfer properties of "polymer matrix-interface-filler". These contributions provide theoretical and technical support for the precise construction and quantitative characterization of thermal models and interfacial thermal resistance.

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# Plenary Lecture

## S08 - 433

## Innovative Processing, Structures and Properties of Porous Material and Foam Applications

**Park Chul B.**(1)*

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This plenary talk will consist of 4 sections: our earlier contributions to industry with some snapshots of case examples, and 3 sections of the currently on-going research activities that will be eventually transferred to industry. Firstly, I will present how the innovative lab-scale technologies developed earlier in our academic lab could contribute to industry successfully, using examples of the MuCell® technologies, the rotomolding foam technology, the Crocs shoe technology, the insulation PS foam technology with supercritical fluid, the expanded PLA bead-foam technology, and the GNP exfoliation technology. Secondly, I will present how the foam technology can significantly enhance the functions of conductive polymer composites for energy storage, dielectric and EMI shielding applications. Thirdly, I will talk about how the nanofibrils can be used for enhancing the toughness, the impact strength, and the elongation at break of the brittle materials of PLA, PMMA, SAN/ABS, etc., without sacrificing the stiffness. Fourthly, I will present how flexible aerogels can be made for superinsulation clothing to dramatically improve people's mobility during Winter. I will also talk about how we can decrease the notoriously long aerogel processing time based on spinodal decomposition.

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# Abstracts of PPS - 39

## Abstracts of Distinguished Keynote Lectures

# Distinguished Keynote Lecture

## S19 - 443

## Bioplastics, Biocomposites, Bioprocessing and Biodegradability: Current Scenario and Future Vision

**Mohanty Amar K.**(1)*
(1) School of Engineering & Department of Plant Agriculture, University of Guelph, - Ontario - Canada

This presentation will provide an overview on the present development and future vision on bioplastics, their bio-blends, and the biodegradable composites. The polymer processing of those emerging bio-based materials is critical and challenging. In 1950s, the “Age of Plastics” begun to replace natural resources with manmade materials. It was very successful, but it also led to 9B tons of plastic waste today. This means every person created one ton of plastic waste on average. These wastes also led to micro-plastics. The questions are, can we harness the benefits that plastic brings to the society, without harmful waste? Single-use plastics and their environmental pollution concerns are daily headlines. There are ongoing efforts to reach 100% reusable, recyclable or compostable plastic packaging by 2025. Bioplastics show promise as an alternative to a certain class of single-use plastic, but the “end-of-life” for biodegradable and compostable plastics are quite challenging. There is an increasing interest in “home compostable” types of bioplastics. We are currently facing limited opportunities with universal biodegradable plastics e.g. home and industrial composting, soil as well as marine biodegradable. Innovations and groundbreaking technologies are required to meet the needs for new materials and processes, but only an integrated approach with new policies, incentives, options for proper disposal, and other creative paths can help to address the complex journey to develop biodegradable polymeric materials in reducing and in eliminating plastic made environmental pollution.

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## Distinguished Keynote Lecture

### S08 - 452

# Processing of polymer bead foams - state of the art, perspectives, and trends

**<u>Neumeyer Thomas</u>(1)*, Salmins Maximilian(1)**
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Polymer bead foam parts consist of fused, mostly closed-cell foam particles and have densities ranging from 15 to app. 200 kg/m3. These foams are characterized by their ability to produce extremely mechanically robust, thermally insulating, and lightweight parts with complex shapes, making them versatile for packaging, insulation, furniture, and increasingly automotive applications where weight reduction is critical for fuel and material savings. This presentation will focus on the aspects of manufacturing parts based on expanded beads, examining both conventional steam-based processes and novel emerging technologies. The main driver for the development of new part production technologies is the increasing need to improve energy efficiency. In addition, part manufacturers are seeking solutions to incorporate bio-based and recycled materials and to replace polyurethane foams with bead foams, driven by the imperative of sustainability. Recent advances include the concept of using metal 3D printing technologies to minimize mold weight and thus steam consumption. In addition, an approach using electromagnetic heating to introduce the energy to fuse the beads is described. By using non-polar tool materials and polar thermoplastics for the beads, the energy can be absorbed only where it is needed to weld the particles. This presentation will highlight the potential, challenges, tooling technologies and future applications for this up-coming processing approach. In addition, hybrid processes that integrate bead foaming with other manufacturing techniques will be presented, enabling the creation of sandwich structures that combine bead foams and thermoplastic composites. These mono-material hybrids are becoming increasingly attractive for their sustainability benefits, particularly in adhesive-free joining methods that allow easier recycling.

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# Distinguished Keynote Lecture

## S20 - 461

## Circular Economy and the Single Use Plastic Discourse

**Bart van Hoof**(1)*
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"What you see is not necessarily what you get, and what you get is not necessarily what you see." Our decision making on single used plastics and how to handle their waste is influenced by our subjective beliefs and perception of the reality. The lasting global debate on single used plastics manifests divergence in beliefs and perceptions on how to take action on one of the most prominent environmental issues in political and social spheres. Perceptions differ from positivist views understanding plastics as a beneficial material enabling efficiency in raw material use, reduce cost of products, and expand access to safe and hygienic consumption. Opposing views emphasize pollution of plastic waste, toxicity of additives influencing human health, and fossil feedstock dependency related to climate change emissions. In its origin, the debate on single used plastics started in Europe and has spread globally reaching out to emerging markets including countries in Latin America where public policy instruments on single use plastic ban's and regulation on extended producer responsibility, are proposed and adopted.

The different narratives, their underlying values, and arguments, have been studied by discourse analysis as part of social science study. Analysis of discourses and narratives used by diverse stakeholders such as the plastic industry, NGOs, and social actors, is useful to shape the practice, policies and strategies in a more reflective, responsible, and accountable way. Moreover, outcomes of enquiry on discourse analysis identified the language of the circular economy as a bridging concept, for convergent negotiations among stakeholders. The framework for analysis of narratives on single used plastics are useful to analyze the debate on single used plastics in light of the institutional context of Latin American countries. This presentation addresses the divergent narratives on single used plastics in the context of Latin America, using existing frameworks for analysis. Reflections on their implications for public policy and strategy development in the region are proposed. Ideas on circular economy models are prioritized as alternative narratives for bridging opposing positions and enhance communications strategies of stakeholders.

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# Distinguished Keynote Lecture

## S21 - 447

## State of the Art and the Vision of the Future of Polymer Degradation

**Fayolle Bruno**[(1)]*
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Polymer degradation is associated with irreversible chemical changes. These chemical modifications originate from oxidation or hydrolysis mechanisms that depend on the nature of the polymer and its environment. These mechanisms will be predominant depending on environmental conditions (water or oxygen concentration) and the nature of the polymer, in particular the presence of oxidizable and/or hydrolyzable sites. We propose here to show the last developments to simulate degradation which will limit a polymer's use (durability) and may make it impossible to recycle (circular economy). Simulating and predicting chemical degradation and its consequences on physical and mechanical properties requires a multi-scale approach. Historically, the chemical degradation of polymers has focused primarily on the degradation mechanisms themselves, in particular oxidation mechanisms. Following the proposal of these mechanisms, the establishment of kinetic scheme then made it possible to build kinetic models. We will review some kinetic models that take into account the competition between oxygen uptake by the oxidation process and diffusion of oxygen into the polymer from the surface, otherwise known as diffusion-limited oxidation (DLO) [1,2]. Degradation-induced chemical reactions modify the polymer at the macromolecular level. Indeed, degradation mechanisms are always accompanied by chain scission and/or cross-linking processes. The main consequence of these modifications at macromolecular level is a loss of functional properties, particularly mechanical properties. We will show the recent advances on the structure-properties relationships that are essential for predicting polymers durability [3]. Using a few examples, we will illustrate our multi-scale approach to simulating polymer degradation and predicting the loss of mechanical properties. The first step is to build a kinetic model adapted to the type of polymer and its environment. The second step is to establish structure-property relationships relevant to our examples. Finally, we present how degradation can be taken into account in multiphysics simulation codes associated with the design of a polymer part [1].

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# Distinguished Keynote Lecture

## S02 - 440

## Extrusion Theory Today and Challenges for Tomorrow

**Rauwendaal Chris**(1)*
(1) Rauwendaal Extrusion Engineering - CA - USA

The presentation will review the state of the art of the theory of plasticating extruders today. This will include the major functions of the extruder: solids conveying, melting, melt conveying, mixing, and degassing. Both analytical and numerical approaches will be covered. Remaining challenges in extrusion theory will be discussed with possible approaches to meet those challenges.

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# Distinguished Keynote Lecture

## S18 - 442

# The challenges of artificial intelligence and surrogate modelling for polymer processing

**Ammar Amine**[(1)]*
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Over the last years, the growing interest in highly accurate simulations resulted in the increase of the complexity of the embedded models and thus to higher computational costs. This is especially problematic in case of using such simulation models for optimization routines or uncertainty quantification. One way to overcome this challenge is by using a surrogate model based on artificial intelligence, also known as a metamodel, of these high-fidelity simulations, to perform such analyses in a cheaper way. These models are usually generated using a relatively low number of simulations obtained by varying a specific number of input parameters and are then able to approximate the output of interest in a matter of seconds instead of minutes or hours using the high-fidelity simulation. What we have just said here is also valid for experiments which require a cost for their setup and instrumentation. We can generate data from real measurements, but we must be able to build a surrogate model from the measurements so as not to have to repeat experiments for each new situation. In the last two decades, the use of surrogate models to approximate outputs from polymer processing simulation has been growing steadily especially in the field of process parameter optimization to enhance product quality and processing efficiency. Applications for surrogate models seen in literature are used for the optimization of chemical and mechanical properties of polymers, processing conditions, in-service behavior, and recycling conditions. Most of the research in this field is directed towards optimizing process or material parameters using a surrogate model representing the simulation. For this, the simulation needs to accurately reproduce the physical phenomena, which are subject of optimization. After a presentation of the state of the art we will detail some contributions of our team as part of the approach described above. In the first study we will detail our approach to set up a surrogate model which is based on a space-time evolution of physical fields such as temperature. In the second study we focused on the prediction of the injection molding pressure as a function of the process parameters. We will finally show a situation where the previous techniques do not give the desired precisions and where artificial intelligence plays a primordial role in predicting defects and local properties.

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# Abstracts of PPS – 39

## Abstracts of Industrial Keynote Lectures

# Industrial Keynote Lecture

## S03 - 445

## Chemical recycling, Driver to Achieve the Sustainability in the Plastic Industry

**Mogollón Rincon Enrique Giovanny**(1)*
(1) Esenttia - Cartagena - Colombia

The circular economy proposes a solution for the use of plastic waste by creating strategies to return it to the productive system through technologies such as mechanical recycling and chemical recycling, which must be complementary and not compete between them. In the case of polyolefins, the main technology for chemical recycling is the pyrolysis, in which it is possible the production of pyrolytic oils which are feed it back into the refineries for the manufacture of monomers and other chemical products. Pyrolysis is a thermochemical process to decompose thermally the polyolefin molecules by the action of heat and in the absence of oxygen, resulting in a gas fraction, a liquid fraction and a solid fraction, whose composition and yields will depend strongly significant of quality of the raw material used, the type of technology chosen and the pyrolysis process conditions. The objective of the presentation is to give a general overview of the state of the art of the main pyrolysis technologies, their differences, and the challenges of the pyrolysis process are faced now.

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# Industrial Keynote Lecture

## S20 - 454

## A Review of How PVC Contributes to Sustainability

**Cabrera Cleinest**(1)*
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This conference presentation will focus on how PVC and its different applications support the fulfillment of sustainability goals, including: Offer from Orbia in sustainability. We will review the challenge the sustainability poses and its reasons. World trends supporting main needs will be put on sight: Food and Water security, Information and Connectivity Access, Decarbonization, Energy transition, and Urbanization. Solutions to fundamental problems where PVC participates. Figures, assessments, and success cases will be presented to show the advantages of PVC based solutions to fundamental problems. Energy transition, Building & Infrastructure, Healthcare, Food security, Water and Sanitation, Data & connectivity, an efficient sole utilization will be analyzed. Challenges facing the PVC value chain. Technological challenges lighted by new research will be listed to invite scientific community to joint in tackling them. Invitation to join the vinyl chain will be issued for the scientific community.

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# Industrial Keynote Lecture

## S20 - 451

## Sustainability Path at Taghleef Industries

**Molinaro M.(1), Battistella M.(1), Gabriel D. (1), Rodriguez Giraldo Carlos(1)***
(1) Taghleef Industries - Bolivar - Colombia

As one of the world’s largest manufacturers of BOPP, BOPLA, and CPP films for packaging, labels, industrial, and graphic arts applications, Taghleef Industries foster sustainable innovation by leveraging its global reach, scale, and research and development capabilities, to look beyond its immediate industry scope. In today's world, main environmental concerns revolve around global warming, pollution, and resource depletion. Aiming to address these pressing challenges, Taghleef incorporates a multifaceted strategy that starts by enhancing food protection. Through the implementation and development of innovative barrier solutions, food waste can be reduced throughout the supply chain and at the end consumer. Moreover, dedicated work is being done to improve recyclability of its packaging materials, offering solutions based on PP-based structures, and promoting a circular economy. In line with its commitment, Taghleef actively incorporates advanced recycled polypropylene into its products under the ISCC Plus scheme. Additionally, the company is pushing the limits to reduce packaging film thicknesses and densities, aiming to decrease plastic pollution and contribute to resource conservation. Furthermore, Taghleef Industries is at the forefront in the development of compostable (home and industrial) and biodegradable films, incorporating materials like PLA and PHA to offer alternatives to traditional oil-based plastic packaging. Despite significant progress in recent years, it is acknowledged that much work remains to be done. The company is unwavering in its pursuit of maximizing the positive impact of plastic packaging on the environment while simultaneously mitigating the adverse effects of its misuse. Through ongoing research, innovation, and collaboration, Taghleef Industries is dedicated to realizing a future where sustainability is not just a goal but a perceptible reality.

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## Industrial Keynote Lecture

### S20 - 453

# Development of flexible packaging with PCR resins - Ciclolene® as a contribution to the circular economy of plastics in the region

**Garcia Yohana**(1)*
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Reciclene, a company within the Plastilene Group, has developed Ciclolene® recycled resins 100% post-consumer (PCR) and certified with the LOOP seal from ICIPC in Colombia. These resins are obtained through a mechanical recycling process of post-consumer plastic waste supplied by informal waste pickers and environmental managers. Subsequently, they are reincorporated into flexible films manufactured by Plastilene, Altalene, companies within the Plastilene Group, and other sector actors. The study covers the following aspects: 1) a detailed description of a highly qualified process for obtaining high-performance PCR resins Ciclolene® and Ciclolene Plus®, along with their technical characteristics. 2) Specific examples of how these resins are incorporated into packaging and flexible films, comparing them with products made from virgin resins. Mechanical resistance, optical properties, and sealability tests are conducted on the samples. 3) The results of environmental indicators GWP, fossil fuel use, and water consumption obtained through a screening-type life cycle analysis using the Compass® calculation tool. 4)conclusions with the study's findings and recommendations.

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# Industrial Keynote Lecture

## S05 - 444

## Integrated Rheometer-Raman Monitoring: Unraveling Crystallization and Polymerization Dynamics of Polymers

**Zagorec Viktor** (1)*
(1) Anton Paar OptoTec GmbH - Seelze-Letter - Germany

Raman spectrometers have many benefits in the polymer market. Identity testing of incoming material, quantification of monomers inside copolymers, monitoring of polymerization process, polymer characterization and others are some of Raman use cases in this market. This presentation explores the synergistic capabilities of Raman spectroscopy integrated with a rheometer, focusing on the assessment of chemical and physical changes during polymer crystallization. The presentation employs Raman spectroscopy to provide real-time insights into crystalline structures, conformations, and molecular structures within polymer matrices. The rheometer-Raman combination concurrently measures rheological parameters, such as viscosity and elasticity, offering a comprehensive understanding of how these physical changes correlate with the evolving chemical structure. The integration of these techniques enhances our understanding of the interplay between chemical and physical transformations of polymers. This approach holds promise for tailoring polymer materials with improved properties while addressing sustainability challenges associated with the recycling process. The presentation showcases the potential of the rheometer-Raman combination in providing valuable insights for the development of environmentally conscious recycling processes and polymer materials.

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# Industrial Keynote Lecture

## S11 - 302

## Towards versatility of POSS nanoparticles in thermoplastic compounds

**<u>Ozkoc Guralp</u>(1)*, Kodal Mehmet(2)**
(1) Xplore Instruments BV - Sittard - Netherlands
(2) Kocaeli University - Kocaeli - Turkey

The development of polyhedral oligomeric silsesquioxane (POSS) nanoparticles containing an inner inorganic (SiO1.5 )n core and organic substituent shell with sizes of 1 ~ 3 nm in diameter offers new opportunities to tailor traditional thermoplastics providing a nanoscale control of the properties. With the increased availability of commercial POSS materials, the inclusion of POSS in polymeric systems by conventional techniques, such as melt-blending, has become attractive. Mechanical, thermal, viscoelasticity, chemical compatibility, surface hydrophobicity, and flame-retardancy of the POSS-based nanocomposites can be easily varied to target properties by adjusting POSS structure, amount, processing condition, etc. In this work, we highlighted how POSS molecules can customize the properties of a thermoplastic when compounded to target a specific application. Mainly, we focused on the multifunctionality of POSS nanoparticles on the performance of thermoplastics in terms of structure-property relationship. Examples of chemical compatibilization in blends, the nucleating ability of biodegradable polymers, thermal stabilization, interface enhancement in rubbers, crosslinking enhancement via irradiation, etc., will be presented. Besides, the positive impact of chemically functionalized POSS nanoparticles on the recycling processes will be highlighted.

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# Industrial Keynote Lecture

## S20 - 11

## New Opportunities for Polyamides

**Desbois Philippe**(1)*
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Plastics provide innovative solutions for many societal challenges. Together with our customers, BASF is systematically developing the properties of plastics to open up new applications. BASF's plastic portfolio is divided into two main areas: performance polymers and polyurethanes. Performance polymers are and remain innovative trendsetters; they have become an indispensable fixture of everyday life. BASF has become one of the leading producers of polyamides (Ultramid®) and of PBT (Ultradur®) as well as of polysulfones (Ultrason® E, S and P). Ultramid® is the trade name for polyamides supplied by BASF for injection molding and extrusion. The polyamide product range is broad and includes PA 6 grades (Ultramid® B), PA 66 grades (Ultramid® A) and various specialty (co)-polyamides. Ultramid® offers high thermal stability, dynamic strength, impact resistance and long-term performance. Owing to its excellent properties, this material has become indispensable in a wide array of components and machine elements. As the worldwide leading polyamide producer, BASF is from one side continuously exploring new areas of application and developing unprecedented technical properties and on the other side is developing new concepts for a sustainable PA portfolio. After a short introduction to BASF's PA portfolio, recently developed green polyamides basis resin will be introduced and new production processes to access high stiffness materials will be depicted. In a second part, the compounding of polyamides will be discussed. Advanced polyamide engineering plastics solutions to support eco-friendly applications will be introduced as well as new routes to incorporate recycled and renewable additives. To conclude, new recycling technologies will be presented.

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# Industrial Keynote Lecture

## S20 - 456

## Microplastics: Tackling the Invisible Enemy

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Plastic pollution is a serious global concern. Although a relatively new phenomenon, the extent of the environmental damage caused by plastics is now well documented. Plastic packaging, such as water bottles, single-use plastic bags, and disposable medical supplies are some of the more recognizable offenders. Removal and recycling of these bigger plastic pieces (macroplastics) has been a growing priority in recent years. Meanwhile, microplastics — small plastic pieces or particles between 1 µm and 5 mm in diameter — have been mostly ignored while they stealthily make their way into our water, food, air, and soil.1 Scientists have seen microplastics nearly everywhere they have looked, from falling rain, to arctic snow, to human cells.2 Their ubiquitous nature has led researchers to investigate the global impact of these tiny specks of plastic. In this presentation, we analyze the CAS Content Collection™ to provide an overview of the research trends in the growing field of microplastics to understand the general progress of the field, as well as the classes of materials and concepts driving research and innovation.

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# Abstracts of PPS – 39

## Abstracts of Keynotes Lectures

## Keynote Lecture

### S03 - 347

# Thin films from modified polyglycolic acid with excellent water vapor barrier

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Commercial biodegradable polymers with high oxygen and water vapor barrier properties at the same time are scarce. In the packaging industry usually, multilayer materials are used to achieve the barrier requirements, however they are usually not recyclable and not biodegradable. Poly (glycol acid) PGA has the best credentials for a biodegradable oxygen and water vapor barrier material. At the same time, its processability in standard converting equipment is an issue. Low melt strength, high processing temperatures and fast crystallization at the die limit its use in film applications. Chain extenders can be used to improve processability and increase melt strength, however they may affect the intrinsic barrier properties of the material. The reactivity of PGA with different chain extenders was studied. It was found that using small amount of specific reactive chain extenders the processability of PGA could be highly improved while maintaining the intrinsic barrier and mechanical properties of the material. After compounding PGA with this chain extender, stable flat sheet extrusion of the material was possible resulting in sheets thinner than 10 µm. The multidirectional stretchability of the melt was improved, indicating an increase in the melt strength of the polymer. Barrier properties were measured, and it was found that the WVTR (water vapor transmission rate) is not affected by the addition of the chain extender. This improvement in the processability of PGA offers a feasible solution for biodegradable high barrier packages.

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# Keynote Lecture

## S12 - 427

## Non-Linear Fracture Mechanical Response of Polymers

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Polymers constitute a large class of engineering solids which exhibit a wide range of stress-strain and fracture behaviors. Such behaviors are known to exhibit strain rate, temperature, and pressure dependent yield, as well as true strain softening and hardening after yield. For ideal quasi-brittle bodies, material constants such Young's modulus, Poisson's ratio, yield strength and fracture toughness can be determined rather easily by experiment using solutions to certain special problems and problems of structural design would be reduced to computing the solutions of well-defined solid mechanics theories. This relatively simply picture is very far from reality for polymeric materials. Even the existence of theoretical models, the nonlinear response is still poorly understood. Addressing this challenge is critical for the development and design of new and traditional polymer products. The essential mechanisms driving the nonlinear response under different loading conditions are rate-dependence, tension-compression asymmetry, elastic-plastic-viscous behavior, unloading characteristics, interaction between stress components, damage mechanisms, etc. Polymers are increasingly employed in load bearing applications. During service, cracks can initiate and propagate in polymeric structures until final fracture under different loading conditions , compromising service life. For many demanding applications of engineering plastics, fracture behaviour under various loading conditions is of prime practical importance. As it is well known, the use of fracture mechanics theory allows description of the toughness of a material by parameters which are true material properties. However, the toughness determination in the framework of fracture mechanics theory is conditioned to the behavior displayed by the material itself. The limitations associated with conventional fracture test methods may, at least in principle, be overcome by the use of appropriate fracture mechanical approaches, which properly account for the temperature and rate dependence of the mechanical behaviour of plastics and should provide geometry-independent fracture toughness values. Linear elastic fracture mechanics (LEFM) has been widely applied to the evaluation of the fracture behavior of brittle polymers when the size of the plastic zone is much smaller than the in-plane specimen dimensions and the initiation of unstable fracture can be accurately described by KIC or GIC parameters. On the other hand, for tough polymers, exhibiting nonlinear behavior due to strong viscoelastic-viscoplastic behavior and /or significant crack tip plastic deformation during crack propagation . Fracture toughness determination implies the application of non-linear theories. Among others , one suitable approach is the so-called J-Integral fracture toughness criterion, which it is also suitable in structural integrity assessment under non-linear conditions . This approach has been extensively used to characterize fracture of polymers at short times, i.e. monotonic testing under quasi-static or impact condition. However, at larger time scales and when secondary creep conditions are dominant, the use of the so-called C*-Integral (C*), appears to be more appropriate to describe crack growth rate under steady-state creep conditions. The characterization of nonlinear elastic plastic fracture behaviour is challenging and requires a lot of testing knowledge. There exist many influencing factors from the testing procedure and the method itself. Hence, the determination of further parameters to characterize the fracture propagation of a nonlinear elastic material behaviour is going on. In this keynote some main contributions of the application of J-Integral and C*-Integral methodologies to characterize the nonlinear fracture response of polymers are described and analyzed . Advantages, drawbacks, and open challenges are discussed. Regarding the future, it is expected that the combined of numerical, analytical, and new experimental ( basically DIC) methodologies would lead to improve current methods.

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# Keynote Lecture

## S14 - 448

# Digital Twin or Distant Cousin? The practical realities of modeling polymer material behavior in complex manufacturing processes

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“In theory, theory and practice are the same. In practice, they are not.” – Benjamin Brewster, 1882 The Simulation of Injection Molding and other polymer manufacturing processes promises a valuable tool for industrial designers and engineers to optimize their designs virtually. Such virtual prototyping has the potential to reduce the number of physical prototypes required and therefore to reduce the time to market and tool prototyping costs. Simulation can also provide guidance on methods to reduce cycle time and material usage as well as to increase part quality. All these optimizations serve to decrease the cost of production as well as the environmental impact of manufacturing. There are times however, when the promise of simulation fails to deliver an accurate prediction of that which will occur during production. The reasons for this are varied, ranging from production control, material data, numerical approximation, and modeling simplifications. Frequently in industrial settings, comprises are also required to meet user expectations of the time available for process modeling. Material characterization must be done in a timely and cost-effective manner. Computation times and memory requirements must be limited to fit within the available design cycles and compute resources. Most importantly, the accuracy of predictions will never exceed the accuracy of the process input data, which is often poorly understood or monitored. Drawing on over 30 years’ experience supporting users of commercial manufacturing simulation software, this presentation will discuss the practical limitations and comprises which are inherent in the industrial adoption of modeling and simulation of polymer processing and provide an understanding of what is achievable today and what challenges remain.

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# Keynote Lecture

## S15 - 314

# The interplay of shear-induced uncoil and disentanglement of polymer chains

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The chains of an amorphous polymer are initially randomly coiled and entangled. While being sheared isothermally at temperatures well above its glass transition temperature the imposed shear, helped by the chain entanglements, uncoil the original chain's morphology. At the same time, the polymer chain reptation mechanism takes place helping to disentangle irreversibly the coils. The level of uncoil and disentanglement increases with the applied shear rate. Following, as the shear rate is reduced the chains coil back reversibly, but the level of disentanglement already achieved at the previous cycle is maintained, being an irreversible effect. For this evaluation we will test the use of a rheo-optical property, the melt flow birefringence, to quantify the varying level of polymer chain orientation along the flow direction. For that a Cambridge Shearing System CSS450 from Linkam Scientific Instruments was fitted to a polarized light optical microscope from Leica, model DMRXP, to impart controlled shear and varying temperature to a pristine polystyrene sample. The flow birefringence as cross-polarized transmitted light intensity was measured with a specially built quantitative optical plate, set in the analyzer slot of the microscope. The optical signal is converted by a NIDAC plate and collected by a LabVIEW software. Polymer flow birefringence data of isothermally cycling the shear (running at least three times up to 180 s-1) at different temperatures (180°C < T < 240°C), will be presented showing the irreversible decrease in the chain orientation, due to the decrease in the level of chain entanglement. The rheo-optical technique of birefringence is another suitable technique to quantitatively follow the interplay effect of uncoil and disentanglement of polymer chains under melt flow.

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## Keynote Lecture

### S22 - 70

# Virgin and degraded polyamide microplastics as vectors of contaminants in aquatic systems

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The benefits of plastics to the mankind are unquestionable! However, in the macro or the micro scale, they are presently a serious concern for the environment. Microplastics are polymeric particles in the environment smaller than 5 mm. These are formed by the fragmentation of plastics or made on a micro-scale. They can transport contaminants (organic, inorganic or microorganisms) for long distances, acting as vectors of these species1. This work highlights polyamide, PA, whose use in textile fibers is a relevant source of microplastics in aquatic systems2. We investigated the sorption capacity of virgin and photodegraded PA, PdPA, microplastics. Five contaminants, frequently found in aquatic systems, with different physicochemical properties (water solubility, octanol-water partition coefficient-KOW, and acid dissociation constant), were chosen; two pesticides (atrazine-ATZ and tebuconazole-TEB), a pharmaceutical (caffeine-CAF), and two hormones (testosterone-TTR and progesterone-PGT). PdPA sorbed ca. 17% more ATZ than virgin PA. This increase could be related to the hydrophilic characteristics of PdPA, due to the insertion of polar groups in its chemical structure. Similar behavior was noted for ATZ sorption in polyolefins3. This confirms that the interactions with polar compounds, such as ATZ (KOW < 3), is favored. From the environmental viewpoint, the degraded microplastics could transport even a higher amount of ATZ than those used in the control experiments performed at the laboratory. A decrease in PdPA sorption was observed for the other contaminants; ca. 8% for TEB, 6% for TTR and 9% for PGT. These three compounds present a higher hydrophobicity (KOW > 3), and the chemical changes in PdPA could decrease the interactions with these molecules. We conclude that, when studying the interactions of microplastics with the environment it is necessary to consider the effects of their degradation.

1. Dias, M.A. et al. Chemosphere, 318, 2023, 137949.
2. De Falco, F. et al.

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# Keynote Lecture

## S22 - 43

# Meeting the Challenge of Microplastics Pollution: Formation Pathways and Impact on Living Organisms

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The production and demand for plastics have grown over the last century, resulting in intentional and accidental release of plastic waste into the environment, leading to severe plastic debris pollution. The long-term accumulation accompanied by waste mismanagement and succeeding fragmentation of plastic litter into marine and terrestrial ecosystems, provokes the generation and release of small-sized particles, designated as microplastics (MPs, plastic items with diameter <5mm) [1]. Today, the estimation that 51 trillion MPs are floating in the oceans is a well-established fact [2]. Plastic litter discharged into the environment is subjected to different fragmentation mechanisms based on the physicochemical characteristics and environmental conditions in which the materials are exposed to (heat, UV radiation, oxidation, micro-organisms, and mechanical abrasion). Many studies indicated that wastewater treatment plants also play an important role in releasing MPs to the environment. MPs can possibly pass by drinking water or food chain to human body as well, with their effects after their intake being still a debatable issue [3]. Within the several adverse effects provoked to living organisms, the reduced feeding activity, inhibited growth, oxidative stress, neurotransmission malfunction, genotoxicity and even mortality in some species are reported [4,5]. Despite the significant advances in the analytical techniques obtaining structural and spatial knowledge for MPs, there are many knowledge gaps whereas standardization is still lacking. In this light, the present work aims to discuss the main pathways for microplastics formation, highlighting especially the effect of UV exposure on the properties of synthetic polymers, investigated by a series of microscopic, spectroscopic, and chromatographic approaches. Finally, the toxicity of biomaterials and synthetic plastic MPs as well as their effect on biochemical parameters of several species is thoroughly discussed.

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## Keynote Lecture

### S06 - 428

# Compatibilization Polymer Blends by Electron Beam Irradiation

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Polymer blends based on homopolymers are mostly incompatible and lead to phase separation due to their low entropy of mixing attributed to their high molecular weight accompanied by limited enthalpy change as a result of their low molecular interactions. The combination of the enthalpy and entropy leads, in most cases, to a positive Gibbs free energy of mixing and phase separation. To overcome the incompatibility phenomena a variety of functional copolymers (compatibilizers) have been developed to yield useful compatibilized blends. Furthermore, chemical grafting, reactive compatibilization, and dynamic crosslinking are used to acquire high-performance blends. Consistently, with these principles, electron beam irradiation of a variety of polymer compositions has been studied with the aim of obtaining compatibilized blends and alloys via the activity of the free radicals that are generated by electron beam irradiation. In line with the thrust for upcycling of post-consumer plastics, electron irradiation may offer an attractive process to compatibilize incompatible plastics mixtures comprising polyethylene (PE), polypropylene (PP), and polyethylene terephthalate PET) that are abundant in municipal waste centers. In the first step of the overall study, PE and PP blends were treated with electron beam radiation. Irradiation may result in cross-linking of PE or chain scission of PP. In the case of PE/PP blends, interfacial bonds may be formed between the incompatible PE and PP phases, which may lead to enhanced compatibility and mechanical properties. Post-processing irradiation of PP and low-density polyethylene (LDPE) blends was performed in two different methods: state of art solid irradiation and novel melt-state irradiation in a temperature-controlled open mold under 15-75 kGy doses. Melt-irradiated samples show different crystallization and crosslinking behavior compared to solid-irradiated samples. Crosslinking is more efficient in solid-state irradiation. Furthermore, adding a low level of PP (20%) into LDPE proved to be beneficial for the crosslinked PE, leading to optimal mechanical and thermal properties. Some compatibilization between the phases was achieved as evident by Differential Scanning Calorimetry (DSC) of melt irradiated samples compared to solid irradiation, which led to some decrease of elongation but enhanced modulus and strength. The DSC results were supported by scanning electron microscopy demonstrating that phase separation was reduced. These results open new routes for upcycling of post-consumer resins of PE/PP mixtures. Future studies will include PE/PET and PP/PET blends with the objective of forming new upcycled polymer blends.

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# Keynote Lecture

## S14 - 67

## Film Blowing Simulations with Integral Constitutive Equations

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One of the most important polymer processes deals with the forming of plastic films. This process is called film blowing and represents the main manufacturing process of plastic bags and sheets. The process involves shear-free flow of a polymer melt, where its rheological character is manifested through its extensional properties, mainly its biaxial extensional viscosity. In the process of film blowing, the mathematical modelling can be simplified into a quasi-unidirectional flow because of the film thickness, which is very small with respect to the flow and transverse directions. The simplified transport equations are well-established for the case of Newtonian inelastic fluids. For the case of viscoelastic polymer melts, the constitutive equation must be able to describe adequately the rheological behaviour of the polymer in all types of extensional flows, steady or time dependent. A good candidate for such modelling is the K-BKZ integral constitutive equation with a spectrum of relaxation times, that captures well the non-linear viscoelastic response of polymer melts. The present work addresses the rheological implications of extensional viscosity in the process of film blowing by using a variant of the K-BKZ equation (the PSM model), where the extensional effects can be modelled separately by varying a single extensional parameter in the model. The results are compared with previous simulations, and against experiments from industrial practice available in the literature.

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## Keynote Lecture

## S19 - 127

# Evaluation of Polyhydroxyalkanoates machine learning- generated compounds for medical devices applications

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In order to achieve circularity and reduce environmental impact in high-end medical applications, this research was initially motivated by an interest to use bio-based polymers. This study investigates the compounding of Polyhydroxyalkanaotes (PHAs) with the aid of a machine learning program. Although injection molding can be used to process PHAs, certain material properties and processing conditions impede their development for high-end applications such as medical devices. The objective of this study is to assess the suitability of machine learning-generated compounds for use in industrial applications characterized by high volume and demanding specifications. PHA of industrial grade was combined with Polylactic acid (PLA), amorphous PHA, fillers, plasticizers, heat stabilizers, an antioxidant, and a chain extender. Different compound formulations were used to train machine learning programs, which were then mechanically evaluated following the injection molding of dumbbells. A Taguchi design of experiment will be used to evaluate the performance of the various machine learning models that are being tested, such as the Support Vector Regression and Random Forest Regressor. The evolution of properties during the crystallization of bio-polyesters after molding will be looked at. A consideration of the identified obstacles for industrial applications of PHAs in medical devices is provided along with the results of these analyses.

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# Keynote Lecture

## S12 - 123

# Sustainable Manufacturing: Enhancing Mechanical Behavior of Common Polymers Through Deformation Processing

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There is significant interest in adding performance value to existing high-volume polymeric materials, from commodity polyolefins through engineering plastics. One timely possibility is to consider rather less common yet scalable processing approaches that are solventless and have low scrap. Two options pioneered in the Department of Macromolecular Science and Engineering at Case Western Reserve University are forced assembly coextrusion (a unique additive manufacturing approach) and solid-state deformation processing. A recent example of the latter is cross-rolling of poly(p-phenylene sulfide) which leads an order of magnitude enhancement of ductility (McMullen et al., ACS Appl. Eng. Mater., 1, 1176 (2023)). Deformation processing, with an emphasis on semi-crystalline polymers, and mechanisms for ductility enhancement, specifically via cross-rolling, will be discussed in detail. In addition, more recent work focused on other engineering plastics, such as PEEK, will be summarized.

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## Keynote Lecture

### S01 - 48

# How polymer-based pharmaceutical additive manufacturing can heal millions of patients via personalized medicine

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Polymer-based pharmaceutical additive manufacturing holds immense promise for revolutionizing healthcare through personalized medicine. By leveraging the few existing approved pharma polymers as building blocks, this talk highlights our recent findings in using advanced materials to 3D-print drug delivery systems, enabling precise control over drug release. In the first use case, the focus is on the development of vaginal pessaries made from ethylene vinyl acetate. Vaginal pessaries are used for treating various gynecological conditions and require materials with excellent elasticity and mechanical strength. By utilizing 3D-printing, we realized to fabricate pessaries with tailored shapes, sizes, mechanical properties, and drug release, offering enhanced patient comfort and improved therapeutic outcomes. The second application explores the fabrication of drug-loaded subcutaneous implants based on biodegradable poly(ether ester) multi-block copolymers. Subcutaneous implants have gained significant attention for sustained drug delivery and targeted therapies. However, conventional manufacturing techniques often limit the design flexibility of these implants. Leveraging 3D-printing technology, implants with intricate geometries were produced, allowing for personalized drug release profiles and improved therapeutic efficacy. Both use cases prove enhancement of the therapeutic efficacy and mitigation of adverse effects, optimizing patient outcomes. The process's implementation in the healthcare landscape offers a cost-effective solution for producing small batches of highly specialized medications. This has significant implications for niche patient populations, where traditional manufacturing approaches are economically unfeasible. The ability to tailor drug delivery to individual's needs therefore can revolutionize treatment strategies, offering hope for improved therapeutic outcomes and enhanced quality of life for millions of individuals worldwide.

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## Keynote Lecture

## S15 - 122

# Exploring Fluids' Behavior: Lab-Scale Capillary Breakup Extensional Rheometer and Its Applications in Polymer Processing

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The flow behavior of low-viscosity complex fluids under extensional deformation is of paramount importance to several processes and technologies, such as electrospinning or spray drying. However, its characterization is far from easy, and the study of this behavior is still in its infancy. To achieve this rheological characterization, a Capillary Breakup Extensional Rheometer (CaBER) can be used. This instrument observes the evolution in the diameter of a liquid filament obtained by step-motion separating the two plates sandwiching that liquid. By modelling the filament thinning as a function of time, and assuming that the liquid surface tension is known, it is possible to infer its extensional viscosity and relaxation time1, 2. The current difficulties to commercially purchase this type of extensional rheometer hampers the progress of the scientific field. This work presents the design and production of a lab-scale CaBER, outlining the specific mechanical, optical and software systems of the machine. The effectiveness of this technique was found to depend on three interrelated parameters: the diameters of the plates and the initial and final gaps between them. The influence of these parameters on the success of the experiments was evaluated. The reliability of lab-scale CaBER rheometer developed in this work was successfully tested using Newtonian solutions. It was shown that the measured extensional viscosities of these fluids were approximately three times their shear viscosities obtained using a rotational rheometer. Viscoelastic solutions were also tested, and their characteristic extensional relaxation times were determined. These data were used to predict the processability and characteristics of nanofibers obtained by electrospinning. 1 L.E. Rodd, et al., Applied Rheology, 15, 12 (2005). 2 J.H. Yu, S.V. Fridrikh, and G.C. Rutledge, Polymer. 47, 4789 (2006).

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## Keynote Lecture

### S06 - 399

# Impact of stratification on mechanical properties of SAN/PC and ABS/PC multilayered films

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Multilayer coextrusion enables the fabrication of films with up to several thousand layers, with an individual layer thickness ranging down to nanometric scale. Such nanolayering may induce substantial enhancement of properties, such as gas barrier properties, mechanical properties, or changes in deformation mechanisms. Aiming to upgrade polymers from Waste Electrical and Electronic Equipment (WEEE), the benefits of this original processing method on PC/SAN and PC/ABS multilayered films are studied here. PC/SAN and PC/ABS multilayered films with up to 2049 alternating layers were fabricated from PC (Trinseo, Calibre 201-22), SAN (Trinseo, Tyril 867 E) and ABS (LG chemical, HF 380) with 80 and 20 wt.% composition respectively. The films were then characterized by optical, electronic, and atomic force microscopes, while mechanical properties were assessed by tensile tests, DMA, and impact strength. For PC/SAN multilayered films, we report an enhancement in toughness when the thickness of the layers is decreased. On the contrary, for PC/ABS films, the decrease of the layer thickness leads to a loss of elongation at break and impact strength. The role of the polybutadiene nodules is highlighted.

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# Keynote Lecture

## S01 - 286

## 3D Printable Advanced Composites with Energy and Biomedical Applications

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3D printing has challenges in processing speed and manufacturing resolutions. We will discuss the 3D printing of polymer-based composites in energy and biomedical applications. In the context of energy, we explore composite materials designed to enhance energy storage and conversion systems' performance and sustainability. Our research focuses on augmenting energy storage capacity via a unique mixture of polymers and particles, optimizing charge-discharge efficiency, and extending operational life. In the biomedical field, we utilize 3D printing to create customizable, biocompatible composites. These materials hold immense promise in tissue engineering, regenerative medicine, and drug delivery. We pioneer patient-specific implants, scaffolds, and drug carriers with precisely controlled microstructures, facilitating personalized healthcare and innovative disease treatments. Our multidisciplinary approach in 3D printing blends materials science, nanotechnology, additive manufacturing, and bioengineering. We employ cutting-edge characterization techniques to understand the intricate relationships between composite structure and properties.

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## Keynote Lecture

### S08 - 42

# Understanding the Foamability and Mechanical Properties of Foamed Polypropylene Blends by Shear and Extensional Rheology

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In this work the influence of the rheological behaviour of miscible blends of a linear and a high melt strength, branched, polypropylene (HMS PP), on the cellular structure and mechanical properties of cellular materials fabricated with these polypropylenes (PPs) has been investigated. The rheological properties of the polypropylene melts were investigated in steady as well as oscillatory shear flow and in uniaxial elongation in order to determine the strain hardening coefficient. While the PP blends display very similar behaviors in shear, there are substantial differences in the elongational behaviour. Cellular materials with a fixed relative density of 0.2 have been fabricated by Improved Compression Molding (ICM), a technique that allows controlling the foam density by mechanical means. The open cell content has been quantified and a characterization of the cellular structure has been performed. In addition, mechanical properties in compression have been measured. While the linear PP does not exhibit strain hardening, the blends of the linear and the HMS PP show pronounced strain hardening, increasing with the concentration of HMS PP. A relation has been observed between the strain hardening coefficient and the open cell content: more strain hardening leads to a lower open cell content. Related with cellular structure, in general, the cell size and the width of the cell size distribution, increase with the amount of linear PP in the blends. These results indicate that the cell walls are less stable when large amounts of linear PP are used. Also, mechanical properties are conditioned by the extensional rheological behaviour of PP blends. Cellular materials with the best mechanical properties are those that have been fabricated using large amounts of HMS PP. The results demonstrate the importance of the extensional rheological behaviour of the polymers for a better understanding and steering of the cellular structure and properties of the cellular materials.

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# Keynote Lecture

## S10 - 441

## Interdiffusion of PLLA and PDLA to form fibers consisting of highly oriented stereocomplex crystals

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The development of stereocomplex crystals (SC) consisting of a pair of poly(L-lactic acid) (PLLA) and poly(D-lactic acid) (PDLA) molecular chains is desirable because SC has a significantly higher melting temperature (Tm) than the homo crystals (HC) of either PLLA or PDLA. High-speed melt spinning of the PLLA/PDLA blend revealed the development of a higher amount of SC under higher tensile stress in the spinning line. Melt blending of PLLA and PDLA of high optical purity is difficult because of the necessity of higher blending temperatures. Bicomponent melt spinning of fibers with the sheath-core (S/C) and sea-islands (S/I) cross-sectional configurations was performed feeding PLLA and PDLA separately from two extruders. The fibers consisting of highly oriented SC could be prepared through the annealing of the high-speed spun S/I fibers at 190 deg, a temperature between the Tm of HC and SC, suggesting that the interdiffusion of PLLA and PDLA with the distance of 500 nm proceeded in the fiber cross-section. To obtain the thinner fibers, laser-heated melt electrospinning (LES) was applied to the as-spun S/C and S/I fibers. The prepared fibers had estimated core and island diameters of 1500-3000 nm and 40-80 nm, respectively. After annealing at 190 deg, the S/C fibers fused to form a fiber bundle, whereas the S/I fibers were well-separated from each other, and the fine fibers with highly oriented SC were developed.

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## Keynote Lecture

## S14 - 32

# Global Process Modeling. Extrusion vs Injection Molding

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Extrusion and injection molding are the most important techniques in the polymer processing industry. It is a challenge the global modeling of these, i.e. description of the flow in the plasticating unit and in the forming tool (die/mold). It requires the modeling of solid transport; polymer melting and melt flow. The solid transport and polymer melting are poorly understood. An issue of global modeling of polymer extrusion has been recently discussed [1] and the concept of DEM/CFD modeling has been presented [2]. The models of polymer melting are based on experiments to get to know the melting mechanism. However, the existing models for injection molding have no strong experimental basis. Recently, an extensive experimentation has been performed [3], and the melting mechanism in the injection molding machine has been recognized. In this paper an issue of modeling of injection molding has been discussed, which includes both the plasticating unit and the injection mold. This has been related to the modeling of extrusion process. When modeling the melt flow in the injection mold, the input data are basically unknown, e.g. the polymer temperature. Thus, the global model of injection molding is needed that will describe both the flow in the plasticating unit and in the mold. The process output parameters from the plasticating unit will be the input parameters for the mold. An effect of the polymer flow (incl. melting) in the injection molding machine on the polymer flow in the injection mold has been studied by simulation (using Moldex-3D) and experimentations. Limitations of existing software has been discussed, and the novel concepts of injection molding modeling based on our previous experimentations have been presented.

[1] K. Wilczyński et al. Polymers 2019, 11, 2106; doi:10.3390/polym11122106
[2] K. Wilczyński et al. Proceeding of PPS-38 Meeting, May 22-26, 2023, St Gallen, S11-60
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# Keynote Lecture

## S17 - 299

## Conductive elastomers nanocomposites for IP²C soft sensors

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In flexible electronics, the use of Conductive Elastomeric Composites (CECs) is of increasing interest, grouping unique mechanical behavior with electrical conductivity. In this work, rubber nanocomposites were prepared to achieve high electrical conductivity with carbon nanotubes incorporation via latex mixing. The latex method was chosen to increase the nanofiller's deagglomeration and dispersion due to the possibility of accepting non-covalently functionalized fillers in water suspension and applying high sonication power to this mixture without prejudice to the polymer or the fillers. The nanocomposites were tested using electrical impedance spectroscopy, showing greater electrical conductivity. Plasma treatment was applied to the elastomer's surface to improve nanoroughness, as observed by AFM, for adhesion to other substrates. The elastomeric nanocomposites were stacked with an ionomeric polymer (Nafion®), in a sandwich-like form, acting as a flexible electrode to strain and displacement sensors (IP²C - Ionomeric Polymer-Polymer Composites). The electrochemical and electromechanical results were satisfactory when compared with the conventional ionomeric polymer-metal composite (IPMC) sensors based on platinum electrodes, presenting greater potential amplitude sensing in low actuation frequencies and the capability of sensing different types of displacement velocities with linear, quadratic, and cubic accelerations.

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## Keynote Lecture

### S19 - 231

# On the Cryo-Moulding process and subsequent forming processes of biopolymers with low glass transition temperature

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Bio-based as well as biodegradable polymers are increasingly finding their way into applications such as the packaging of food. Here, certain biopolymers with a high degree of crystallinity can be of interest due to their superior barrier properties. Conversely, forming processes including high deformations often require an almost amorphous material state to avoid brittle behavior associated to crystal structures. For some of those biopolymers, the narrow window in which they can be processed has held back their potential use for packaging applications. In packaging applications, two-step processes are common for the production of containers form thermoplastic polymers. These processes, such as thermo forming or injection stretch blow molding, are a combination of a conversion step as injection molding or film extrusion and of a deformation step. These two-step processes economize the production and increase the quality of the final product. However, to enable a forming process, the material properties after the first (conversion) step need to fulfill the mechanical requirements of the forming process. For semi crystalline polymers, these requirements are closely linked to the morphology of the converted material. The new method, developed by the authors uses tailored equipment to showcase the possibilities as well as challenges granted by the Cryo-Moulding process. The Cryo-Moulding uses a mold that is cooled by liquid nitrogen. This mold is insulated and used in a lab scale injection process. This process is capable of cooling specimens down into their amorphous state (or semi-crystallin state with a very low degree of crystallinity) and allows the mechanical characterization in a softened state at a temperature above glass transition. To prevent unintended changes of the morphology after the production process, the samples are stored at temperature below glass transition and heated using custom convectional heaters in a setup of a tensile testing machine. In this context biopolymers such as PBAT, PBS and PHA are tested exemplarily.

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## Keynote Lecture

### S10 - 14

# Melt-spun liquid-core filaments for microhydraulic applications

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Spurred by the deformability and structural stability provided by veins in insect wings, microscale liquid-core filaments (LiCoFs) were created, comprising of a polymeric sheath and a liquid core. The ability to produce a continuous LiCoF is attractive since, due to capillary resistance, post-filling of a fine hollow filament within reasonable time can only be achieved with fibers of limited length. To overcome this bottleneck, a microfluidic co-extrusion spinneret was designed, assisted by computational fluid dynamics studies, to melt-spin fine polymeric filaments with a continuous liquid core filled during production. The incompressible liquid is injected with a high-pressure pump through a capillary and meets pressurized polymer melt within a co-flow channel before exiting the spinneret. The resulting melt strand can be quenched, drawn, and wound like regular melt-spun fibers to achieve a filament with high tensile strength. An intriguing application aimed for is soft robotics, where pressure resistant LiCoFs could form a net of microhydraulic elements, embedded in various forms and shapes with restricted available space, actuated by powerful external pumps. This would be beneficial since LiCoFs can be embedded in flexible structures that deform in a predefined way when the fluid is pressurized. In order to prove the feasibility of the LiCoFs for force transmission in microhydraulics, hydraulic pressure transfer tests were applied on fine, up to 10 m long, oil-filled polyamide fibers. The results showed a pressure transfer with a fiber length-dependent delay of ∼ 20–100 s for fiber lengths of ∼ 1–10 m, and a viscoelastic behavior with relaxation times that behave linearly with fiber length. These findings enable the development of resilient and deformable microhydraulic systems within restricted available space, predestined for applications in soft robotics.

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## Keynote Lecture

### S17 - 138

# Correlation between Manufacturing Conditions, Crosslink Density and Fatigue Behavior in Nitrile Butadiene Rubber

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The fatigue behavior of elastomers plays a decisive role in their durability. In the ongoing research, it was revealed that curing time and temperature have a decisive impact on the latter. It has been shown that crack growth in nitrile butadiene rubber (NBR) increases significantly with increasing curing time and decreasing curing temperature. In samples produced at a temperature of 180°C, crack growth was found to be up to 40x slower than in samples produced at 150°C mold temperature. To explain this behavior, multi-stage swelling analyses were performed to determine the exact sulfur chain composition. 2. Method and Results The method applied involves the swelling of cylindrical 4 mm thick NBR specimens in four steps. Step 1 is the dissolution of organic additives using acetone, step 2 is an equilibrium swelling in toluene to determine the general crosslink density, step 3 consists of swelling in hexylamine and propane-2-thiol for cleavage of the polysulfidic bonds, and additionally swelling in hexylamine and 1-hexanthiol for cleavage of the poly- and disulfidic bonds. By means of a renewed equilibrium swelling in step 4, respective percentages of various sulfur chains (poly-, di- and mono-) in the total crosslink density can thus be determined. First results show that the crosslink density determined by equilibrium swelling decrease with increased curing temperature. This could be an explanation for the clear differences in the previously tested fatigue behavior. A reason for the decreasing crosslink density is enhanced decomposition with rising curing temperatures. Further swelling results also show the phenomenon of desulfurization with increased curing time. This is accompanied by a degradation of the sulfur chains from poly- to monosulfidic. At the end of the research, the aim is to be able to make a statement about the crosslinking properties and the subsequent fatigue behavior of the material by means of short-term tests such as the RPA.

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## Keynote Lecture

### S01 - 379

# A study of the use of dry natural rubber in 3D printing

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Natural rubber, recognized for its high elasticity in comparison to commercially available printing materials, holds immense potential in 3D printing. However, its application has been limited due to characteristics exhibited before vulcanization. In its pre-vulcanized state, natural rubber behaves as a high molecular weight polymer with complex rheological behavior, characterized by high melt viscosities, pronounced elasticity, and long relaxation times. Despite these challenges, this research investigates the printability of dry natural rubber by modifying the level of plasticizer and adjusting printing parameters such as printing rate, temperature, and geometrical factors to control the elastic response of the rubber melt. Rubber compositions were prepared in a Brabender Plastograph using paraffin oil as a plasticizer in proportions between 20 phr to 50 phr. Sulfur, ZnO, stearic acid, and TMTD were added in proportions leading to a semi-EV system. The compositions were characterized using oscillatory shear rheometry at frequencies ranging from 0.01 Hz to 10 Hz, and stress relaxation after a shear deformation of 2%. Vulcanization endotherms were measured by DSC at heating rates of 1 K/min and 10 K/min, and thermal degradation was determined by TGA. 3D-printed structures were produced using a single-screw-extruder 3D printer. The printing temperature was maintained at 70 °C, and a printing speed of 100 mm/min was fixed for all rubber compositions. Printability was assessed through visual inspection and the evaluation of tensile properties after vulcanization.

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# Keynote Lecture

## S07 - 98

# Formulation of highly electro-conductive thermoplastic composites using PEDOT based fillers with controlled shape factor

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The objective of this study is to develop a new conductive thermoplastic material with superior electrical properties. Currently, conductive polymers are filled with carbon or metallic objects [1]. However, these filled thermoplastics displayed drawbacks such as high rigidity, toxicity, and high viscosity [2]. An alternative way investigated in this work is to substitute such fillers by intrinsically conductive polymers like Poly(3,4-ethylenedioxythiophene) (PEDOT). In fact, PEDOT can reach stunning electrical conductivities (more than 1000 S/cm) when combined with polymeric dopant like poly(styrene sulfonate) (PSS) and is frequently used (thin film or gels) in areas such as medical and energy's sectors [3]. However, incorporation of PEDOT in the classical hot melt processes of plastic industry is still challenging [1]. In a previous work we performed the synthesis of electro-conductive PEDOT particles in order to incorporate it into polyethylene oxide (PEO) matrix by extrusion process [4]. Composites with interesting conductivities up to 12 S.cm-1 were obtained but a high amount of PEDOT fillers was necessary to reach the electrical percolation threshold. To reduce this percolation threshold, a new approach based on supported polymerization process is investigated in this work. Our goal is to control the shape factor of the synthetized conductive PEDOT particles by using different fillers like silica, graphene, or clays for the EDOT polymerization. The objective is to coat these different fillers with a conductive shell of PEDOT and then study the impact of the different shape factor on the electrical percolation threshold of the associated composites. Relationships between process, morphology and properties were analyzed using SEM, X-Ray tomography and four probe resistivity measurements. Percolation curves for different shape factor were also achieved and compared to the initial one obtained with micrometric PEDOT particles.

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# Keynote Lecture

## S10 - 402

## Layer Multiplying Co-extrusion of Filled Polymer Composites

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Recent work in the area of multi-layer co-extrusion has led to the creation of multi-layer structures of highly filled polymer composites. Glass and polymer microspheres of particle sizes around 5-7 microns were examined in multi-layer co-extrusion via the layer multiplication technique. The glass microspheres were utilized as a model system to examine the capabilities and limitations of the processing technique to achieve high numbers of thin layers when utilizing high filler loading levels in particular the stability during co-extrusion. Cross-linked polymer microspheres of varying particle rigidities were utilized to examine particles in confinement in layer multiplication. Mechanical properties were increased to greater than that of control unfilled layered polymer sheets with 20 vol% cross-linked polymer particles.

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## Keynote Lecture

## S11 - 329

# Recipe Development and Cast Film Extrusion of PVDF/Carbon Nanotube/Carbon Black Composites for the Application in Bipolar Batteries

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For the intended application of replacing aluminum foil current collectors in bipolar lithium-ion battery applications, thin and dense electrically conductive polymer composite films were developed. Poly(vinylidene fluoride) (PVDF) was chosen as the matrix polymer and composites with fillers of different aspect ratios (carbon nanotubes (CNTs), carbon black (CB)) and their mixtures were produced by melt mixing. The focus was on the electrical conductivity of the materials. The processing-related orientation of CNTs with a high aspect ratio leads to direction-dependent electrical properties. The differences between the directions could be reduced by using the hybrid filler system. For selected suitable combinations, the melt mixing was upscaled from small scale to laboratory scale. In particular, the combination of CB and CNTs in PVDF increased the electrical conductivity through the film compared to PVDF/CNT composites due to additional contact points in the sample thickness [1]. The orientation of the fillers in the two directions within the films was deduced from the differences in the electrical properties, which showed higher values in the extrusion direction than perpendicular to it [2]. Films down to a thickness of 50 micrometers were produced from extruded materials with 1 wt.% CNT and 3 wt.% CB on a laboratory cast-film extrusion line by varying the processing parameters such as melt temperature and take-off velocity. For extruded films with a thickness of 65 micrometers and a width of 22 cm, electrical volume conductivities of 130 S/m in the direction of extrusion, 39 S/m transverse to the extrusion direction and 4.9 S/m through the film were achieved. The films proved to be suitable for this application and also have the advantage of 50 % lower density than aluminum [3].

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# Keynote Lecture

## S19 - 29

# Multiscale Structural Characterization of Biocompatible Poly(trimethylene carbonate) Photoreticulated Networks – From Conception to Mechanical Behavior

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Photo-cross-linked biodegradable polymer networks are highly interesting materials for use in biomedical applications compared to current alternatives (PCL, PLA, chitosan), since a wider range of physical and mechanical properties, crosslinking densities, and degradation characteristics can be obtained. In this work we consider Poly(trimethylene carbonate) (PTMC), a biodegradable, biocompatible, amorphous, and flexible polymer. By photo-cross-linking PTMC macromers, tough, tear-resistant networks can be obtained. Thus, PTMC networks have been investigated for applications such as meniscus and bone implants, and microvascular networks. The application of PTMC networks depends largely on their mechanical behavior which depends on the network morphology. For these materials, these structure-property relationships have been successfully investigated by combining macroscopic tensile and Dynamic Mechanical Analyses (DMA) mechanical characterizations with calorimetric (DSC) measurements, and in particular molecular-scale Time-Domain Double-Quantum (DQ) 1H NMR analyses. Firstly, PTMC networks with macromer molecular weights between 3 and 40 kg/mol, were studied. A linear correlation between the crosslink density measured by DMA and NMR was observed, prompting the conclusion that the macroscopic mechanical behavior of crosslinked PTMCs is directly linked to their intrinsic network structure. Then PTMC networks obtained by solvent casting were studied. Networks from macromers with molecular weights of 3, 18 and 32 kg/mol were prepared with various solvent contents. It was shown that when the solvent content increases, the crosslink density measured by DMA and NMR decreases. Moreover, for the PTMC with a molecular weight of 18 kg/mol, its mechanical toughening behavior was greatly increased without damaging its Young's modulus when the solvent content increased, attributed to a synergetic effect of free and dangling chains. These results allow a better understanding of PTMC and the tailoring of their properties to enhance their use in biocompatible applications, achieved by combining macroscopic techniques with solid-state NMR through a robust scientific approach.

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# Keynote Lecture

## S01 - 4

# Eliminating non-negativity constraint from Tomographic Volumetric 3D Printing by a novel a binary photoinhibitory system

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Tomographic volumetric printing (TVP) is an emerging additive manufacturing (AM) technique inspired by reversed computed tomography (CT). The main difference of TVP compared with the traditional layer-by-layer additive manufacturing is that in TVP process the entire three-dimensional object is simultaneously solidified from the pool of liquid photopolymer by dynamic light patterns from multiple angles. The key advantage of the TVP project is the printing time is not dependent on the number of voxels in the part making the process extremely fast and truly intrinsically 3D manufacturing process. TVP eliminates the layering of the material, eliminate the need of support structures, provides extremely smooth surface finish and is even capable of modulating internal properties within the same structures. However, a fundamental limitation to this fascinating technology is the non-negativity constraint means the light engines are unable to deliver the information carried by the negative values in a tomogram. To solve this issue, we introduce binary photoinhibition to create a stationary state with controllable stability for every individual voxel. We employ a second light engine to deliver the information carried by negativities. We could implement the BPS system in TVP with the development of dual color tomographic vat photopolymerization (DCTVP) setup and by employing an orthogonal chemistry in the used resins. We demonstrate that removing the non-negativity constraint increases print accuracy, prolongs process window, makes the process more controllable, accelerates printing and enhances property modulation with the use of the oxygen–lophyl radical pair in free radical polymerization.

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# Keynote Lecture

## S07 - 146

## Braided Composite System with Haptic Feedback for Teleoperation

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When performing teleoperation tasks under unpredictable conditions, relying solely on visual feedback is not sufficient. Therefore, the presence of haptic feedback becomes crucial, allowing humans to control a robot effectively and instinctively while providing an immersive experience.[1][2] Since hands play an essential role on perception tasks, haptic gloves are among the most relevant types of haptic devices.[3] In this work, we present a pneumatic-driven soft robotic actuator capable of providing haptic feedback to the fingers using a new fabrication process involving braided composites. The utilization of braided composites allows for the customization of mechanical properties, and it preserves the much-needed attributes of flexibility, foldability, and impermeability to air. Through the manipulation of the braiding angle, we fabricate multiple devices, focusing on both mechanical properties and their effectiveness in transmitting haptic sensations to the user's finger. The resulting haptic device is designed to be flexible, lightweight, and wearable, offering a comfortable user experience. The pneumatic subsystem exhibits anisotropic properties, achieving desired inflation time scales and a duty cycle range response spanning from 20% to 100%.

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## Keynote Lecture

### S11 - 203

# Tailoring the Hierarchical Self-Assembly in Bioinspired Halloysite Nanotubes/Glass Fiber Hybrid Composites

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Living organisms are masters of creating high-performance materials from limited resources, often surpassing the properties of their constituent components. This is due to their hierarchical structure, which spans from molecular to macroscale assemblies. Inspired by nature's strength and toughness, we have developed technology that mimics these natural structures. Our approach involves engineering bio-inspired composites using Halloysite Nanotubes (HNTs) and Glass Fibers (GF) within a polypropylene matrix. HNTs are bioderived, naturally formed tubular aluminosilicates that possess high aspect ratios, easy dispersion, solvent stability, low cost, and abundance. They naturally self-assemble onto the aminosilane modified GFs, creating a multi-scale reinforcement through tailored interfacial chemistry. Tailoring the microstructural architecture to optimize the synergistic effect, has shown to significantly enhance the mechanical performance, industrial processability, and fire-retardancy of these hybrid composites. Specifically, our bio-inspired multi-scale hybrid composites surpasses the industrial polymer substitute for metallic structural components mechanical properties, exhibiting improvements of 42% in specific tensile strength, 56% in impact strength, and 23% in flexural strength compared to the industrial standard, while also providing an 18% weight reduction. Additionally, the material is intrinsically fire-retardant due to the HNTs, a critical feature for meeting the stringent safety standards of the transportation industry.

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## Keynote Lecture

### S19 - 33

# A Novel Foaming Technique to Develop Solvent-Free Functional open-cell PLA Scaffolds for Bone Tissue Regeneration

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The aim of this study was to develop a solvent-free polylactic acid (PLA) open-cell porous scaffold for bone tissue regeneration using compression molding and a new chemical foaming compound, that we called CFCO. This CFCO, compounded at 160°C, is composed of PLA and azodicarbonamide (ADA) as chemical foaming agent, and varying concentrations of chitosan-grafted PLA (CS-g-PLA) copolymer. Compounding temperature was deliberately chosen below the decomposition temperature of ADA to keep the CFCO active for scaffolds foaming. The CFCO was then used to create open-cell PLA/CFCO porous scaffolds. A unique feature of this approach is that during foaming, as ADA decomposes, the CS-g-PLA copolymer within the CFCO migrates to the expanding pore surfaces and adheres firmly there, which was confirmed by both SEM and confocal microscopy. The covalent bonding of CS to PLA chains ensures its immobilization on the pore surfaces, facilitating its availability for osteoblast cell binding. This strong binding contributes to an increased proliferation rate, as evidenced by the hydrolytic stability and biological characterizations of the PLA/CFCO scaffolds. After 24 hours of immersing the scaffolds in a Phosphate-buffered saline (PBS) solution, the pH variation remained minimal, ranging between 6.9 and 7.1, indicative of their high hydrolytic stability. Quantitative assessment using the MTT colorimetric assay revealed that, after five days of culture, the proliferation of osteoblast cells within the PLA/CFCO scaffold containing 6.90 wt.% of CS-g-PLA was approximately 52% higher compared to the pure PLA control sample. Additionally, there was a 26% improvement compared to scaffolds that incorporated a greater CS-g-PLA copolymer concentration (10 wt.%) dispersed within the entire PLA matrix.

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# Keynote Lecture

## S11 - 307

## Graphitized GNP: A New Carbon Material with Excellent Electrical Conductivity and Outstanding EMI Shielding

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To reduce the carbon footprint, waste carbon dioxide (greenhouse gas) has been used in the production of filler materials, recently gaining significant attention. For instance, graphite is combined with carbon dioxide on an industrial-scale ball mill to produce graphene nanoplatelets, which are extensively used to reinforce construction materials like concrete and produce water purification membranes. Despite its industrial relevance in certain applications, this material has low electrical conductivity due to long exposure inside a ball mill, which leads to the fragmentation of graphene layers. Herein, we report a facile strategy to convert the fragmented materials into a new type of carbon material, which could be considered graphite-like graphene films as our approach involves graphitization. The process requires a moderately high temperature and extremely high pressure to restack the fragmented layers constructively. Though the process includes graphitization, the obtained material is completely different from raw graphite as demonstrated by several characterization techniques. Further investigation reveals that the stacking is efficient and permanent, and the resulting material not only possesses high electrical conductivity but also shows excellent EMI shielding effectiveness, indicating that this recently developed graphitization technique could pave a new pathway to fabricate a highly electrical conducting material with outstanding EMI shielding.

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## Keynote Lecture

## S19 - 40

# Fabrication and characterization of Biobased Polyurethanes, from Cradle to Cradle

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Nowadays, the use of renewable biobased carbon feedstock from different resources, such as vegetable oils, is highly taken into consideration because it offers the intrinsic value of a reduced carbon footprint with an improved life cycle analysis, in agreement with a sustainable development. Besides, compared to conventional fossil-based materials, innovative macromolecular architectures with improved or additional properties can be obtained. In this presentation, we report decades of active research on the synthesis, characterization, and processing of several innovative and renewable polyurethanes (PUR, PIR, TPU and NIPU) (1,2), with controlled macromolecular architectures to elaborate different designs and morphologies (membranes, foams,) (3), for a large range of green applications, through several processes. These materials are synthesized from different biobased building blocks, which can be directly extracted from biomass or obtained from white biotech (fermentation,): (i) Aliphatic structures from different glycerides and derivate (dimer fatty acids,), sugar-based molecules, bacterial polyesters … (ii) Aromatic structures from lignins (4,5), tannins (6) and furans. A large range of materials with improved properties and durable applications have been developed for a greener and durable future. The end of life of these materials is also fully considered, by e.g. bio-recycling (7), from cradle to cradle.

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# Keynote Lecture

## S20 - 421

## What LCA can tell us about the impacts of microplastics

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Plastic litter is a growing environmental issue. Once plastics enter the environment, they can be transported between different environmental compartments (air, terrestrial, freshwater, and marine), through wind, rivers, or flooding events. Over time, plastics can fragment into smaller pieces, and thus the size of plastic litter in the environment ranges from macro to micro and nano scales. Plastics can affect aquatic and terrestrial species through ingestion or entanglement, and they have the potential to affect human health, for example through drinking water or ingestion of seafood containing microplastic. Environmental decision-makers are beginning to act and implement regulations that aim to reduce plastic use and waste mismanagement. In this context, it is important to assess the potential environmental benefits and trade-offs of decisions based on plastic bags or substitution initiatives, in order to prevent unintended consequences on ecosystems and/or human health. Life cycle assessment (LCA) is a tool that can assist this environmental decision-making process. LCA can assess and compare various potential environmental impacts (climate change, water use, ecotoxicity, etc.) of products over their life cycle (cradle-to-grave). In the past five years, LCA methodologies for assessing the potential impacts of plastic litter have been developed. Particularly, a methodology for assessing the potential impacts of microplastic emissions on aquatic ecosystems is already available. This methodology has been tested in five case studies within the UNEP meta-analyses on single-use supermarket food packaging and its alternatives (UNEP, 2022) and sustainable and circular textile value chains (UNEP, under review). Based on the latest research and case studies of plastics in LCA, this keynote will discuss what LCA can tell us about plastic and its impacts compared to plastic alternatives.

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## Keynote Lecture

## S01 - 64

# Multifunctional 3D-Printed Cellulosic Constructs via a Sequential Cold Chemical Vapor Polymerization Technique

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Cellulose nanofibers (CNFs), as naturally harnessed sustainable compounds, have demonstrated promising potential for developing versatile 3D-printed structures with tunable spatial arrangements. However, CNF-based constructs suffer from a set of drawbacks, low electrical conductivity, and weak elastic resilience. Here, these challenges were addressed by introducing a versatile multi-step approach titled "cold chemical vapor polymerization" (CCVP). This method starts with direct ink writing of an engineered 2,2,6,6-tetramethylpiperidine-1-oxy-oxidized (TEMPO-oxidized) CNF hydrogel, followed by impregnation with Fe3+ oxidation sites, freezing and lyophilization, and subsequent CCVP to integrate interconnected conductive pathways of poly(3,4-ethylenedioxythiophene) (PEDOT) throughout the 3D structure. This process enables the precise customizability of electrical conductivity, allowing the generation of conductive (145 S/m) and mechanically flexible (70% compressible) patterned constructs. This shape, mechanical, and electrical tunability broadens the application horizon of 3D-printed structures based on naturally occurring nanomaterials. Herein, we capitalized on the applicability of these advanced multifunctional 3D constructs in absorption-dominant shields (absorbance (A) of 0.71), and sensitive piezoresistive sensors. The introduced method paves the way for generating functional ultra-lightweight systems through green and sustainable approaches.

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## Keynote Lecture

### S07 - 401

# Functionally Graded Materials: Innovative Multilayer composites based on Poly(D,L lactide)/Bioactive Fillers fabricated by 3D Direct Pellet Printing Multi-Extrusion process

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The aim of the present work was to investigate an innovative 3D manufacturing process dealing with 3D Direct Pellet multi-Extrusion (DPPmE). Throughout this study and in comparison, with the state of the art, original functionally graded materials (FGM) were obtained with tailored properties for bone regeneration. On the one hand, a deep rheological study of poly(D,L-lactic-acid) (PDLLA) without and with bioactive model fillers was firstly carried out towards a modelling of their healing properties during 3D DPPmE. The influence of DPPE processing conditions is investigated in terms of temperature, time, and printing speed. For this, we propose a modelling of the process-induced interphase thickness between two deposited layers considering the non-isothermal polymer relaxation and accounting for the contribution of entanglement rate. Hence, considering the induced chains orientation and mobility coming from filament deposition, this model quantifies the Degree of Healing. Furthermore, the proposed model is validated by an experimental investigation using a tensile properties and lap shear results. PDLLA matrix and Bioglass S53P4 (BG) or hydroxyapatite (HA) bioactive fillers were chosen to obtain hybrid FGM in comparison to composite references. Different compositions and shape factors (from microspheres to fibers) of fillers were used to reach and tune the desired gradient of properties. PDLLA matrix degradation during DPPmE process was reduced. Interestingly, good interfaces and adhesion properties were obtained. Subsequently, SEM observation, SEC and tomography measurements corroborate the present findings. Besides, tensile as well as thermomechanical properties showed the potential of the DPPmE process to fabricate FGM composites with tailored architectures with this original 3D multi-extrusion printing for orthopedic applications.

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## Keynote Lecture

### S19 - 403

# Biochar, production, and use: a detailed review of the Art

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A detailed description of the technologies and processes for obtaining biochar and its formation from the fundamental structures of aromatic groups is presented. Those aromatic groups come from biomass pyrolysis; therefore, the complex relationship between biochar structural characteristics and the reactions involved in its formation during the pyrolysis process are explored in this lecture, specifically: analysis of the generation of a cross-linked network, structural features, and the impact of free radicals on biochar formation. The journey will culminate with an analysis of microwave absorption and heat transfer dynamics among microwave-absorbent materials and biomass or plastic particles. This examination aims to understand the temperature profiles in various heating modes, providing insights into their impacts on the overall performance of microwave-assisted reactors dedicated to these processes. Through this narrative, this talk intends to provide an understanding of the multifaceted world of biochar and its diverse applications, drawing meaningful connections between its formation, structural attributes, and practical implementations.

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# Keynote Lecture

## S20 - 450

## How much virgin fuel displacement can a complimentary recycling cascade achieve?

**Ragaert Kim**(1)*
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Whereas society is in agreement that plastic waste should be as much and as high-quality as possible, there is much less agreement on the "how". While mechanical recycling continues to dominate in industrial practice, many different new technologies have emerged, each of them often claiming to be the silver bullet that will resolve our issues. What is less clear, is the realistic role such technologies could play in a complimentary cascade of plastics recycling. This lecture will discuss a complimentary recycling cascade, which proposes different recycling technologies per incoming polymer type. The cascade is based on suitability of polymer types for each technology, expected yields and expected quality. It is matched with an assessment on cost and energy use. From this, we will have a look at what this could mean in effective displacement of virgin fuels.

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## Keynote Lecture

### S04 - 446

# Co-injection and foam injection molding as enablers for sustainability

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The efficient use and recycling of plastics play a major role towards a sustainable development of the industry. Special injection molding technologies for thermoplastic materials provide a promising route by offering lightweight design and integration of recycled plastics without compromising on performance and aesthetics. For this purpose, the advantageous combination of co-injection and foam injection molding will be presented. A high potential for lightweight construction is achieved through a foamed core and compact skin layers. Co-injection molding furthermore minimizes surface defects and leads to haptic surfaces. Moreover, recycled material can be used as core material without compromising on mechanical performance and surface quality. In our study, thermoplastic elastomer based on SEBS will be used as skin compo-nent and polypro-pylene as core component. As key properties for the uniform distribution of skin and core components, the rheological prop-erties of the skin as well as core component and the solidifi-cation process will be investigated. Results are validated by mechanical as well as microstructure analysis and supported by melt flow simulation. Finally, the transfer to larger scale parts is demonstrated, leading to significant savings in carbon footprint (minus 30 %) and weight (minus 50 %) of the selected showpiece.

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## Keynote Lecture

### S11 - 273

# Smart Hybrids with Multi-scale Architecture and Surface Engineering Enabled by Nanocoatings

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In nature, some marine organisms, such as Cephalopods, have evolved to possess camouflage traits by dynamically and reversibly altering their transparency, fluorescence, and coloration via muscle-controlled surface structures and morphologies. To mimic these display tactics, we designed a series of scalable, simple, and low-cost nanocoating/elastomer hybrids, which exhibit similar deformation-controlled surfaces to realize various mechanochromisms, including transparency change mechanochromism, luminescent mechanochromism, color alteration mechanochromism, and encryption mechanochromism. Based on similar elastomer-based composites, a series of moisture and/or laser responsive wrinkle dynamics inspired by human skin featuring different reversibilities and stabilities were also designed and fabricated. These unique responsive dynamics resulted in the invention of a series of responsive materials triggered by moisture and/or laser, whose response can be either reversible or irreversible by tailoring the dimension, morphology, and/or composition of the hybrid structure. The above multifunctional biomimetic elastomer-based composites are promising for applications in smart windows, dynamic optical switches, encryption, anti-counterfeit tabs, water indicators, etc.

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## Keynote Lecture

## S16 - 310

# Study on the regulation of porous structure of ultra-thin ultra- high molecule weight polyethylene separation membranes through biaxial stretching

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Membrane separation is an important way to solve the problem of water scarcity. The simultaneous enhancement of permeability and selectivity in membrane separation is a great challenge. Bimodal porous structure with large pores connected by small pores, large pores provide high separation efficiency and small pores ensure selectivity. The width and length of the elongated pores also correspond to high rejection rates and high permeability, respectively. A novel bimodal porous structure with uniform small pores on the surface and a unique laminated large pore structure in the thickness direction was successfully constructed in ultrahigh-molecular-weight polyethylene (UHMWPE) membranes by biaxial stretching of gel membranes. UHMWPE gel membranes based on biaxial stretching with reduced membrane thickness and increased homogeneity of the molecular chain network. The membrane with 256 times biaxial stretching reduced thickness to 0.91 μm, increased permeability to 2008.2 L/ (m2 h bar), achieved 98.9% rejection of 40-600 nm particles, increased strength to 237 MPa, and provided long-term serviceability. Based on biaxial stretching, further constrained uniaxial stretching making molecule chains oriented, and obtained elongated porous structure. Further constrained uniaxial stretching based on biaxial stretching to orient the molecular chains can lead to elongated porous structures. At a total stretching ratio of 144 times, the pore size of the porous membrane with only biaxial stretching (12-12) is 0.098 μm, while that of the porous membrane with biaxial stretching (4-4) and further constrained uniaxial stretching (1-9) is 0.048 μm. The separation accuracy and stability of the porous membrane improve distinctly, ascribing that the small pore size can reject small particles and prevent the particles from entering the membrane. This study provides one novel strategy to regulate the porous structure of porous polymer membranes for improving the separation efficiency.

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## Keynote Lecture

## S20 - 15

# Unlocking the Potential of Recycled Polypropylene in Food Packaging

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In the Pack2theLoop project, Austrian household waste polypropylene (PP) packaging was examined for potential reuse in yogurt cup food packaging. This involved assessing reprocessing parameters like cold and hot washing, flake sorting, and multiple processing with various additives to understand changes in the material's properties. Initial analysis comparing cold and hot washing revealed a significant variability in the colored rPP-stream, posing challenges in comparing washing processes. Based on these findings and considering hot washing is the industry standard for PET [1], and that previous studies [2] demonstrated a reduction in off-odor in polyolefins, further characterizations were performed with hot-washed, color-sorted, and decontaminated rPP granules. GC/MS screening of extracts, odor analysis, and biological assessments yielded promising results. The odor discrepancy with virgin material was minimal, with no DNA-reactive effects, and no unusual contaminations were detected. Tensile tests indicated good mechanical properties but a decrease after five cycles (ε-60%, E-20% and σ-6%). Although rheological assessments revealed a viscosity insufficient for film extrusion and thermoforming cup manufacturing, the industrial study affirms that a high melt flow rate of 17 g/10min presents no issues up to 100% rPP. Processability is excellent, requiring only minor adjustments. While top load analyses up to 70% rPP meet the specifications, color and weight limits are already reached at 30% rPP. The cup dimensions are within limits, but with a notable fluctuation of the data. Furthermore, macroscopic impurities in the cups underscore the need for heightened filtration during the decontamination step. Ongoing research involves exploring vacuum conditions during extrusion and utilizing inline Raman and NIR sensors to analyze material decontamination and properties as well as degradation products, addressing challenges in recycling polyolefins.

[1] doi:10.1016/j.resconrec.2020.105143
[2] doi:10.1016/j.tifs.2015.12.003

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# Keynote Lecture

## S21 - 155

# Crystallization temperature as a proxy for fundamental degradation behavior of PBAT based plastic films in composting environments

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Biodegradable plastics are increasing in usage as customer expectations towards sustainability is addressed. However, their biodegradation processes/mechanisms/dynamics in real applications are still not well understood. Commonly available analytical techniques such as differential scanning calorimetry (DSC) and Fourier transform infrared (FTIR) spectroscopy can help to better understand the biodegradation kinetics of biodegradable plastics in different environments, i.e., home compost (HC), industrial compost (IC), soil. Fundamental polymer degradation, i.e., loss of molecular weight, is a challenging measurement in uncontrolled environments that requires expensive instrumentation and chemical solvents. This work presents how DSC can be linked and used to evidence fundamental plastic degradation of fully biodegradable polybutylene adipate-co-terephthalate (PBAT) based plastics in home and industrial compost settings. Significant increases in crystallization temperature, Tc, were found in degraded samples using DSC. By plotting the melt crystallization peak temperature Tc vs the inverse of the reduced viscosity 1/η, a positive monotonic relationship was observed. After normalization, the Euclidean distances between the first and last samples were calculated for both environments. The HC distances were found to be 7%, 16% and 31% of the IC, similar to the HC sample's weight losses 18%, 10% and 44% for pure PBAT, ECOVIO® and weathered ECOVIO® respectively. A fundamental relationship was evidenced, suggesting that crystallization temperature during cooling could be used to track plastic disintegration. A new empirical degradation proxy based only on Tc, for the most degraded samples in HC and IC computed values of 0.08 and 0.91 for PBAT, 0.11 and 0.70 for ECOVIO® and 0.22 and 0.80 for weathered ECOVIO®, for HC and IC respectively. This proxy is based on fundamental properties and appears to correlate to PBAT degradation.

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# Keynote Lecture

## S02 - 294

# Improving the thickness gradient in thermoformed parts by using sheets with non-uniform thickness

**Pequeneza Leonor(1), Duarte Fernando(1), Covas Jose Antonio(1)**
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Abstract: In thermoforming, a previously extruded thermoplastic sheet is heated above its softening temperature and forced against the contours of a female or male mold through the application of pressure or vacuum, with the eventual support of a mechanical load. Since portions of the sheet will contact distinct regions of the mold surface at different times, local deformations will develop, and the final part will exhibit a thicknesses distribution. The thermoforming technique, the operating conditions and the part geometry will influence the resulting deformation pattern, which, in turn, will affect the part's performance under service conditions. Although optimal performance does not necessarily require a part with uniform thickness, it is important to develop practical strategies towards controlling the thickness distribution of thermoformed parts. This work presents and discusses the feasibility of combining thermoforming with other manufacturing technologies. Specifically, sheets with a predefined thickness distribution are produced either by removing material by CO2 ablation, and/or adding an over-thickness by additive manufacturing (material extrusion), to conventionally extruded sheets, followed by thermoforming. Simple case studies are used to demonstrate that either route can yield the desired thickness gradient in the part, if the appropriate thick-ness non-uniformity is produced in the initial sheet.

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## Keynote Lecture

### S04 - 18

# Modeling of polymer processing of thermoplastic polymers: application to the injection molding process

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In the transformation operations of polymeric materials, there is a complex interplay between transport phenomena and crystallization. In particular: the polymer in the molten state is a viscoelastic fluid with rheological parameters depending on temperature, pressure, crystallinity, and molecular stretch. The molecular stretch is a tensor variable with values determined by the history of the flow, temperature, and pressure fields. During polymer processing operations, several phenomena proceed simultaneously by interacting with each other. The combination and interplay of the models that describe each of the phenomena mentioned above provides the evolution of all the relevant quantities and therefore also the overall model that describes the evolution of the solidification which, generally, proceeds starting from the walls (where the temperature is lower and furthermore the shear is higher). In this work, an overall model of the behavior of an isotactic polypropylene during the injection molding process is presented, the model includes the kinetics of spherulitic and fibrillar crystallization and their dependence upon the level of molecular stretch; the modeling is carried out up to the prediction of molecular stretch and morphology distributions along the molded part thickness. The model predictions satisfactorily describe the evolution of temperature and pressure during the process and the fundamental aspects of the morphology distribution inside the part.

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# Keynote Lecture

## S11 - 425

# Field Assisted "Z" orientation of Nanophases to Produce Thickness Functionalized Films for Flexible Electronics using a New Roll to Roll manufacturing Platform

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Electric1,2, Magnetic3, and Thermal gradient5,6 fields are three important methods used in Field Assisted Self Assembly (FASA) of polymer blends, block copolymers, liquid crystals, and polymer nanocomposites. These assisted assembly techniques have been used in laboratory scale, but for potential applications such as flexible electronics7, membranes8, supercapacitors, fuel cells, photovoltaics', etc. a large-scale manufacturing platform is needed. We introduce a novel roll to roll process developed in our laboratories to achieve "Z-direction" alignment of nanostructural units. A 40ft line was designed which uses a casting system to deposit desired thickness of liquid such as a monomer, polymer solution as well as melt up to 6" wide on a flexible substrate. The substrate is then carried to an electric field application zone which consists of temperature controlled opposing roll to roll electrodes. The electric field applied can be a DC, AC, or a biased AC, hence using the various fields we can maximize the orientation by increasing the dielectric contrast between the particles and the matrix. If orientation and self-assembly through magnetic field is desired, the second tool located downstream is activated. This electromagnet can apply magnetic fields up to 2.2 T to the material supported by a flexible substrate through the opposing poles. This line also contains a movable UV lamp which can be used to freeze the structure of required morphology using photocurable resin after electric field or magnetic field application zones. Electric and magnetic field alignment of particles and polymer chains is studied through real time birefringence measurement, to determine various parameters effecting the orientation of particles/phases inside a polymeric film under the magnetic or electric field. The birefringence system is based on the solution drying process developed in our lab9. In this talk, we will review our recent results on the use of this machine to produce Z-( thickness direction) functional films for wound dressing with directional swelling, piezoelectric sensors, nanogenerators and transparent audio speakers10, and piezoresistive 11,12 films.

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## Keynote Lecture

### S16 - 349

# Correlative studies of temperature-controlled structures and morphologies in polylactic acid

**<u>Boldt Regine</u>(1)*, Meinig Laura(1), Euchler Eric(1), Sambale Anna Katharina(1), Uhlig Kai(1), Schwartzkopf Matthias(2), Stommel Markus(3)**
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PLA, or polylactic acid, is indeed a commonly used biopolymer with various applications. It is often used in food packaging as films and in agriculture as mulch films, in medicine as implants or suture material. To ensure that PLA meets specific requirements for different applications, it is crucial to understand how its properties are determined by its structures and morphologies and how these structures and morphologies can be influenced by process parameters. In this particular study, the focus was on investigating the formation of crystalline structures and morphologies at different temperatures. It is known that PLA can crystallize in two different modifications depending on the temperature: (i) the metastable α'-phase and (ii) the thermodynamically stable α-phase. Using a newly developed experimental set-up, we monitored the formation of the different phases by means of in situ X-ray scattering experiments. PLA was heated to melt and then cooled to different temperatures. During the cooling process and subsequent isothermal crystallization, the formation of crystalline structures was observed by synchrotron X-ray scattering. Microscopic examinations of the solidified samples revealed distinct variations in morphology. In analogy to the scattering experiments, hot stage experiments were carried out on the light microscope with the same temperature profiles that were used for the X-ray scattering experiments. The formation of crystalline superstructures was recorded as a function of time and temperature. Following the hot stage experiment, the crystal modifications were determined using X-ray diffraction. As a result, we can correlate crystal growth with crystal modification as a function of time and temperature. The set-up used here for PLA is a very useful tool for investigating in situ crystallization processes of other polymers.

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## Keynote Lecture

### S20 - 100

# Recyclates for sustainable food contact-method development for the validation of plasma-induced barriers

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Ideological changes of industrial approaches set a higher demand of ecological thinking. Regarding plastics the integration of plastic waste into circular economy is from urgent need alongside the design and development of sustainable alternatives. The primary objective of a recycling process is to ensure a consistent quality of recycled plastics that matches the original product. The assessment and prevention of safety and potential hazards of possible contaminants in recycling streams, recycling processes and recycling technologies are specified by regional authorities and regulations. Especially for food packaging the set specific limits regarding migrating substances are challenging to achieve through recycling. Since food packaging's inherit the largest plastic global share alternative approaches for the valorization of recyclates as food contact materials need to be carried out. One possible way to achieve this goal is a barrier development via plasma enhanced chemical vapor deposition to potentially prevent migration of contamination and enable the application field as food contact materials. To efficiently evaluate migrations and barrier efficiencies, a novel contamination approach for virgin materials is introduced. Through achieving higher concentrations inside a virgin polypropylene matrix, the analysis approaches are simplified. Further, an analysis chain regarding migration evaluation via gas chromatography coupled mass spectrometry and barrier developments are conducted.

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# Abstracts of PPS – 39

## Abstracts of Oral Presentations

# S01 – Additive Manufacturing (3D Printing)

## S01 - 107

## Fully bio-based short fiber composites for material extrusion additive manufacturing

**Gonzalez-Gutierrez Joamin(1)*, Naik Mahesh Anil(1), Huber Tim(1), Westermann Stephan(1)**
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Lightweight in the mobility industry is crucial for greater vehicle efficiency, regardless of the power train used. One way to reduce weight is to use composite materials, but traditional composite materials are not easy to recycle and are derived from fossil fuels. Further, lightweight can be achieved by designing complex structures manufactured only by additive manufacturing methods. An additional functionality of natural fibers is their vibration damping capabilities, which can be helpful in mobility applications. Therefore, new research is needed to develop new composite materials derived from bio-based sources that can be processed by additive manufacturing and easily recycled. Polylactic acid (PLA) was selected as a matrix, and short flax fiber was used as a reinforcing agent to create a fully bio-based composite. Virgin PLA was used, while the fibers were obtained from offcuts of thermoplastic prepregs consisting of PLA/flax yarns. The fiber content varied in different formulations, and the composites were prepared using a micro-compounder. The thermal properties were evaluated by thermogravimetric analysis and differential scanning calorimetry to check their thermal stability and processing temperatures. The mechanical properties were evaluated in tension and by performing dynamic mechanical analysis to check their damping capabilities. Finally, 3D printing trials were performed using a filament-based material extrusion machine. Based on this analysis the most suitable composite for the mobility industry were selected.

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# S01 – Additive Manufacturing (3D Printing)

## S01 - 114

## Impact of Processing Parameters on the Mechanical and Self-Healing Behavior of a 3D Printable Thermoplastic/Thermoset Polymer Blend

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Self-healing polymers (SHPs) are biologically inspired, stimuli responsive materials capable of mending mechanical damage. In this work, a photo-curable SHP based on 2-phenoxyethyl acrylate (POEA) and 1,6-hexanediol dimethacrylate (HDDMA) blended with linear thermoplastic Polycaprolactone (PCL) as a healing agent was prepared. Upon heating of this two-phase system, the difference in specific volume of the thermoplastic healing agent compared to the matrix allows for flow into cracks, partially recovering the mechanical properties. Here we investigate the role that MSLA 3D printing parameters (i.e. layer height and temperature) have on the thermal, mechanical, and self-healing behavior of 3D printed specimens. Prior to 3D printing (3DP), the resin system is homogenous, but phase-separates upon curing; this polymerization induced phase separation (PIPS) was observed through photo-DSC, DSC, and optical microscopy. The addition of PCL led to an increase in stiffness and tensile strength while maintaining its ability to elongate, ultimately increasing its toughness. Self-healing was also found to scale with PCL concentration: for example, the 20wt% PCL blend printed at 20°C exhibited >90% healing efficiency based on toughness. Mechanical testing of samples printed at various layer heights exhibited little change in mechanical properties while showing an increase in self-healing performance as layer height increased. Early testing of 20wt% PCL specimens 3DP at elevated temperature exhibited an increase in mechanical properties; in fact, healed tensile bars printed at elevated temperature exhibit comparable or greater mechanical properties to that of room temperature printed, pristine tensile bars. Further development of the understanding of the relationship between 3DP processing, material composition, and material properties of these types of self-healing materials will enable highly engineered materials for a wide range of applications.

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# S01 – Additive Manufacturing (3D Printing)

## S01 - 116

## Characterization and 3D printing of PLA/PBAT blends compatibilized with epoxidized canola oil

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Poly (lactic acid) (PLA) stands as a widely used biodegradable thermoplastic polymer in material-extrusion 3D printing. However, PLA encounters several limitations, such as inherent brittleness, inadequate toughness, low crystallization rate, and undesired warpage and shrinkage during the printing process. Various plasticizers and compatibilizers have been employed to address the constraints of PLA, yet most of these additives are not environmentally friendly. In this study, we combine the elastic characteristics of poly(butylene adipate-co-terephthalate) (PBAT) with the compatibilizing properties of epoxidized canola oil (ECO) to obtain environmentally friendly formulations having improved thermomechanical properties and printability. We prepared a set of PLA/PBAT blends with and without ECO, containing PBAT concentrations of 20, 30, and 40 wt%, by melt-compounding and we investigated their processing using MEX 3D printing. The morphology, mechanical properties, crystallization behaviour and rheological properties of these blends were investigated. The results indicate that the incorporation of ECO into the PLA/PBAT blends led to improved dispersion of the PBAT particles within the PLA matrix, resulting in improved impact strength, elongation at break, and crystallinity of PLA. Also, the effect of ECO on the interface between the printed strands was examined by Scanning Electron Microscopy, and the analysis showed that the addition of ECO facilitated the printability, and the interlayer adhesion. Furthermore, the introduction of ECO led to pronounced improvements in interlayer adhesion and smoother deposition of the extruded strands, resulting in a substantial reduction in void size between the neighboring layers. We anticipate that the results presented here could pave the way for increasing the volume of PLA used in 3D printing applications, where improved toughness and ductility are required.

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# S01 – Additive Manufacturing (3D Printing)

## S01 - 130

## Bio-Based Backbone for Highly Reactive Metal Alloys Feedstocks for MEX

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The material extrusion (MEX) process for metal parts has gained considerable prominence owing to its cost-effectiveness. The metal MEX comprises 4 basic stages: mixing, shaping, debinding, and sintering. In the first step, metal powders are mixed with a suitable binder system that encompasses diverse polymers to the so-called feedstock. The binder system exerts a substantial influence on both the quality of the feedstock and the final properties of the fabricated parts. Aluminum (Al) and its alloys present an intriguing prospect for the production of lightweight components. However, the MEX of Al poses significant challenges due to the low sintering temperature close to the temperature range of thermal degradation of many polymers, and specific feedstock requirements such as flexibility. It is widely acknowledged that a complete removal of binder constituents (debinding) before sintering is imperative to prevent the occurrence of mechanical defects such as cracks in the final product. Additionally, incomplete debinding can lead to high levels of oxygen and carbon, thereby diminishing the mechanical performance. A further complication is the presence of a stable oxide layer on the powder particles. Consequently, characteristics of the binder system, including thermal and rheological behaviors, assume a critical role in each stage and necessitate thorough investigation. By considering all the above-mentioned requirements, compatible, suitable and - moreover - biobased feedstocks for Al alloys were developed. The printability of the feedstocks was investigated by printing complex geometries. The printed parts were debinded by a solvent debinding step and a thermal debinding step. The following results will be presented: 1) Rheological behavior of the feedstock 2) Solvent debinding behavior with emphasis on the selection of solvents 3) Printing performance 4) Investigation of thermal debinding/sintering regimes by FTIR-based In Situ Process Gas Analysis 5) Optimized thermal treatment strategies

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# S01 – Additive Manufacturing (3D Printing)

## S01 - 145

## Multimaterial Printing of Thermoplastics in Combination with Fully Compounded Thermoset Elastomers

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Printing of fully compounded thermoset elastomers alongside thermoplastics presents significant challenges due to the contrasting processing conditions required for each material. Overcoming the inherent difficulties associated with printing rubber further amplifies these challenges[1]. Merging the characteristics of such different materials through 3D printing offers unique advantages of combining rigid and flexible materials, as well as the ability to manufacture complex geometries with rapid design changes. This fusion becomes especially pertinent in applications where high temperatures or chemical exposures are prevalent, scenarios where the inherent properties of rubber-like materials, such as thermoplastic elastomers (TPE), are insufficient.[2] In this work, we study the printing of fully compounded elastomers using a unique printer designed specifically for thermoplastics in combination with fully compounded rubber that has fillers (e.g., carbon black) and chosen cure packages (e.g., sulfur). Results of the bond strength between selected thermosets and thermoplastics during 3D printing are presented, studying the parameters influencing the adhesion.

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# S01 – Additive Manufacturing (3D Printing)

## S01 - 150

## Electromagnetic Interference Shielding Aerogels based on 3D Printed Cellulosic Inks

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The integration of advanced 3D printing technology with gel processing has opened up new possibilities for creating lightweight, functional materials suitable for a wide range of uses. Despite this progress, there are notable challenges in using 3D printing, specifically direct ink writing, to produce electrically conductive, biobased aerogels. These challenges include limited electrical conductivity, weak mechanical strength, and less precise printing resolution. This study tackles these issues by employing molecular engineering to develop conductive hydrogels. The hydrogel inks used, specifically CNC/PEDOT-DBSA, feature a novel composition that combines cellulose nanocrystals with a poly(3,4-ethylene dioxythiophene) (PEDOT) coating and dodecylbenzene sulfonic acid (DBSA). By adjusting the solid content and the interactions between components, the rheological properties of these inks were finely tuned, leading to 3D-printed structures with superior resolution. Remarkably, the aerogels produced after freeze-drying displayed exceptional qualities, including high electrical conductivity (110 ± 12 S m–1), high mechanical strength (Young's modulus of 6.98 MPa), and fire resistance. These durable aerogels have been utilized to combat global issues like electromagnetic pollution, achieving a notable shielding effectiveness of 4983.4 dB cm2 g–1. A key finding of this work is the ability to alter the aerogels' electromagnetic shielding through their geometric design, highlighting the crucial role of additive manufacturing in material development.

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# S01 – Additive Manufacturing (3D Printing)

## S01 - 158

## 3D printing of syntactic thermoset foams via frontal polymerization

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Polymer foams are widely used in many industrial applications due to their good combination of low density, specific mechanical properties, acoustic properties, and thermal insulation. Polymer foams are typically manufactured through conventional methods such as in-situ formation of bubbles using foaming agents, templating, mechanical frothing, and decompression of liquid polymer resins containing dissolved gasses. These methods involve bulk processing of materials using dies or sealed mold to define the form of the produced parts. These constrains limit the design of final products to basic shapes with minimal internal attributes or features. Moreover, such methods require post-processing of the final part, resulting in significant material loss and additional costs. Additive manufacturing (AM) is promising for flexible design and creation of complex foam products with desired properties; however, AM of thermoset foams are challenging as it requires rapid, local curing of the uncured thermoset resin after deposition from a printing nozzle. Here, we present a novel AM approach by integrating frontal polymerization (FP) of thermoset resins with direct ink writing (DIW) technique to enable rapid, energy-efficient, and high-fidelity 3D printing of thermosetting foams. Incorporation of hollow particles into a frontally polymerizable resin ink allows for controllable creation of pore volumes in the material. Use of such inks in the printing process enables in-situ curing of the thermosetting material following the deposition from a printing nozzle via a controlled, self-sustaining frontal polymerization reaction. We first discuss the effect of particles on the frontal properties of the resin as well as the properties of produced foams. The processing science of the AM process using the developed inks are then presented to elucidate the effect of key process parameters on the quality of produced foams.

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# S01 – Additive Manufacturing (3D Printing)

## S01 - 164

## 3D printing of food gels: A novel vegetable-based bio-ink

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Water based solutions of κ-Carrageenan/Konjac glucomannan, were proposed as a new 3D food printing ink. In this study the material is printed by controlling the thermally reversible sol/gel transition taking place during the process. A careful rotational rheometry characterization of the mixtures across the gelation stage has been carried out, since the material rheological response is the crucial factor affecting the printing performance. Moreover, direct pressure and flow rate measurements in the 3D printer have been used to obtain the viscosity vs. shear rate curves under processing conditions. The data obtained were also useful to validate a scaling law relating the printing filament diameter to the relevant process and material properties. the 3D printing performance of inks of different composition under different processing conditions has been evaluated by means of a novel score systems, which allows for the optimization of the printing in terms of both processing conditions and material formulation. This work is funded by the European Union – Next Generation EU.

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# S01 – Additive Manufacturing (3D Printing)

## S01 - 191

## Enhancing Biofabrication with Magnetic Fields: Advancing 3D Bioprinting through Multiphysics Simulations

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The urgency to diminish animal testing has spurred the pursuit of advanced technologies replicating physiological conditions, surpassing traditional experimental models. Notably, 3D bioprinting, especially with cell spheroids, promises to create intricate tissue models mimicking complex physiological features. However, a major challenge persists effectively managing and expediting the maturation process of these bioprinted tissues. This study addresses this challenge by introducing a pioneering mathematical model and exploring magnetic fields' potential in transforming 3D bioprinting. Using COMSOL Multiphysics 6.1®, we developed a multiphysics stochastic phase field model based on principles from differential adhesion theory. Our focus centered on analyzing fusion parameters within HeLa cell spheroids bioprinted using SISMA hydrogel (methacryloyl-modified decellularized small intestinal submucosa). To expedite fusion kinetics, we employed a targeted strategy involving magnetite nano-bioconjugates functionalized with the Buforin II peptide. This innovative approach precisely applied a magnetic field, catalyzing and enhancing both fusion and migration processes within the constructs. Our mathematical model demonstrated exceptional accuracy, with a mere 7% average errors. Achieving complete spheroid magnetization within a swift 20-minute timeframe using nanobioconjugates marked significant progress. Moreover, the transformative impact was evident, drastically reducing the fusion duration from a week-long process to an impressive two days. This underscores the immense potential of magnetic manipulation in revolutionizing 3D bioprinting methodologies. In summary, our study integrates sophisticated modeling and innovative magnetic field applications within bioprinting, promising accelerated and controlled tissue assembly processes using polymers. This advancement holds promise for advancing regenerative medicine and tissue engineering through bioprinting.

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# S01 – Additive Manufacturing (3D Printing)

## S01 - 205

## Advancing 3D Printing: Enhancing Speeds and Strength through Rotating Nozzle FFF Technology

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Fused Filament Fabrication (FFF) has long dominated additive manufacturing (AM) due to its cost-effectiveness, but its limitations, including slow melting rates and inferior mechanical performance, hinders its widespread adoption in high-volume production. Addressing this, we introduce a patented FFF rotating nozzle 3D printer proven to outperform conventional FFF 3D printing technologies. Fully instrumented to capture print forces, temperature, RPMs and print speeds, this technology is responsible for transforming plastic product manufacturing by facilitating the data acquisition and allowing for data-driven modeling to provide statistical insight into the most influential processing parameters. This innovative technology enhances energy efficiency, accelerates production, and improves mechanical properties of 3D printed components by introducing relative motion between the nozzle and filament. Unlike traditional FFF, this technology incorporates a rotating nozzle, proven to increase the melting speed threefold at RPMs exceeding 10,000. Preliminary trials with PEEK and PA66 demonstrate significant improvements in melting speeds and mechanical properties. Additionally, this work focuses on studying the effects of the rotating nozzle on microstructural, thermal, and mechanical properties of 3D printed components. When printing with fiber reinforced plastic filaments, the rotating nozzle deposits fibers randomly, departing from the conventional preferential orientation in the print direction. This results in a remarkable 23% improvement in ultimate tensile strength due to fiber migration across printed beads, providing reinforcement in the cross-bead direction.

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# S01 – Additive Manufacturing (3D Printing)

## S01 - 234

## Foam Additive Manufacturing

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Traditional foams production technologies are used to create quickly and cost-effectively high-strength and low-weight structures, lately there have been efforts to produce foams in Additive Manufacturing (AM), making it possible to produce free-form foamed structures. The Foam Additive Manufacturing (FAM) technology presented use a physical blowing agent (PBA), which, to foam produces foam directly in the extruder of a 3D printer. This process can work with almost any thermoplastic polymer without altering its chemical properties. Controlling in-line the printing parameters the FAM process allows the production of complex structures with variable morphology and density gradients with a simple and cost-effective method, and it is possible to increase the degrees of freedom of 3d printing. Enabling designers to fabricate complex structures with variable density from a single material not only offers a polymer lifecycle advantage but also simplifies recycling. The presented research aims to investigate the effect of process parameters on the morphology and properties of 3D printed physical foams, in terms of density, dimensions, and mechanical properties.

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# S01 – Additive Manufacturing (3D Printing)

## S01 - 280

## Interfacial bond strength of hard-soft material combinations in extrusion based additive manufacturing

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Extrusion-based Additive Manufacturing (EAM) is rapidly growing since it provides highly customizable parts with great freedom of design while being able to process a wide range of materials. The combination of two or more materials for the integration of different functionalities in one part is a common practice in injection molding. The implementation of this principle into EAM is therefore important to increase possible applications for this process. In this work, the focus is put on the achievable bond strength between hard and soft materials produced in EAM. Therefore, Peel test specimens, where a thermoplastic elastomer is printed on top of a thermoplastic substrate, are produced using Fused Filament Fabrication (FFF) and the novel Arburg Plastic Freeforming (APF) and tested to quantify the resulting bond strength regarding the type of materials selected and different process parameters. Specimens produced by injection molding are used as a benchmark. Since surface and temperature play a major role when combining polymers, an analysis of the condition of these two parameters in EAM is conducted. A demonstrator is designed and printed to showcase a possible application with the combination of hard and soft materials, using the results obtained from the tests described above.

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# S01 – Additive Manufacturing (3D Printing)

## S01 - 305

## Microstructure in Laser-Based Powder Bed Fusion of Polymers

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A common practice in conventional manufacturing processes is adjusting the morphology of the component to meet specific requirements. Studies examining the influence in laser-based powder bed fusion of polymers are scarce, if at all existents. This work first introduces possible nucleation agents and subsequently manufactures components to assess the impact of the structure for Polypropylene, alongside of the analytical investigation. It was demonstrated that the material can be processed despite significantly higher crystallization kinetics and, that the morphology of the components can be precisely tuned.

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# S01 – Additive Manufacturing (3D Printing)

## S01 - 333

## Thermoplastic olefin blends and composites with improved processability in material extrusion

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3D printing, also called material extrusion (MEX) has been proven very challenging for most thermoplastics and their composites, owing to their fast crystallization kinetics that cause warpage in the printed parts. Components prepared by 3D printing techniques rarely meet the material property standards needed for engineering applications, due to weakness in bonding between the melt-deposited filaments. Articles printed from most commodity semi-crystalline thermoplastics suffer from poor mechanical strength and impact resistance, as well as highly anisotropic material properties. In this work we investigate blending technology to promote interfacial bonding between strands and to improve the mechanical properties of the printed articles. We investigate processing of polypropylene (PP) and its blends by MEX. PP printed specimens exhibited severe warpage, and debonding of the strands under tensile deformation. Adding 20-40 wt.% of an elastomeric ethylene-octene copolymer (EOC) with PP resulted in thermoplastic olefin (TPO) blends having droplet matrix morphology. The EOC dispersed phase facilitated the material extrusion process, and reduced the degree of crystallinity of the blend, thus reducing warpage. Owing to its amorphous structure and low crystallization temperature than PP, the EOC remained in the melt state for longer time after extrusion, and thus promoted fusion between the printed strands, resulting in improved and more consistent mechanical properties. We further prepared PP and PP/EOC based composites containing graphene nanoplatelets (GNPs). The composite blends had droplet-matrix morphology at compositions as high as 40 wt% EOC, whereas the GNPs resided in the interface. Even though the PP/GNP composites exhibited severe distortion, and inadequate fusion of the strands, addition of the elastomeric EOC resulted in improved interfacial adhesion between the strands, better part consolidation and more consistent mechanical properties.

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# S01 – Additive Manufacturing (3D Printing)

## S01 - 345

## Developing polypropylene for extrusion-based 3D printing

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In the technology field of additive manufacturing, the broad property profile of polypropylene offers enormous potential and is becoming increasingly important for the manufacture of 3D-printed products. For successful industrial 3D printing of polypropylene using established extrusion-based processes such as Fused Filament Fabrication (FFF), Fused Deposition Modeling (FDM) or Fused Granular Fabrication (FGF), three critical components are essential. First, the 3D printed material should have low warpage and high interlayer bonding strength. Second, the 3D printing build surface must allow reliable 3D printing of PP parts and non-destructive and residue-free removal of the product without need of additional adhesives. Third, a support material is needed to print more complex structures with overhangs and openings. In this context, polymer materials or material formulations specifically tailored towards extrusion-based additive manufacturing are of great interest. A miniature small-scale material processing and testing approach was developed as a screening method to evaluate novel polymer materials for fused deposition modeling (FDM). This approach is suitable for a small material input of less than 10 g using a mini compounder in combination with an injection molding machine to manufacture short rods, usable as FDM feedstock. Compared to conventional continuous filament extrusion, in which typically 2 – 10 kg are required. In order to demonstrate the approach, semi-crystalline commercial grades of polypropylene and polypropylene/ethylene random copolymer (raco PP) are processed into rods and compared to commercially available filaments. Most important is the optimization to reduce warp deformation caused by shrinkage without sacrificing interlayer bonding.

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# S01 – Additive Manufacturing (3D Printing)

## S01 - 405

## Polyolefin Aerogels from Wastes: 3D Printing-Assisted Fabrication of Filter Media

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This talk presents methods of fabrication of polyolefin aerogel filter media assisted by 3D-printing. We are currently developing means for upcycling plastic waste streams into valuable filter media products for separation of airborne nanoparticles. Polyolefins are the largest class of plastic resins produced globally and present many challenges in recycling mixed waste streams consisting of high-density polyethylene (HDPE) and isotactic polypropylene (iPP). The present research develops a framework for physical upcycling of polyolefins into aerogels and examines their viability as filter media. The process involves thermos-reversible gelation of polyolefins from solutions in plant-based solvents such as orange terpenes and limonene. The issue of poor mechanical strength of polyolefin aerogels is circumvented by growing aerogels inside 3D-printed, gyroid-shaped iPP scaffolds. Such porous aerogel constructs are found useful as filter media for air and liquid-liquid separation. The meso- and macropores of aerogels contribute to filtration efficiency of 99% for 25-150 nm diameter nanoparticles suspended in air. The air filtration efficiency and permeability are correlated with internal microstructures, in-fill ratio of iPP scaffolds, and specific surface area. The mixed wastes consisting of iPP, and HDPE produce aerogel media with discotic HDPE crystalline lamella and spherulitic iPP crystals each with unique contributions to mechanical integrity, air permeability, and filtration efficiency.

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# S01 – Additive Manufacturing (3D Printing)

## S01 - 411

## Role of different ABS matrixes and processes for multifunctional ABS/CNT nanocomposites

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Fused filament fabrication (FFF) is one of the most disseminated additive manufacturing (AM) technics and seeks multifunctional materials to increase the industrial applications. Acrylonitrile-butadiene-styrene copolymer (ABS) is among the preferred polymer for FFF, and its nanocomposites with multi-wall carbon nanotubes (CNT) are excellent candidates for the production of conductive and electromagnetic functional filaments with high mechanical properties. Nevertheless, the effect of the ABS matrix characteristics, such as the melt flow index (MFI), on nanocomposites for that application is not fully understood. Thus, this work aimed to evaluate the effect of ABS with different MFI on the mechanical and electromagnetic properties of ABS/CNT nanocomposites processed by FFF. Two ABS matrix (47 - ABS MG47 (MFR of 5.6 g/10min 230°C/3.8kg) and 94 - ABS MG94 (MFR of 11.7 g/10min 230°C/3.8kg)), and CNT (Nanocyl7000®) were used to produce the filaments. The nanocomposites were prepared in a twin-screw extruder in a two-step process: first, two ABS/CNT masterbatches with 6 wt% of CNT were prepared, and then, the ABS/CNT nanocomposites with 1, 2, and 3 wt% of CNT were prepared. The filaments were produced with a diameter of 1.75 ± 0.05 mm, and the samples were molded in a 3D printer Ender 3 Pro (Creality ®) and by injection-mold. The compositions were analyzed by tensile test, Izod impact strength, EMI SE (in VNA with a rectangular waveguide for the X-bad frequency), impedance spectroscopy, and FEG-SEM. A DOE was designed considering the factor as the ABS type (47 or 94), the process (injection mold or FFF), and the CNT content (1, 2, and 3 wt%). The mechanical properties were evaluated with a statistical analysis revealing differences for the ABS 47 presented superior tensile strength, elastic modulus, and impact strength, and the FFF presented a higher impact strength for the nanocomposites. Not only the EMI SE and electrical properties were mainly correlated to the CNT content, but also with the ABS and process applied. The maximum EMI SE and electrical conductivity results of 17 dB and 10-6 S/cm were achieved for 3 wt% using ABS 47, the FFF samples of the ZX (10 dB and 10-8 S/cm) direction had higher attenuation values than (6 dB and >10-10 S/cm) for the direction XY. The FEG-SEM correlated and explained those properties from the morphological point of view.

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# S01 – Additive Manufacturing (3D Printing)

## S01 - 58

## Screw-based Material Extrusion Additive Manufacturing of Inflatables Using Ultra Soft Thermoplastic Elastomer

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Additive manufacturing (AM) of inflatables using material extrusion (MEX) is a desirable technique due to its low cost and high flexibility. Such inflatables find application in multiple fields including soft robotic actuators for automation [1]. Unlike fused filament fabrication (FFF) systems, which are limited to relatively hard thermoplastic elastomers (TPEs) [2], screw-based fused granulate fabrication (FGF) extruders can use much softer TPEs [3]. This study investigated the manufacturability of inflatables using an FGF extruder from an ultra-soft (32 shore 00) and non-silicone TPE, namely TF3ZG0-LCNT. The initial material characterization revealed that this TPE contains polyamide (PA) which led to successful build plate adhesion using Magigoo PA adhesive on a glass bed heated at 70°C. Following an extruder calibration, the optimal extruder temperature was found to be 195°C. Tensile testing along layer orientation (XY) reached around 1 MPa of stress at machine limit strain of 3500%, surpassing the Z orientation which broke at 2300% strain and 0.7 MPa stress. For the inflatability test, hexagonal and cuboid prism specimens of various wall thicknesses were manufactured. Video-image processing of the inflation tests reported a longitudinal and perimetric strain at failure greater than 700%. These inflatability results were used to develop an additively manufactured inflatable gripper which could successfully grab an object, weighting 100 g.

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# S01 – Additive Manufacturing (3D Printing)

## S01 - 69

## 3D printability criteria for the elaboration of microwaves absorbers

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The increase in the use of wireless technologies leads to a significant diversification of the application contexts of systems based on electromagnetic waves emission. The remarkable development of 3D printing by fused deposition modelling allows developing innovative formulations of composite materials dedicated to the design of microwave absorbers. This leads to complex geometries with controlled electromagnetic performances at each stage of the elaboration process (mixing, extrusion and 3D printing). In this study, we focus on composites based on neat ABS matrix or [ABS/PE] masterbatch filled with either spherical or lamellar Fe particles. Firstly, visualization of 3D printing suspended geometries, such as bridges with different bridge deck lengths, makes it possible to evaluate a minimum static yield stress under gravitational field. This threshold, determined in the solid state from bending tests on suspended structures, is related to a yield stress measured by shear rate sweep rheological tests on filament formulations in the melt state. Secondly, the ability to control electromagnetic properties by structuring this composite on the form of honeycomb is studied. In these regular hexagonal cells, porosity and electromagnetic properties can be controlled by the radius and the wall thickness of the cell. This approach provides a wide range of properties for a single material and new degrees of freedom in the design of microwave absorbers. These geometry-dependent microwave properties can be easily used to progressively change the refractive index along a direction so as to design gradient-index materials. To conclude, suitable formulations of 3D printable composites for microwave absorber applications are proposed. The investigation of filaments rheology/printed suspended structures mechanical properties relationships allows suggesting a mapping of 3D printability criteria of relevance to applications in microwave absorption.

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# S01 – Additive Manufacturing (3D Printing)

## S01 - 97

## Additive manufacturing of dynamic covalent polymer networks into self-healing soft robotic grippers

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Dynamic covalent chemistries enable reversible network polymerization to combine the (re)processability of thermoplastics with the superior properties of chemically crosslinked networks. Dissociative networks show a decrease in crosslink density upon activation of the dynamic bonds, that ultimately leads to a drastic solid-liquid transition at the critical gel conversion. This gel transition temperature and the viscoelastic behaviour depend strongly on the monomer and network architectures. The thermoreversible Diels-Alder reaction has shown great promise for extrusion of filament and printing of fully functional robotic grippers [1]. The low viscosity upon degelation offers excellent covalent fusion between the deposited layers, near perfect isotropy and almost no porosity. However, it also limits the accuracy and resolution that can be achieved. Multiple approaches have been investigated to improve the extrudability, while retaining these advantageous properties. The addition of fillers enabled to tune the rheological behaviour to extrude finer filaments for deposition of structures with higher accuracy and resolution. Electrically conductive composites were used to create self-healing sensors [2]. In contrast, associative networks do not undergo a net change in network connectivity as the temperature is raised, while the rate at which bonds exchange increases, e.g. transesterification. These associative networks require higher temperatures and pressures for reprocessing, leaving opportunities for formative methods, while not reaching the flow behavior required for additive manufacturing. Partial crosslinking using thermally dissociative and associative covalent chemistries enables tuning the dynamic character and viscoelastic behaviour of these double dynamic covalent networks for a wide range of processing and manufacturing techniques.

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# S01 – Additive Manufacturing (3D Printing)

## S01 - 332

## Additive Manufacturing of Polymer Covalent Adaptable Networks

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Selective laser sintering (SLS) is one of the mainstream 3D printing technologies, which use the laser energy to melt and fuse the powders and then stack layer by layer to form a printed part based on 3D model data. The major challenges for SLS technology is incomplete fusion, lower interlayer interaction and Z-direction strength, as well as the easily breaking in low-dimensional area. Herein, polymer covalent adaptable networks (CANs) were utilized to solve the challenge of SLS. Two types of novel cross-linked polymer elastomers, poly(bromophenol-urethane) (PBP-PU) and poly(pyrazole-urea-dimethylsiloxane) (PDMS-CANs), containing dynamic halogenated bisphenol carbamate bond and pyrazole urea bond were examined. The obtained PBP-PU and PDMS-CANs both exhibited excellent mechanical strength and self-healing efficiency, in addition to SLS processing ability. Small molecule model studies confirmed the dynamic reversible characteristics of dynamic bonds: chlorinated bisphenol carbamate dissociates into isocyanate and hydroxyl at 120 °C and reforms at 80 °C, pyrazole urea bond dissociates into isocyanate and pyrazolamine and reforms rapidly at 110 °C. SLS 3D printing using the self-made healable PBP-PU and PDMS-CANs powders was successfully realized. The interface interaction between the adjacent SLS layers can be significantly improved via dynamic chemical bond linking instead of traditional physical entanglement. The printed samples exhibited improved Z-direction strength, exhibiting nearly isotropic mechanical properties.

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# S02 – Extrusion

## S02 - 117

## Novel intrinsic extrusion process for the production of aluminum-polymer-composites

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Complex profiled semi-finished products are mass-produced in significant quantities using the metal forming process of hot extrusion for light metals and the primary forming process of extrusion for polymers. Hybrid components, combining metal and plastic offer potential for lightweight construction and increased functional integration. In comparison to pure metal solutions, these hybrid components can achieve weight savings of up to 40%, while applications such as window frame profiles or water pipes drive the motivation for producing hybrid metal-plastic profiles. Currently, the production of such hybrid profiles requires several successive production steps. The novel intrinsic co-extrusion process combines aluminum hot extrusion and polymer extrusion into a single process, resulting in a hybrid aluminum-polymer profile in a single production step. This technology facilitates the production of long profiles with a continuous cross-section. Beyond reducing the number of process steps, this approach allows for the continuous production of hybrid profiles with variable inner and outer diameters along their length through adjustments in polymer pressure. Moreover, the technology ensures an oxide-free interface between pure aluminum and polymer by eliminating atmospheric oxygen throughout the entire process.

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# S02 – Extrusion

## S02 - 177

## Improving the Layer Uniformity of Multilayered Films Produced with Interfacial Surface Generators

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Extruded films with hundreds or thousands of layers can be produced by using sequences of layer multipliers, also known as Interfacial Surface Generators (ISG), at the die inlet. Each ISG splits, stacks, and merges the inlet flow by means of various geometrical channel transformations (GT), doubling the number of layers at the outlet. The thicknesses of the individual layers generated are often non-uniform. This work deals with the numerical simulation of the flow of Newtonian polymer melts in ISG channels, aiming at investigating the influence of the ISG flow channel geometry on the resulting layer uniformity. It was found that uneven layers may form due to the development of unsymmetrical velocity profiles perpendicular to the fluid interface. Based on this data, improved ISG dies capable of producing coextruded films with uniform layer distribution are proposed and numerically evaluated.

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## S02 – Extrusion

## S02 - 202

# In Silico Process Design and Scale-up for an Amorphous Solid Dispersion Manufactured by Hot Melt Extrusion

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Hot melt extrusion (HME) is a continuous manufacturing process increasingly used as an environmentally sustainable technique to produce amorphous solid dispersions (ASDs) of poorly water soluble active pharmaceutical ingredients. A careful selection of the screw configuration and process parameters is required for achieving a stable ASD. Considering potential process setup permutations, HME requires high amounts of API than typically available in the early development stages. Additionally, significant experimental iterations are required to generate substantial process understanding for establishing controls that would apply from development to commercial scales. To address these challenges, our groups have worked on the development of in silico and experimental tools for simpler process development and scale-up. To this date, most of the HME process development and scale-up activities are performed experimentally and empirically. To enhance sustainability and the speed of rational, science-based process development, the objective of this work was to create supportive in silico tools. The fundamental idea behind HME process modeling is the breakdown and the detailed analysis of the key process aspects, among which the most prominent can be the analysis of flow patterns developed as a result of the rotation and geometry of the individual screw element pairs. In this work the process design space identified at a small scale was further studied and scaled up to the pilot and production scales using in silico tools. This was achieved by Smoothed Particle Hydrodynamics simulations and reduced order 1D HME process simulations. The 1D HME simulations guided the process setup and scale-up by providing process maps for different experimental permutations. Process understanding generated through this approach allowed rapid process scale-up, in a sustainable manner by minimizing the number of actual experiments and the API use.

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# S02 – Extrusion

## S02 - 282

## Influence of processing methods on the crack resistance of a polypropylene/recyclate blend

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In recent years, an increasing trend involves processing more recyclates and blends of virgin material with recyclates to create new products. The properties of recyclates depend on feedstock, treatment, and further processing [1]. Each additional processing step not only incurs higher costs but also subjects the material to elevated thermal and/or mechanical stress [2]. In industrial practices, pure materials are blended in a single processing step, avoiding an extra compounding process. This study explores the impact of various manufacturing methods on short-term properties and crack resistance of a polypropylene (PP) blend. Three blending methods for a PP blend were employed, utilizing 90% virgin PP and 10% PP post-consumer recyclate for all methods. The first blend (P1) underwent blending in a compounder with a twin screw and granulation. Blends P2 and P3 were mixed in a single-screw extruder and granulated. P2 underwent this process once, while P3, for better homogeneity, underwent it twice. Compression-molded sheets were produced for mechanical parameter evaluation (tensile and Charpy impact tests) and crack resistance using CRB tests. To understand rheological properties, the MFR value was determined. Due to higher thermal and shear stress from the twin screw and the second extrusion process, P1 and P3 exhibited a higher MFR value compared to P2. Manufacturing methods showed no significant influence on Young's modulus, yield stress, and impact strength of the blends. However, notched impact strength and crack resistance were notably affected. P3, exposed to high thermal and shear stresses, exhibited the lowest impact strength and reduced crack resistance compared to P2, also the compounding reduces the crack resistance significantly. In summary, the manufacturing process minimally influences short-term properties but significantly impacts the crack resistance of the blend.

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# S02 – Extrusion

## S02 - 316

## New Degassing Technology for Single Screw Extruders – Experimental Results

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This paper presents experimental results of a super degassing screw in a 45-mm highly instrumented single screw extruder at ICIPC. Two hygroscopic polymers were tested, PET and ABS. PET is susceptible to hydrolysis. As a result, it is difficult to remove moisture from PET in a single screw extruder without significant loss in intrinsic viscosity (IV). Measurements of IV were made before and after extrusion to determine the change in IV of the PET. For ABS the melt index was measured before and after extrusion. For both polymers the moisture level was measured before and after extrusion. Testing was done with and without vacuum at several screw speeds. The experimental results will be compared to typical degassing results in single screw and twin-screw extruders.

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# S02 – Extrusion

## S02 - 418

## Analytical Model of Melt Temperature Distribution in Single Screw Extruders

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Melt temperatures are not uniform in single screw extruders. There is significant melt temperature variation in each cross section of the extruder. In addition, melt temperatures vary along the length of the extruder. Prediction of melt temperature distribution typically requires computer simulation. This creates a stumbling block for those who want to do a quick analysis. In this presentation analytical expressions will be presented that allow prediction of the axial and cross-sectional melt temperature distribution. Several examples will be presented showing how melt flow properties, process conditions, and thermal properties affect melt temperatures in the extrusion process. Control of melt temperature is critical in achieving a sustainable extrusion operation

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# S02 – Extrusion

## S02 - 449

## Twin Screw Extruder Configurations to Process Bioplastics (PLA/PHA/PHB) Filled Formulations

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Twin screw extruders (TSEs) are commonly used to mix bioplastics with natural fibers and starches with other additives. Commercial twin screw extruder models used to process bioplastics includes both co-rotating intermeshing and counterrotating intermeshing modes with the process section configurations dictated by the formulation, including for: 1. Dry fibers/powders and pre-mix 2. Wet fibers/powders and split feed 3. Dry fibers/powders and split feed Co-rotating and counterrotating twin screw modes each have benefits, particularly when the process section (screws/barrels) has been optimized for the intended purpose. Examples of how to stage unit-operations in the twin screw process section for various bioplastics formulations will be presented and explained, with test results for different twin screw extruder configurations.

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# S02 – Extrusion

## S02 - 63

## Analysis of Spiral Mandrel Dies with Novel Channel Geometries to Draw Conclusions on the Purging Time of the Melt Using CFD

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Spiral mandrel dies are deeply integrated into the extrusion process and are the predominant die type for manufacturing products with a ring-shaped cross-section, e.g. blown film. The geometry of the axial spiral mandrel die is characterized by a spiral mandrel with one or more feed holes that merge into the spiral channels. The spiral channels themselves are embedded in the mandrel and have a characteristic u-shape in cross-section, which is dictated by the milling head used during manufacturing. In the past, numerous geometric parameters of the conventional axial spiral mandrel distributor have been examined in the course of optimizations, but the general design is still largely based on the concept of the 1960s. Therefore, this paper presents two concepts for new channel geometries that deviate from the conventional spiral channel cross-sectional shape. Both variants were optimized using a CFD-based algorithm for the automated geometry optimization by changing the general parameters describing the spiral channel. Other defining parameters were kept constant. The first geometry variant will be referred to as the "double-circle variant" and uses a square with two rounded corners in the spiral base in the spiral channel cross-section instead of the u-shaped profile. The second variant presented adds an inclined flank on the outlet-near side of the cross-section to the conventional channel. This is referred to as a "one-sided flank angle" variant. Both concepts address the purgability issues associated with the conventional u-shape and are also investigated regarding standard quality criteria for extrusion dies. The results provide insights into the influence of geometry parameters for spiral mandrel dies.

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# S02 – Extrusion

## S02 - 77

## Optimization of a Profile Extrusion Die using OptiXtrue Software

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The main objective in design of an extrusion die is to develop a die channel geometry which gives a uniform velocity distribution at the die exit. The uniform velocity at the die exit is required to minimize the extrudate distortion after the polymer exits the die. In the past, most extrusion dies were designed by a trial-and-error approach using the experience of the die designer. With the development of computationally efficient three-dimensional flow simulation software for extrusion die design, designers can now virtually fine-tune their extrusion die before the die is machined. This can reduce the development time for extrusion dies by 40- 50%. However, virtual fine tuning of extrusion dies still requires the die designers to modify the die geometry themselves after each flow simulation using their experience. To eliminate this need for the die designer to modify the geometry after each flow simulation, in the present work, a die optimization software, optiXtrue [1], is used to automatically improve the geometry of a profile die after each flow simulation. The software then simulates the flow again, in the improved die geometry. This cycle of geometry improvement followed by a flow simulation is repeated till a geometry with a uniform exit velocity distribution is obtained in this automatic die optimization process. Besides eliminating the need for designer intervention for die improvement after each flow simulation, this extrusion die optimization software further reduces the development time for extrusion dies, and also provides a better die geometry than the geometries obtain by trial-and-error or by virtual fine-tuning.

1. OptiXtrue software, Plastic Flow, LLC, 920 W. Water Street, Hancock, MI 49930.

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# S02 – Extrusion

## S02 - 78

## Improved melt-mixing in single-screw extrusion by geometry modification based on mixing mechanism

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Melt mixing in screw extrusion is a key operation for a successful polymer processing in subsequent molding steps. The control of melt mixing quality depends not only on screw rotation speed and material throughput, but also on the geometry of the mixing screw. Dulmage screw is one of the mixing screws used for distributive mixing. In our previous study, we revealed that mixing by a Dulmage-type screw (DS) does not improve monotonically with the screw rotation speed but changes non-monotonically. In this study, we investigate geometry modification to suppress the non-monotonic operating condition dependence of the mixing characteristics of DS. We reported that the degree of mixing by a DS with uniform fin zone length is minimal when the number of swirls in a fin zone is half integer. Based on this DS mixing mechanism, we investigated modified DS geometry. Mixing by modified DS was evaluated by using numerical simulations. Non-isothermal flow in single-screw extrusion was solved using SCREWFLOW-Multi (R-flow Co. Ltd.). The mixing process was analyzed by the solving the tracer kinetics. A minimal mixing degree occurred in the unmodified DS was found to be improved in the modified DS. In other words, the minimal mixing caused by one swirl in unmodified fin zone was suppressed by the geometry modification. The geometry modification based on the mixing mechanism is found to be effective to improve mixing performance.

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# S03 – Functional Additives and Reactive Processing

## S03 - 128

## Rheological investigation of chain modified recycled polyethylene terephthalate/polybutylene terephthalate blends and their corresponding foaming behavior

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To address the growing concerns about plastic waste and enhance the sustainability of polymers, recycling stands out as the initial and straightforward step. However, commonly used polymers, such as Polyethylene terephthalate (PET), face challenges in recycling that affect melt and rheological properties. To recover lost properties and improve existing ones, chain modification and blending provide easily implementable and cost-effective solutions. Both epoxy-based (e.g., Joncryl) and anhydride-based (e.g., PMDA) chain extenders have been successfully used. In this study, recycled PET (rPET) and polybutylene terephthalate (PBT) underwent melt compounding using a melt mixer with chain modifiers (i.e., Joncryl ADR 4468 and PMDA). rPET, PBT, and rPET/PBT blends with ratios of 75/25, 50/50, and 25/75 were melt compounded with the addition of 0.25, 0.5, 0.75, and 1.0wt% of each chain modifier. Melt properties were examined using small amplitude oscillatory shear (SAOS) rheological analysis to reveal the effect of chain extender addition in all samples. Furthermore, extensional viscosity and foaming behavior were also examined through sentmanat extensional rheology (SER) and batch-based autoclave foaming, respectively. Both chain extender additions above 0.25 wt% resulted in significant enhancements in complex viscosity and storage modulus values in rPET and blends. While Joncryl showed substantial improvements in the melt properties of all blend systems, PMDA was unreactive with neat PBT. The addition of chain extenders also increased the extensional viscosity of samples and imparted strain-hardening behavior with higher chain extender contents. The foaming behavior of the modified samples was also improved, with clear observations of enhancements in cell stability and foam expansion ratio.

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# S03 – Functional Additives and Reactive Processing

## S03 - 186

## Synthesis of cardanol derived from cashew nutshell liquid and utilization as an epoxy resin plasticizer

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The cashew nutshell liquid (CNSL) is a viscous liquid contained inside the honeycomb structure of the cashew nut shells (CNSs), which are discarded during the cashew nut processing in Vichada, Colombia. Still, this substance has become a topic of great interest because it contains a mixture of aliphatic phenols, among which are cardanol (CDN), cardol (CD) and anacardic acid (AA). CDN has emerged as a noteworthy resource that can be subjected to chemical synthesis for the development of innovative products. In this work, two synthesis products were obtained from CDN, namely cardanol acetate (CA) and epoxidized cardanol acetate (ECA). CA and ECA were studied as epoxy resin plasticizers and compared against CNSL, CDN and the commercial plasticizer dibutyl phthalate (DBP). The results showed that CA and ECA were able to improve the ductility of the resin, increasing the elongation at break from 3.55 ± 0.89% for the neat resin, to 23.66 ± 1.87 for CA and 27.58 ± 1.65 % for ECA. This came with a decrease in tensile strength from 53.16 ± 3.99 MPa for the resin without plasticizer, to 17.07 ± 1.11 for CA and 15.48 ± 1.17 MPa for ECA. The Izod impact test revealed that CA and ECA improved the material's impact resistance from 6.35 ± 1.72 kJ/m2 to 10.15 ± 2.12 for CA and 11.43 ± 2.26 kJ/m2 for ECA, increasing the amount of energy that the resin can absorb. Similarly, the plasticizers lowered the glass transition temperature of the resin from 66.75 ± 0.49°C to 47.93 ± 3.84 for CA and 46.65 ± 1.96 °C for ECA, thus presenting a higher ductility. Moreover, CA proved to act as a flame-retardant additive by decreasing the linear burning rate of the material from 22.99 mm/min to 16.29 mm/min, being a feasible solution to the flammable nature of the neat epoxy resin. CDN showed its potential as a valuable low cost and renewable bioresource for the development of epoxy resin plasticizers for applications requiring increased epoxy resin impact and elongation.

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# S03 – Functional Additives and Reactive Processing

## S03 - 194

## Adsorption Influence of Blend Surfactants with Silica Nanoparticles Mixture on a Highly Heterogeneous Rock Undergoing Chemical Injection

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Due to interfacial tension reduction between oil and water, chemical flooding based on surfactant application, is a potential Enhanced Recovery Method (CEOR). However, the high retention rate of surfactants associated to the adsorption in the porous media, and the complexity of the mineralogical composition of the reservoir rock can affect the efficiency in oil displacement. This work evaluates the adsorption influence of a mixture of anionic-non-ionic surfactants with silica nanoparticles in a rock sample composed by 25.14% clay minerals (kaolinite, chlorite, halloysite and montmorillonite) among others sedimentary types known from X-Ray Diffraction analysis and Scanning Electron Spectrometry (XRD and SEM, respectively) experimental tests. The amount of surfactant mixture adsorbed on clay rock minerals was measured by an Ultraviolet-visible (UV-vis) spectroscopy and analyzed by the construction of a calibration curve with 24 concentration points and a 4-Region Isothermal Model. The average static adsorption of the surfactant mixture in the clay rock was 60%, because of a surface about 1.6 m2/g in the substrate and the mineralogical composition of the sample that increased the cation exchange capacity (CEC). Analyzing the 4-region model, the region I was not observed, due to the ionic nature of the blended surfactant, its affinity with the clay type rock and its low concentration. However, it was possible to use concentrations in Region II, III and IV; where adsorption has an increasing slope and values of interfacial tension in the order of x10-1 mN/m were reached. The main conclusion of this work emphasizes the potential use of CEOR method in a field case, where using blend surfactants in outcrops from a geological complex formation, such as the highly heterogeneous rock sample used, was possible to evaluate their potential application.

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# S03 – Functional Additives and Reactive Processing

## S03 - 94

## Incorporation of carbon-based materials as functional additives into anionic polymerized cast polyamides for tailor-made industrial applications

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Cast polyamides are particularly high-molecular homogeneous engineering thermoplastics with high crystallinity, which outperform extruded polyamides with their outstanding mechanical properties. These polyamides are produced via anionic polymerization of lactams (ε-caprolactam as the precursor of PA6 and ω-laurolactam as the precursor of PA 12), which is a basic-initiated ring-opening polymerization with short polymerization times and low process temperatures around 150-160°C. The propagation and subsequent termination of the reaction, take place in a mold with the geometry of the desired component, allowing the removal of the polymerized component after a short cooling phase. Previous attempts have been carried out to incorporate reinforcement materials in situ through different processing techniques, including vacuum infusion, pultrusion, and resin transfer molding. In this work, we study the influence of different processing parameters on the performance of anionic polyamides reinforced with carbon-based nanomaterials obtained by the traditional casting method. Special attention is paid to the variables that affect the dispersion and sedimentation behavior, as well as the homogeneity of the polymerized caprolactam. Conversion degree is monitored using differential scanning calorimetry and dispersion quality is studied by scanning electron microscopy. Further characterization is additionally performed, upon targeted applications. Even though cast polyamides have been commonly used for robust applications that demand toughness with high hardness, good abrasion resistance, and good damping capacity, among others; preliminary testing yielded promising electrical conductivity values that, according to the state of the art, are in line with those required for electromagnetic shielding, antistatic behavior, and even biocidal activity.

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# S04 – Injection Molding

## S04 - 106

## Injection moulding of multi-material TPU-ABS locally resonant metamaterials to combine vibration stopbands by increased damping capacity

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Increasing restrictions on emissions together with tightening noise exposure limits have raised the need for lightweight noise and vibration solutions. So-called locally resonant metamaterials have recently emerged as promising candidates. They allow creating stopbands, targeted frequency zones of strong vibration attenuation, resulting from sub-wavelength integration of resonant elements in a flexible host structure. At present, these metamaterials still lack mass-manufacturing possibilities and broadband performance, preventing widespread use in industry. To advance these metamaterials from ad-hoc academic realizations to mass-manufacturable solutions, injection moulding has come in view as a viable manufacturing process. Moreover, multi-material injection moulding may allow to widen and merge multiple stop bands, by exploiting the targeted presence of high damping phases in the resonators. Therefore, this work investigates the potential of multi-material injection moulding for the manufacturing of locally resonant metamaterials with broadened vibration performance. The main idea is to design resonators containing two materials: ABS is mainly used to provide strength and stiffness, and combined with TPU which has high material damping. To this end, the static strength of ABS-TPU tensile bars is first investigated. Next, the eigenfrequency and damping ratio of resonators with different ABS-TPU material distributions are experimentally assessed and compared to numerical predictions. Based on these findings, a resonator is specifically designed to achieve an increased stop band width, when periodically added to an aluminum host plate. Therefore, parameter optimization is used to tune the ABS-TPU distribution as function of the desired eigenfrequencies. Vibration measurements on the manufactured plate reveal an increased vibration attenuation frequency range, showing the potential of multi-material injection moulding for locally resonant metamaterial production.

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# S04 – Injection Molding

## S04 - 144

## Design of an injection mold with local displacement of heating coatings for warpage compensation

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The influence of the thermal injection mold design crucially affects the geometric precision of injection molded parts. The local heat flux and the resulting local cooling rates influence the morphology of the material and therefore shrinkage and warpage. A suiting thermal mold design provides the necessary local cooling via cooling channels or locally differing thermal conductivity within the mold. However, the adjustability of the heat flux distribution is limited with these techniques and cannot cover the variable cooling demand. A proposed approach of using heating coatings on the cavity surface to manipulation the part's cooling rate indicates to be advantageous, due to the close and localized application to the part [1-3]. A simulative optimization routine determines the necessary position and surface power of the heating coating. This methodology is based on the inverse thermal mold design with cooling channels and has the objective to homogenize the surface temperature, inner cooling rate and freeze time inside the part [4]. However, the thermal and electrical boundary conditions need to be determined to apply this method for practical use and design a mold to validate the possible warpage compensation. This work defines the homogeneity of the heat flow to the molded part with heat outputs of up to 32 W/cm² through tests with the heating coating on a simple mold geometry. These results are used to apply the simulative design method for the optimized placement and heating power on a mold for a three-dimensional part. As temperature field of the heating coating depends on the contacting, an electro-thermal simulation is used to establish the optimal heat flux distribution. A process simulation study compares the resulting warpage of the part with and without a local heating coating.

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# S04 – Injection Molding

## S04 - 169

## Development and Performance Testing of a Novel Active Vacuum Venting System for Sustainable Injection Molding

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Air traps in the mold result in a plethora of quality issues ranging from functional, such as high residual stresses in the part which ultimately lead to part failure, to cosmetic, such as sink marks or burn marks on the part surface. It is paramount to address air trap issues in injection molding to ensure high-quality manufactured parts. Traditional methods by machining passive vents in the mold are challenging due to design constraints in the mold and would be in many cases insufficient. The other current alternative is to use an active vacuum venting system (AVVS). However, this is a relatively bulky and costly solution, which requires intensive machining to seal all possible gaps in the mold. Therefore, this study introduces a seamlessly integrable novel AVVS for injection molding, requiring minimal mold space and machining while remaining relatively cost-effective and contributing to an overall lower energy consumption. To validate its efficacy, a case study part susceptible to air trap was designed and validated using Moldflow simulation software. The respective mold was machined and assembled by incorporating a ComoNeo system from Kistler (Winterthur, Switzerland) for a comprehensive assessment of the cavity pressure and temperature. As expected, the initial molding experiments without the vacuum system resulted in quality issues like sink marks and burn marks. The results also showed that regardless of the burn mark, the relatively high injection pressure was still insufficient to produce parts without sink marks, affirming the necessity for an AVVS. The performance of the innovative AVVS during molding will be determined by analyzing the air evacuation rate, decrease in injection pressure, and overall part quality. For the latter, residual stress in the parts will also be analyzed using a hole-drilling strain-gage method and stress relaxation test. The working principle and the performance of this novel AVVS will be disclosed and discussed during the presentation at the PPS conference.

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# S04 – Injection Molding

## S04 - 184

## Exploring Processability of Polyoxymethylene /Carbon Black Composites Through Low-Pressure Injection Moulding

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In recent years, low- pressure injection moulding (LPIM), a special type of powder injection moulding (PIM), has emerged as a versatile technique for the production of intricate, micro-scale components with high precision requirements and the ability to create complex geometries. This study focuses on the comprehensive evaluation of the processability of polyoxymethylene (POM)/carbon black composites using low-pressure injection molding (LPIM). For the initial adjustment of the LPIM processing parameters, detailed investigations of the thermal properties, i.e., the melting temperature (Tm), the glass transition temperature (Tg) and the crystallization temperature (Tcry) of the composites were carried out. To ensure optimum quality and enhanced mechanical properties, a thorough investigation of various LPIM processing parameters was carried out, including injection molding temperature, injection pressure, cooling time and mold temperature. In addition, a detailed determination on the flow properties of composite melt was carried out. Morphological characterization of the injection-molded components was performed to ensure quality. Finally, an in-depth study of the mechanical properties was carried out, focusing specifically on the processing parameters of LPIM. In summary, the study shows that the components prepared from (POM)/carbon black composites by low-pressure injection molding (LPIM) with improved thermal stability and mechanical properties can find applications in various industrial applications and consumer products.

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# S04 – Injection Molding

## S04 - 2

# Investigations on injection mould inserts with reduced thermal masses using additive manufacturing

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In this work injection mould inserts with reduced thermal mass, regarding lightweight construction approaches, were developed by the Institute of Design and Production in Precision Engineering (IKFF) and furthermore adapted for the process and manufactured together with the Materials Testing Institute (MPA), both at the University of Stuttgart. These were at first optimized for oil-variothermal temperature control using simulative support and then compared with a reference insert, which was manufactured using conventional methods. Monitoring of the market shows that the fluid-variothermal process is still of great importance, although there are already processes which can transfer energy more quickly into an injection mold. Additive manufacturing, with its high degree of freedom in design, enables the implementation of individual, conformal cooling channels and can additionally support the efficiency of the variothermal process. The limiting factor with respect to process efficiency is often the thermal mass of the injection mold, which is addressed in the analysis and optimization of the mold inserts considering the possibilities of additive manufacturing. A simulative comparison of the lightweight inserts with comparable variants made of solid material revealed a significant difference, especially under consideration of several tempering cycles. The validation of selected inserts confirmed the simulation results. These investigations show that additive manufacturing combined with lightweight construction approaches can support an additional increase in efficiency as well as a reduction in cycle times for the fluid-variothermal process control.

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# S04 – Injection Molding

## S04 - 212

## Material selection for injection moulding hollow microneedles

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Hollow microneedles, miniature needle-like structures, are designed to painlessly pierce the skin for medical substance delivery or fluid extraction. Over the years, various types of materials, including silicon, metals, ceramics, and polymers have been reported in literature for manufacturing microneedles. Polymers particularly stand out as an excellent material for microneedles, as they can be very cost-effective for mass production through injection moulding. While several polymers have been proposed in the literature for microneedle fabrication, there is a notable absence of studies comparing their processability and performance during needle penetration tests. Existing research tends to highlight individual polymers, emphasizing their advantages without providing a systematic exploration of differences among various candidates. This study addresses this gap by conducting a comprehensive analysis of hollow microneedles fabricated from five biocompatible thermoplastic materials: polycarbonate, polybutylene terephthalate, polylactic acid, polyamide 12, and glass-fiber reinforced polyarylamide. First, each material is examined for its injection moulding characteristics, considering factors such as melt flow, cooling rates, and mould release properties. Second, the replication fidelity will be investigated, encompassing a microscopy analysis of the microneedle dimensions and surface morphology. Third, the penetration behaviour, an essential aspect of microneedle functionality, is tested through penetration tests on piglet ears. These tests will include factors such as the penetration success rate, the required penetration force, and post-penetration microscopy analysis to detect missing or broken particles of the needle. This systematic approach is aimed at identifying the most suitable polymer for microneedle manufacturing with injection moulding, paving the way for the future development of reliable transdermal drug delivery systems and fluid sampling devices.

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# S04 – Injection Molding

## S04 - 243

## Development and validation of an injection moulding production cell to facilitate individual product traceability

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The currently prevailing approach in injection moulding to product traceability and quality control, involves batch-level processes. Typically, traceability is achieved through the use of inserts in the mould, leaving identifiable markings, and periodic product sampling is applied for quality assurance. However, such an approach poses quite some disadvantages as the entire batch is linked to the same data, potentially leading to mislabeling due to false positives or negatives. This research aims to address these disadvantages by developing an integrated production cell. Each product receives a unique identifier. The production data, but also the information resulting from real-time quality assessment is captured on an individual product basis. The integrated production cell comprises of the following key components: (i) The injection moulding machine manufactures the individual products, but also stores and communicates the relevant production data. (ii) A continuous inkjet printer applies unique identification codes. (iii) A custom measuring station weighs the part for quality assessment. (iv) A dedicated server handles data communication, processing, and storage in a database. Validation of the production cell involves cross-referencing captured data with that stored by the injection moulding machine, ensuring data integrity. Additionally, the measured weight is validated against a calibrated scale to ensure its accuracy. This functional prototype enables gathering labelled data and thus exploring correlations between output quality and processing parameters, fostering a data-driven feedback loop for increased industrial efficiency. In conclusion, this research paves the way for a transition from batch-level to individualized traceability and quality control in injection moulding, promising improved efficiency and product quality.

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# S04 – Injection Molding

## S04 - 59

## Investigating the post-aging adhesive properties in multicomponent injection molded made of liquid silicone rubber (LSR) and acrylonitrile-butadiene-styrene (ABS) for medical device applications

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Multi-component injection molding of liquid silicone rubber (LSR) with thermoplastics is used in a wide range for industrial products, also in medical applications. Liquid silicone rubbers offer hypoallergenic properties, biocompatibility, and resistance to most liquid drugs. They are physiologically well tolerated and can be subjected to various sterilization methods. Almost all thermoplastics used in medical devices, such as acrylonitrile butadiene styrene (ABS), have a low heat deflection temperature (HDT) and therefore cannot be overmoulded with silicone rubber during injection molding. By using a new variothermal production method the processing of silicone rubber and thermoplastics with a low HDT value becomes possible and replace the traditional costly production and assembly of individual components. This integrated production technology not only enables the economic realization of high-performance new products, but also improves product safety for patients through simplified, more automated, and higher-quality production processes. In this investigation, we will present a new 2C-molding technology for producing ABS-LSR test specimens in accordance with the VDI guideline 2019. This involves the use of variothermal mold heating and the special surface treatments for ABS. As these experiments are intended for use in medical technology, they must comply with various medical standards. Different post-treatments were therefore carried out. This study highlights the change in adhesion properties in conjunction with the alteration of the mechanical properties of the components under the influence of different sterilization methods (gamma and ETO) and artificial ageing (humidity and temperature).

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# S04 – Injection Molding

## S04 - 87

## Microstructural and Mechanical Properties of Weld Lines in Injection-Moulded Short Glass Fiber-Reinforced Polyamide 6

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Weldlines are created when two or more flow fronts meet during injection moulding. Although weldlines are known to generate local weaker mechanical properties, they are often unavoidable. The study analyses the composite's microstructure at the weld line and the influence of injection moulding parameters on it. Using this information, a prediction on weld lines strength can be made. While the presence of a weld line hardly influenced the strength of a tensile bare made out of unfilled PA6, short glass fiber reinforced PA6GF samples showed reduced mechanical properties. Unfilled PA6 takes advantage of its high healing capability to retain its strength at the weldline, while glass fibred filled PA6 suffers from unfavorable fiber orientation at the weld line. Fracture surfaces revealed a bell-shaped structure linked to the 'underflow' process caused by flow imbalances during injection moulding. The 'underflow' is simulated using Autodesk Moldflow®, predicting enhanced fiber alignment along the flow direction. Regarding processing parameters, both melt and mould temperatures showed negligible impacts, while enhanced mechanical properties were observed at elevated packing pressures. The analysis of fracture surfaces showed intensified 'underflow' with increased packing pressure. A relationship is established between weld line strength and fiber orientation at the weld line, potentially serving as a predictive tool for estimating weld line strength. Acknowledgements The work leading to this paper has been funded by the ICON project "ProPeL", which fits in the MacroModelMat (M3) research program, coordinated by Siemens (Siemens Digital Industries Software, Belgium), and funded by SIM (Strategic Initiative Materials in Flanders) and VLAIO (Flemish government agency Flanders Innovation & Entrepreneurship). The authors would like to thank Domo Chemicals for providing the material.

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# S05 – Polymerization and Synthesis

## S05 - 255

## Thermal and mechanical behavior of biobased vitrimer of epoxidized vegetal oil and lactic acid-based oligomers

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Vitrimers represent a new group of polymers that can offer a combination of the advantages existing in thermoplastics and thermosets. These thermosetting polymers are malleable at high temperatures and become solid when cooled. This property of vitrimers is associated with the existence of Associative Dynamic Covalent Adaptive Networks in the structure of these thermosets. Several vitrimers obtained from different types of dynamic covalent bonds have been reported in the literature, but those with dynamic transesterification reaction are the most extensively studied by researchers because they can be applied in several types of commercial epoxy resins. This work reports the production of biobased vitrimers obtained from epoxidized vegetal oil (EO) and lactic acid-based oligomers (LAO) using different catalysts like zinc acetate and tin octoate as transesterification catalysts. Reactions containing EO and LAO generate materials with properties varying from rubber-like to rigid-though behavior with average enthalpy of cure of approximately 85 mJ/mg and materials cured in the presence of the catalysts showing lower enthalpies of cure. ECO-LAO reaction produced materials with Tg ranging from -25◦C to 50◦C, depending on stoichiometry and lactic acid oligomer molecular weight, and Tg increasing as molecular weight increased. The presence of catalysts gave the material vitrimer properties, with softening point associated with transesterification reactions and topology freezing temperature transition (Tv) at temperatures between 195-235◦C. Mechanical properties of these vitrimers as well self-healing behavior is also discussed.

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# S05 – Polymerization and Synthesis

## S05 - 278

## SYNTHESIS OF PROTON EXCHANGE MEMBRANES FROM STYRENE-ACRYLIC ESTER AND CHITOSAN FOR FUEL CELL

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Membranes were synthesized from the mixture of the styrene ester-acrylic copolymer and the biopolymer chitosan, modified with the sulfonation reaction at 1h, 2h and 3h to evaluate their properties as an electrolyte for a fuel cell. The membranes were characterized with the following properties, the water uptake by gravimetric method, the samples are dried and weighed initially then immersed in distilled water for a day, after that time they are weighed, the difference in weights determines the water retained; the ion exchange capacity measures the ability of the material to exchange one cation for another in an aqueous medium; infrared spectroscopy was performed with a Nicolet 6700 Fourier transform spectrophotometer, this technique is used to verify the sulfonation reaction; the conductivity of the membranes was measured through electrochemical impedance spectroscopy, the equipment used was the Wayne Kerr 6420 impedance analyzer; the mechanical properties were determined on the Shimadzu EZ-S universal testing machine. The results show that the mixture of styrene acrylic ester and chitosan, when performing the sulfonation, increased the water absorption in the membrane that was sulfonated in a reaction time of 2 h, obtaining 75.47%, compared to the unmodified membrane 50.7 %. The ion exchange capacity had an increase, 0.98 meq/g in the sulfonated membrane at 3 h compared to 0.12 meq/g in the unmodified membrane. The best conductivity obtained from the modified membranes was 2.35*10-9 S/cm under dry conditions, for the sulfonated membrane at 1h. The FTIR analysis showed the bonds that indicate the modification of the polymer mixture given by sulfonation. These results confirm that sulfonation improves the properties of water absorption and ion exchange capacity in the membranes; however, sulfonation did not favor the mechanical properties or conductivity.

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# S05 – Polymerization and Synthesis

## S05 - 344

## Incorporation of aminoalcohols to tune the properties of polyurethane sytems

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To enhance polyurethane (PU) material performance, the incorporation of low-molecular-weight molecules, known as chain extenders, is a common practice. They usually increase the phase separation between the soft and hard domains which has a significant impact on the density of hydrogen bonds. Aminoalcohols, molecules having both hydroxyl and amine functional groups, are important building blocks in the synthesis of pharmaceuticals but are also widely used in cosmetics or paints and coatings. Easily derived from abundant natural sources, such as amino acids, aminoalcohols align with the need of renewable and sustainable sources. Despite their importance, the specific reactivity of aminoalcohols towards isocyanates and their contribution to PU-based formulations remain underexplored. In particular, they can act as chain extenders, but also crosslinkers and catalysts. This study addressed this knowledge gap by assessing the feasibility of adding various aminoalcohols to create hybrid poly(urethane-urea) formulations. By measuring the exothermicity of the polymerization and gel times, we calculated that all tested aminoalcohols have a catalytic activity on the formation of the polymer network. We also identified a promising reactive catalyst whose integration in the network is of primary interest to formulate products that do not emit volatile organic compounds. At high concentration of added amines, very large hard domains were produced and their segregation from the soft domains resulted in turbid materials. When added in PU foam formulations, we observed that the aminoalcohols accelerate the blowing of the foam. Moreover, increasing amounts of aminoalcohols stiffened the foams while maintaining the density constant. X-ray tomography completed the characterizations of the foams. Taken all together, these results open perspectives for the use of aminoalcohols to enhance and tune material performances while contributing to more environmentally friendly PU formulations.

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# S05 – Polymerization and Synthesis

## S05 - 412

## Dispersion and distribution of additives in polyhydroxybutyrate (PHB)-polylactic acid (PLA) films as a replacement for polyethylene in agroindustry

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In response to increasing global restrictions on using non-biodegradable or toxic plastics and petrochemical additives, technologies must be developed that allow agribusiness to continue supplying food to the world and remain an essential economic sector in many developing countries. For the specific case of polyethylene and its additives, used as packaging in crops and post-harvest of tropical fruits, any material that intends to replace them, in addition to complying with the physicochemical properties, biodegradability, toxicity, among others, must consider its processability. Therefore, in this work, we will show the requirements in terms of processability through the extrusion of: 1. PHBV/PLA packages as a replacement for polyethylene for post-harvest handling of tropical fruits and cocoa. 2. The incorporation of additives of natural origin in PHBV/PLA as a replacement for toxic pesticides in banana crops. 3. The use of hydrophobic microcellulose as a compatibilizer in PHBV/PLA films.

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# S05 – Polymerization and Synthesis

## S05 - 79

## Synthesis of orderly packed nanofibrous membranes with thermo- and pH-responsive behavior

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We produce controlled nanostructured membranes from crosslinking of self-assembled diacrylated Poloxamer. At sufficiently high concentrations, Poloxamers form lyotropic phases, such as lamellar, cubic packing of spherical micelles, and hexagonal packing of rod-like micelles. These mesophases have a periodic structure with a domain size on the order of 2-50 nm. The oil-in-water (i.e., normal) hexagonal (H1) packing of rod-like micelles can be used as a template to produce orderly packed nanofiber membranes. The obtained nanostructure has a continuous 3D transport pathway. This study presents a polymerized mesophase with H1 structure, which can alter its transport-through properties in response to changes in temperature and pH. The formulation includes diacrylated Poloxamers, which are thermoresponsive components acting as both macromer and structure-directing amphiphile. Therefore, the membrane pore size changes with temperature when is in contact with water. Furthermore, the precursor contains acrylic acid (AAc) as the charged component, which upon copolymerization with diacrylated Poloxamers, not only enables ion separation through Donnan exclusion, but also imparts pH-responsive behavior for the separation of ionic species. We show that the nanostructured polymer can be used as a nanofiltration membrane with separation properties adjustable with temperature and pH. The membrane also has an exceptional resistance to fouling by various solutes due to its highly hydrophilic surface.

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# S06 – Polymer Blends and Alloys

## S06 - 103

### Towards the design of stretchable encapsulants for self-healing liquid metal-based electronics using blended Diels-Alder networks

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The wide recognition of liquid metal-based soft electronics made with polymer materials stems from their flexibility, high electrical conductivity, self-healing properties, and adaptability. The stretchable polymer serves as the flexible substrates, while also providing a protective barrier for the liquid metal. In this study, a robust method is presented for the effective encapsulation of liquid metals by the development of polymer elastomers that balance the trade-off between mechanical flexibility and impermeability against both water and oxygen. Two furan-functionalized polymers, polypropyleneoxide (PPO) FD4000 and polydimethylsiloxane (PDMS) FS5000 were reacted with bismaleimide DPBM to form a single polymer network. The immiscible backbones were covalently bonded by way of the thermoreversible Diels-Alder reaction, which presents the blend with self-healing ability and re-processability. Altering the composition of two polymers from 75/25 to 50/50 and 25/75 led to the evolution of phase-separated blends. The morphology depends on the competition between the reaction and phase separation kinetics yet is controlled by the concentration of backbones. Starting from 25% PDMS, a dilute droplet morphology formed. By increasing the content of PDMS to 50% or 75%, the growing concentration of droplets built a hydrophobic layer that is impermeable against water. On the other hand, the presence of the PPO backbone with a more hydrophilic nature decreased the diffusion of oxygen. This blending strategy not only adjusts the hydrophobicity of encapsulants for their barrier properties but also allows tuning of the mechanical properties. For instance, PPO yielded higher stretchability while PDMS improved the hysteresis and creep resistance in blends. Moreover, the concentration of the crosslinker has a big impact on the network properties. Decreasing this concentration increased the chain mobility in networks and favored mechanical flexibility and more importantly, self-healing properties at room temperature. Finally, the self-healing sensors fabricated with Galinstan, and the best blend exhibited promising electromechanical response and efficient recovery after damage.

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# S06 – Polymer Blends and Alloys

## S06 - 195

## Effect of Steady Shear on Electrically Conductive co-Continuous Morphology Blends

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In this work the rheological behavior of co-continuous morphology polypropylene (PP)/polystyrene (PS) blends to which conductive nanoparticles have been added has been studied. Multiwall carbon nanotubes (MWCNT) or graphene (Gr) of different particle size was added to the blends in concentrations ranging from 0 to 2wt% (MWCNT) and from 0 to 10wt% (Gr). The blends were prepared by melt mixing and subjected to annealing to favor migration to the interface between the two polymers prior rheological characterization. The blends were then subjected to a sequence of small amplitude oscillatory shear (SAOS), steady shear (SS), and SAOS using a MCR501 rotational rheometer. The electrical conductivity of the blends was evaluated during the SS using a dielectro-rheological device (DRD with ST2826/A high frequency LCR meter) coupled with the rheometer. The rheological behavior of the materials, when subjected to SAOS, was used together with constitutive equations to quantify the morphology of the blends1,2,3. The results indicated that the minimum percolation threshold concentration, to result in electrical conductivity, is insufficient to stabilize the morphology of the blend during processing. Indeed, deformation resulted in coarsening of the blend morphology. This change of morphology resulted in a drastic decrease of electrical conductivity of the material. However, upon increase of nanofiller concentration, which corresponded to interface saturation, it was possible to recover the morphology and electrical conductivity if the blends were subjected to stress relaxation.

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# S06 – Polymer Blends and Alloys

## S06 - 219

## High-Performance Thermoplastic PEEK-based Hybrid Systems for the Lunar Environment

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Currently, most rovers sent to the Moon or Mars are constructed using aluminum and its alloys since they provide strong mechanical resistance and the capacity to resist the harsh spatial and lunar environments. The severe conditions on the lunar surface include extreme temperature cycles (-200 °C to +120 °C), high vacuum, high-energy radiation, the accumulation of electrical charges within the material, and the presence of abrasive and electrostatic nanoscale dust. For the chassis of a rover, aluminum presents limitations such as high density, high thermal conductivity, and limited on-site repairability. High-performance polyetheretherketone (PEEK) based blends and nanocomposites are promising substitute materials since they can potentially combine lightness, low thermal conductivity, repairability, 3D printability, and remarkable thermal, chemical, and mechanical resistance. For example, blending PEEK with meta-polyetherimide (m-PEI) significantly increases the glass transition temperature while maintaining high mechanical properties [1]. It is well known that m-PEI is fully miscible with PEEK in the melt state [2, 3] and in this work, we examine in detail the dynamics of phase separation as PEEK crystallizes during cooling. Conversely, the phase behavior of PEEK/para-PEI (p-PEI) blends remains much less understood [4]. Melt-processed binary blends of PEEK with either m- or p-PEI are compared over the full composition spectrum, to understand the detailed influence of both PEI types on the morphology, thermal, and mechanical properties of the systems. Differential scanning calorimetry (DSC) and electron microscopy results confirm the miscibility of m-PEI in the amorphous PEEK domains and the formation of a fine nanostructured PEI phase upon cooling, whereas p-PEI is only partially miscible in PEEK, with a sub-µm morphology and a very low, but measurable, interfacial tension. As a result, the complementary phase behaviors of m- and p-PEI allow for the preparation of nano- and microstructured hybrid PEEK materials, with characteristic phase sizes tunable from around 5 nm, to over 50 µm after controlled annealing.

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# S06 – Polymer Blends and Alloys

## S06 - 27

## Enhancing Toughness and Interfacial Compatibility in PLA/PBAT/Joncryl Blends through Two-Step Blending

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The aim of this study is to investigate the impact of incorporation sequence on the reactive compatibilization efficiency of Joncryl in a (70/30 w/w) poly (lactic acid) (PLA)/poly(butylene-adipate-co-terephthalate) (PBAT) blend during the injection molding process. To achieve this, PLA/PBAT blends were subjected to injection molding with 0.5 and 1 wt.% of Joncryl simultaneously or in a two-step process. In the two-step process, PBAT and Joncryl were injection molded during the first step, followed by the granulation of PBAT/Joncryl, which were then blended with virgin PLA, knowing that PBAT is less reactive to Joncryl.[1] This can encourage the motion of Joncryl towards the more reactive phase, PLA, and interface during the 2nd step and thus enhance the interfacial compatibility.[2] The results indicated a significant improvement in the impact strength of PLA/PBAT blends when injected with 0.5 and 1 wt. % of Joncryl in a two-step process, with increases of 140% and 47%, respectively, compared to their counterparts prepared in a single injection process. Also, the tensile tests revealed an increase of 41% and 35% in elongation at break for two-step molded blends injected with 0.5 and 1 wt. % of Joncryl, compared to those produced in a single injection. Microscopical images of the impact fractured surfaces unveiled intriguing findings. In the neat blend, a distinct droplet morphology with voids was observed, suggesting poor adhesion and PBAT droplets being pulled out. The addition of Joncryl revealed fibrillated structures at the interface between PBAT droplets and the PLA matrix, indicating an enhancement in the interface. Remarkably, this improvement was further enhanced in two-step prepared blends, where morphologies evolved from the droplet-matrix to complex interwinding stretched droplets without any instances of being pulled out or holes. The result suggests the effectiveness of a two-step injection molding in preparation of a highly toughened material.

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# S06 – Polymer Blends and Alloys

## S06 - 68

## Study of a new 3D printing composite for microwave absorption applications

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A long time limited to the stealth of military systems; microwave absorbers are now used in a wide variety of configurations. The multiplication of use cases requires the development of new materials and elaboration techniques. In comparison with other technologies, 3D printing by fused deposition modelling is a low-cost alternative allowing preparing complex geometries. In this context, the development of innovative composite materials with controlled electromagnetic properties appears as a potential development of additive manufacturing techniques. This study is focused on neat ABS matrix-based composites, with either spherical or lamellar Fe particles, elaborated using a microcompounder. The investigation of structure/rheology/electromagnetism relationships shows that similar complex viscosities and magnetic losses are obtained at 30% spherical or 10% lamellar Fe particles vol. fractions, suggesting the potential interest of lamellar particles for the development of microwave absorbers with reduced amount of Fe. Then, [ABS 80%/PE 20%] masterbatch are prepared by simultaneous melt mixing of the components in an internal mixer; spherical or lamellar Fe particles are incorporated into the mixture using a microcompounder. [ABS 80%/PE 20%] /Fe formulations make it possible to obtain yield stress composites adequate to control 3D printed complex geometries, without altering electromagnetic properties. In contrast, flow instabilities, due to PE inclusions relaxation with spherical Fe particles, give shark skin appearance compromising 3D printability of filaments. To conclude, adequate formulations for 3D printable composites dedicated to microwave absorber applications were determined, based on a mapping of 3D printability criteria, through structural, rheological, and electromagnetic characterizations of the composites but also through the observation of the filaments surface state and flexibility and the compliance of 3D printed geometries with the referent 3D model.

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# S07 – Polymer Composites

## S07 - 168

## Characterization of local electrical properties of carbon fiber reinforced thermoplastic composites using a potential field method in terms of fiber orientation influenced by injection molding

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Electrically conductive carbon fiber-reinforced thermoplastic composites are already used in various application areas, for example in electromagnetic shielding or resistance heating. In application-oriented and scientific practice alike, it is not common to determine the local electrical conductivity distribution of such highly anisotropic components but only to measure the volume or surface conductivity of the entire part. Thus, a single value is used to characterize a complex conductivity network. In order to evaluate the conductivity of such a component in order to take advantage of its benefits, a suitable measurement method is essential, also in terms of functional reliability. For this reason, an electrical potential field measurement method was developed to measure electrical voltages with local resolution in a fine grid, generating a two-dimensional insight into the electrical properties of the sample. In this collaborative project involving materials and electrical engineering, both the electrical and structural properties of carbon fiber-filled thermoplastic composites are being investigated in direct relation to each other. The fiber parameters (e.g., local fiber concentration, fiber orientation) must be analyzed first, since they determine the current paths. These parameters are significantly influenced by the injection molding process, which causes the carbon fibers to essentially form a core shell alignment structure. It is also influenced by characteristic areas such as weld lines or mold features like wall thickness variation. This fiber orientation can be quantitatively assessed using an algorithm developed for this method based on high-resolution light microscopic images. By comparing all the results, structural and electrical correlations can be determined on a large scale. On the other hand, further structural analysis methods such as microcomputer tomography can be used to evaluate the methodology on a smaller scale, as a proof of concept.

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# S07 – Polymer Composites

## S07 - 189

## Influence of carbon nanotube deposition onto Jute Fibre in dynamic mechanic properties of epoxy composites

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Natural fiber composites (NFC) have been the focus of research due to their biodegradability, lightweight, and strength-to-weight ratio. On the other hand, the NFC show some limitations such as low thermal stability and poor adhesion between the fiber and matrix. A weak fiber-matrix bonding implies a poor load transfer onto the natural fiber due to its hydrophilic character, affecting the mechanical performance of the NFC. However, several surface modifications can promote an enhancement of the interfacial adhesion. Recently, studies have shown that introducing carbon nanotubes (CNT) into conventional fiber-reinforced polymer composite improves the mechanical and functional properties. Among the techniques used to introduce CNT on the fiber surface, electrophoresis deposition (EDP), has been highlighted. In this way, this study proposed to evaluate the effect of the CNT incorporation onto the jute fiber surface by intermittent high voltage pulsed EDP in the interfacial bonding of the jute fiber epoxy composite (JFEC) using the dynamic mechanical analysis (DMA). Two types of composites were fabricated using the Vacuum Assisted Resin Transfer Molding (VARTM). The first one, the composite was made with epoxy and JF as received (JFEC). The second one, the composite was made using the JF incorporated by CNT and epoxy (CNT_JFEC). DMA analysis was performed using the NETZSCH DMA 242 instrument. The experiment is carried out under bending mode at a frequency of 1 Hz and conducted at temperatures from room temperature to 120ºC at a heating rate of 3 K/min. According to the DMA results, not significantly change on glass transition temperature was observed. However, the CNT_JFEC magnitude of the storage modulus increased around 100% about JFEC, determining a good interfacial bonding between the fiber and matrix. This enhancement can be ascribed to the nanoscale roughness promoted by the CNT deposition, which can act as mechanical interlocking.

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# S07 – Polymer Composites

## S07 - 196

# Influence of the Processing Temperature in the Calendaring Process of Staple Fiber Yarns on the Degree of Consolidation and the Thermal Properties

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The rising use of carbon fiber reinforced polymers (CFRP) leads inevitably to a growing need for efficient recycling methods for CFRP components at the end of their service life. Currently, recycling is mainly focused on production waste, constituting about 60% of total CFRP waste. This includes dry waste in the form of coil remnants, faulty CF production and offcuts from textile production. One way to process this dry CF waste into semi-finished products with maximum fiber length and orientation is to produce staple fiber yarns (SF). These SF yarns, consisting of cut-to-length and spinnable rCF and PA6 fibers, are further processed into semi-finished tape products in a modified impregnation and calendaring process. The process involves the application of heat by two hot air blowers connected in series, which melt the polymer contained in the yarn. The difference in speed between the pre-consolidation rollers and the consolidation rollers causes the molten yarns to be stretched, which aligns the individual fibers in the longitudinal direction. The impregnation and consolidation of the stretched yarns into tapes is carried out by a pair of tongue and groove rollers under pressure. Different tapes were produced depending on the temperature of the hot air blowers and then measured in width and thickness using a laser profile sensor. The degree of consolidation, fiber distribution and orientation of the tapes were characterized by microscopic examinations. In addition, the influence of the hot air blower temperature on the thermal properties of the tapes was investigated. Results reveal that higher temperatures improve impregnation quality, while reducing tape thickness. At the same time a decrease of in the peak melting temperature of the impregnated tape is observed, indicating thermal degradation. With this knowledge, SF tapes can be produced in replicable quality without degradation of the matrix polymer by selecting suitable parameters on a laboratory scale.

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# S07 – Polymer Composites

## S07 - 28

## High performance recycled CFRP composites based on reused carbon fabrics through mild solvolysis route

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A novel environmentally friendly recycling method is developed for large carbon-fibers reinforced-polymers composite panels whose efficiency is demonstrated through a proof-of-concept fabrication of a new composite part based on recycled fibers. The recycling process relies on formic acid as separation reagent at room temperature and atmospheric pressure with efficient recycling potential of the separating agent. Electron microscopy and thermal analysis indicate that the recycled fibers are covered by a thin layer of about 10wt.% of residual resin, alternating with few small particles, as compared to the smooth virgin fibers. The recycled composites show promising shear strength and compression after impact strength, with up to 93% retention of performance depending on the property as compared to the reference. The recycled carbon fibers can thus be reused for structural applications requiring moderate to high performances. The loss of properties is attributed to a lower adhesion between fresh epoxy resin and recycled carbon fibers due to the absence of sizing, partly compensated by a good interface between fresh and residual cured epoxy thanks to mechanical anchoring as well as chemical reactions. The room temperature and atmospheric pressure operating conditions combined to the recyclability of the forming acid contribute to the sustainability of the entire approach.

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# S07 – Polymer Composites

## S07 - 283

## Hybrid Twin for manufacturing thermoplastic composite wound parts

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The use of thermoplastic composite materials in the different industrial sectors has expanded considerably over the past few decades, notably wound structures such as pressure pipes, tanks, and reservoirs. Filament winding is a widely used manufacturing technique to produce these thermoplastic composite structures which present multiple advantages such as an increasing productivity. Rapid manufacturing usually involves thermal gradients through the thickness of the structure. The addition with other phenomena such as in-situ chemical reactions leads to residual stresses in the final structure. This is due to the difference in the thermal expansion coefficients of the different constituents and the evolution of the matrix volume due to polymerization or crystallization. The residual stresses then affect the structural integrity of the part and can lead to premature cracking when external service loads are applied. In this study, an experimental characterization of the residual stresses is carried out along with a numerical model in order to assess the residual stresses level in a two steps process wound structure, then process parameters effect on these stresses are discussed. Finally , different solutions are proposed in order to reduce the residual stress linked to the manufacturing parameters.

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# S07 – Polymer Composites

## S07 - 304

# High performance sustainable biopolymers and their composites based on CNCs. Structure- rheology- forming and properties relationships

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Abstract. Through this work, we first present some promising routes to enhance processing ability and performances of which presents challenges mainly due to the poor shear and elongation properties of this biopolymer. To our knowledge, there is few papers dedicated to the investigation of foaming and/or blown extrusion and coextrusion of PLA based systems that involves structural, rheological, and thermo-mechanical properties. Three main routes were selected: (i) the modification of its structure and rheological behaviour, (ii) blending it with another ductile thermoplastic biopolymer such as PBAT, PA11 or PHB-V, iii) PLA reinforced by CNCs. Various formulations of PLA with multifunctionalized epoxy, nucleants and plasticizer were prepared and characterized on the basis of their linear viscoelasticity and extensional properties. The balance of chain extension and branching has also been investigated using solution viscosimetry, steric exclusion chromatography (SEC) and rheology (Shear and elongation rheology). On one hand, a batch foaming assisted with supercritical CO2 was achieved. The influence of the foaming parameters, the extent of chain modification as well as the contribution of crystallization on cell morphology was evaluated. On the other hand, the stability maps of blown and coextrusion processing for neat and modified PLA were established at different die temperatures. We have achieved a great enhancement of the blown processing windows of PLA with high BUR (Blow Up Ratio) and TUR (Take Up Ratio) attained. We were able to demonstrate that a higher kinetic of crystallization can also be reached for chain-extended and branched PLA formulated with adequate amounts of nucleants and plasticizers. On another hand we have studied and optimized the processing of multi nanolayers based on PLA reinforced by CNCs. Hence, blown films with interesting thermo-mechanical, mechanical and barrier properties have been produced using an optimal formulation for PLA.

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# S07 – Polymer Composites

## S07 - 311

## Double-layered wood-plastic composites made of recycled polyethylene and capirona wood particles recovered from scrap processed by rotational molding

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There is a growing interest in using natural fibers for making composite materials by rotational molding, as an alternative to traditional materials. In most cases, there is a weakening of mechanical properties when such fibers are incorporated in the process. It is true that it is possible to reduce its negative effect by treating the fibers to improve the compatibility with the thermoplastic matrix, but this can be also negative for the environment. In order to deal with this problem and improve the properties of the single-layered wood plastic composites (WPC) processed by rotational molding, the main purpose of this work was to develop rotomolded double-layered WPC made of recycled high-density polyethylene (HDPER) and capirona wood particles (CWP) recovered from scrap. In this case, the WPC had an outer layer made of 85% de HDPER y 15% CWP, and an inner layer made of 100% of HDPER. To achieve the principal objective of this investigation, the parameters of the process were identified, first. Then, using them, an experimental procedure was designed in order to obtained different rotomolded double-layered WPC. During their processing, the internal air temperature (IAT) profile was registered in each case. Using these profiles, it was possible to identify the temperatures that define the beginning and end of each of the six phases of the rotational molding process. It was found that these temperatures are independent of the parameters of the process, but they are dependent of the HDPER characteristics. Finally, the obtained materials were subjected to mechanical and physical characterization. In general, results indicated that the peak internal air temperature (PIAT) define the final characteristics of the rotomolded double-layered WPC, and a PIAT between 193 °C and 207 °C is required to reach optimal properties. In addition, characterization test results have demonstrated that the properties of rotomolded WPC improve significantly when a second layer of HDPER is employed.

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# S07 – Polymer Composites

## S07 - 312

## Wood-plastic composites processed by rotational molding: a relationship between properties and peak internal air temperature

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As wood is a lignocellulosic material, it can be subjected to thermal decomposition because of the high temperatures that are required when wood-plastic composites (WPC) are processed by rotational molding. However, the information provided by the internal air temperature (IAT) profile, registered during the process, can be used to avoid such condition. In that perspective, the principal objective of this investigation is to find the influence of the peak internal air temperature (PIAT) on the mechanical and physical properties of the rotomolded WPC. In order to achieve this, several WPC were rotomolded using different molding conditions. Consequently, each rotomolded WPC reached a specific PIAT at the end of the molding cycle. In addition, the obtained materials were subjected to mechanical and physical characterization, and test results were used to find a relationship between the PIAT and the properties of rotomolded WPC. In all cases, materials were made of 85% of recycled high-density polyethylene (HDPER) and 15% of capirona wood particles (CWP) recovered from scrap, but materials made of 100% of HDPER were rotomolded as well. Results prove that a PIAT of 208 °C is necessary for a rotomolded WPC to achieve optimal proprieties without undergoing from thermal degradation. In the case of the material made of 100% of HDPER, PIAT of 233 °C is required. Density test results show that both materials are fully densified at that point, and, for that reason, their proprieties are the best possible. On the other hand, from the second derivative of the IAT profiles, it was possible to identify the temperatures that define the beginning and end of each of the six phases of the rotational molding process. It can be affirmed that these temperatures are not affected by the quantity of the CWP when it is less than 15%. Particularly, all powder is fully adhered to the mold cavity (end of sintering) once the IAT is 126 ± 1 °C.

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# S07 – Polymer Composites

## S07 - 337

## Epoxy Biocomposites Reinforced with Hemp and Fique Fibers: Thermal and Viscoelastic Performance for Sustainable Applications in the Aerospace Industry

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This research proposes to analyze the thermal and viscoelastic performance of epoxy biocomposites reinforced by hemp and fique fibers. This approach is presented as an alternative for applications in the aerospace industry. This assessment also includes the effect of the fiber fraction used to manufacture the biocomposite materials on the energy consumed during the primary production of the natural fibers and the evaluation of the specific strength and stiffness of the biocomposites. Biocomposites are defined as materials in which at least one of the two components, either the matrix or the fiber reinforcement, originates from biological sources. Thus, biocomposites can be derived by employing either biobased or biodegradable polymeric matrices, incorporating natural fiber reinforcements, or, ideally, integrating both phases. The substitution of synthetic fiber reinforcements with natural fibers is attracting considerable attention in composite materials research, spanning various industrial sectors. Several research supports that composites reinforced with natural fibers offer significant advantages compared to synthetic materials. These materials not only exhibit a lower environmental impact but also require lower energy consumption during the production phase. They have potentially biodegradable characteristics, lower costs and lightweight compared to composites reinforced with synthetic fibers. This study aligns with the Sustainable Development Goals established by the United Nations, contributing especially to goals related to responsible consumption and production within a more circular framework, as well as actions related to climate change. The study details the mechanical, viscoelastic, and thermal performance of various combinations, including fique boards, hemp boards, and quasi-isotropic hybrid boards incorporating both fibers. Special attention is given to the effects of the curing process and the evolution of thermal and mechanical properties.

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# S07 – Polymer Composites

## S07 - 457

## Fiber orientation-induced strain hardening in uniaxial extensional flow of fiber-filled polymer composites

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Fiber-filled polymer composites are important materials for the high-tech industry because they combine important material properties such as increased strength, low weight, and low cost of manufacturing. One big challenge for fiber-filled systems is the prediction of the fiber orientation during processing as this influences various mechanical properties. Understanding the rheology during processing is as important because the rheology influences the local flow fields, which in turn influence the fiber orientation. In this work, strain-hardening induced by fiber orientation in uniaxial extension of fiber-filled polymer composites is investigated using numerical direct FEM simulations as well as constitutive modelling. The considered fiber-filled systems have a fiber aspect ratio, L/D, up to 10 and a fiber volume fraction up to 10%. The numerical simulations show that the transient uniaxial extensional viscosity is a function of fiber aspect ratio, fiber volume fraction and fiber orientation, which could be accurately described using a constitutive model having only 2 parameters. At higher strains, for increasing fiber volume fractions, the numerical direct FEM simulations show additional strain hardening, which we attribute to a local change in microstructure.

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# S07 – Polymer Composites

## S07 - 46

## Effect of Pigments on Laser Beam Transmission in Diode Laser Transmission Welding of Poly(propylene)

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Abstract. Welding technologies are state of the art for joining polymer composites, with one of the two joining parts to be laser transmissive (LT) and the other to be laser absorptive (LA) [1]. Pigments are often added to LT to enhance the crystallinity of the polymer matrix. However, pigments lead to internal scattering of the laser beam and the rate of transmission or the laser energy density decreases [2]. Depending upon the type and number of pigments added in the formulation of LT, the percentage of the laser beam transmitted, absorbed, or scattered differs. Laser welding performance depends upon the laser energy available for welding after considering the losses [3]. In the present study, optical transmission of injection molded isotactic polypropylene (iPP) samples were analyzed with a varying dosage of organic pigment (neat PP, 2%, 3%, 4%, 5%, 6%, 8% and 10%) using LPKF TMG 3 transmission tester. The device uses a wavelength of 980 nm and simulates the optical radiation conditions of diode laser transmission welding (LTW). The percentage transmission varied with the sample thickness as well as with the dosage of pigment. The modified Bouguer-Lambert law described the transmission energy and apparent extinction coefficient. The model was validated with the experimental value of transmittances of the samples with varying samples thickness of iPP. There was a decrease in the percentage of laser transmission with an increase in the pigment content of the samples. It was found that the apparent extinction coefficient is the function of the pigment levels.

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# S07 – Polymer Composites

## S07 - 6

## Study of the viscoelasticity of conductive composite polymers for electronic applications

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Polymeric composite materials are an increasingly used option in electronic applications. Therefore, there is a great demand for new materials with good electrical properties, electrical conductivity, or electromagnetic shielding, for use in conventional polymer processing techniques such as extrusion and injection or for use in 3D printing, for both melt deposition and digital light curing. However, the development of new polymeric composite materials can lead to a series of difficulties to obtain a good balance between electrical and mechanical properties or an adequate balance cost-property. In addition, composite materials often present dispersion problems that also make it necessary to select compatibilizers that improve dispersion and therefore the processability and electrical properties of the compound. All this makes it necessary to carry out a large number of tests in order to develop a new polymeric composite material with the desired properties with the consequent cost of time and materials. Rheological analysis is a very useful tool to understand the microstructure of polymeric compounds and to be able to approximate parameters such as the electrical percolation threshold, or to verify the viscosity of compounds, which is a determining parameter in 3D printing applications. This paper describes different examples of polymeric composite materials, developed by the authors in recent years, in which the analysis of the viscoelastic properties has allowed to optimize the amounts of filler and additives for different applications. For example, the development of new photocurable conductive acrylic compounds based on polyanilines for application in flexible electronic sensors printable by digital light processing, the development of environmentally friendly polymeric materials, based on polylactic acid and PHBV for applications with a good EMI shielding or for the development of biobased filaments, easily printable and highly conductive by melt deposition.

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# S07 – Polymer Composites

## S07 - 65

## Investigation of optical fiber properties and fiber segment interferometry in composite applications

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In the area of structural health monitoring (SHM), the integration of strain sensors in composites has emerged as a strategy to mitigate failures arising from overloads and unwanted inhomogeneity. Among strain sensors, fiber optic sensors have considerable advantages over other sensors like electrical strain gauges, strain rosettes, and linear variable differential transformer sensors. In particular, they can leverage their lightweight nature, compact size, accuracy, remote sensing, stability, durability, high sensitivity, versatility, and multiplexing abilities. Most fiber optic sensors used in SHM are based on the evaluation of the spectral properties of inscribed fiber Bragg gratings (FBGs), however, the recently introduced fiber segment interferometry (FSI) approach can typically achieve much higher strain resolutions. A particular advantage of FSI over regular, localized FBG sensors for embedded applications is the ability to freely adapt the sensor gauge length (cm to m) to the requirements of the monitoring task and the higher immunity to strain gradients, leading to improved sensing fidelity in the presence of local structural inhomogeneities. In this work, the influence of optical fibers and their coatings on the composite properties is investigated. Additionally, the use of FSI in composites is demonstrated. Polyimide-coated fibers display superior resilience compared to other coatings and their uncoated counterparts. Furthermore, the alignment of optical fibers parallel to adjacent plies proves instrumental in averting delamination issues. It is commonly agreed that optical fibers parallel to the reinforcement are an ideal way to achieve the best strain measurement to keep intrusive effects to a minimum. The study underscores the influence of embedded optical fiber sensors on the mechanical properties and reveals the potential of FSI.

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# S08 – Polymer Foams and Membranes

## S08 - 115

## The effect of type of processing in obtaining membranes based on esterified Poly(vinyl alcohol) (PVOH)

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During the 21st century, one of the biggest public health problems worldwide is the increase in patients with chronic kidney disease (CKD) characterized by kidney failure [1], [2]. This problem is reflected in the high demand for human, economic and infrastructure resources [3]. In 2019, it was estimated that approximately 850 million people around the world suffered from a kidney disease for which kidney replacement therapies such as dialysis and kidney transplant are required, although the latter is less likely due to the availability of donors and the first being the most used therapy [4]. Hemodialysis is considered a highly effective treatment and unlike peritoneal dialysis, it uses semipermeable polymeric membranes in an extracorporeal system to filter the blood [1]. Thus, in this work, membranes based on PVOH functionalized with carboxylic acid and cross-linked with a diol were obtained. The results of the Fischer esterification reaction were evaluated by FTIR, DSC and contact angle. Subsequently, this product was processed by electrospinning and phase inversion to generate porous membranes which were evaluated by contact angle, DMA, light scattering, hemocompatibility, and cytocompatibility. The results obtained show a substantial difference in performance depending on the type of processing with which the membrane has been prepared; the one obtained by phase inversion being the most effective for the rejection of uremic toxins while the one obtained by electrospinning offers the greatest permeate.

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# S08 – Polymer Foams and Membranes

## S08 - 133

## From vibrating molecules to a running shoe: Connecting dielectric properties with process feedback in radio-frequency welding of TPU bead foams

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From packaging to sports equipment - a multitude of products made from bead foams are part of our daily lives. In recent decades, many new materials based on bio-based or recycled polymers have emerged on the market and in research [1]. Another current focus has been on technical and high-performance materials to extend the application range to higher operating temperatures. In addition to the material side, new processing technologies have also been introduced welding single beads together in order to create three-dimensional, durable parts in a more energy and resource efficient way [2]. Probably the most important of these is based on direct dielectric heating of the beads by an external electromagnetic field in the radio-frequency range. Once dipoles are present in the affected volume, the interaction with the oscillating field generates heat through intermolecular friction during constant realignment [3]. In order to optimize the process for maximum energy efficiency and part quality, these physical phenomena need to be thoroughly investigated. Therefore, this study aims to bridge the gap between the dielectric properties of the material and the interaction in the process. Impedance spectroscopy was used to determine the temperature and frequency dependence of the complex relative permittivity of both the base polymer (TPU) and the corresponding foam beads (ETPU). A specially developed measuring cell was used to evaluate the influence of varying densities on the dielectric properties. These properties are translated into direct feedback during the welding process by power consumption and heating curves based on fundamental physical relationships. This is supported by a coupled electrical and thermal simulation at a component level using COMSOL Multiphysics. With the fundamental knowledge acquired, the boundaries of this novel technology can be pushed towards a more sustainable future of lightweight consumer goods.

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# S08 – Polymer Foams and Membranes

## S08 - 143

## Pressure Dynamics in Foam Injection Molding: Unraveling the Impact on Expansion Ratio and Cell Morphology

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High pressure foam injection molding (HP-FIM) with core-back technology is known for its ability to produce a uniform foam morphology with a high cell density that exceeds that of conventional foam injection molding. The advantage of HP-FIM is that the mixture of polymer and blowing agent is pressurized by both an external force and an internal gas pressure. In this case, it is possible to control the formation and expansion of cells by controlling the pressure drop through cavity volume expansion. Specifically, the study is concerned with the change in the three-dimensional cell form as a function of the pressure drop rate resulting from the change from saturation pressure to atmospheric pressure in one or two stages. In order to comprehend the behavior of polycarbonate foam formation when saturated with nitrogen, a batch foaming process is used to replicate the pressure profile of the injection molding process. Various process configurations are set up to realize the variation in pressure drop rate. As a result, the effect of the pressure drop rate on the expansion rate is studied in situ, and the resulting density reduction and cell morphology are investigated.

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# S08 – Polymer Foams and Membranes

## S08 - 296

## Sustainable foams

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Apart from intrinsic properties of foams, like energy saving through insulation or material saving through lightweight design, foams offer even more possibilities for designing and developing sustainable applications. Plastics based on renewable resources, like PLA and its copolymers can replace oil-based plastics and post-consumer and postindustrial recycled polymers like rPS, rPET and even recycled mixed polyolefins can be used for foaming. Sulzer's foam extrusion technology is especially suited for materials with a small processing window, because temperature of the melt can be controlled precisely. Some of our sustainable foam developments will be presented.

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# S08 – Polymer Foams and Membranes

## S08 - 368

## Morphology design of polymeric foams via pressure treatment

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Polymeric foams with a controlled morphology have received growing interest for advanced applications. Pores size, pores size distribution, pores spatial distribution, pore's structure (closed or open) and relative position (ordered structures) are the key aspects in defining the foam morphology. During the foaming process nucleation and growth together are the steps that lead to the development of the final morphology. Nucleation step influences the number and position of bubbles, the growth step determines the size and shape of pores. Process parameters influence each step in a different way and only a coupled control over them is possible, thus binding the morphology design. This work investigates the possibility of controlling the nucleation and growth steps separately exploiting the effect of pressure and pressure drop rate. An unusual pressure treatment is applied after nucleation in order to freeze the bubbles growth in a molten state polymer/blowing agent solution. Subsequently the process parameters can be modulated to drive the bubbles growth furthermore and different external stimuli can be applied to induce the formation of complex structures. The effect of the pressure treatment is analyzed using a visual observation apparatus. With this apparatus we can visualize each bubble and measure their evolution during time. Successful bubbles growth control paves the way toward advanced morphology design.

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# S08 – Polymer Foams and Membranes

## S08 - 404

## Topologically optimized foams via physical foaming: design, production, and mechanical validation

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Introduced with the outstanding paper of Bendsøe and Kikuchi (Generating optimal topologies in structural design using a homogenization method, in Computer methods in applied mechanics and engineering 71.2,1988, pp. 197–224) the topology optimization method maximizes the performance and efficiency of the design by removing excess material from areas that do not need to withstand significant loads. Additive manufacturing, the most widely used technology to produce optimized structures, has the drawback of not providing the required productivity on a large scale, and products usually show diminished properties in comparison to conventional technologies. Here, we propose an alternative solution using physical gas foaming technology to produce a polymeric foamed beam whose density map is optimized for three-point bending load conditions. Optical and scanning electron microscopy and X-ray tomography are used to analyze the optimized foamed structure and showed the effective- ness of the foaming design protocol in producing the FEM optimized structures. A twofold increase in the stiffness of the optimized structures is measured compared to that of the uniformly foamed counterpart with equal overall mass.

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# S10 – Fibers and Films

## S10 - 151

## Characterization of Multivalent Alginate Fibers

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Alginate-based fibers represent a highly promising material class with diverse applications spanning wound dressings, pharmaceuticals, textiles, and food encapsulation. The quest for biodegradable fibers that offer versatility while adhering to eco-friendly principles remains paramount. Sodium alginate, derived from algae, presents a compelling solution due to its propensity to form a complex network. Wet spinning, leveraging the crosslinking capabilities of alginate with cations, emerges as a technique of particular interest for fiber production. Traditionally, a divalent Ca^(2+) cation, has been employed to induce crosslinking, yielding a structural analogy often referred to as the "egg-box" model, whereby the carboxyl groups of alginate chains interact with ions dissolved in water. This research investigates the potential of leveraging higher valency Ce^(3+) or Ce^(4+) ions to promote increased aggregation of alginate chains, aiming to fortify fiber strength and wetting properties. Through systematic variations in cation type, concentration, and gelling time during fiber formation, we evaluate the mechanical and wetting properties of the resultant fibers. This comprehensive exploration through X-ray characterization and imaging, optical microscopy and polarized microscopy coupled with modeling sheds light on the multifaceted impact of multivalent ions on formation of alginate fibers, offering insights into their structural enhancement and potential applications.

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# S10 – Fibers and Films

## S10 - 232

## Polyketone-Polypropylene Core-Shell Fibers for Concrete Reinforcement

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The corrosion of the commonly used steel reinforcements weakens the structural strength of concrete. To oppose this issue, concrete reinforcements in the form of non-corrosive materials e.g. polymer fibers become more interesting. To be suitable as reinforcement material, polymer fibers need a good bonding ability to concrete and good mechanical properties. The bonding ability is influenced by chemical and structural behavior of the fiber e.g. the polarity of the chosen polymers or the fiber roughness. The mechanical properties of the fiber can be varied by e.g. the polymer selection and their chain orientation. It has been proven that combining two different materials in bicomponent core-shell fibers simplifies reaching both requirements, as long as the core and shell material are compatible. This study investigates core-shell fibers produced from polyketone (PK) and polypropylene (PP). The core consists of PK, while PP was used as the fiber shell. To achieve a compatibilized core and shell and an increased bonding between fiber-shell and concrete, a maleic anhydride grafted polypropylene (PP-MAH) was added to the shell material in quantities from 0 to 75 wt.% using compounding. The core-shell fibers were produced by coextruding a strand, which was drawn to fibers in a second step. Tensile tests were used to evaluate the mechanical properties of the fibers and the fiber-concrete adhesion was examined by a single fiber pull-out test. The added MAH leads an increased tensile strength and an improved bonding between fiber and concrete. In addition, comparative contact angle measurements show a higher surface energy and polarity for fibers containing MAH, which explains the very good mechanical and bonding properties. Changes in surface deformation of the different fibers during fiber pull-out can be observed from pictures taken by scanning electron microscopy. Further, thermogravimetric analysis indicates a slightly increased thermal stability by the addition of MAH.

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# S10 – Fibers and Films

## S10 - 269

## Investigation of Performance Metrics for Meals, Ready-to-Eat (MRE) Ration Packaging towards Sustainable Packaging Options

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The U.S. Military Meal, Ready-to-Eat (MRE) operational rations present significant challenges to the packaging industry due to their stringent mechanical performance requirements during exposures to austere environments and harsh distribution conditions. These challenges have previously been addressed by using multilayer laminates comprised of foil and polymeric layers, which are generally not considered environmentally sustainable. New materials and technologies encompassing environmentally sustainable characteristics are limited for use due to the high barrier and durability packaging requirements. The goal of this project is to determine the barrier and mechanical properties necessary to meet the MRE's 3-year shelf-life and rigorous rough handling protocols for retort and non-retort applications. In this study, selected food items were packaged in various retort and non-retort pouches and then subjected to accelerated aging storage conditions and simulated distribution scenarios. For barrier metrics, the oxygen transmission rate (OTR) and water vapor transmission rate (WVTR) of the films were monitored throughout the storage study, while the food items were also tested by sensory analysis. Durability metrics will be determined after rough handled pouches are assessed for failures. With success, correlations will be made between the barrier and mechanical properties of the materials and their shelf-life stability and durability performance. The reassessment of MRE requirements completed in this study will allow for innovation such as weight and volume reduction or the integration of more sustainable materials that could successfully perform as military rations with reduced logistical burdens.

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# S10 – Fibers and Films

## S10 - 284

## Improving the gas barrier properties of polvinyl alcohol using oppositely charge nanoparticles

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In this study, we synthesized positively charged, high-aspect-ratio layered double hydroxides (LDHs) using the hydrothermal treatment method. These high-aspect-ratio LDHs were subsequently combined with oppositely charged cellulose nanofiber (CNF) within polyvinyl alcohol (PVA) and coated onto a polyethylene terephthalate (PET) substrate using a lab-scale automatic bar coating machine. We employed various characterization techniques, including transmission electron microscopy, scanning electron microscopy, wide-angle X-ray diffraction, atomic force microscopy, rheological measurements, and differential scanning calorimetry, to investigate the microstructure of the PVA/LDH-CNF coatings. We observed that the combination of oppositely charged nanoparticles within PVA has a synergistic effect on the oxygen barrier performance of the coating, attributed to (i) the presence of electrostatic interactions and hydrogen bonding within coatings, (ii) the improvement of re-agglomeration of LDH after CNF addition, and (iii) enhanced crystallinity resulting from the combination of oppositely charged nanoparticles within PVA. The final PVA/LDH-CNF coatings exhibited a very low oxygen transmission rate, measured as 0.003 cc/m2d. Importantly, these coated films demonstrate transparency and mechanical resilience, rendering them suitable for flexible food packaging while also presenting recycling opportunities.

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# S10 – Fibers and Films

## S10 - 328

## Multifunctional Flexible Sensors with 3D Fiber Network for Rapid Humidity Response and Long-Term Respiratory Monitoring

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Slow humidity response and poor tolerance to high humidity environments limit the application of humidity sensors for respiratory monitoring. Herein, a flexible humidity sensor with a structure composed of multiwalled carbon nanotubes (MWCNTs) and silica nanoparticles firmly attached to the multilayered 3D fiber network of thermoplastic polyurethane (TPU) fiber film was fabricated by a simple electrostatic spinning combined with swelling-self-assembly method. Benefiting the weak interaction bond between MWCNTs and water molecules, the sensor afforded a humidity response (0.73s), a wide humidity detection range (0-100%), wide strain sensing range (0-120%), enabling it to be used to accurately detect human respiration at a frequency of 1 Hz. The multilayered 3D fiber network of the sensor surface increases the contact area between the MWCNTs and the airflow, accelerates airflow transfer rate, thus improving the sensitivity to humidity in the airflow. The near-superhydrophobic surface (contact angle = 147.8°) enables the sensor to be used to accurately detect human respiration for extended periods of time in high humidity environments. Strong 3D fiber skeleton and the firmly attached MWCNTs ensure the stability and robustness of the sensor for humidity detection. In addition, the sensor is breathable and portable, increasing wearer comfort. The above advantages enable the sensor to be used to monitor a user's respiration in real time. It is promising to build human-computer interfaces and apply them to early warning of sleep-related diseases.

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# S10 – Fibers and Films

## S10 - 36

## DEVELOPMENT OF ANTIMICROBIAL FILMS FOR FOOD PACKAGING USING MELT COMPOUNDING TECHNIQUE

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In this study, the synergistic antimicrobial effects of six different mineral carriers (halloysite nanotubes (HNTs), kaolinite (Kao), mesoporous silica nanoparticles (MSNPs), zinc oxide nanoparticles (ZnONPs), and molecular sieve type 4A (Z4A)) loaded with limonene essential oil in LDPE films as well as the antibacterial and antiviral effects of ethyl lauroyl arginate (LAE) in its commercial form as LAM (10% LAE, 90% maltodextrin) incorporated into LLDPE films were investigated. All carrier-limonene hybrids were added into LDPE films using melt compounding and a full characterization was performed by the evaluation of thermal, mechanical, optical, barrier and functional properties. The resulting films exhibited outstanding antimicrobial properties against E. coli. Thermogravimetric analysis (TGA) showed 20-25% of the initial limonene content was retained against thermal degradation by melt compounding. For LAM added LLDPE films, the thermal stability of the developed films decreased with increasing concentrations of LAM. The films containing 14 and 16.5% LAM showed interesting antibacterial properties against E. coli, however, they lost their antimicrobial activity after 10 days immersion in water. Nevertheless, their activity was recovered after 5 months storage at room temperature with a reduction rate of 2 log (CFU/mL) due to LAE migration from bulk to the film surface. The film containing 14% (w/w) LAM showed also antiviral activity against Human Coronavirus (HCoV-229E) and reductions of 0.7 and 1.18 log TCID50/mL were observed after 1- and 2-hour contact time, respectively.

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# S10 – Fibers and Films

## S10 - 66

## Effect of ionizing irradiation on PLA- fiber properties

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Polylactide fibers (PLA) have excellent high tensile strength and due to their biocompatibility, they are potential alternatives for Woven and Non- Woven Medical Products, or they can substitute some of the petroleum-based synthetic fibers. However, for a large number of medical applications, textile fibers must be sterilized during the manufacturing process or subsequently in order to reduce microbial surface contamination. The use of sterilization techniques, e.g. heat-, chemical-, UV-, plasma- or irradiation–based sterilization, affect the properties of PLA-fibers. The impact of the short-time electron irradiation sterilization process on the PLA properties will be discussed. Therefore, melt spin PLA- fibers were post-drawn with different draw ratios in the range 1.0 - 1.6. The Influence of a typical sterilization dose, of 25 kGy, on thermal- and mechanical properties and the molar mass will be presented. During irradiation, the electron-induced polymer chain radicals in the crystalline fiber areas inhibited intermolecular covalent bonding reaction by restricted polymer chain movement. Hence, these trapped radicals are undergoing termination reactions with oxygen /moisture or intramolecular chain scission. An elevated temperature and strict moisture-, atmosphere control during irradiation can minimize such degrading effects. These studies are intended to raise awareness of the fact that sterilization is always accompanied by a change in the material properties. Therefore, it should be considered while planning medical products.

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# S11 – Nanotechnology and Nanocomposites

## S11 - 120

## Improving SWCNT dispersion in aprotic solvent via ordered non-covalent polymer wrapping and co-solvents

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Production of various polymer nanocomposites with single wall carbon nanotubes (SWCNTs) is done via solution processing. Aprotic solvents like dimethylformamide (DMF), dimethyl sulfoxide (DMSO) and dimethylacetamide (DMAc) are commonly used in polymer synthesis and processing. However, solubility of SWCNTs is limited in these solvents and SWCNTs readily aggregate due to SWCNT-SWCNT interactions and its high aspect ratio. Covalent functionalization or grafting strategies, common to improve dispersion of multiwall carbon nanotubes, are not ideal for SWCNTs given their single wall structure. Here we show non-covalent strategies to improve SWCNT dispersion in DMF. Upon sonication in DMF, PMMA orderly wraps around SWCNTs1; experimental2 and molecular simulation3 data is presented. Ordered wrapping is demonstrated via XRD (0.83 nm pitch) and HR-TEM imaging and depends on the polymer tacticity. Simulations show that ordered wrapping is controlled by chain conformations and CH-π and van der Waals interactions with free energy of binding of ca. -2 kcal per monomer. Co-solvents can be selected using Hansen Solubility Parameter prediction. Dispersion and dispersion stability of SWCNTs in DMF in the presence of co-solvents was studied via dynamic light scattering4. The calculated hydrodynamic diameter of individual SWCNTs is 80 nm, and the one measured for SWCNTs with polymer wrapping and polymer wrapping + co-solvent strategy was 169 ± 10 and 127 ± 7 nm, respectively. The effect of these SWCNT dispersion strategies on the homogeneity of polyacrylonitrile/SWCNTs/DMF solution was also studied, and rheology data is presented.

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# S11 – Nanotechnology and Nanocomposites

## S11 - 13

## Femtosecond Laser Engineering of Polymers: Transforming the Microfluidic Medical Device Industry

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The utilization of laser sealing has evolved into an established method for uniting thermoplastics across diverse applications. Employing laser energy as a concentrated heat source enables the selective melting of thermoplastics and their subsequent fusion upon contact with another thermoplastic substrate, resulting in the formation of resilient joints. This technique holds notable promise, especially when sealing thermoplastic microfluidic medical devices for reasons of fast processing speed and minimum heat spread. Furthermore, the deployment of ultra-short, pulsed laser sources like the femtosecond laser facilitates precise localized heating within the bulk of optically transparent thermoplastic polymers, this has revolutionized polymer processing of optically transparent polymers used in the medical industry. Additionally, this investigation will encompass an in-depth exploration of the supplementary advantages offered by femtosecond laser technology in the broader context of polymeric microfluidic device fabrication.

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# S11 – Nanotechnology and Nanocomposites

## S11 - 153

## Effect of graphene particle size on the electrical conductivity and the morphology of immiscible polymer blends

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Electrically conductive polymer composites incorporating graphene nanoplatelets (GnP) have recently undergone extensive investigation. Within the existing literature, a broad spectrum of electrical percolation thresholds has been documented in different GnP systems [1-2]. This diversity can be ascribed to variations in the chemical and rheological properties of the polymer matrices. Moreover, the disparities in the specific surface area (SSA) and geometry of the GnP utilized across different studies contribute significantly to this variability. Currently, there are only a few systematic studies on the effect of SSA and GnP geometry on the electrical properties of composites containing GnP [3]. In this work, the effect of GnP lateral particle size and SSA on the electrical and rheological behavior of single-phase polymers and immiscible polymer blends was evaluated. GnP grades featuring lateral particle size ranging from sub-micron to 25 µm and surface area ranging from 50 to 750 m2/g were investigated. GnP concentrations varying from 1 to 10 wt.% were respectively added to polymethylmethacrylate (PMMA), polystyrene (PS) and PMMA/PS blends, by melt compounding. The nanocomposites were obtained by extrusion. The morphology and electrical properties of the composites were respectively evaluated by scanning electron microscopy and broadband dielectric spectroscopy. The rheological properties were also investigated in the linear viscoelastic range. In PS/GnP and PMMA/GnP single-phase polymer nanocomposites, it was shown that the GnP grade featuring the largest lateral particle size presented a lower percolation threshold compared to the GnP grades with smaller lateral particle size. Interestingly, in PS/PMMA/GnP blend nanocomposites, the lowest percolation thresholds were observed in the blends containing the smaller particle size GnP. This behavior has been attributed to a more efficient migration of the smaller particle size GnP to PS/PMMA interface.

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# S11 – Nanotechnology and Nanocomposites

## S11 - 156

## Strong, tough, and transparent poly(methyl methacrylate) composites incorporating thermoplastic polyester/polyamide/polyurethane elastomer nanofibrils

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Improving the tensile toughness and impact strength of glassy polymers, such as poly(methyl methacrylate) (PMMA), almost always involves a trade-off, the improvements come at the expense of reduced tensile strength, stiffness, transparency, glass transition temperature, etc. Our findings present a facile approach to markedly enhance both tensile toughness and impact strength without compromising other vital properties of glassy matrices. This is accomplished through the incorporation of nanofibrils of various thermoplastic elastomers (with diameters less than 100 nm), such as thermoplastic polyester elastomer (TPEE), polyether block amide (PEBA), and thermoplastic polyurethane (TPU). By adopting the nanofibril network structure with a very high aspect ratio, as opposed to the conventional sea-island morphology employed in traditional rubber toughening, we show that the required amount of rubber for effective rubber toughening (brittle-to-ductile transition) can be significantly reduced to only 1-3 wt%. Achieving effective toughening with such a minimal content of soft rubbery materials is the key to preserving other crucial properties of the matrix. Herein, we studied the effect of both rubber structure (spheroids vs nanofibrils) and concentration on the rheological, optical, and mechanical properties of the composites. Our studies also revealed that multiple crazing is the primary toughening mechanism in the nanofibrillar composites at a slow deformation speed (i.e., tensile testing), while rubber cavitation and subsequent ductile shear yielding of the surrounding matrix is the most dominant at a high deformation speed (i.e., notched Izod impact testing). The glassy polymer (i.e., PMMA) based composites presented in this work possess immense potential for applications requiring a unique combination of attributes such as high strength, stiffness, tensile toughness, impact strength, and optical transparency.

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# S11 – Nanotechnology and Nanocomposites

## S11 - 171

## Process transfer of PECVD gas barrier coatings between PE-HD and PP hollow bodies

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The increasing relevance of plasma enhanced chemical vapor deposition (PECVD) coatings for the circular economy becomes clear, when looking at the European Union's post-consumer plastic waste emissions of 29.5 t in 2020. Of these only 35 % were sent to recycling. A main limiting factor for the introduction of packaging waste to recycling processes is the still widespread reliance on multi material packaging. A completely recyclable substitute for those materials is provided by the application of PECVD coatings on mono material products, that allows for a functionalization against oxygen ingress. Therefore, the PECVD internal coating process for hollow containers was developed at IKV and continuously refined. This allows for coating systems to be developed for different functionalities, geometries, or materials. However, the transferability of barrier coatings to different substrate materials poses a challenge, as the coatability can vary greatly with the base polymer and any additives. For this reason, a study on polyolefinic hollow bodies was carried out at IKV in collaboration with the DWK Life Sciences GmbH in order to investigate the influence of the substrate material on coatability. A dual layer coating consisting of an intermediate and a barrier layer was analyzed. The two sample types were geometrically identical, but made of different materials (PE-HD, PP). Using the definitive screening design, the influence of the process parameters (power, pulsation) on the oxygen transmission rate was analyzed in order to respectively compare the performance of the gas barrier. The derived coating systems were subjected to chemical and physical analysis methods as well as electron microscopy. It was observed that for both substrates a similar process gas composition during deposition of the barrier layer was favorable for the barrier performance. The properties of the intermediate layer, on the other hand, were dependent on the substrate material.

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# S11 – Nanotechnology and Nanocomposites

## S11 - 188

## Layered double hydroxide – a versatile structure for designing function integrated materials

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Layered double hydroxides (LDHs) are popular functional fillers increasingly used in composite materials. They can be designed via metal and anion selection as well as the specific processing method to prepare structures with specific desired functional properties. This makes LDHs suitable for many different applications, including as flame-retardants, UV stabilizers, and antimicrobial agents in polymer nanocomposites as well as a photo-absorber in a solar cell. An overview of LDH synthesis and modification, composite preparation as well as characterization is given to highlight the unique ability for customization of LDH.

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# S11 – Nanotechnology and Nanocomposites

## S11 - 199

## Bio-inspired Hierarchical Hybrid Composites for High-Performance Structural Applications

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In light of the global energy crisis, high-performance transportation sectors are rapidly embracing lightweight materials to enhance energy efficiency and achieve long-term sustainability. In fact, a mere 10% weight reduction yields a significant 14% increase in mileage, emphasizing the critical role of light weighting in emerging electric vehicles. Our laboratory focuses on advancing the field of lightweight structural composite materials, through the development of synergy-induced hybrid composites, consisting of multiple nanoscale and micro-scale reinforcements within a common matrix material. These composites utilize widely employed polymer matrices as industrial substitutes for metallic structural components within the automotive sector, specifically non-polar Polypropylene (PP) and polar Nylon (PA). Our hybrid composites are strategically enhanced through the incorporation of various bio-inspired fibrous reinforcements, mimicking the hierarchical architectures of biological systems. These unique self-assembled reinforcements were demonstrated using either nano-sized Graphene Nanoplatelets (GnP) covalently bonded, or Halloysite Nanotubes (HNTs) electrostatically attached to chemically modified micro-sized Glass Fibers (GF). The tailoring of the interface of these meticulously crafted hybrid composites, by optimizing the density of the nano-filler leads to outstanding mechanical performance and improved processability, induced by synergy. Specifically, our hybrid composites surpass the industrial polymer substitute for metallic structural components mechanical properties, exhibiting improvements up to 34% in tensile strength, 86% in impact strength, and 37% in flexural strength compared to the industrial standard, while providing a 20% weight reduction.

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# S11 – Nanotechnology and Nanocomposites

## S11 - 201

## Tri-layered Hybrid Composites for Structural Thermal Management Applications

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Environmentally driven policies and sustainability targets are driving automotive, aerospace, and other high-performance transportation sectors towards the adoption of lightweight multifunctional materials to meet energy efficiency requirements with long-term sustainability. In response to these rising demands, this work presents a novel approach to develop structural thermal management materials for advanced components such as electric vehicle battery enclosures, avionics systems in aircraft, and fuselage structures in aerospace applications. Our meticulously engineered tri-layered composite utilizes our patented Polypropylene-based hybrid composite material, comprised of Graphene Nanoplatelets (GnP) covalently bonded onto chemically modified micro-sized Glass Fibers (GF) which mimics the hierarchical architectures of biological systems. Specifically, the top and bottom layers (i.e., skin layers) are solid, while the middle layer (i.e., core layer) is foamed to various void fractions. In this solid-foam-solid (SFS) configuration, the solid skin layers contribute to robust structural integrity and efficient heat dissipation, due to the inherent thermal conductivity of the GnPs, complemented by the cellular-structured core that imparts lightweight properties and effective thermal insulation. As a result, this work has led to the development of an SFS hybrid composite that maintains the required tensile strength, exceeds the flexural strength by 4%, and exceeds the impact strength by 114%, while providing a 25% weight reduction, compared to the leading biphasic composite adopted in the automotive industry. Ultimately, this study has demonstrated the feasibility of manufacturing SFS hybrid composites with synergy-induced properties that can be tailored for a variety of novel applications, where multifunctionality, mechanical performance, and light weighting are simultaneously imperative to meet the energy efficiency requirements of the future.

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# S11 – Nanotechnology and Nanocomposites

## S11 - 266

## Electrospun polycaprolactone scaffolds for nerve guidance conduits

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Despite the regenerative potential of the peripheral nervous system, injuries leading to the loss of a segment of the nerve bring up the challenge of the functional recovery of these individuals. In these cases, it is vital to develop materials that can aid the regeneration. This work aimed to evaluate the effectiveness of electrospinning in the production of nanofibrillar Polycaprolactone (PCL) nerve guidance conduits (NGC) and it's in vivo effectivity. The NGCs were obtained with a 10% wt PCL solution electrospun at 17.5Kv, 0.5 ml/H flow rate and distance between the needle tip and the collector of 13.5 cm. Nine rotation velocities were tested to obtain a tube. Fibers obtained at 900 RPM were continuous and randomly arranged with a diameter of 644 ± 233 nm and a lumen of 700 µm. Those NGCs were used to bridge a 6mm gap in the sciatic nerve of C57BL6 male adult mice (n=5), which were evaluated weekly for their sensitive and locomotor regeneration. Animals treated with the NGC presented a response at the 2nd post-operatory week at the Von Frey analgesimeter test and after 10 weeks the animals were back to their basal level of tactile sensitivity. The locomotor function was evaluated through the Sciatic Function Index (SFI), where after 10 weeks the animal presented an increased SFI, similar to animals treated with an autograft implant. The electroneuromiographic study revealed that the animals treated with the NGCs presented a return of the electrical conductivity with the amplitude of the compound action muscular potential of 9.742 ± 1.754 mV. Finally, histological analysis revealed that the nerve inside the tube presented newly formed blood vessels and myelinated fibers. The regeneration can be attributed to a fibrillar structure similar to the extracellular matrix and a porous characteristic of the electrospun NGC, which allowed for the influx and efflux of nutrients and cellular debris and presents a viable option in regenerative medicine.

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# S11 – Nanotechnology and Nanocomposites

## S11 - 268

## Influence of Thermomechanical Conditions in Twin-Screw Extrusion and Injection Molding on the Morphology of Crystalline Nanocellulose and Polypropylene Composites

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Studies in literature have observed the phenomenon of rapid reagglomeration of carbon nanotubes in a PP matrix with subsequent reheating after the dispersion of nanoparticles through an elongational flow device. However, for the polypropylene/nanocellulose system, there are no studies regarding this reagglomeration due to reheating. For this reason, it is important to analyze the effect of reheating in the injection molding stage on the dispersion of nanocellulose crystals in a PP matrix processed via twin-screw extrusion. Thus, samples with and without compatibilizer, polypropylene grafted with maleic anhydride, were morphologically characterized via electronic and optical microscopy after the twin-screw extrusion process and subsequently after the injection process at two speeds. The extrusion process promoted a more effective dispersion of clusters in samples with compatibilizer than in samples without compatibilizer. It was observed that the injection process further dispersed the NCC clusters compared to samples only subjected to extrusion. Therefore, the effect of shear and elongational flow in injection molding prevailed over the tendency of reagglomeration due to reheating of the samples. However, it was observed that the injection speed did not have a significant effect on the dispersion of NCC clusters. Rheology results showed that the amount of compatibilizer was suitable for the reinforcement amount, not exhibiting a lubricating action in the compounds. Dynamic Mechanical Analysis (DMA) results showed that samples with 2.5% NCC had a 23% increase in storage modulus E´ compared to pure PP.

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# S11 – Nanotechnology and Nanocomposites

## S11 - 323

## Metal Nanoparticles on Flexible Polyurethane Sponges: A Hydrothermal Route towards Catalysts for Lab-Scale and Continuous Flow Automation

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In the realm of catalytic nanoparticles (NPs), gold NPs have gained significant attention for their intriguing physicochemical properties, specifically their activity at low temperatures and in aqueous systems. Traditionally, AuNPs are produced by reducing gold salts. Various syntheses employing different reducing agents, solvents, and surfactants, have been reported. However, these methods can result in unstable and deactivated particles, and require energy intensive processes to separate or recover the NPs in solution. As we show here, the use of a suitable support to immobilize them can solve these issues: the support can act as effective reducing agent towards AuNPs and eliminate the recovery issue by anchoring the AuNPs to a macroscopic object. In this work, we present a method that eliminates the need for hazardous chemicals during synthesis, by using only "hot water" to produce AuNPs supported on a monolithic polyurethane foam (PUF) – the PUF acts as both a support and reducing agent. We also extended the methodology to other NPs relevant to catalysis: AgNPs and PdNPs. The PUF allows for the repeated use of the NPs as a catalyst, as it can be soaked and squished repeatedly without losing the well-anchored NPs, facilitating the separation process. To assess the catalytic properties of the NPs@PUF, we used the reduction of 4-nitrophenol to 4-aminophenol as a model reaction. We first manually soaked the NPs@PUF in reactant solutions and then developed a fully automated platform for their use – this framework can be integrated in a straightforward fashion as a step to automate parts of more complex organic syntheses. We thoroughly tested the NPs@PUF materials, demonstrating their high catalytic activities for the reduction of 4-nitrophenol to 4-aminophenol and their high reusability. Finally, we are developing the use of the NPs@PUF in continuous-flow setting, which will enable us to perform the reaction under efficient conditions towards an industrial setting.

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# S11 – Nanotechnology and Nanocomposites

## S11 - 356

## Enhanced electromagnetic interference shielding performance of reduced titanium carbonitride MXenes incorporated into porous polymer structures

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The growing demand for effective shields against electromagnetic interference (EMI) has sparked interest in conductive polymer composites. Polymer composite shields have gained significant recognition for seamless integration into electromagnetic protective coatings and shielding layers in modulated microwave absorbers. Interestingly, MXenes are characterized by unique shielding properties and ease of processing, surpassing both metal and carbon fillers. Accordingly, these two-dimensional (2D) nanomaterials have emerged as a widely adopted candidate to get incorporated into EMI shielding polymer nanocomposites with enhanced performance and mechanical stability. Meanwhile, postprocessing treatments can potentially exert profound impacts on the shielding effectiveness (SE) of MXene materials. This study first explores the transformative potential of hydrazine and heat-treated titanium carbonitride (Ti3CNTx) MXene material for polymeric EMI shields. The controlled application of hydrazine and heat allows precise regulation of the reduction processes, enabling tailored control over the chemistry and electrical properties of the MXene. The EMI SE values are theoretically and experimentally determined. The treated MXene films exhibit significantly enhanced SE values compared to the pristine MXene, with dominant improvement observed in the heat-treated samples. Subsequently, enhancing the interlayer interactions with polyvinyl alcohol (PVA) in a porous freeze-casted structure could further enhance dielectric polarization, and thus the EMI shielding performance, while promoting the mechanical properties. Overall, the findings of this work hold significant practical implications for advancing high-performance, polymeric EMI shielding materials.

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# S11 – Nanotechnology and Nanocomposites

## S11 - 362

## Bacterial Cellulose: Discovering the Potential for Advanced Sustainable Materials

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The increasing popularity of sustainable environmental trends can be attributed to individual concerns about the impacts of global warming and their dedication to addressing environmental issues. Sustainable materials are a solution that optimizes the use of materials while also addressing environmental concerns. The primary objective is to transform industrial waste or natural substances into more beneficial uses. Enhancing material efficiency, e increasing challenges in material advancement. Additionally, when evaluating production expenses in comparison to other currently utilized materials, it is essential to consider cost-efficiency. Our research group is interested in bacterial cellulose (BC), which is a byproduct derived from the food sector. It possesses favorable characteristics like as purity, high crystallinity, ease of modification, and others. BC was fabricated for many applications, such as the production of films for food quality control, membranes for water treatment, and separators for batteries. The development of these materials was not solely reliant on environmentally friendly resources as the fundamental strategy. Additionally, it considers the eco-friendly manufacturing method and its capacity to address environmental concerns. In the future, the industries sector will prioritize the development of sustainable materials as substitutes for traditional materials that have adverse environmental effects, while also meeting social needs.

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# S11 – Nanotechnology and Nanocomposites

## S11 - 367

## Development of food packaging films able to be recycled

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The most important characteristic of packaging films to preserve food is the ability to prevent permeability to oxygen and water vapor, which delays lipid oxidation and the appearance of mold and fungi in the food. This double barrier in flexible plastic packaging is achieved by combining different polymers in a multilayer structure, where polymers, such as polyethylene (PE) and polypropylene (PP) constitute the water vapor barrier and ethylene vinyl alcohol (EVOH) and polyamide (PA) serve as oxygen barrier. Unfortunately, this combination of polymers is not ideal for recycling purposes. Rules imposed by some European markets already restrict the incorporation percentage of EVOH in a flexible LDPE film. To keep the packaging's oxygen barrier properties and reduce the amount of EVOH and tie materials (<5 wt.%), this study analyses the incorporation of nanoclays (NC), cellulose microcrystals (MCC), silicon dioxide nanoparticles (SiO2) and cellulose nanocrystals (CNC) in an EVOH matrix. Masterbatches of these particles were previously produced and subsequently diluted to produce EVOH monolayer film. The results indicate that some of the particles induce a stable process in blown film extrusion and have better dispersion, as it is the case of NC and MCC. Thus, three-layer films (ABA configuration) of LDPE (A) and EVOH/micro and nanocomposites of MCC and NC (7 µm layer) (B) were produced to protect EVOH from humidity and support blown film processing, with low percentages of micro and nanoparticles (0.5 and 1 wt.%). OTR and WVTR results were considerably different for multilayer films with 0.5 NC and 1 wt.% MCC giving the lowest OTR values. Although haze has increased in films with micro and nanoparticles, this increase did not affect the good visibility of the food to be packaged.

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# S11 – Nanotechnology and Nanocomposites

## S11 - 37

## Morphology Evolution Under a Controlled Flow of Polystyrene/Polypropylene/Few Layers Graphene Nanocomposites

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Polymer blends with co-continuous morphology have gained interest for their potential application as conductive composites when used with electrically conductive fillers, such as carbonaceous nanoparticles. Indeed, their use can significantly reduce the percolation threshold concentration, which corresponds to the concentration of nanoparticles above which the materials start to be electrically conductive. This is achieved when the filler is located within one of the phases or at the interface between the two polymers, forming the co-continuous morphology, resulting in a double percolation. After achieving the double percolation effect, it's crucial to study matrix morphology and filler network stability during further processing, which may involve higher strains and strain rates (e.g., injection molding). This can be assessed using rheological tests with a proper test design involving small amplitude oscillatory shear (SAOS) and a deformation step. In this work, co-continuous blends of two immiscible polymers, polypropylene (PP) and polystyrene (PS) filled with few-layer graphene (FLG), (PP/PS/FLG), with FLG concentration ranging from 0 to 9 wt.% were prepared by melt mixing and characterized rheologically, morphologically, and electrically. In order to investigate PP/PS/FLG composites properties evolution under a controlled flow, two test-designs involving a sequence of SAOS and a steady shear (simulating deformation flow), or annealing step (stress relaxation step), was used to evaluate the morphology before and after applied controlled flow and evolution of electrical properties during applied flow. The results obtained from both SAOS and SEM observations before any deformation indicated that, upon the addition of FLG, the characteristic domain size of co-continuous PP/PS/FLG decreases drastically, indicating that FLG refined the morphology. It was also shown that FLG could stabilize the morphology of a co-continuous blend once added at a certain concentration even if high deformation was applied. The same behavior was observed for the electrical conductivity.

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# S11 – Nanotechnology and Nanocomposites

## S11 - 414

## In situ growth of ZIF-67 at PVDF nanofibers: influence of solvents on particle morphology

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Metal-Organic Frameworks (MOFs) have drawn much attention from researchers due to their unique physical structures and potential applications in many fields such as biomedicine, gas storage, and biosensing applications. Such characteristics are enhanced when such materials have nanometric scales. Particles on such a scale can be difficult to handle, especially for applications such as filtration and water treatment. This work aims to synthesize particles from a cobalt-based MOF (ZIF-67) on the surface of electrospun Polyvinylidene fluoride (PVDF) nanofibers, evaluating the influence of solvents on the morphology of the particles formed. The solvent used can impact both the shape and size of the ZIF-67 particles, thus influencing their applications. In this work, a solution of PVDF and cobalt nitrate was electrospun, and from this process, blankets were obtained. These blankets were immersed for 24 hours in a solution containing 1.5 mg/mL of 2-methylimidazole. The liquids used for the solution varied between water, methanol, ethanol, and isopropanol. The morphology of the fibers was analyzed through scanning electron microscopy (SEM), which showed that fibers have diameters between 200 nm and 1 µm before immersion and between 50 nm and 300 nm after immersion. SEM also showed that the morphology of the formed particles was different, from flakes to prisms, the size of the particles ranged from 10 to 50 nm. The structural characterization was confirmed by XRD and FTIR. The mass concentration of ZIF-67 was estimated by TGA. These materials are excellent candidates for applications such as textiles, filtration, and gas separation.

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# S11 – Nanotechnology and Nanocomposites

## S11 - 426

## High-performance barrier coatings using a rotational coating method

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Clay coatings on polymer substrates can reduce permeability of a base film by a factor of 10 or more. The key to high permeation resistance using clay/polymer coatings is to force the clay nanosheets to lie flat on the substrate. While conventional coating methods might suffice, a more direct method is to push the nanosheets against the substrate using a body force normal to the substrate surface. Such can be accomplished using a rotating cylinder wherein the film substrate is deployed on the inside the cylinder. To test this idea, an aluminum cylinder was made and mounted such that it could be turned around its central axis using a speed-controlled motor. The equipment was capable of applying a radial acceleration of over 3000 m/s2 (~300 G). Using a substrate of polyethylene terephthalate (PET) "glued" to the inner surface of the cylinder with water, aqueous suspensions of clay (Montmorillonite, MMA) coated with poly(vinyl alcohol) (PVA) were introduced. The effects of various concentrations and accelerations were then explored. Coating thickness, IR spectroscopy, SAXS and oxygen permeability were the principal observables. As might be expected, the coating thickness increased with concentration; however, it declined with acceleration, which might be taken as evidence that the hypothesis of body-force flattening is correct. Permeability also declined with acceleration, and reached levels that were lower than is usually observed with other coating methods. As for continuous coating, it's difficult to imagine the geometry and equipment that might be effective. However, some thoughts will be presented.

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# S11 – Nanotechnology and Nanocomposites

## S11 - 432

## Industrial uses of polymeric capsules made via microfluidics

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The development of microfluidics-based systems in the recent years has provided a rapid and controlled method for the generation of monodisperse microencapsulates for multiple applications. Here, we explore the design, manufacture, and characterization of a low-cost microsystem for the encapsulation of the fungal laccase in alginate microcapsules. Multiphysics simulations were used to overview the fluid behavior within the device and estimate the resulting capsule size. Different flow rates of the continuous and discrete phases were evaluated for microcapsule fabrication. Microscopy technology and image analysis was used to measure the final particle size. Laccase encapsulation was evaluated using spectrophotometry and with the aid of fluorescent dyes and confocal microscopy. Results showed microcapsule size was in the range of 203.13–716.00 µm and continuous phase was found as the dominant parameter to control capsule size. There was an effective enzyme encapsulation of 65.94% with respect to the initial laccase solution. [1] Fertilizers and natural extracts were encapsulated, manually and using the proposed microsystem, and their diffusion in paper membranes was verified. Additionally, some drone spraying tests were done for precision agriculture applications [1] On the other hand, we developed a patented dispensing device with an American Company. The dispensing device allows for application of nourishing compounds, such as microcapsules, during rest. The elements of the device are separable from the body of the device. Thus, the body of the device is washable without risk of washing away the desirable compounds. The device can take one of multiple embodiments and is preferably formed from a compressible material. When a user places her head on the device, the downward force created against the relevant storage body pushes the compounds/microcapsules out of the internal reservoir, exiting through the orifices and into the user's skin. [2]

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# S11 – Nanotechnology and Nanocomposites

## S11 - 52

## Design of PLA-based nanocomposites with high barrier properties

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Poly(lactic)acid nanocomposites containing impermeable nanofillers have been widely used in the last decades with the aim to improve barrier properties [1]. If some general trends have been drawn from experimental work, notably showing the efficiency of lamellar type nanofillers [2] as a mean to bring significant tortuosity effect, only few works focused on spherical or nanotube fillers and on the influence of the crystallinity[3]. Moreover, the comparison of the effect of these different types of impermeable phases on the PLA microstructure and the barrier properties has been rarely established. In this work a detailed analysis of PLA based nanocomposites was performed through physics models and a machine learning approach with the support of experimental data. To achieve this goal, a selected series of amorphous and semi-crystalline PLA-based nanocomposites containing lamellar, spherical, and nanotubes fillers were prepared by different processes. The microstructures were characterized by transmission electron microscopy (TEM) to assess the dispersion of the fillers. Differential Scanning Calorimetry (DSC) was used to characterize the mobility of the polymer chains as a function of the filler fraction and the crystallinity degree. Permeability measurements were carried out for O2 and water vapor on the amorphous and semi-crystalline nanocomposites. Relations between permeability and materials structures were established using two different approaches. On the one hand, experimental results have been fitted with physical models by considering the material microstructures and laws of equivalence between the different type of fillers and the crystalline phase have been drawn. On the other hand, two Machine Learning models have been used to predict the relative permeability form the materials microstructures. The predicted results have been shown to be in good agreement with experimental results and enable to design nanocomposites for a given permeability.

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# S11 – Nanotechnology and Nanocomposites

## S11 - 53

## Effect of Temperature on the Tensile Behavior of Polyamide 1010 Nanocomposites Reinforced by Different Two-dimensional Materials

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Castor oil-based polyamides, such as polyamide 1010 (PA 1010), are some of the most interesting biopolymers currently on the market [1]. Because of that, this polymer is already being employed in numerous industries, including the electronics and automotive sectors, as well as for the production of sports equipment, textiles, and coatings [2]. Furthermore, it is possible to further improve its characteristics by adding nanoparticles [3,5]. However, most works still use extremely high contents of nanoparticles, which inevitably compromises the processability, flexibility, and ductility of thermoplastic materials. Figuring out how temperature affects a material's properties is another often overlooked component when investigating polymer nanocomposites. Therefore, we explored the use of different two-dimensional materials, i.e., graphene oxide (GO), hexagonal boron nitride (h-BN), and molybdenum disulfide (MoS2), both individually and in hybrids, as fillers for PA 1010 nanocomposites, investigating their tensile behavior not just at room temperature, but also at -40 °C to simulate a more demanding environmental condition. Even though all nanomaterials toughened PA 1010 at room temperature, with a greater impact of the nanoparticles' physical characteristics, it has been observed that this effect is suppressed to some extent at low temperature, where the polymer microstructure seems to play a more important role. The greatest enhancement at room temperature was achieved by GO, increasing PA 1010's toughness by 121% at 0.5 wt%. On the other hand, 0.1 wt% h-BN led to the largest improvement at -40 °C, with a toughness 44% higher than neat PA 1010 under the same conditions. Ultimately, this work demonstrates how crucial it is to take into account external aspects when developing polymer nanocomposites and choosing an appropriate nanomaterial as filler.

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# S12 – Mechanical Properties and Fracture

## S12 - 148

## Influence of fiber orientation and temperature on the creep-fatigue behavior of short fiber reinforced high-performance polymers

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Polymers, especially short fiber reinforced (sfr) polymers are used more and more in structural applications in great growing industrial fields like (electro-) automotive and green energy (for example wind turbines). To use their lightweight potential, the manufacturing and in use influence factors needed to be known and considered in the design process. For sfr thermoplastics, the manufacturing generated fiber orientation is one of the most material performances controlling factor [1,2]. Additionally, the temperature during the use has an impact on the lifetime behavior of sfr thermoplastics [3]. This effect is reinforced with complex loading situations due to the viscoelastic behavior. Especially creep loads between fatigue loads (for example in a resting car between two trips) have an influence on the resulting lifetime of components. The results show a non-neglectable lifetime shift depending on the load, temperature a fiber orientation configuration. In this researching work, the effect of fiber orientation, complex loading and temperature is investigated and insights or rather models for the consideration in a lifetime assessment are derived. The goal is to get a more precise lifetime assessment based on injection molding and structural simulation for structural components. As a result, the material selection as well as the manufacturing can be improved for a specific use.

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# S12 – Mechanical Properties and Fracture

## S12 - 178

## Exploring the Interplay Between Process, Structure, and Resulting Properties in Polymeric Multi-material Composites Inspired by Lithomimetics Principle

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The design of the internal makeup of materials to meet the requirements of modern engineering applications has long been a focal point for materials scientists. Among the numerous pathways within the extensive toolbox of potential options for materials design, lithomimetics [1] stands out as a recent and relatively unexplored design paradigm. This concept is rooted in inspiration derived from the varied structures and patterns inherent in the Earth's lithosphere. This study marks the initial foray into the realm of polymeric materials, focusing specifically on the manufacturing process and the resultant structure-property relationships. The primary objective was to enhance the balance between stiffness and toughness, a challenge often encountered in linearly layered polymeric multi-material composites [2,3]. To address this, two materials with distinct mechanical properties were chosen. A glycol-modified poly(ethylene terephthalate) was selected as the brittle matrix, while a copolyester-based thermoplastic elastomer served as the soft interlayer (IL) material. Both materials were first mixed in different specific mass ratios. After that, a specially developed closed-rotating manufacturing technique was used at various temperatures, pressures, frequencies, and retention times to amalgamate the materials in their molten state to fashion lithomimetic structures. The resulting structures were examined morphologically and fracture mechanically. Findings revealed a substantial enhancement in the toughness-stiffness interplay compared to traditional linearly layered polymeric multi-material composites attributable to the local constraining of the soft IL and a kind of geometrical interlocking during bending. However, achieving a stiffness equivalent to the pure matrix material remains an ongoing challenge.

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# S12 – Mechanical Properties and Fracture

## S12 - 210

## Influence of Process Parameters on Morphology and Fatigue Behavior of Short-Fiber-reinforced Polymers

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The increased utilization of short-fiber-reinforced thermoplastics in structural applications necessitates more precise models for predicting the fatigue life of components under intricate loading conditions. Effects induced by the manufacturing process, including the emergence of local weak spots attributed to weld lines, as well as, in the context of semi-crystalline polymers, different crystalline structures, remain largely unexplored and are presently focus of investigations in this domain. Thorough exploration of the influence of these factors on fatigue behavior is imperative for targeted lifetime prediction, performance enhancement and cost reduction in plastic component production. Consequently, the primary objective of this study is to describe cause-effect relationships directly by process-dependent morphological properties that are measurable or predictable, rather than to scrutinize purely phenomenological correlations. Given that the effects of fiber orientation and converging melt flows are intertwined, tensile and fatigue tests were performed on injection molded PA12-GF50 specimens with a stagnating weld line. This approach enables the derivation of suitable models without such interactions. Microscopic examinations, employing both optical and electron microscopy, were conducted to ascertain the local fiber orientation. To gain a more profound understanding of the morphology, the crystallinity was investigated. Measurements were conducted under process-oriented conditions using Chip Calorimetry, allowing for cooling rates within the range of a genuine injection molding process.

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# S12 – Mechanical Properties and Fracture

## S12 - 24

## Electrolyte Resistance of Amine Based Epoxy´s used for Lithium-Ion Battery Cell Housings

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Filled epoxy potting materials are seen as promising polymer for applications in future automotive battery systems. Hence the electrolyte resistance is of crucial importance. This work examines the electrolyte resistance of potential material candidates for such applications. The material is stored hermetically in electrolyte for several weeks at an elevated temperature of 45 °C. Swelling values are determined, and the mechanical behavior of the specimens is analyzed. Additionally, the electrolyte contamination is measured using head space injected gas chromatography and mass spectroscopy. Based on procedure of exclusion, the impact of filler- and matrix-system upon the swelling behavior is derived. The aim of this work is to identify possible amine-based epoxy materials, that are suitable for polymer metal joint applications, while being in contact with battery electrolytes.

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# S12 – Mechanical Properties and Fracture

## S12 - 290

## DETERMINATION OF CREEP CRACK GROWTH KINETICS OF ABS VIA THE C* APPROACH AT DIFFERENT TEMPERATURES

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Crack initiation and propagation under creep is one of the main failure modes of service equipment made of plastic. This paper explores the feasibility of using creep C* integral approach to deduce creep crack growth data obtained for a polymeric material, specifically an acrylonitrile butadiene styrene polymer, which exhibits nonlinear mechanical behavior. Experimental creep crack growth data, measured at 60 and 80 °C, was used to obtain the relationship between the time rate of crack growth, da/dt, due to secondary creep and the applied value of the appropriate loading parameter. A mastercurve could be determined, which describes experimental data at both temperatures. These promising results suggest that C* integral approach can be used as powerful and convenient tool to describe crack propagation of polymeric materials under secondary creep conditions. The approach may also be of interest for the prediction of creep lifetime for ductile polymers.

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# S12 – Mechanical Properties and Fracture

## S12 - 393

## TPMS lattice structures characterization under quasi-static conditions

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Sandwich panels, composed of two rigid sheets separated by a lightweight core, generate an increase in the moment of inertia that enhances their resistance to bending and buckling loads. This core, commonly formed by honeycombs, polymeric foams, or cellular structures, is chosen due to its desirable characteristics in the packaging industry, such as its low weight and high energy absorption capacity. However, there is currently a great interest in studying other structures to replace foams and honeycomb-type panels, known as lattice structures. This is due to the ability to modify mechanical properties by varying the topology, the size of the unit cell, or the base material. The research conducted focuses on analyzing the influence of geometry, generation direction, and relative density on the mechanical properties and energy dissipation capacities of lattice structures, specifically Diamond skeletal-based and Schwarz sheet-based, types of Triply Periodic Minimal Surfaces (TPMS). Compressive tests were carried out under quasi-static conditions on structures printed via SLA with ductile and brittle photopolymers. The analysis of the force versus displacement curves revealed that the topology and generation direction of the structure directly affect the behavior of the plastic zone, exhibiting either a stable plateau behavior or a behavior governed by strain hardening. Additionally, the relative density and the maximum strain percentage of the base material impact the amount of energy absorbed by each structure and the controllability of its failure. Finally, it was identified that the Schwarz sheet-based and Diamond skeletal-based structures exhibit a stable plateau behavior, with the Schwarz sheet-based structure with a relative density of 0.5 showing the greatest resistance and energy dissipation capacity before reaching densification.

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# S14 – Modeling and Simulation

## S14 - 110

## Anisotropic Effect of Fiber Orientation on Thermal Conductivity in Injection Molding Simulations of Composites

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Fibers are commonly added to polymer materials to enhance mechanical properties and strength in injection molded parts. However, this inclusion also leads to nonuniform and anisotropic thermal conductivity during the molding process. The higher thermal conductivity of fibers and their orientation in the flow contribute to this effect. In thin molded parts, where fibers align parallel to cavity surfaces, thermal conductivity in the thickness direction is typically lower than in other directions. To consider the anisotropic effect of fiber orientation on thermal conductivity, a micromechanics model is used in injection molding simulations. Initially, the isotropic thermal conductivity of the matrix resin is calculated based on bulk conductivity data. Then, anisotropic thermal conductivity is determined at each location using matrix and fiber properties, along with local fiber orientation predictions. This anisotropic thermal conductivity is incorporated into the energy equation of the polymer melt flow. To validate the impact of fibers on thermal conductivity, plaques with varying thicknesses were injection molded using a carbon fiber-filled polymer composite. Thermal conductivity was measured using the transient plane source method, which allows the composite's thermal conductivity to be measured as a bulk value, but also decomposed into the thickness and planar directions. The predicted thermal conductivity in the thickness direction agrees well with experimental measurements. These anisotropic thermal conductivities were then used in injection molding simulations, and pressure predictions were validated against experimental data. Comparisons were made with predictions that do not consider the effect of fiber orientation on thermal conductivity. These comparisons demonstrate improved predictions of pressure history during the packing stage, thanks to more accurate cooling rate calculations achieved by considering anisotropic thermal conductivity.

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# S14 – Modeling and Simulation

## S14 - 125

## Simulation of the Melting Region in Additive Manufacturing Material Extrusion Dies for Highly Filled Feedstocks

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Material Extrusion (MEX) is a simpler AM technology, affordable also for home use. There are different designs of the dies, and we investigated two designs (MK10 and E3D), with each two variants. We assumed that the forces of the filament are related to the melt pool and not on the friction. For the investigation we used Ansys Polyflow and constructed the nozzle assemblies. We used a highly filled feedstock (55 vol.% 316L steel powder in a polymeric binder) and measured the temperature and shear dependent viscosity and the other material data. The region where we assume solid filament has a temperature dependent slip condition as a boundary, to obtain a smoother transition between the solid area and the melting region. The thermal conditions are different for each variant. The MK10 variants are an all-metal construction and a PTFE tube inside. The E3D version has a shorter or longer PTFE insert. The calculations showed interesting results, especially for the temperatures, whereas the pressures were not satisfactory as the temperature dependent viscosity model had to be adapted to calculate lower temperatures. The temperature of the all-metal design showed that, at low extrusion speeds, the melt pool was approximately 15 mm, while in the PTFE version it was only 10 mm. At higher speeds the temperature in the all-metal does not change much, but in the PTFE the desired temperature cannot be reached. In the E3D version we can see similar results between the long and short PTFE tubes. One thing is the high thermal conductivity of the feedstock at 0.98 W/(m·K), in contrast to polymers having about 0.2 W/(m·K). The MEX printer is set at increasing speeds until the gears can be heard trying to push the filament, but the solid filament is blocked in the die because there is not enough heating capacity. This can be heard during trials to achieve maximum printing speeds. The next steps are measurements with a die equipped with a load cell between the die and the gear.

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# S14 – Modeling and Simulation

## S14 - 131

## Fatigue lifetime analysis of POM gears for generalized tooth root loading and shapes

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Today, commonly used calculation methods for the determination of the tooth root load capacity of polymer gears (e.g. VDI 2736) are based on the same assumptions as for steel gears. Due to the widely varying material properties of polymers in terms of non-linear material behavior and rate dependency, the predicted lifetimes of polymer gears are inaccurate [1]. In a previous study, rate-dependent nonlinear viscoplastic finite element (FE) modeling of POM allows the quantification of material influences that are not considered in standard assumptions for metal parts [2]. Based on a physically motivated material model, a lifetime model was developed and validated to predict tooth root fracture as a function of rotational speed. In the present study, the existing lifetime model is extended and validated to include the torque (tooth loading) and notch (tooth root shape) dependency. It is found that a cyclic increase in the cumulative strain energy density occurs in the polymer gear tooth root, as can be investigated for uniaxial loading [3]. This strain energy density can be used as a damage variable that causes crack initiation and leads to tooth root fracture. Using the lifetime model, the evolution of the damage variable(s) can be predicted to derive a critical level of loading cycles, thus forming a damage criterion. Numerical results show that the damage criterion is independent of speed, load, and geometric influences, whereas the validity of the damage criterion is proven by comparison with experimental results obtained from a gear test bench.

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# S14 – Modeling and Simulation

## S14 - 173

## Design Optimization of Rotationally Moulded Hydrogen Pressure Vessels

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Type IV hydrogen pressure vessels are made up of three components, a metallic boss, and polymer liner, and a composite overwrapping layer for reinforcement. Leak-proof design of bosses is critical for safety, ensuring a gas-tight seal to prevent explosions due to leaks. Yet, their design has been largely overlooked. Using rotational molding it is possible to fully encapsulate bosses within liners during moulding, but there are numerous challenges to overcome relating to boss design for effective moulding. FEA software was applied to virtually prototype boss designs and optimize their mechanical performance under pressure. CAD and FEA software were integrated in this work, enabling basic geometry constraints to be input in CAD, which were then fine-tuned in FEA in response to stress distribution results. This allowed the model to optimize boss designs autonomously. To ensure mouldability, initial boss designs were generated existing rotational moulding experience regarding the encapsulation of small inserts during moulding. The autonomous optimization technique was then applied to minimize the boss weight by controlling the size of design features, while ensuring mechanical performance constraints were met.

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# S14 – Modeling and Simulation

## S14 - 206

## Injection molding simulation with crystallization kinetics of Polyoxmehtylene and comparison with experimental data

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Polyoxymethylene is a thermoplast widely used in structural applications due to its excellent (fracture) mechanical properties and wear resistance [1] . Commonly processed by injection molding, the morphological and (fracture)-mechanical properties of the final part are strongly dependent on the processing parameters [2]. A powerful tool to facilitate part design and predict a part's performance is injection molding simulation. In the present study, injection molding simulations (Autodesk Moldflow) in both 3D and 2.5D were carried out for two different sample geometries. Previously measured crystallization kinetics data [3] was employed to simulate the morphological evolution within the parts. Also, the usability of the crystallization analysis tool in Moldflow was of interest here. The two specimen geometries were injection molded following a design of experiments to introduce different morphological and mechanical properties. Morphological analysis was then carried out by polarized optical light microscopy and X-ray measurements (small and wide angle), mechanical properties were assessed by tensile tests, monotonic fracture tests and fatigue testing. Then, all simulation approaches and experimentally obtained data from the processes were compared and assessed regarding their plausibility. The simulations with crystallization analysis were emphasized here. Furthermore, morphological, and mechanical properties were brought into context with the simulations. Overall, a rather good correlation between simulation and experimental data was observed.

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# S14 – Modeling and Simulation

## S14 - 217

## Simplified movement model to predict the thickness distribution of Robomould products

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Robotic rotational moulding is a cutting-edge improvement on conventional rotational moulding, integrating automation, electric heating, and various cooling systems. This polymer processing technique enables the cost-effective production of stress-free hollow parts with improved durability compared to the traditional methods. One example is the Robomould® machine, which utilizes a robotic arm to manipulate the mold's movement and makes use of electrically heated molds instead of the traditional oven. Due to the freedom of movement for the robotic arm combined with heating settings, also more flexibility is achieved to steer the layer thickness for complex products. However, currently a trial-and-error approach is used to find the proper parameter settings of the employed rock-and-roll motion and heating to achieve the desired thickness distribution, often resulting in a long set-up phase. Therefore, this paper presents a simple motion model to roughly assess the thickness distribution for given motion parameters. The model only accounts the geometry of the mould and its motion, thermal effects are ignored. A model, which uses a volumetric mesh of the mould, is written in MATLAB and is used to approximately simulate the location of the powder in the mould during the molding process. The model estimates the powder-mold contact time for each element, which is used to estimate the formed product's local thickness. Via an experimental validation, it is shown that the method, while simple, has a good predictive value, allowing to reduce the trial-and-error phase during process set-up.

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# S14 – Modeling and Simulation

## S14 - 324

## Simulative flow study to assess the processing stability of recycled polypropylene during injection molding

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The extensive use of plastics, including polypropylene, presents both opportunities and challenges for sustainability. Mechanical recycling, a common method for recycling of polymers, subjects them to thermal and mechanical stress, leading to physical and chemical changes. The impact that these changes have on flow behavior during industrial processing techniques are not yet understood. Predicting these changes in material properties as well as the resulting processing behaviors is essential for the accountability of the industrial use of recycled material. In this work, measured material data of mechanically recycled polypropylene polymers are used as input material data for a simulative flow study on the stability of the flow properties of these recycled materials. An analysis of the temperature, stress, and pressure profile using injection molding simulation gives insights into the most stable processing conditions that fit for material recycled to different extents. Gaining this knowledge helps in estimating the applicability of mechanically recycled materials in industrially stable injection molding processes. This study bridges the gap between theoretical modeling and practical application, offering a comprehensive understanding of the flow properties of recycled polypropylene, pivotal for sustainable industrial practices.

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# S14 – Modeling and Simulation

## S14 - 396

## Simulation of the Fused Deposition Modeling Process with Moving Meshes

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Fused Deposition Modeling (FDM), a prominent additive manufacturing method, involves the layer-wise extrusion of thermoplastic materials, necessitating a precise and adaptable simulation for optimizing process parameters and enhancing product quality. This work introduces a novel approach to model the FDM process. The proposed methodology harnesses the moving mesh capabilities within OpenFOAM to emulate the intricate dynamics of the FDM process. By integrating fluid dynamics principles with moving mesh strategies, this approach accommodates the continuous and dynamic changes in geometry during material deposition, nozzle movement, and subsequent layer formation. Key elements of this model encompass the dynamic representation of the molten filament deposition, nozzle motion, and substrate interaction. The moving mesh feature allows for real-time geometry and mesh adjustments, aiding in capturing the evolving geometry and intricate flow physics inherent in the FDM process. Validation and verification of this innovative approach against experimental data and existing models will be presented, showcasing its efficacy in accurately simulating FDM processes. This moving mesh-based simulation framework aims to allow a more comprehensive understanding of the complex interactions within FDM, thereby facilitating improved process optimization and enhanced control over final part properties. Ultimately, this research seeks to advance the capabilities of FDM simulations by leveraging moving mesh techniques in OpenFOAM, paving the way for more accurate predictions, design enhancements, and material selection strategies in additive manufacturing applications.

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# S14 – Modeling and Simulation

## S14 - 62

## Virtualized engineering of injection-molded thermoplastic parts – Fast emulators and uncertainty quantification

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In a manufacturing landscape where virtualized engineering is the norm, the product development process is both lean and rapid, ensuring reliability as well as the efficient utilization of manufacturing physical resources such as machines and raw materials. To realize this vision, we must comply with three basic requirements for the digitalized engineering process: credibility, simulation speed and software quality. Credibility is associated with modeling capability and accuracy. Simulation speed is necessary for enabling uncertainty quantification in virtualized product design and is a key aspect for deploying the full potential of digital twins. Finally, software and data quality are preconditions for democratization and reduction of development time. In the context of plastic components, particularly of injection-molded thermoplastic parts, there is a plethora of simulation-based methods for estimating the influence of raw material, geometry, and processing conditions on component behavior. The most credible methods are often based on finite element simulations, which usually replicate virtually the injection molding process and subsequently emulate the mechanical performance by considering the process-induced structure/properties. We showcase our research efforts for adapting this high-fidelity simulation framework to the basic requirements of the virtualized engineering vision, particularly in the direction of increased credibility. On the one hand, we foster the prediction accuracy of the injection molding simulation by implementing a thermo-mechanical crystallization model, which is efficiently calibrated by means of a metamodel-based optimization. A metamodel here is basically a fast emulator of the high-fidelity simulation. On the other hand, metamodel generation enables the deployment of uncertainty quantification, which allows for example to estimate the impact of the larger variability of recycled materials on the process-induced fiber orientation.

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# S14 – Modeling and Simulation

## S14 - 7

## Simulative Approach for Predicting the Heating Behavior of Elastomers in the Solid-State Microwave Heating Process

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The increasing demand for energy efficient vulcanization of rubber extrusions requires the optimization and further development of existing vulcanization processes. Microwave vulcanization allows the energy required for vulcanization to be coupled directly into the material via dielectric losses. Microwave heating requires the polarity of the rubber so that the electromagnetic wave can cause the polar components of the material to vibrate. These vibrations cause internal friction, resulting in an increase in temperature of the rubber compound. In this research project, microwaves were used to heat a rubber strand placed in a specially prepared waveguide. This method offers advantages over conventional methods such as hot air vulcanization. A key advantage is that the energy is coupled directly into the material, resulting in low losses. In contrast to hot air vulcanization, where the air must first be heated, the heating of the material also takes place within the product to be heated. This results in a significant increase in energy efficiency, with efficiencies of up to 90%. In addition, internal heating provides a more homogeneous heat distribution in the rubber strand compared to external heating by hot air vulcanization. To predict the heating behavior of rubber in the microwave heating process, a simulative model is created in the multiphysics simulation environment CST Studio Suite®. The model describes the microwave heating behavior of rubbers based on the thermodynamic and electromagnetic material data of the rubber compound. The simulation is what is known as a bi-directional simulation, so that temperature-dependent variables such as dielectric loss and thermal conductivity can be considered. The model is used to analyze parameter variations of the electromagnetic wave frequency, waveguide geometry and strand orientation in the waveguide. Finally, optimized settings for the real process are recommended.

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# S14 – Modeling and Simulation

## S14 - 73

## One-dimensional CFD-based model for downdrawn polypropylene in spunbondin

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We present a one-dimensional model for Spunbonding (SB) that uses Computational Fluid Dynamics (CFD) to simulate the crystallization of polypropylene (PP) along the drawing length of SB. After a mini-review, we categorized the literature on flow-induced crystallization simulation into four types: I) empirical models, II) the Avrami paired with one flow equation, III) analytical methods, and IV) molecular dynamics. We discovered that an ongoing pattern in the applied research on polymer processing is the gradual increase of preference for types I and III. While the latter offers a great understanding of the crystallization on both micro and macro scales for a particular process, the former is relatively simpler and offers great adaptability. Conversely, type IV is limited to only micro-scale simulation, and type II relies too heavily on empirical coefficients. We present our type I model to provide insights into the variation of fiber diameter distribution along the drawing length. This model sheds light on fiber formation changes resulting from minor process variations with minimal experimental demands. Such variations are commonplace and may include force differences on side fibers, slight feed fluctuations, and changes to drafter airflow. Initially, the user inputs the properties of the melt at the die and the surrounding air velocity. Subsequently, the model provides a range of final fiber diameters corresponding to different crystallization rates. After that, the user finds the one that most closely matches their fiber diameter, which yields the crystallization rate. This process only requires one simple measurement obtained through experimentation, making it easier compared to similar models. Knowing the crystallization rate, this model enables the user to anticipate how the fiber will be affected by minor adjustments to the process. We used cryogenic nitrogen to freeze molten fibers at various locations between the die and the conveyor belt of a lab-scale spunbonding machine to validate the diameter distribution along the drawing length.

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# S14 – Modeling and Simulation

## S14 - 75

## Theoretical insights into wall slip effects on displacement flows of non-Newtonian fluids for polymer processing applications

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Displacement flows are integral to polymer processing, for example in injection molding, extrusion, coating processes, polymer blending, foaming processes, polymer synthesis, fiber spinning, etc. Wall-slip combined with non-Newtonian fluid effects can be significant in these processes. In this context, our study explores displacement flows of two generalized Newtonian fluids in a two-dimensional channel with wall slip, employing a theoretical framework. Our work assumes a pseudo-interface separating miscible or immiscible fluids under negligible molecular diffusion or surface tension, respectively. A classical lubrication approximation model is developed, incorporating dimensionless parameters such as buoyancy number, viscosity ratio, non-Newtonian characteristics, and wall slip coefficients. This model can provide the flux and velocity profiles for the fluids involved. Numerical solutions for various wall slip conditions (ranging from no slip to slip at one or both walls) are presented, delineating the temporal progression of the interface. These solutions offer predictive insights into the displacement front dynamics, including front heights, shapes, speeds, and spreading lengths. The findings illuminate the significant impact of wall slip on the displacement flow and interface evolution, for both Newtonian and non-Newtonian fluids, and quantify the effects on the formation and dissolution of static residual wall layers in relation to different slip scenarios.

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# S14 – Modeling and Simulation

## S14 - 76

# Calibration of Mechanical Properties of Fiber Composites for Improved Injection Molding Shape Prediction

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A key objective of process simulation of thermoplastic injection molding is the accurate prediction of the final part shape. Deviation of the molded part shape from the intended design is known as warpage. In this research, we present a method to improve the accuracy of warpage prediction of fiber-reinforced composites by calibrating the mechanical properties based on measured shrinkage molding data. The molding data is from a series of standardized test plaques with a variety of molding thicknesses and using a variety of process condition settings (packing pressure, melt temperature and injection velocity). The calibration method is known as the "Shrinkage Test Adjusted Mechanical Properties" (STAMP) method. At the level of the overall polymer composite, the calibrated mechanical properties can be the overall composite's modulus, Poisson's Ratio and Coefficient of Thermal Expansion. However, a key challenge for the calibration of fiber-reinforced composites is whether to calibrate properties at a component or composite level. In this present work, a method is presented for deriving calibrated properties of the polymer matrix based on the calibrated composite properties. The fidelity of this calibration is validated using both a large database of laboratory moldings as well as complex real-world validation cases.

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# S14 – Modeling and Simulation

## S14 - 90

## Optimizing Modeling the Multi-Layer Co-Extrusion Flow of Non-Newtonian Fluids Through Rectangular Ducts: Appropriate Shear Rate Definition for a Local Power-Law Formulation

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The accuracy of viscosity predictions is a crucial aspect in polymer melt flow modeling, and hence, essential for the design of co-extrusion die systems. In the field of non-Newtonian fluid modeling for co-extrusion flows through rectangular ducts, substantial progress has been achieved in understanding multi-layer flow dynamics. Our fundamental research, employing numerical techniques like the shooting method, finite element method, and finite difference method for flow evaluation, has established a critical base for the field. Our current research advances fluid dynamics by refining our existing numerical solver1, specifically developed for multi-layer co-extrusion flows. We aim to enhance the solver's performance by implementing more sophisticated calculations of shear rates that surpass the traditional approach. This traditional approach, which often relies on average flow velocities and channel heights, can sometimes underrepresent the complexity of experimentally studied polymer multi-layer flows. Our study systematically compares various definitions for characteristic shear rates (e.g., average shear rates for each of the layers) to describe the local shear-rate dependent viscosity behavior by, for instance, a local power-law model. A thorough error analysis quantifies each model accuracy and its predictive limitations for industrially relevant material combinations and operating conditions. This includes CFD simulations and experimental data comparisons, employing methods aligned with our fundamental research in this area. Furthermore, our work also paves the way for integrating these advanced fluid dynamics models into the evolving field of process digitalization. By bridging the gap between detailed fluid dynamics modeling and practical industrial applications, we contribute to the development of more efficient, digitally integrated manufacturing processes.

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# S14 – Modeling and Simulation

## S14 - 91

## Advancing Profile Extrusion Modeling: Evaluating a Viscoelastic Model through User-Defined Functions in Ansys Fluent

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Keywords: Profile extrusion modeling, user-defined functions (UDFs), viscoelastic model, pressure drop, velocity distribution, Fluent, OpenFOAM. In the context of profile extrusion die design and processes, the transformative potential of numerical modeling and digitalization emerges as a pivotal force, promising enhanced accuracy, efficiency, and innovation. This study introduces an innovative approach to profile extrusion modeling by implementing a viscoelastic constitutive model. In contrast to previous simulations conducted in OpenFOAM, we focus on incorporating a User-Defined Function (UDF) in Fluent (Ansys). The UDF is designed to implement a specific viscoelastic constitutive model, the Giesekus model, recognized for its ability to realistically capture the intricate rheological behavior of polymer melts. The study concentrates on critical aspects of the profile extrusion process, notably the assessment of pressure drops within the flow channel, along with a detailed analysis of velocity distribution and flow balance at the die outlet. Furthermore, we emphasize practical implications associated with UDFs in industrial computational fluid dynamics simulations. Additionally, we will compare the performance of Fluent's UDFs in terms of reliability of predicted results, calculation time, and required computational setup to a similar study conducted in OpenFOAM. We demonstrate the potential of viscoelastic constitutive models implemented in UDFs within Fluent. This approach serves to enhance the accuracy of numerical modeling predictions across various industries, specifically in optimizing the profile extrusion process.

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# S15 – Rheology and Characterization

## S15 - 165

## Rheological behavior of soft Thermoplastic Elastomers based on polyolefin blends: Process-oriented representation by rheometric data

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Repeated melt processability is one of the outstanding advantages of Thermoplastic Elastomers (TPEs), as this enables highly efficient manufacturing technologies that provide additional design freedom for the resulting product with elastomer-like application properties. However, the complex multiphase morphology of some TPE groups pose manufacturing challenges because it affects their flow behavior significantly. On the other side, the determination of process-relevant rheological properties needs at first a breakdown of the complex flow to simplified conditions, which comes with several assumptions about the materials flow behavior. Since the available rheometric data of TPE are limited and often exclude the details of the test setup and measurement method, there is little information on whether the assumed boundary conditions are actually met for manufacturing-relevant flow processes, such as capillary flow in a hot runner or extrusion die. In the present study therefore several commercially available TPE based on polyolefin blends, all with a hardness up to 60 Shore A, are investigated. They are characterized using the Small Amplitude Oscillatory Shear (SAOS) and the High-Pressure-Capillary Rheometric (HPCR) testing. The study provides an overview of the process-relevant rheological behavior of TPE and how this can be represented by rheometric data. It therefore indicates how important the experimental boundary conditions are for the significance of rheological data in process optimization and in the design of hot runners, gates, sprues, and extrusion dies.

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# S15 – Rheology and Characterization

## S15 - 200

## Dynamic Mechanical Analysis: A Tool for Quality Control of Rubber Products

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The areas of application and the requirements for rubber products are extremely versatile and range from damping elements to seals and tires. The variety of potential use fields leads to very different compositions, from the matrix to the fillers and other additives, that allow to tailor the mechanical material properties according to application [1]. In order to ensure a high and consistent quality of rubber products, the first step is to select the right materials and subsequently to carry out an appropriate quality control. For both purposes, dynamic mechanical analysis is an effective tool [2, 3]. As shown in this work, DMA allows statements about the matrix material, a variation of the filler content or even the type of filler. Thus, on the one hand, the formulation can be optimized for a specific application, and, on the other hand, consistent quality can be guaranteed, as even relatively small changes in the formulation can be detected in the measurements. In addition, it is possible to draw conclusions about the degree of cross-linking using DMA measurements. As is also shown here, the data obtained can be correlated well with classic methods such as the compression set.

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# S15 – Rheology and Characterization

## S15 - 213

## Determination of Uniaxial and Planar Extensional Viscosity Using High-Pressure Capillary Rheometry

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Extensional viscosity (η_e) represents one of the key rheological properties that has a significant influence on processing polymer melts. η_e can easily be determined from entrance pressure drop (Pen) measurements using a high-pressure capillary rheometer, orifice die (zero-length die) and the Cogswell method. When measuring Pen, there is a possibility that material exiting the orifice die may stick to the underneath, leading to an overestimation of Pen and inaccurate η_e. Typically, uniaxial, and planar η_e plays a crucial role in material processing. The ratio between uniaxial and planar η_e determines the magnitude of neck-in phenomenon (unwanted film width shrinkage during the casting process). While the measurement of uniaxial η_e is relatively simple, the determination of planar η_e is challenging because the generation of pure planar flow is complicated, and its measurement is therefore considered unsuitable for routine use. Based on the pioneering work of Zatloukal et al., the current designs of the ROSAND dies have been optimized to create a new series of FreeFlow circular and rectangular orifice dies. These dies prevent the possibility of overestimating the entrance pressure drop, allowing precise determination of uniaxial and planar η_e. This means uniaxial and planar η_e can be estimated for different materials under controlled conditions with minimal effort. In addition, using these FreeFlow orifice dies enables a new way of evaluating extrudate swell (Barus effect), which is frequently dismissed or overestimated in conventional orifice dies because the extrudate can fill the underside of the die due to inherent swelling leading to unwanted sticking. In addition to standard shear flow curves, measurements using the ROSAND capillary rheometer can now provide in-depth studies of extrudate swell including uniaxial and planar η_e. This information can be used in various simulations to achieve ecological, energy and resource efficiency.

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# S15 – Rheology and Characterization

## S15 - 254

## The Development of Polycarbonate Properties via In-situ Nanofibrillation Method Using Elastomer Nanofibril Network

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In this study, we introduce an innovative approach – namely, in-situ nanofibrillation – as a cost-effective and environmentally friendly tailored method to enhance the properties of polycarbonate (PC). PC-nanofibril Ethylene Propylene Diene Monomer (EPDM) composites were prepared via a twin-screw extruder, followed by hot stretching in the spunbond system. By incorporating a coupling agent and enhancing the PC-EPDM compatibility, resulting in polar-polar nanocomposites, a significant improvement in the rheological and mechanical properties of the PC was observed. Improved crosslinking of the rubber phase and the nanofibrillation process played pivotal roles in enhancing these properties. Morphological assessments revealed a well-dispersed and distributed EPDM fibrillar phase with a high aspect ratio within the PC matrix. Maximizing mechanical and rheological properties was effectively achieved through increased fibril stretching due to enhanced matrix-nanofibrillar network compatibility. PC with nanofibrillated EPDM, combined with a coupling agent, displayed enhanced mechanical properties, particularly increased ductility and toughness while augmenting stiffness compared to PC-EPDM composites. Variations in tensile, Izod impact and flexural properties were influenced by the stretching level, EPDM content, and presence of coupling agents. Rheological investigations demonstrated significantly improved melt elasticity in PC with nanofibrillated EPDM with modification structure by coupling agents, compared to neat PC and even fibrillated PC with EPDM. Small amplitude oscillatory shear measurements indicated a strain-hardening, solid-like behavior in the fiber-spun PC-EPDM, distinguished it from the behavior observed in neat PC or melt-blended PC-EPDM composites. In addition, coupling agents in nanofibril EPDM improved the PC-nanofibril EPDM composite transparency, promising diverse transparent applications.

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# S15 – Rheology and Characterization

## S15 - 277

## Development of an Extraction and HPLC Quantification Method for Plasticizers as a Valuable Tool for Quality Control and Prediction of Adhesion Between Topcoat Layers in Vinyl Coated Fabrics

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Vinyl coated fabrics have applications in residential, automotive marine upholstery, among others. Because of the rigid nature of PVC, high quantity of plasticizers is employed to provide the required flexibility and processability to this material. Therefore, significant efforts have been oriented to prevent a plasticizer migration and guarantee the products durability by extending their lifespan. Several methods have been explored to determine plasticizer migration from PVC products, including gravimetric, extractive, chromatographic and spectroscopic approaches. However, limitations ascribed to significant deviations from one another make the results not fully comparable. To accurately quantify plasticizer migration in our materials, we have developed a reliable and straightforward analysis using a solvent extraction method followed by HPLC. The calibration curve demonstrated a high correlation coefficient of 0.9999, spanning a linear range from 80 to 1310 ppm. Limits of detection (LOD) and quantification (LOQ) were determined at 11.8 and 35.8 ppm, respectively. Precision and accuracy were evaluated by preparing samples with known analyte concentrations. The relative standard deviations (RSD%) were consistently below 4%, and recovery percentages were under 110%. These parameters confirm the efficacy of the method for quantifying plasticizer migration. This methodology has allowed the identification of products with reduction in the plasticizer migration profile. In addition, studying the extracted plasticizer concentration after applying individual layers of the topcoat system on a standard vinyl coated fabric construction has served as a reference test to predict adhesion features. Results have demonstrated that the plasticizer barrier properties between coating layers remarkably increase when there's good adhesion between them, as corroborated with SFE measurements. In overview, the implementation of this HPLC method ensures the manufacturing of vinyl coated fabric products with a greater durability and a significant reduction in the release of plasticizers to the environment.

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# S15 – Rheology and Characterization

## S15 - 322

## Material Property Prediction of Recycled Polypropylene via Data Driven Modeling

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The extensive applications of plastics, such as polypropylene, in a multitude of industries, in particular the automotive industry, present a complex landscape of challenges and opportunities for sustainable recycling. Mechanical recycling, one of the most employed methods for polymer recycling, subjects these materials to a range of thermal and mechanical stresses. These stresses induce alterations in the polymers' physical and chemical properties, thereby affecting their reusability and application potential. This study employs a comprehensive array of industrially relevant analytical techniques, including tensile testing, shear rheometry, and Melt Flow Index (MFI), to investigate the mechanical integrity and reprocessing capabilities of polypropylene, enabling the identification of optimal recycling conditions. A data-driven predictive model is developed, enabling a deeper analysis of the various parameters involved in polymer processing. This facilitates the formulation of tailored recycling strategies that can be universally applied. Unlike traditional approaches that often rely on incorporating virgin material to maintain polymer properties, this research explores the potential of fully recycled polymers. It examines their suitability for a range of open-loop applications, which often involve a change in the inherent properties of the recycled material. This work not only offers a more sustainable pathway for polymer recycling but also serves as a foundational framework for future research and industrial applications in the field of polymer science and engineering.

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# S15 – Rheology and Characterization

## S15 - 383

## Rheological analysis of modified PLA by reactive process aiming at the production of foams

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This study aimed to evaluate the rheological properties of chemically modified PLA through reactive processing to relate such properties with cellular structures formed by the subsequent production of foams using supercritical CO2. The chemical modification of PLA by reactive processing was carried out using glycidyl methacrylate (GMA) and dicumyl peroxide (DCP) as initiator, in a Haake mixer, at 180ºC, with different concentrations of GMA and DCP. Rheological analyses were carried out in permanent and oscillatory states. The foaming process was carried out using supercritical CO2 as a foaming agent, and SEM analyses were carried out to evaluate the cellular structures formed. Results show that the steady-state shear viscosities are higher for all modified samples when compared to pure PLA, which indicates that there was an increase in molar mass. Using the Cole-Cole graph, it is possible to observe the formation of an arc for the pure PLA sample, which is characteristic of linear polymers. On the other hand, for modified samples, it is not possible to observe the formation of arcs, which is a consequence of the high relaxation times of the materials, suggesting that long branches were formed, making the material more elastic. Similar observations were made for the graphs of first difference of normal stresses (N1), tan δ vs frequency, G' and G'', in which an increase in the elasticity of the modified samples can be observed. It is also possible to make a relationship between viscosity at low shear rates and extensional viscosity ($\eta e = 3\eta$), which provides information about the resistance of the material during deformation in extension, which is important for the foaming process. As a result of the modification, pure PLA foams present large cells, thick walls, and heterogeneous distribution, while for modified PLA, which has high viscosity and elasticity in molten state, cells are more regular, smaller in size and thinner cell walls.

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# S15 – Rheology and Characterization

## S15 - 39

## Rheology of PVC plastisols containing a recycled fraction: study of model systems

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Current environmental issues regarding disposal of polymer wastes encourage PVC industry stakeholders to replace the linear economic system in force by a circular process. Mechanical and chemical recycling of PVC materials to manufacture new rigid products are extensively described in literature but there has been little attention given to the reuse of plasticized PVC wastes into plastisols despite their industrial importance. Processing of the latter is indeed subjected to strict rheological specifications, widely affected by the addition of recycled PVC. Its presence indeed tends to increase the extent of aging and to speed up the gelation process. Model systems have been studied to assess the effect of initial plasticizer content in processed PVC, suspected to cause a plasticizer over absorption. A kinetic study of plasticizer diffusion into recycled PVC particles, performed by optical microscopy and mass uptake, enabled to determine diffusion coefficients of samples containing various initial amounts of plasticizer and the role of glass transition temperature has been elucidated. Based on these results, a model was developed to predict aging and gelation behaviors of plastisols containing a recycled fraction. The model accounts for concentration, composition, and size of the processed PVC particles. Another issue arises when adding plasticized PVC into plastisols though. The presence of recycled PVC indeed causes a loss of mechanical performance. Additional tensile and peeling tests will therefore be conducted to understand the role and interactions of processed PVC with the matrix composed of virgin resin and plasticizer.

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# S15 – Rheology and Characterization

## S15 - 413

## RAMAN & NANORAMAN/ NANOPHOTOLUMINESCENCE: MULTIMODAL CO-LOCALIZED SPECTROSCOPY FOR PHYSICO-CHEMICAL CARACTERIZATION OF POLYMERS

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This presentation will focus on Raman and NanoRaman applied to the most diverse branches of knowledge. In this presentation you will learn the basic principles of AFM-Raman spectroscopy applied to a wide range of physico-chemical characterization of polymers for materials science, ceramics, biomaterials, life sciences and two-dimensional (2D) materials. Raman and NanoRaman microscopy are one of the only techniques capable of providing non-destructive, accurate analysis combined with high resolution images. Raman spectroscopy provides valuable information about the studied sample, such as chemical and structural composition. Based on the light-matter interaction, we obtain relevant information, such as: fiber orientation, particle distribution, homogeneity, lamellar crystal size, real time polymerization tracking, phase changes and several other characteristics of the sample through the chemical evaluation of the material. The hyphenization of Atomic Force Microscopy (AFM) and Raman spectroscopy provides extensive understandings into the complex dynamics of several kinds of samples, recognizing the crucial role of a comprehensive characterization, enabling the nanostructural and chemical characterization of the specimen, including the analysis of contamination and trace materials. HORIBA will present multimodal characterization solution built on an automated AFM platform and integrating a Raman/Photoluminescence spectrometer, enabling true colocalized measurements of physical and chemical properties. Raman spectroscopy, within this colocalized approach, facilitates the identification and characterization of various compounds, providing essential data on their molecular structures and compositions, including potential contaminants at microscale. Simultaneously, AFM contributes vital information on the topographical and mechanical properties of these samples, offering detailed data into their surface textures, surface adhesion, roughness, and stiffness at nanoscale. The development of instrumentation makes possible the hyphenation of Raman with other techniques, such as Photoluminescence and AFM, being able to reach resolutions on a nanometric scale. The technique can also be applied in several areas of knowledge, such as pharmaceuticals, photovoltaics, graphene, cells, nanoparticles, microplastics, among others.

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# S15 – Rheology and Characterization

## S15 - 44

## RAMAN & NANORAMAN/ NANOPHOTOLUMINESCENCE: MULTIMODAL CO-LOCALIZED SPECTROSCOPY FOR PHYSICO-CHEMICAL CARACTERIZATION OF POLYMERS

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Electron and ion microscopy methodologies, in particular when combined in a Focused Ion Beam (FIB) Scanning Electron Microscope (SEM) system, offer a broad spectrum of simultaneous nano-processes, including cross-sectioning, beam-induced deposition, surface modification, and micromanipulation, besides conventional imaging, and chemical analyses [1]. Nevertheless, the use of a cryo-stage for the processing of organic and polymeric materials is essential, since electron and ion beam exposure on soft matter causes irradiation damage, resulting in irreversible material degradation in complex forms. Accordingly, ambient temperature-operated dual-beam configurations can be used for nanomachining and nano-analysis of polymer compound systems only when sample-specific custom routes and parameters are followed. In this research, rubber and biocompatible polymeric materials were processed and investigated in 3D in dual-beam instruments operated at ambient temperatures; FIB milling techniques were applied to form cross-sections on the bulk samples for the subsequent SEM imaging and elemental mapping of the inner volume of the materials. Meanwhile, preserving the original physical and chemical stability throughout the samples while nanoprocessing was highly important. This study also covers the examination of rubber compounds with different compositions for examining the alterations in elemental distribution and morphology at the micro/nanoscale in particular volumes. The dispersion of sulfur content throughout the rubber matrix is crucial for determining the characteristics of the ultimate products. Besides, monitoring the spreading of fillers added into rubbers for improved performance is essential.

[1] Meltem Sezen, Focused Ion Beams (FIB): Novel Methodologies and Recent Applications for Multidisciplinary Sciences" (Full Chapter); Modern Electron Microscopy in Physical and Life Sciences, InTech; Book: Edited by Miloš Janeček; ISBN 978-953-51-4599-8; 2016

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# S16 – Morphology and Structural Development

## S16 - 129

## Flow-induced crystallization in micro-injection molding – Experiments and simulation with POM-H

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Micro-injection molding is advantageous in the context of polymer composite development and the fine-tuning of polymer-based formulations, as substantially lower quantities of material are required for shaping samples (e.g., micro tensile rods), which can be used in mechanical characterization. To establish a characterization method comparable to standardized tests, the triad process-structure-properties must be well understood. In the case of semi-crystalline thermoplastics, for example, the micro-injection molding processing conditions have a strong impact on the induced crystalline morphology and therefore in its mechanical performance. To study the process-structure relationship for a polyoxymethylene homopolymer (POM-H), a design of experiments (DoE) was performed by varying mold temperature and injection velocity. Thin cross sections taken from the center of the micro rod were analyzed under a polarized light microscope for studying the process-induced crystalline morphology. Recently, a thermo-mechanical crystallization model (comprising flow-induced crystallization) along with coupled viscosity, PVT and solidification models were implemented in Autodesk® Moldflow® Insight 2021 using the Solver API feature. The material-dependent parameters corresponding to the POM-H in this work were identified elsewhere using a data-driven calibration approach (metamodel optimization). This novel simulation model framework was used here to emulate virtually the experimental DoE and estimate the process-induced crystalline morphology for the different DoE levels. We discuss the capabilities of the simulation model for estimating the injection pressure evolution as well as the thickness of the transcrystalline layer in the micro tensile rods. Finally, we raise the open challenges in micro-injection molding with respect to machine process control and crystallization modeling and simulation when dealing with semi-crystalline thermoplastics.

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# S16 – Morphology and Structural Development

## S16 - 152

## Polymeric Microwave Patch Resonator based on Doped PEDOT:PSS

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Intrinsically conducting polymers possess unique electrical properties arising from their conjugated backbone, which enables versatile applications in electronic devices, sensors, and energy storage systems. The study of these polymers is of significant interest in the context of microwave frequencies due to their tunability, non-intrusively microwave sensing capability, integration capability with microstrip structures, etc. This work presents a microwave resonator comprised of a polymeric patch and a feeding layer of two-port 50-Ohm-matched microstrip structure. The patch resonator is a one-layer thin film of Poly (3,4-ethylenedioxythiophene) :Poly (styrenesulfonate) (PEDOT:PSS) and is doped with 8% of dimethylsulfoxide (DMSO) to enhance the conductivity of the polymeric structure. The resonator is fabricated on a microscopic glass substrate and operates at the resonant frequency of 5.85 GHz with a resonant amplitude of -46 dB. The integration of polymer-based structure and resonance capability makes the patch versatile and adaptable for various potential applications ranging from wearable sensors in healthcare monitoring to electromagnetic shielding devices in military contexts.

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# S16 – Morphology and Structural Development

## S16 - 192

## Tailoring Morphology of Polymer Composites from Multilayer Film Waste

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Microfibrillar reinforced composites are attractive as they could partially replace composites with inorganic reinforcement. The idea of reinforcing the polymer matrix with polymer micro- or nano-reinforcement is appealing because of the lower weight of such composite and less complex processing compared with glass or carbon fibre reinforced composite [1]. The similar nature of matrix and reinforcement makes end-of-life treatment easier [2]. The same idea of microfibrillar reinforced composite can be used to recycle mixed polymers. When a mixture of immiscible polymers is extruded, the final material usually consists of a matrix with a dispersed minor phase. Usually, the interface attachment between matrix and dispersed phase is poor for immiscible polymers. However, the lack of interaction, which causes immiscibility, can be used to produce different morphology structures by changing the temperature profile and extruding and drawing speeds. Changing the material's morphology can enhance certain properties such as impact and tensile strength or barrier properties [3]. This could help to boost the application of recycled materials. In this work, different mixtures of PE-PLA and PE-PA6 were prepared. The influence of the blend composition, temperature and extrusion and drawing speed on the morphology were examined. The mechanical properties (tensile test) of each sample were tested and compared with its morphology. In the next step, a ternary blend of PE, EVOH and PA6 was prepared and tested. Finally, the PE, EVOH and PA6 plastic waste mixture was processed the same way as the PE-EVOH-PA6 ternary blend and compared with the ternary blend's results. The results showed that it is possible to prepare morphologies with different properties from one blend with the same composition. The same procedure can also be applied to plastic waste recycling. Even though plastic waste contains additives, it allows the production of samples with different morphologies from one mixture.

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# S16 – Morphology and Structural Development

## S16 - 256

## Tailoring Morphology of Polymer Composites from Multilayer Film Waste

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As widely known, shear, evident in polymer melt-processing, has a significant influence on polymer crystallization, structure and eventually properties. Therefore, the evaluation of the effect of shearing the melt on crystal nucleation is an indispensable task for understanding the relationship between processing, structure, and properties of products. In this work, the concept of specific work of flow has been applied for analysis of critical shearing conditions for formation of crystal nuclei in poly (L-lactic acid) (PLLA).[1, 2] The critical specific works of flow, above which shear-induced nucleation occurs, for PLLA with the molar mass of 120 kDa is around 25 kPa. For proving the concept, the role of shearing the melt in short-cycle-time-PLLA processing on the number of crystal nuclei in fully amorphous injection-molded test bars was estimated by evaluation of the kinetics of cold-crystallization by differential scanning calorimetry (DSC). It was found that the cold-crystallization kinetics in the skin is faster than in the core of the component related to higher shear rates, estimated by simulation shown in Figure 1. This study demonstrates that knowledge about the crystallization kinetics of the sheared melt of PLLA can be used to predict structure formation in industrial processing.

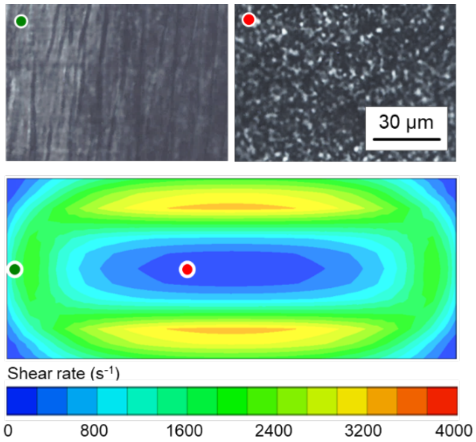

Figure 1. Polarized-light optical microscopy (POM) micrographs of the skin and core-region, taken after cold-crystallization at 90 °C for 400 s (top). Shear-rate distribution in the cross section of the injection-molded test bar after completion of form-filling (bottom).

[1] – H.Janeschitz-Kriegl; E.Ratajski; M.Stadlbauer, Flow as an effective promoter of nucleation in polymer melts: a quantitative evaluation. Rheol. Acta, 42, 355–364 (2003).
[2] – N.Iqbal; K.Jariyavidyanont; A.M.Rhoades; R.Androsch, Critical specific work of flow for shear-induced formation of crystal nuclei in poly (L-lactic acid). Polymer Crystallization, **2**, e10073 (2019).

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# S16 – Morphology and Structural Development

## S16 - 358

## Shear-induced crystal nucleation of poly (l-lactic acid)

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As widely known, shear, evident in polymer melt-processing, has a significant influence on polymer crystallization, structure and eventually properties. Therefore, the evaluation of the effect of shearing the melt on crystal nucleation is an indispensable task for understanding the relationship between processing, structure, and properties of products. In this work, the concept of specific work of flow has been applied for analysis of critical shearing conditions for formation of crystal nuclei in poly (L-lactic acid) (PLLA).[1, 2] The critical specific works of flow, above which shear-induced nucleation occurs, for PLLA with the molar mass of 120 kDa is around 25 kPa. For proving the concept, the role of shearing the melt in short-cycle-time-PLLA processing on the number of crystal nuclei in fully amorphous injection-molded test bars was estimated by evaluation of the kinetics of cold-crystallization by differential scanning calorimetry (DSC). It was found that the cold-crystallization kinetics in the skin is faster than in the core of the component related to higher shear rates, estimated by simulation shown in Figure 1. This study demonstrates that knowledge about the crystallization kinetics of the sheared melt of PLLA can be used to predict structure formation in industrial processing.

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# S16 – Morphology and Structural Development

## S16 - 55

## Powerful analytical methods in polymer science: Confocal Raman spectroscopy and X-ray diffraction

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High-resolution confocal Raman spectroscopy and X-ray diffraction are powerful analytical tools to study the chemical and physical structure of e.g. polymer fibers or films. Melt-spun fibers have to meet high demands for different types of applications. Thus, it is crucial to understand structure-property relationships in order to optimize fiber properties. For some applications (e.g. for technical textiles) the surface characteristics of fibers are of high importance. Therefore, the cross-sectional microstructure (crystallinity, molecular orientation, phase distribution) becomes of particular interest. It is, however, very challenging to obtain such 2D micro-structural information across polymer filament cross-sections with diameters below e.g. 100 µm. In this presentation, (polarized) confocal Raman maps of a variety of fibers are exemplified in order to highlight this unique high-resolution technique. In addition, we present results from complementary methods; wide-angle x-ray diffraction and small-angle x-ray scattering to cover the smaller structural dimensions in the Angstrom to nanometer regime.

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# S16 – Morphology and Structural Development

## S16 - 85

## Study of HDPE/PET/E-GMA blends: toughening, rigidity, thermal and morphology behavior

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Mechanical, thermal properties and morphology of high-density polyethylene, polyethylene terephthalate and ethylene-glycidyl methacrylate (HDPE/PET/E-GMA) ternary blends were studied by using Izod impact, flexural behavior, rotational rheometry, DSC, DMA, and SEM. The results showed that toughening increases without lose rigidity. Flexural strength improved by 11% and impact strength by 8% when the PET content is 20% indicating that E-GMA acts as a compatibilizer. This behavior can be corroborated by the thermal properties and morphology of the blend. Comparing the DMA and DSC results for the pristine polymers and the ternary blend can be observed a shift of transition temperatures of HDPE and PET towards each other and in SEM images is observed a reduction of the size of the dispersed PET phase into the HDPE matrix showing enhancing the interfacial interaction between HDPE and PET. These results can be applied to improve the mechanical properties of recycled materials in an upcycling context.

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# S17 – Rubber and Elastomers

## S17 - 260

## Processing of Thermoplastic Elastomers (TPE) by in-situ Ground Tire Rubber (GTR) vulcanization using waste ethylene-vinyl-acetate (wEVA), recycled high-density polyethylene (rHDPE) and dicumyl peroxide (DCP)

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Tire rubber waste (TRW) is a complex mixture of materials, such as rubbers, steel, textile fibers, carbon black and other additives. Its pollution capacity is a severe environmental problem, especially in landfills and waste management processes, due to its lixiviation process and low degradation rate. Thus, as a solution to mitigate TRW environmental impact, thermoplastic elastomers commonly reuse the Ground Tire Rubber (GTR). This work presents an in-situ devulcanization of ground tire rubber (DGTR) and re-vulcanization of devulcanized ground tire rubber (RGTR) using dicumyl peroxide (DCP), waste ethylene-vinyl-acetate (wEVA) and recycled high-density polyethylene (rHDPE). The procedure of melting processing was carried out using torque rheometer and differential scanning calorimetry (DSC) analysis, which allowed to determine the reaction in each crosslinked effect. The GTR was devulcanized by thermo-mechanical action and it was blended with wEVA (binding agent), rHDPE, and DCP to obtain the TPE. Results showed that in-situ vulcanization occurred in the rheometer mixing chamber where an increase in viscosity was observed. In addition, DSC analysis was performed in the DGTR-DCP system, prior to its vulcanization to confirm the curing reaction. Consequently, a TPE with in-situ vulcanization was obtained to guarantee a better adhesion of the components. This research provides a perspective of a non-advanced and scalable process to obtain vulcanized TPE, allowing its incorporation into local plastic industries for developing countries.

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# S17 – Rubber and Elastomers

## S17 - 3

# Improvement of an alternative method for the correction of wall slip effects in rheological studies of filled rubber compounds

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The continuous further development of formulations for rubber compounds to ensure increasing demands on the application-specific product properties requires knowledge of suitably accurate material properties for predicting the process and processing behavior (1). In this respect, rheological material properties are of central importance. The high-pressure capillary rheometer (HPCR) represents the state of the art in the determination of rheological properties of plastics and rubber compounds. Rubber compounds have an increased tendency to flow anomalies (2) and non-isothermal effects due to dissipative material heating depending on the compound ingredients and the processing parameters. Because the basic analytical and numerical approaches assume isothermal flow and wall adhesion, rheological material measurements and the material parameters derived from them are erroneous. In the literature, various approaches for the description of wall slip effects exist (3), which partially lead to negative slip velocities and slip volume flows exceeding the total volume flow in the capillary. The purpose of this paper is to present an improved model for the description of wall slip effects within the rheological measurements at the HPCR based on the Coulomb wall slip model taking into account the dissipative material heating. Two EPDM rubber compounds of practical relevance were used, which can be differentiated according to the type of filler into carbon black-filled and silica-filled. By using slit capillaries of different geometric dimensions, the pressure dependence of the wall slip effects was confirmed. This allowed the separation of the flow curve into wall-adhering and wall-slipping areas was possible. The application of the improved analytical approach results in physically plausible rheological data and also shows the error potential that can occur when wall slip effects are not taken into account.

(1) Pahl; Gleißle; Laun: Praktische Rheologie der Kunststoffe und Elastomere. 1995
(2) Hatzikiriakos: Slip mechanisms in complex fluid flows. 2015
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# S17 – Rubber and Elastomers

## S17 - 348

## Recycling of multi-component parts with Thermoplastic Elastomers

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Thermoplastic Elastormers (TPE) offer several advantages for use in multi-component parts. Adhesion to a wide variety of other polymers, such as PP, ABS, PC, PA, and others allows for the design of parts that combine several functional requirements, such as sealing, connections or “soft touch”. This offers savings in material costs, easier assembly, and improved reliability. In today's market the requirements for recycling capability are a challenge for multi-component parts. One approach to negate this drawback is to recycle the complete multi-component part. The resulting material composition necessitate extensive analysis to ensure the requirements regarding emissions and smell as well as physical properties. Depending on the source of the recyclate, continuous analysis is needed to ensure the long-term compliance. In order to reduce these often expensive and time-consuming tests, we use Pyr-GC/MS for analysis of the chemical composition. Different materials in the recyclate can be monitored simultaneous and changes in composition are detected. Once a base line is established, this allows for a single measurement to ensure a consistent material quality. Tests for volatile organic carbons (VOC) ensure the compliance with automotive requirements. Similar to a fingerprint, follow up measurements can be compared to the established base and variations in the recyclate can be identified. This approach allows for monitoring of a variety of different emission test standards with just one measurement.

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# S17 – Rubber and Elastomers

## S17 - 390

## Recycling of multi-component parts with Thermoplastic Elastomers

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Tire retreading is essential for ecological and economic reasons; a well-maintained tire can be retreaded up to four times, which means that by doubling its initial cost, a tire has a lifetime up to four or five times than the original. Due to the fact that tire failures due to poor quality of the tire or its retread are reimbursed to customers, determining the exact reason for a failure is paramount as it requires qualified and highly experienced personnel. A detailed and comprehensive study of the main defect manuals from renowned tire associations allowed the preparation of a set of indexed tables. The main table contains in every entry the page where the description and photograph of each particular type of defect is located in its corresponding manuals. A total of 161 different damages are classified and coded into ten visual-inspection groups which constitute the input data of the defect identification tables. Next, in a synoptic table, they are crossed against ten subgroups, each of which constitutes a potential cause of the tire damage. These ten subgroups contain 720 well-known bad practices, which are ultimately responsible for tire failure. The tables also provide information regarding the defects that are most common for each of the different tire and vehicle classes. The guide that is herein presented for the inspection of damaged tires is by itself a valuable and didactic tool; even without having to refer to the defect manuals. The guide also helps users understand the care necessary to maximize the performance and lifetime of the tires for all types of vehicles. Finally, no other guide in the industry is as comprehensive and practical.

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# S17 – Rubber and Elastomers

## S17 - 391

## Acidic-Stabilized Natural Rubber Latex: Characterization & Processes

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Typically, natural rubber latex is a sap that is collected from the Hevea Brasiliensis Tree. This raw material is composed of polyisoprene, water, minerals, protein, sugar, among others. It behaves as an anionic colloid suspension. This material can be used on solid state (after a chemical coagulation treatment) and/or liquid state (after a chemical preservation treatment). Since this sap tends to coagulate easily, it is commonly stabilized with an alkaline ammonium-based solution for using it in the liquid phase, thus guiding to pH above 9.5 and negatively affecting the allergenic protein content. As a natural rubber latex liquid phase, it is widely used for producing gloves, balloons, condoms, glues, foams, and so on. However, due to the allergenic properties and content of the proteins, this material has restricted use in the medical field. A new preservative and stabilizer in an acidic environment were develop, with a pH value under 5. Thus, research is based on characterizing this material based on natural rubber latex concepts, filling some technical gaps related with the use of this material for latex rubber goods (mainly gloves, balloons, membranes). Since ammonia – based stabilizer is not used, there is a significant reduction of allergenic protein content due to the fact that the protein – phospholipid barrier is preserved without rupture during the preservation treatment.  A key aspect is the reduction of protein content from the four most allergenic ones, which was proven using electrophoresis technique and ELISA test based on ASTM 7427. The results show a reduction of total allergenic proteins by 65% and almost elimination of the Hev B1 and Hev B3 allergenic proteins.

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# S18 – Machine Learning in Polymer Processing

## S18 - 108

## Machine learning with finite element modeling to enhance the process of fabrication of hydrogen storage vessel of type 4

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Type 4 hydrogen storage vessels exhibit a central role in the strategy of renewables energies and carbon free mobility. However, the fabrication process based on roto-molding of thermoplastic polymer followed by winding of fiber induces different modes of degradation (delamination, matrix crack, or fiber breakage) [1]. To investigate the observed damage, finite element modeling (FEM) simulation coupled with machine learning and deep learning methods were employed. The microstructure of the composite was studied at the micro scale level through the representative volume element (RVE) approach. Homogenization's method, with periodic boundary condition, allowed to realize numerical experiment to characterize the composite stiffness [2]. Postprocessing is realized by using machine learning and deep learning means. Strain degradation was extracted because of ductile damage law of evolution. Classification of local degradation by k-nearest neighbor algorithm coupled with dynamical time warping (DTW) metric allowed to build an agglomerative dendrogram [3]. Dissimilarity measurements were used to extract knowledge by showing the impact of fiber type, matrix type and the size of the volume fraction on damage. The time evolution of ductile damage degradation was treated as a time series by deep learning neural networks (LSTM, Bi-LSTM, Attention, CNN). These artificial neural networks were used to reproduce the local degradation curve within an RVE over time. In addition, this approach highlighted the need to combine clustering and forecasting [4].

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# S18 – Machine Learning in Polymer Processing

## S18 - 137

## Quantitative Impact of Process Expert Knowledge on Developing Pumping Models for Single-Screw Extruders Using Symbolic Regression

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Reliable process models are a valuable asset in polymer extrusion to reduce downtimes and rejects, to improve process efficiency, and to accelerate the development of new screw designs. With ongoing progress in computational power and capacities, increasing attention is paid to data-based modeling techniques that infer predictions directly from the process data. Out of these, symbolic regression is an attractive option for process engineers since it provides information in the form of ready-to-use analytical mathematical expressions. However, extensive workload for both data curation and model generation impede obtaining generalized regression models with a large scope of validity. In the field of polymer extrusion, integrating domain-specific expert knowledge into the regression procedure is already known to support the search for accurate prediction models. To assess this benefit systematically and quantitatively, we developed symbolic regression models for the pressure-throughput characteristics of single-screw extruders. These models are derived from the same source of flow simulation data within a hybrid modeling approach by successively adding several levels of process expert knowledge: Initially, models are created (i) without any a priori included expert knowledge, followed by models that (ii) accept derived physical parameters as alternative input features, and models that (iii-iv) contain theoretical reference solutions at two degrees of sophistication. For each stage of expert knowledge integration, the regression models are evaluated in terms of their interpolation and extrapolation capability on unseen data, training time, and structural complexity. This case study demonstrates that including domain-specific expertise significantly enhances the performance-to-cost ratio of symbolic regression analyses for solving polymer extrusion problems.

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# S18 – Machine Learning in Polymer Processing

## S18 - 289

## Strategies to reduce energy consumption in plastic injection moulding using novel Industry 4.0 tools

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This article presents results of the implementation of advanced energy management in synergy with Industry 4.0 technologies for a plastics injection moulding plant. Strategic implementation of real-time monitoring systems, supported by machine learning algorithms, optimizes operational efficiency and product quality, while addressing the critical challenge of rising global energy costs. In a context where energy costs are experiencing a significant increase worldwide, the application of Industry 4.0 tools becomes a prevailing necessity for the economic management of industrial processes. Official data in Colombia reveals an average 22% increase in energy prices in the last year, underscoring the urgency of taking proactive approaches. In this regard, the combination of IoT devices and machine learning algorithms not only offers meticulous monitoring of the plastic injection moulding process, but also enables precise management of the associated energy consumption. It is estimated that the efficient implementation of these technologies can lead to substantial economic savings, with case reports showing reductions of up to 20% in total operating costs. This approach not only responds to the need for economic efficiency, but also highlights the commitment to environmental sustainability by reducing the carbon footprint associated with production. In summary, the convergence of advanced energy management and Industry 4.0 technologies is presented as an essential strategy to face today's economic challenges, allowing companies not only to survive, but to thrive in an ever-evolving industrial scenario.

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# S18 – Machine Learning in Polymer Processing

## S18 - 38

## Application of Bayesian optimization to polymer engineering problems

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Optimizing formulations or processing parameters to develop novel biopolymers or to improve the property of existing ones is in general a challenge, especially when many parameters must be simultaneously optimized. Bayesian optimization (BO) is a machine learning (ML)-based technique from which multiple parameters can be simultaneously optimized aiming at maximizing and/or minimizing one or more target properties like the glass transition temperature (Tg), the foam density, among others. During the active learning rounds, a Gaussian Processes (GP) model is trained with the current dataset, then new parameters are suggested and subsequently the corresponding experiment is performed, from where a new experimental target property is measured and in turn used to update the GP model again. These BO rounds continue until one is happy with the results or until the whole budget to perform new experiments is spent. In this work, we show some examples of using the BO technique. We minimize the density of PLA foams [1] by optimizing three processing parameters (pressure, temperature, and residence time). We maximize/minimize Tg of bio-based epoxy resin systems [2] by optimizing the 7D composition (seven aminoacids as hardeners). Finally, we simultaneously maximize three target properties (Tg, flexural modulus and flexural strength) by optimizing the composition of an eight-component biobased epoxy resin system [3]. After the dataset is large enough, ML models are trained to perform predictions on customized formulations or processing parameters, as well as to perform inverse design, where the best parameters leading to desired properties are suggested.

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# S19 – Biopolymers, Biocomposites and Bioprocessing

## S19 - 12

## Chlorella Microalgae as a Biomass Filler to Fabricate Eco-friendly Composite

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Biomass has been used to fabricate eco-friendly polymer composite. Recently, microalgae biomass, consisting of micron-sized organic-complex particles with a high carbon density, has been identified as an alternative type of biomass for the fabrication of bio-based plastics due to its ability to grow in wastewater and consume significant amounts of atmospheric CO2 through oxygenic photosynthesis, as well as its high carbon density [1, 2]. In this study, protein-rich microalgae (Chlorella sp. HS2) as a CO2-derived biomass filler were investigated to fabricate biodegradable green composites. HS2 was combined with a biodegradable polymer, namely poly(butylene adipate-co-terephthalate) (PBAT), and the resulting mixtures were characterized [3]. The dispersion of cells in PBAT and the compatibilization of the mixture in accordance with mechanical reinforcement effect are investigated depending on temperatures. The HS2 cells underwent disruption at the temperature higher than 130ºC, which changes the surface properties of the cells from hydrophilic to neutral and reduces water absorption. It improved compatibility of HS2 with the PBAT matrix, in turn, maintains the ductility of PBAT until the content of HS2 reaches as high as 30%.

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# S19 – Biopolymers, Biocomposites and Bioprocessing

## S19 - 134

## Investigation of pine hardwood extract as antimicrobial additive in biodegradable polymers

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Antimicrobial additives and polymers from polymers biobased resources are of increasing interest as sustainable alternatives to petroleum-based solutions. This work aims to study the influence of pine (pinus sylvestris) heartwood extract on the physical, thermal, mechanical, and chemical properties when incorporated into biodegradable polymers like polylactic acid (PLA) and polybutylene succinate (PBS). Pine extract has a high concentration of stilbene and resin acids, which can introduce antibacterial properties to polymers. To incorporate pine extract into the polymer matrix a twin-screw extruder is used. To determine the pine wood extract distribution in the polymer matrix RAMAN spectroscopy is applied. The investigated sample area showed homogeneous distribution of the pine extract in the polymer matrix. Thermogravimetric analysis couples with FTIR revealed a slight decrease in degradation temperature for the polymer blended with pinewood extract compared to the virgin polymer. Differential scanning calorimetry (DSC) revealed a decreased crystallization temperature of the polymer with the addition of the pine wood extract. While the observed changes in DSC are small, the influence of the addition of the pine wood extract to the polymers is noticeable, when measuring the viscosity of the polymers: The incorporation of extract reduced the viscosity, especially for PLA. This effect could prove to be an important factor for the application of polymers blended with pine wood extract in melt-blown processes, e.g. for respirator masks. Antibacterial properties were tested for the polymer blended and for melt-blown nonwoven fibers. The fibers were used in a test chamber to measure the filtration efficiency against viral and bacterial aerosols.

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# S19 – Biopolymers, Biocomposites and Bioprocessing

## S19 - 141

## Synthesis of bio-composites using newly designed hybrid filler (cellulose/LDH) and polylactic acid (PLA)

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With the growing environmental concern of using conventional plastics in daily life, the demand for bio-based polymer products is increasing. Natural and biodegradable raw materials are alternatives to make the plastics product sustainable for the environment. Cellulose-based fibers have gained attention in preparing biodegradable polymer composites because of their biodegradable nature, eco-friendly, low cost, and low weight in comparison to synthetic fibers (glass and carbon). In this research work, hybrid fillers based on cellulose and layered double hydroxide (LDH) were synthesized and used in biodegradable polylactic acid (PLA) to prepare a bio-composite. Hybrid fillers of cellulose were synthesized with MgAl LDH using the re-generation method of LDH synthesis. Hybrid fillers were characterized using scanning electron microscopy (SEM) and thermogravimetric analysis (TGA). Bio-composites of hybrid filler and PLA were prepared using small scale melt compounding machine. The amount and composition of hybrid filler in PLA and mechanical properties will be analyzed and optimized in order to generate partially or fully bio-degradable composites with optimized mechanical properties with a newly designed hybrid filler system.

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# S19 – Biopolymers, Biocomposites and Bioprocessing

## S19 - 175

## Reactive extrusion of lignocellulosic biomass to produce biopolymer-monomers using high energy radiation and catalytic acids

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Biobased succinic acid, which is a monomer for the biopolymer Polybutylene succinate, is currently produced mainly by biotechnology processes using microorganisms. However, high raw material prices, low yields, and co-production of low-value by-products decrease the competitiveness of this production method. Biologically derived succinic acid is therefore still not competitive to petrochemically derived succinic acid. To accelerate the transition from fossil to bio-based platform chemicals like succinic acid, a new process was investigated to produce succinic acid from lignocellulosic biomass. The process degrades lignocellulosic biomass into succinic acid very fast and with a high conversion yield. The chemical conversion was investigated using batch reactions. Various catalysts were tested at different concentrations, reaction times, and biomass fractions. During subsequent LC/MS and HPLC analyses, a total of 11 different values and 8 different peaks were identified. Four substances namely levulinic acid, succinic acid, formic acid, and 2-oxoglutaric acid could be identified and quantitatively analyzed. The results show that the use of metal salts in combination with microwaves have significant potential to produce succinic acid, levulinic acid and other platform chemicals with high yields. The results led to a novel experimental setup to investigate the chemical degradation of lignocellulosic biomass into succinic acid in a continuous setting. A twin screw-extruder traditionally used for plastics processing was converted into a continuous reactor. The lignocellulosic biomass is degraded with a combination of thermal and mechanical energy, supported by acid catalysts and high energy radiation. With this setup more experiments can be conducted to transfer the results from batch to continuous reaction for easier scale-up and profitability of the overall PBS production process in the future.

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# S19 – Biopolymers, Biocomposites and Bioprocessing

## S19 - 179

## Synthesis of PLA-PEG-PLA triblock copolymer microparticles using microfluidics technique as potential drug delivery systems

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poly(lactic acid) (PLA), an aliphatic polyester, has been extensively investigated as a drug carrier due to its good biocompatibility and degradability. Nevertheless, PLA is highly hydrophobic which considerably limits its use as a biomaterial. Introduction of hydrophilic polyether blocks into degradable polyester chains is a means to modulate the properties of the parent polymers. A triblock PLA–PEG–PLA copolymer, forming core-shell structure in aqueous environments, is a good candidate for preparing microspheres potentially used as effective drug delivery systems (DDS). The definition of the term “microparticle” is a spherical particle, with a size varying between 1 μm to 2 mm, comprising a core substance enclosed by one or more membranes or shells. Microparticles may be further classified as microspheres and microcapsules based on their internal structure [1]. In the last decades, microfluidic technology has proven to be extremely beneficial in the successful preparation of -micro and -nanoscale particles. This technique has attracted much attention as it allows the exact control of reaction conditions and fluid flow, since it enables the precise and homogenous mixing of the polymer solution with the antisolvent solution, in contrary to the manual bulk mixing method. Thus, it results in the precise growth control of the particles while minimizing the formation of by-products even in scaled up processes. In the current work, the successful ring opening copolymerization (ROP) technique of amphiphilic triblock PLA-PEG-PLA copolymers using various [PLA]/[PEG] molar ratios is reported. Specifically, [20/1], [40/1], [160/1], [320/1] and [640/1] were prepared. The synthesized materials were characterized using FT-IR, XRD and DSC techniques in order to investigate their physicochemical properties. A 3D flow focusing microfluidic device with 100 μm channels was further used for the preparation of PLA-PEG-PLA microparticles.

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# S19 – Biopolymers, Biocomposites and Bioprocessing

## S19 - 21

## Wine by-products as sustainable polymer stabilizers – impact of annual variations on stabilization efficiency

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Sustainability is currently one of the key topics in polymer industry. Biopolyesters show great potential to be used as biobased alternatives to conventional petroleum-based plastics. To increase the applicability of such sustainable materials, their susceptibility to degradation during processing must be addressed while maintaining their biobased character. Previous studies have reported wine grape pomace (WP), a largely unused, low-value by-product of winemaking, to improve the stability of plastics. However, since WP is a natural material, annual variations must be considered for its use as a stabilizer at industrial scale. In this research, the impact of annual variations of WP on the stabilizing effects in biopolyesters was investigated. WP of two different varieties and three vintages was studied. The composition of the native by-products was characterized regarding their constituents (seeds, stems, and skins) and WP-based functional fillers were prepared by industrial mill-drying. The powders obtained were characterized in terms of particle size distribution, thermogravimetric analysis (TGA), and bioanalytical methods such as spectrophotometric assays to determine the total phenolic content (TPC) and the antioxidant activity (AA). The functional bio-fillers were blended into biopolyesters with WP contents up to 20 wt.-% by twin-screw extrusion. The thermal properties of the compounds were investigated by differential scanning calorimetry (DSC) and TGA. The thermo-oxidative stability was determined by dynamic oxidation induction temperature (OIT) and oxidative TGA. All WP varieties and vintages increased the thermo-oxidative stability of biopolyesters. However, the filler content at maximum stabilization varied. The results of the present study were used to determine correlations between the bioanalytical characteristics and the stabilizing effects of WP-based functional fillers to enable a reliable industrial application of WP as a polymer stabilizer.

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# S19 – Biopolymers, Biocomposites and Bioprocessing

## S19 - 214

## Influence of irradiation processing in the melt on stereo complex formation and physical crosslinking of blends from PLLA and PDLA

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Recent studies showed that irradiation processing at elevated temperatures and in the melt provide tools for additive free branching and crosslinking of biopolyesters like PLA and P3HB [1,2]. Irradiation at elevated temperatures increases chain and radical mobility so that branching and crosslinking dominates over main chain scission. Blends from PLLA with PDLA crystallize in two different crystalline structures: (i) a low temperature melting homo crystalline phase (hPLA) and (ii) a high temperature melting stereo complex phase (scPLA). Due to the high melting point of scPLA and the formation of a physical network no additive free crosslinking has been achieved to our knowledge [3]. This talk will cover irradiation processing in the melt of a blend from 50 wt.% PLLA and PDLA and discuss whether irradiation at elevated temperatures leads to branching and crosslinking. We will show how the physical stereo complex network is affected by the irradiation and how crystalline structures in the homo and stereo complex phase change due to irradiation. To discuss the influence of the irradiation we correlate changes in characteristic temperatures from DSC with crystalline structures resolved by XRD, molecular changes though GPC and rheology measurements.

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[3] Quynh, Tran Minh, et al. "Properties of radiation-induced crosslinking stereocomplexes derived from poly (L-lactide) and different poly (D-lactide)." Polymer Engineering & Science 49.5 (2009): 970-976.

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# S19 – Biopolymers, Biocomposites and Bioprocessing

## S19 - 235

## Photoactive films made from alginate and chlorophyllin

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Photodynamic inactivation (PDI) is a process in which a molecule called photosensitizer is irradiated with an appropriated wavelength in order to generate radical oxygen species (ROS) such as peroxides and singlet oxygen, which are toxic to most bacteria. In recent years, photosensitizers have been incorporated in edible films, in order to create photoactive films that can be used to eliminate microorganism form food products or surfaces. Chlorophyllin is a natural photosensitizer that generate ROS after irradiation with green light (520 nm). In this work, chlorophyllin was incorporated into alginate films, using nanoemulsions as protector. Then, the mechanical, optical, and structural properties of the films were studied, showing no structural effect, while changing their mechanical properties. Furthermore, release kinetics and ROS production in simulated media was studied.

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# S19 – Biopolymers, Biocomposites and Bioprocessing

## S19 - 238

## Processability study of thermoplastic starch/poly(butylene succinate) blends in a reactive extrusion

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Growing concerns about ocean contamination from traditional fossil-fuel-based polymers have sparked a pressing demand for the development of inherently biodegradable alternatives, especially within the packaging industry. Thermoplastic starch (TPS), an economical and eco-friendly biopolymer, emerges as a promising solution for creating novel biomaterials. Nevertheless, TPS faces challenges such as poor mechanical properties and high hydrophilicity, making it less stable in different environmental conditions. To address these issues, the approach outlined in this article involves modifying starches through reactive extrusion and blending them with other biodegradable polymers. Specifically, the study evaluates different blends, incorporating native or acetylated starch with poly(butylene succinate) adipate (PBSA), using glycerol as a plasticizer and tartaric acid as a reactive agent in the extrusion process. The processability of the blends was assessed through films obtained in an internal mixer and compression molding. Results indicate that the addition of tartaric acid enhances processability, as evidenced by torque measurements during blending. Additionally, it shows potential for improving mechanical properties, specifically ductility and tensile strength. However, the improvement is not significant. The observed limitations may be evidenced to morphological issues and thermal stability. In summary, despite the challenges in blend compatibility, the use of reactive extrusion with tartaric acid presents a promising approach to address compatibility issues and a promising alternative for new packaging materials.

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# S19 – Biopolymers, Biocomposites and Bioprocessing

## S19 - 246

## Transforming Agriculture: Advancements in Compost-Biopolymers Composites for Enhanced Sustainability

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In Colombia's Cesar Department, sustainable agriculture poses critical challenges despite its thriving livestock sector. Extensive cattle ranching and poor soil management worsen soil conditions. Moreover, significant environmental worries stem from substantial wastewater in the livestock industry's milk processing. This study aims to valorize biosolids derived from wastewater during dairy plant disinfection to enhance sustainable livestock production. It explores using biosolids as the primary matrix for creating composting compounds and biopolymers for agricultural purposes. These composite materials utilize composted dairy biosolids as the primary matrix (60%) blended with polybutylene adipate succinate (PBSA) and polylactic acid (PLA) biodegradable polymers as functional agents. This innovative approach contrasts with prevailing composite polymeric materials literature, where polymers typically form the matrix, and agricultural residues serve as fillers. Biosolids from Freskaleche S.A. undergo controlled thermal treatment and composting before being combined with PBSA and PLA polymers using an internal mixer. The development of these new compounds includes the evaluation of thermal stability, scanning electron microscopy (SEM), Fourier-transform infrared spectroscopy (FTIR), and mechanical and rheological properties. Notably, the Compost/PBSA composites exhibit promising compatibility and thermomechanical properties resembling pure PBSA, suggesting their potential as thermoplastic materials for producing plastic-based agricultural products like biodegradable seedbeds. Regarding the Compost/PLA blends, the compost enhances PLA crystallinity while inducing chemical reactions in PLA polymeric chains, significantly altering their thermomechanical properties. This research provides valuable insights into utilizing biosolids to manufacture composite materials, offering a sustainable approach to address agricultural challenges in the Cesar region.

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# S19 – Biopolymers, Biocomposites and Bioprocessing

## S19 - 250

## Evaluation of the effect of cellulose nanofibers in thermoplastic starch films

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Biopolymer composites are gaining prominence over conventional polymers as they play a crucial role in mitigating environmental impact. Hence, materials like thermoplastic starches are emerging as promising solutions, where such materials reinforce particles that enhance their properties while maintaining environmental viability. This research evaluates the influence of native and modified cellulose nanofibers (CNFs and ACNFs) in native and acetylated thermoplastic starch matrices (TPS and TPSA). Specifically, we explore the impact on processability, mechanical and hygroscopic properties, and film morphology. TPS and TPSA matrices were reinforced with 1 to 3% by weight of CNFs and ACNFs using an internal mixer and a compressed molding process. The structural and chemical characterization were obtained by scanning electron microscopy (SEM), and Fourier-transform infrared spectroscopy (FTIR). Mechanical properties were determined through tension tests, while hygroscopic properties were evaluated using contact angle and moisture absorption tests. Results indicate that the inclusion of CNF and ACNF increases torque and processing temperature across all blends. SEM reveals variations in interaction levels based on the CNF type, with concerns raised about the random distribution patterns of CNF impacting uniform properties within the matrix. FTIR analysis does not show significant variations in CNF/TPS films concerning incorporation levels. Mechanical properties show enhancements correlated with the degree of CNF addition. Contact angle and moisture absorption tests suggest a reduction in the hydrophilic nature of CNF/TPS films across all formulations, with the TPS/ACNF formulation demonstrating superior performance. Observed phase differences are attributed to processing parameter limitations and the tendency of CNF to agglomerate. In summary, the addition of CNFs to starch matrices is a promising option for the fabrication of biopolymeric films.

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# S19 – Biopolymers, Biocomposites and Bioprocessing

## S19 - 252

## Demystifying the crystallization kinetics of polyhydroxyalkanoates (PHAs) through hyperthermal cycles

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Polyhydroxyalkanoates (PHAs) emerge as promising bio-based, biodegradable polymers poised to replace traditional plastics in food packaging applications. As the interest in PHAs continues to rise, this study investigates the challenges and opportunities associated with their thermal properties, particularly in the context of crystallization kinetics. In this study, hyper differential scanning calorimetry (Hyper DSC) was employed to observe the thermal characteristics of polyhydroxybutyrate (PHB) and poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV, with 2% valerate content) under varying processing conditions. More specifically, hyperthermal cycles were employed to examine nonisothermal crystallization kinetics at cooling rates ranging from 10 °C/min up to 500 °C/min, usually found in industrial polymer processes. Isothermal crystallization kinetics was also studied using the hypercooling feature so that the samples were rapidly cooled down to the desired temperature, avoiding crystal formation at higher temperatures. The nonisothermal analysis of both PHB and PHBV showed a decrease in crystallinity with increasing cooling rates. When the cooling rates increased from 10 °C/min to 500 °C/min, the degree of crystallinity of PHB was decreased by 88%, while for PHBV, this resulted in a decrease of 58% in the degree of crystallinity. From isothermal analysis, it was found that the activation energy of PHB is 193 KJ/mol, which is lower than that of PHBV, which has an activation energy of 216 KJ/mol. Also, PHB and PHBV's isothermal and nonisothermal crystallization behaviors were described using the Avrami equation modelling. The variation in PHAs' thermal and crystallization behaviors demonstrates the sensitivity of PHAs' thermophysical characteristics to processing variables.

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## S19 – Biopolymers, Biocomposites and Bioprocessing

### S19 - 253

# Production of a Starch-Based Polymeric Coating with Incorporation of Bioactive Principles from Chemical Synthesis to extend the shelf life of Cavendish banana

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Crown rot is a severe postharvest disease affecting tropical and subtropical fruits like mango, avocado, papaya, and banana. It's caused by fungal pathogens that infiltrate the fruit, reducing its pulp and leading to premature ripening. Systemic fungicides have been used to control these fungi, typically applied to seeds, leaves, or fruits to prevent disease spread. However, traditional fungicides can pose toxicity risks to the environment and human health. Essential oils are chemical substances that can be found in plants and among their properties is their antifungal capacity. Essential oils are being investigated as an alternative to traditional fungicides since they are less toxic to the environment and human health; however, they are more expensive and less efficient than traditional fungicides. Accordingly, to chemically synthesize the chemical compounds being the active antifungal agent inside essential oils can be and ecological and effective approach to produce a new generation of antifungals. In this study, modified starch was investigated as a carrier for thymol (active antifungal agent in thyme oil) incorporation using four distinct methods. Emulsions of starch and thymol were prepared and spray-dried to obtain a soluble powder which was used to produce films (for in vitro test) and coatings (for in vivo test in Cavendish bananas). The most effective method for thymol incorporation yields a retention of approximately 4% according to thermogravimetric analysis. In vitro results indicated that thymol incorporated into the matrix exhibited antifungal effects against key fungi responsible for crown rot disease in Cavendish bananas, with a concentration equivalent to the 12% w/w of thymol added to the starch matrix. In vivo tests, in which bananas were previously exposed to Colletotricum musae and Fusarium spp inoculant, revealed interesting interactions between fungi and coatings having thymol-incorporated matrix which affected bananas ripening rates.

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# S19 – Biopolymers, Biocomposites and Bioprocessing

## S19 - 263

## Evaluation of dicumyl peroxide as a coupling agent in thermoplastic starch and BioPBS composites

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To address plastic pollution from traditional fossil-fuel polymers, various studies propose the use of biodegradable alternatives such as starch and polybutylene succinate (PBS). However, the chemical nature of these alternatives differs significantly: starch is highly hydrophilic due to the presence of hydroxyl groups, while PBS and PBSA exhibit hydrophobic behavior owing to their aliphatic units. This research examines the effect of dicumyl peroxide (DCP) as a coupling agent for blends of native or acetylated thermoplastic starch (TPS/TPSA) and PBS/PBSA, with glycerol as a plasticizer. DCP, an organic peroxide, acts as an initiator of polymerization reactions, creating a chain reaction through the bonding of dissimilar functional groups such as hydroxyl and ester groups in starch and PBS, respectively. Different weight/weight compositions of DCP were added to TPS/PBS, TPS/PBSA, TPSA/PBS, or TPSA/PBSA blends in an internal mixer and subsequently compressed-molded into films. The results indicate that the inclusion of DCP increases the torque and processing temperature of blends with TPS, with the lowest torque observed in blends with PBSA. Moreover, the incorporation of DCP enhances tensile strength, Young's modulus, and ductility compared to blends without DCP. When comparing blends with PBS and PBSA, it is observed that PBS exhibits higher tensile strength, while blends with PBSA exhibit higher ductility. Notably, differences in mechanical behavior—higher ductility and tensile strength—are observed when comparing TPS and TPSA blends, with TPSA/PBSA blends exhibiting the highest mechanical properties. Fourier transform infrared spectroscopy (FTIR), thermal analysis (DSC), and morphological analysis by scanning electron microscopy (SEM) reveal only a physical blend of formulated components. Despite being a physical blend, the mechanical properties are considered suitable for inherently biodegradable flexible films.

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# S19 – Biopolymers, Biocomposites and Bioprocessing

## S19 - 264

## Polymeric biocomposites reinforced with microcrystalline cellulose recovered from agave bagasse: an alternative for the elaboration of materials for the automotive industry

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Growing concern towards the environment has led industries, especially the automotive, to take a greater interest in replacing glass fibers with natural residual fibers (biocomposites) [1]. The average use of polymers in the automotive industry ranges from 10 to 12% of the total weight of a vehicle. Reducing the car's weight by up to 10%, reduces fuel consumption between 6 and 8% [2]. Likewise, the automotive industries also try to optimize the cost without diminishing the quality and safety of the automobile [3]. Currently, biocomposites are made with different types of polymers, such as copolymer polypropylene (CPP) and low-density polyethylene (LDPE). Polypropylene random copolymer (CPP) is a thermoplastic resin produced through the polymerization of propylene and ethylene. LDPE is another polymer considered chemically inert and is a widely used thermoplastic. The aim of this work was to elaborate biocomposites reenforced with microcrystalline cellulose isolated from agave bagasse (MCC-AB) recovered under a biorefinery concept. MCC-AB content at 5% and 10% was evaluated as reinforcement material in LDPE and CPP as polymeric matrices. Likewise, GLYMO at 3% was evaluated as a coupling agent in a CPP biocomposites. Overall, the incorporation of MCC-AB as a reinforcing material resulted in enhancements in the thermal, crystalline, and mechanical properties of LDPE and CPP composites. However, the percentage of MCC-AB proved to be a critical factor. At the lower concentration of MCC-AB (5%), the data from DSC, XRD, and TGA indicated a nucleating effect, leading to improved crystallization, enhanced thermal stability, and a higher Young's Modulus. These findings suggest a more robust and resistant structure. Furthermore, the use of GLYMO as a coupling agent in CPP biocomposites improved the interaction between MCC-AB and CPP. Therefore, the results of this work demonstrated that MCC-AB is a reinforcing material with high potential to use in the automotive industry.

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# S19 – Biopolymers, Biocomposites and Bioprocessing

## S19 - 270

## Processability and properties of Spent Coffee Ground (SGG) and Cocoa Pod Husk (CPH) and Polypropylene Bionanocomposites

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The circular economy promotes optimal plastic use and waste reduction in plastic product manufacturing. This study explores a composite blend of polypropylene (PP), Spent Coffee Grounds (SCG), and Cocoa Pod Husk (CPH) at 30% w/w each, using a torque rheometer. Treatments included sodium bicarbonate surface treatment, 2.5% w/w maleic anhydride grafted polypropylene (MAEP), and 2.5% w/w modified organoclay. SCG and CPH, with phenolic content (17 and 42 mgEAG/g), act as antioxidants, enhancing recyclability. Both fillers remain thermally stable below 200 °C, suitable for melt blending. Processability assessment reveals higher torque values for PP and PP/SCG (24 and 18 N.m). Organoclay-based biocomposites exhibit the lowest initial torque values and specific energy (SE), aligning with prior nanocomposite studies. This suggests organoclay platelets as a promising means to reduce specific energy in processing agricultural waste biocomposites. All treatments enhance mechanical properties compared to the neat biocomposite. Maleic biocomposites are stiffer and less flexible than clay composites. Sodium bicarbonate surface treatment effectively reduces humidity. In conclusion, SCG and CPH show promise in biocomposites, aligning with the circular economy. Formulation design improves physical properties and decreases specific energy, making these fillers suitable for local industries promoting circular economy principles.

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# S19 – Biopolymers, Biocomposites and Bioprocessing

## S19 - 293

## Preparation of polymer-clay hybrid materials for drug delivery processes

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In this study we prepared a novel composite consisting in hybrid lipid-polymer nanoparticles (200nm) covered with Laponite clay. We evaluate the controlled release of drugs of this nanocomposite and another one made of lipid-polymer microparticles (500 nm) covered with Montmorillonite clay. We propose two diffusion models to calculate the amount of drugs released as a function of time. Results show that boundary conditions change with time, depicting quantitative agreement with experiments.

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# S19 – Biopolymers, Biocomposites and Bioprocessing

## S19 - 317

## Synthesis of pullulan derivatives for the coating and postharvest preservation of blueberries

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Fruits are important contributors to a healthy diet. However, they suffer deterioration processes that affect post-harvest quality. Therefore, it is necessary to apply coatings based on compounds of renewable origin, such as pullulan (PU), to extend the shelf life of fruits. PU is an exopolysaccharide that can be chemically modified to induce new functionalities related to solubility, barrier properties, and mechanical, among others. Consequently, the aim of this work was to evaluate PU derivatives as coatings for postharvest preservation of blueberries. For this purpose, PU produced from Aureobasidium pullulans ATCC 15233 was modified to pullulan acetate (PA) and aldehyde of pullulan (OxP) under three different degrees of substitution (DS). Characterization was performed by infrared spectroscopy (FT-IR), nuclear magnetic resonance (NMR) spectroscopy, and thermogravimetric analysis (TGA). In addition, contact angles, opacity, and mechanical properties of tensile strength (TS) and elongation at break (EB) of formulated films were measured. PU, PA, and OxP-based coatings were applied on blueberries and the parameters titratable acidity (TA), total soluble solids (TSS), ripening index (RI), and weight loss were quantified. FT-IR and NMR spectra of PA and OxP showed signals corresponding to acetate and aldehyde groups. TGA showed that acetylation increased the decomposition temperature (Td) of PU (238.84 °C), while oxidation decreased the Td. PA and OxP increased the opacity of PU films (3.09±0.10 mm$^{-1}$). On the other hand, the contact angle decreased with increasing DS in OxP and increased with increasing DS in PA with respect to PU (71.34±0.47°). TS and EB of PA and OxP films decreased compared to PU. Moreover, TA, TSS, RI, and weight loss parameters indicated that PA and OxP-based coatings slowed blueberries' ripening during 35 days of storage compared to the control.

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# S19 – Biopolymers, Biocomposites and Bioprocessing

## S19 - 334

## Characterization of oil palm biomass, derived materials, and applications

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This study case was done with the perspective to identify the value added of existent biomass fibers (i.e., agro-industrial byproducts) and potential blends. The purpose is to explain the facts about sustainable and/or organic oil palm biomass in the energy recovery sector and in the biobased materials industry. Demand for sustainable biobased materials and energy recovery from biomass has caused the agricultural industry to experience rapid growth over recent years [1]. This has led to concerns about its impact on the environment and the ecosystem, and it is currently in the effort to improve sustainability practices, certifications and reduce its carbon emissions based on new technologies. The used biomass, i.e. palm kernel shells (PKS), empty fruit bunches (EFB) and mesocarp fibers (MF), possesses the widely accepted sustainability certifications for oil palm biomass, such as, the Control Union certifications as a RSPO (Roundtable on Sustainable Palm Oil) approved certification body, the Regenerative Organic certification (ROC) for farms and products that meet the highest standards for the health and biomass of the soil, and the certificate of organic production methods and organic EU in compliance with the standards and regulations EC No. 834/2007 and regulation EC No. 889/2008 on organic production of agricultural products. This work presents the main thermochemical characteristics of this studied biomass relevant to its energy conversion and a biobased material application. The shown oil palm biomass characteristics can be summarized as a feedstock of medium energy content compared to fossil fuels and lower levels of sulfur, chlorine, and nitrogen than coal. Pellets of oil palm biomass are proven to meet expectations in both classifications A and B of non-woody pellets, i.e., characterized using the standards of solid biofuels, part 6, non-woody pellets, ISO 17225:2021. The biobased material application ranges from pulp and paper to biobased polymer material.

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# S19 – Biopolymers, Biocomposites and Bioprocessing

## S19 - 350

## Energy Storage Based on Biopolymers

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The utilization of renewable biopolymers for both energy production and storage are now becoming a reality. Our objective is to discover a substitute for critical energy raw materials such as lithium, which are used in the production of batteries and capacitors. The use of natural biopolymers for energy purposes is extensive, especially in the field of gasification. Another possibility is the carbonization processes for peptide-based biopolymers, which form a double bond between nitrogen and carbon during the process. Due to the different electronegativities of the elements, electron shifts occur making carbonized peptide-bonded biopolymers a suitable energy feedstock for the preparation of components in batteries, capacitors, and many other applications. The setup of carbonization processes and the composition of biopolymers affect the electrochemical properties of the resulting carbon structures. Results obtained from the carbonization of nitrogen-rich collagen structures will be presented. It should be mentioned that chromium-tanned leather can have negative environmental impacts, and carbonization may provide a solution to this issue. Sintering processes offer another promising method for the preparation of solid energetic materials. In addition, sintering makes it possible to combine activated carbon with sulphur, which greatly increases energy storage and electron transport capacity. Energy storage devices have a wide range of applications. Here, the results of preparing pouch cells, coin cells and hybrid batteries based on carbonized fibrous carbon structures and sintered biopolymers will be presented. Key electrochemical properties have been considered, including storage capacity, energy density, lifetime, charge/discharge rate and operating voltage. The prototype batteries prepared were compared with commercial Li-ion batteries with good correlations, and the results showed that nitrogen-rich biopolymers can replace strategic energy components in energy storage.

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# S19 – Biopolymers, Biocomposites and Bioprocessing

## S19 - 365

## Synthesis and Characterization of Bio-Based Polymer Composites Using PLA and Agro-industrial Residues for Food Packaging Products

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The urgent necessity of addressing global warming, deriving from the alarming scale of petroleum-derived plastics pollution and the impact caused by the disposal of numerous agro-industrial residues as a consequence of high demand, emphasizes the importance for immediate action. To mitigate this problem, this research is developing a bio-based polymer composite by evaluating it as an alternative for further food packaging as a promising avenue in material science and in response to the environmental impact. This study investigates the synthesis and characterization of bio-based composites comprising Polylactic Acid (PLA) and fillers of by-products of coffee and avocado. PLA, a biodegradable and renewable polymer, is an ideal matrix for these composites, aligning with the global demand for responsible materials. The research encompasses the systematic incorporation (without any coupling agent or plasticizer) of agro-industrial residues into the PLA matrix. Fillers were loaded in PLA from 1 to 10 wt.%. The bio-composites were prepared by solvent-cast films and were subjected to tensile test, FT-IR spectral, TGA, DSC, XRD, and SEM analysis. The formation of the composites was confirmed by FT-IR spectroscopy and SEM analysis. The resulting composites' analysis reveals enhanced thermal properties compared to virgin PLA and low-density polyethylene (LDPE), materials mostly used in the industry. These composites hold promise for applications across the food industry, like disposable and single-use materials and food storage. This bio-based composite can contribute to the global need for eco-friendly materials.

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# S19 – Biopolymers, Biocomposites and Bioprocessing

## S19 - 370

## Biopolymer composites for plant nutrition in aquatic environments

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The hydroponics industry is responsible for using mostly non-biodegradable plastic materials to produce plant supports that often end up discarded in landfills. Therefore, it is important to find new material solutions with less environmental impact and, if possible, that add new properties to the supports. The work involved the production of biopolymeric composites, PBAT biopolymer, from BASF SE and F38 biopolymer, from Nurel, with inorganic NPK fertilizers and spent coffee grounds (SCG) as a means of valorization and fertilizing action, for the nutrition of plants in aquatic environment. The different composites were prepared by extrusion processes and the plates, for subsequent characterization, by compression molding. Thermal (TGA), morphological (SEM), rheological (MFI), mechanical (tensile tests), water degradation (mass loss) and nutrient capacity evaluation (catarometry, ICP-OES) were per-formed on the composites. The incorporation of SCG alone showed to have limited nutrient release. However, in the composites with incorporated fertilizer, the addition of SCG enhanced the degradation of the composites and subsequent nutrient release. Additionally, the introduction of SCG into the biopolymeric matrix improve stiffness to the composites, related with the intrinsic rigidity of lignocellulosic materials. Thermal analysis results showed that the biopolymers played a role as a 'protective shield,' safeguarding the NPK fertilizers from their low-temperature degradation. SEM analysis showed changes in composites morphology after immersion, being highlighted the influence of SCG, acting as a degradation-enhancing agent. Due to their porosity, SCG seems to generate microchannels that facilitated the penetration of water into the matrix, facilitating the dissolution of the fertilizer into the system.

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# S19 – Biopolymers, Biocomposites and Bioprocessing

## S19 - 382

## Don't waste food waste: Materializing (macro)molecules and biocolloids from agricultural side-streams

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Strategies for upcycling agri-food losses and waste into bioplastics and colloidal systems will be discussed from a circular bioeconomy perspective. Low-value or underutilized biomass will be put forward as a plentiful source of biocolloids (nanocellulose and nanochitin) and biopolymers (chitosan and pectin) as materials forming building blocks. Light will be shed on films from orange processing waste and Pickering emulsions kinetically stabilized by surface-engineered nanocellulose from sugarcane bagasse. As a showcase, cellulose nanofibrils (CNF) were regioselectively esterified via imidazole-catalyzed reactions using acetic or isobutyric anhydrides, at functionalization degrees of 0.6 to 1.0 mmol g-1, respectively, altering the rheological profile of sunflower oil-in-water Pickering emulsions and leading to superior metastability, as demonstrated dynamically on a LUMiSizer dispersion analyzer. The latter demonstrated that adding only 0.1 wt% of esterified CNF reduced the dimensionless number instability index —which ranges from 0 (stable) to 1 (unstable)— from 0.91 (surfactant-free) to 0.87 (pristine CNF), 0.79 (acetylated CNF), and 0.66 (isobutyrylated CNF). This mirrors the interfacial energy between a drop of aqueous CNF suspension and sunflower oil, which was reduced from 24 ± 1 mN m−1 by ca. 15% (unmodified CNF), 22% (acetylated CNF), and 20% (isobutyrylated CNF). Furthermore, the net negative charge of the oil droplets opened another avenue for surface modification intending to amplify the driving force for particles to adsorb onto the O/W interface: electrostatic complexation among opposite charges. CNF was then submitted to a cationization protocol based on the grafting of 2,3-epoxypropyl trimethyl ammonium chloride (EPTMAC). Cationic CNF was more efficient in partitioning to the interface compared to the anionic analogue, boosting the stabilization outcome.

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# S19 – Biopolymers, Biocomposites and Bioprocessing

## S19 - 385

## Don't waste food waste: Materializing (macro)molecules and biocolloids from agricultural side-streams

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The growing environmental crisis attributed to widespread use of conventional materials, especially petroleum-based plastics, demands urgent exploration of sustainable alternatives. Over the past two decades, biocomposites have emerged as innovative solutions, combining natural fibers with polymers across various industries such as aerospace, automotive, medical, and packaging. These strategic yields lighter materials with reduced environmental impact, lower production costs and excellent mechanical properties. Global plastic production exceeds 400 million tons per year, with only approximately 16% being recycled, posing a significant environmental challenge, particularly in the packaging sector, contributing to 40% of plastic waste. Recent studies focus on biocomposites using starch as a polymeric matrix, identifying challenges in achieving optimal mechanical and barrier properties. Current research emphasizes the search for reinforcements to address these limitations. Vegetal fibers emerge as promising and sustainable reinforcements for packaging applications. Recent investigations highlight the use of nanotechnology in starch-based composites, enhancing barrier properties and mechanical strength. Also, isolating cellulose as nanocrystals from fibers shows compatibility with starch matrices, offering functional benefits for food packaging. Colombia, despite its rich biodiversity, contributes modestly to the characterization of new natural fibers. Recent studies in the country explore the natural fibers of plants such as achira, guadua angustifolia, luffa and their potential in various industries. This research aims to pioneer the use of Caribbean region plant species as potential natural fibers in starch-based composites, emphasizing renewable sources for sustainable packaging solutions. The study aligns with global environmental concerns, law 2232 de 2022 of Colombia and the strategic focus on bioeconomy for exploring and valorizing the region's biodiversity.

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# S19 – Biopolymers, Biocomposites and Bioprocessing

## S19 - 416

## Supramolecular, reversible, and biodegradable polymers between carboxymethylcellulose and N-nitrophenylmaleimide isomers

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Water-compatible supramolecular polymers have reversible and biodegradable properties and, depending on the type of interaction, show better mechanical resistance values. For carboxymethyl cellulose (CMC), this type of interaction with other molecules has led to several applications in materials, medicine, and other fields. Likewise, maleimides have been useful compounds in the polymer industry, imparting high fire resistance, good dielectric properties and great structural rigidity to the new polymers obtained. Therefore, in the present work, the supramolecular interaction between these two systems is studied for the formation of new water-compatible supramolecular polymers (WCSP). The new materials are based on the non-covalent interaction between medium viscosity CMC with 1.0 degree of substitution and isomers of N-nitrophenylmaleimides: 2-nitrophenylmaleimide, 3-nitrophenylmaleimide, 4-nitrophenylmaleimide. The N-phenylmaleimide derivatives were previously synthesized and characterized by IR, mass coupled gas chromatography and melting point techniques. Blends were then made with 2.0% CMC solutions and N-nitrophenylmaleimides at three different concentrations and temperatures, evaluating viscosity as a response variable, to select the best conditions. The selected blends were formed into films. Their physicochemical, mechanical, and biological properties were analyzed. The supramolecular polymers obtained show, with respect to the CMC, an increase in viscosity and a modification of the thermal and mechanical properties, due to hydrogen interactions between the precursors, as well as biodegradability, regardless of the type of blends.

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# S19 – Biopolymers, Biocomposites and Bioprocessing

## S19 - 72

## Influence of Additive Manufacturing Techniques and Polymer Blends in Chondrogenesis: A Study of Multilayer Scaffold based on PLA-CMC in Human Mesenchymal Stem Cells

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Hyaline articular cartilage, crucial for optimal joint function, has limited regenerative capacity due to its anatomy and histology. Despite recent advances, available treatments often have a prophylactic nature. Tissue engineering (TE) emerges as a promising solution for cartilage repair and regeneration. A bioinspired multilayered scaffold is presented, leveraging the synergy of Poly (lactic acid) (PLA) and carboxymethylcellulose (CMC), crosslinked with citric acid (CA), along with Hydroxyapatite (HAp) and Chondroitin Sulfate (CS). Through 3D printing, electrospinning, and solvent casting, a microenvironment mimicking native tissue was created, providing a three-dimensional structure with porosities, high water retention capacity (up to ≈ 490%), superhydrophilicity ($\theta = 13.8° \pm 1.3°$), mechanical stability, and an excellent biological response to pluripotent stem cells (PSCs). The study demonstrates the feasibility of multilayered polymeric scaffolds for cartilage engineering, offering a promising strategy for effective regeneration. However, limitations in raw material quality and the absence of mechanical compression stimuli must be considered in future research. Despite this, the approach is innovative and could have a significant impact in regenerative medicine and tissue therapy.

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# S20 – Circular Economy of Polymers

## S20 - 105

## From PP Waste to High-Quality Products – Decontamination of the Material Throughout the Entire Recycling Process Chain Using State-of-the-Art Technologies

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How to make waste valuable? This is one burning question of the 21st century. To achieve high-quality products out of waste, recycled plastics should be comparable with virgin plastics. Unfortunately, that is impossible without considerable effort to separate specific materials from others, clean them properly, and convert them again into products. Such a process chain of mechanical recycling was run with an advanced combination of state-of-the-art technologies considering the decontamination of the material throughout the different steps of this study. At a Netherlands-based research facility, mixed post-consumer polypropylene (PP) from Dutch households was first sorted by object level through multiple loops, subsequently shredded to flakes and pre-washed before the actual deep cleaning processes, and finally sorted by flake sorting. This procedure resulted in superficially decontaminated white, transparent, and colored fractions of PP. Additionally, the PP-flakes were divided into fractions with and without deinking agents to investigate any effect on the material quality caused by the chemicals. The material conversion was conducted at JKU with recycling technology including pre-conditioning, filtration, degassing, and granulation. At this stage, residual particles, and volatile organic compounds (VOC) were removed, which can cause odor or be a health risk. In addition to the samples of the sorted and pre-washed flakes, flakes with and without deinking, and the converted materials, yogurt cups were produced to test also on product level. Analytical methods were used to determine the decontamination regarding VOC. The results of this study picture the currently achievable qualities of recycled PP with available state-of-the-art technologies in mechanical recycling. As a consequence, this information should be used to improve the potential process steps to head further to high-quality recycled plastics.

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# S20 – Circular Economy of Polymers

## S20 - 140

## Navigating heterogeneous single-polymer waste streams: mechanical insights into recycling

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The essential shift toward a circular economy in the European Union is emphasized by regulatory initiatives such as the Green Deal containing the Packaging and Packaging Waste Directive (PPWD), which highlights the significance of sustainable plastic use and emphasizes an improved design for recycling. Despite this, due to its adaptability to diverse applications based on specific properties and processing requirements, polypropylene consists of a heterogeneous recycling stream currently leading to downcycling. To comprehensively understand the polypropylene packaging stream, this study characterizes various packaging types commonly encountered in plastic recycling collections. Additionally, it involves the examination of virgin blends comprising distinct molar masses and varying concentrations of high and low molar mass components. Mechanical, rheological (melt mass-flow rate, storage, and loss modulus), thermal, and morphological properties were investigated. The virgin blends exhibit consistent results in terms of the Modulus of elasticity, while the Elongation at break demonstrates greater sensitivity to variations in the blend composition, particularly concerning very high or very low molar masses. Notably, an incremental increase in the proportion of low molar mass polypropylene correlates with a continuous decrease in elongation at break until a tipping point. Polypropylene packaging shows the outliers and pitfalls such a stream must cope with. These findings hold significance for a polypropylene recycling stream, where high and low molar mass polypropylene is represented by different application and manufacturing methods. Despite the complexity and heterogeneity evident in waste streams, comparisons for an idealized post-consumer material stream validate the use of virgin blends as a possible comparison.

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# S20 – Circular Economy of Polymers

## S20 - 147

## Mechanical Recycling of Bulk Moulding Compound: A Technical and Environmental Assessment

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The recent EU directive on Waste Electrical and Electronic Equipment (WEEE) mandates ambitious targets for WEEE collection, recovery, and recycling. Ensuring full circularity of plastics, constituting 20-30% of WEEE, becomes pivotal. Thermoset composites like Bulk Molding Compound (BMC), are widely used in the electrical sector, posing unique challenges in end-of-life waste management. In fact, the high content of inert fillers and flame retardants negatively affects the incineration for energy recovery, while the thermosetting nature of the resin makes thermal reprocessing impossible. Among emerging alternatives for composites waste management, mechanical recycling is particularly promising due to its low technological complexity, easy scalability, and reduced energy consumption. This method involves milling waste into fine particles for use as fillers in the same material (closed-loop recycling) or in new materials (open-loop recycling). In this study, the effect of closed-loop recycling of Bulk Moulding Compound is studied from both a technological and environmental perspective. The technological assessment involved the collection and recycling of post-industrial BMC scrap generated by the compression molding of cases for ABB circuit breakers, a process generating up to 15% of scrap, on a yearly average. Parts with a variable recycled content (5 to 10%) underwent tensile, impact, and flammability tests to assess the effect of recycling on the key properties of the material. The environmental study, conducted using Life Cycle Assessment (LCA), aimed to provide data-driven validation of the full-scale implementation of this technology within ABB's supply chain. The results confirm the feasibility of closed-loop recycling for post-industrial BMC waste without compromising product performance up to a 10% recycled content. Moreover, the implementation of such a process could potentially reduce the carbon footprint of the material by up to 16%.

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# S20 – Circular Economy of Polymers

## S20 - 16

## Enhancing chemical recycling of PET waste using a biopolymer-based heterogeneous catalyst

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Environmental pollution is one of the major concerns of modern society. Among others, the disposal of non-biodegradable plastics stands out. PET materials, like those used in beverage bottles, are currently in high demand worldwide, comprising 70% of the consumer product packaging market by 2022. Unfortunately, most of this plastic waste ends up in garbage landfills, leading to challenges in terms of effective waste management (1). Among several chemical recycling alternatives, PET depolymerization by methanol is the most promising in terms of industrial applications. Methanol's low prices, simple reaction product separation, and high quality are some of the most important advantages. However, PET methanolysis is normally carried out at supercritical conditions, that is, high temperatures (>250 oC) and high pressures (>20 bar) (2,3), involving safety concerns and high-cost inversions. This contribution addresses the kinetic effect of biopolymer-based calcium oxide on PET's methanolysis to produce dimethyl terephthalate (DMT) and ethylene glycol (EG). Depolymerization reactions were developed in a high-pressure Parr reactor with and without a catalyst. PET bottles, obtained from a local market, were cut into 4x4 mm pieces (flakes). SEM imaging, FTIR, XRD, and TPD characterization were developed for the catalyst's characterization. Interestingly, due to the presence of the biopolymer during the synthesis, small particle sizes are obtained, increasing the specific surface area of the material. Moreover, characterization shows highly active basic sites favorable for PET methanolysis. All these catalyst properties are related to the notable increment in the kinetic constant calculated for the formation of DMT. Amazingly, a five-times increment in the kinetic constant is observed. These results implied the possibility of reducing the reaction parameters (temperature and pressure), which can contribute to the industrial application of PET chemical recycling.

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# S20 – Circular Economy of Polymers

## S20 - 185

## Advancing Circularity and Sustainability for Rotational Moulding

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The utilization of recyclate materials is paramount in advancing sustainability within the polymer industry and addressing plastic waste challenges. Action of this nature is crucial in meeting the United Nations Sustainable Development Goals (SDGs),particularly SDG 12 (Responsible Consumption and Production). The use of recyclate contributes directly to SDG 12 by having greater efficiency with valuable resources and reducing waste. Rotational moulding (RM), known for manufacturing large hollow products, holds great potential to significantly contribute to this sustainability focus. The process is extremely diverse, and fundamentally different from other polymer processing techniques. As a result of the unique characteristics of RM, the adoption of recycled plastics in rotational moulding presents very unique challenges. While many studies have highlighted the benefits of using post-consumer recycled (PCR) materials in processes like blow moulding and injection moulding, the availability of specially designed PCR grades for rotational moulding is limited in industry and literature. This work aims to define the challenges and opportunities in the relationship on RM and PCR. Offering a review of current approaches in academic literature on sustainable materials for rotational moulding, whilst outlining approaches taken in research by authors, such as mechanochemical processing, copolymer addition and collection of baseline data studies. Ultimately, portraying the polymer-based research which will enable progress towards sustainable material solutions for the future of Rotational Moulding.

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# S20 – Circular Economy of Polymers

## S20 - 198

## Advancing Plastics Identification and Quantification in Industrial Recycling with DSC

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The increasing focus on plastic recycling and circular economy has created a need for utilizing heterogenous and complex recycled streams, presenting a growing challenge in identifying and quantifying the unknown material compositions present in these sources. Specifically for polyolefins like PE and PP, which together account for over 50% of plastics demand, the inability to easily distinguish between varieties is a major obstacle. The diverse density and melting point ranges for different PE and PP grades makes separation via float-sink or spectroscopic sorting unreliable. Selective dissolution techniques are also insufficient due to similar solvent solubility behaviors. Additionally, the volume of polyolefin wastes contaminated with non-target polymers and organic substances is rising rapidly. Identifying compositions like PE/PP blends in mixed plastic waste is a significant challenge. Quantification is also critical for determining grade purity and end-product utility. Differential Scanning Calorimetry (DSC) offers a potential solution by enabling identification of polymers based on distinct melting and solidification behavior signatures and transitions. Concurrently, DSC permits quantifying the percentages of components in a mixture compared to pure component references. This presentation details the DSC testing methodology and supplementary software tools for identification and quantification using several plastic mixture examples. These tools include peak separation for distinguishing and separating overlapping peaks as well as identification algorithms using the melting temperature and database approach. The examples include multilayer films as well as mixtures of two or more components. Current strengths and limitations of this approach linked to specific material classes, mixtures and analysis limits are presented to understand where the technique shows greatest viability for industry recycling use cases and where further development is needed.

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# S20 – Circular Economy of Polymers

## S20 - 230

## PLA-based Bioplastics for a Circular Plastic Economy: Advantages and Challenges

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Bioplastics are special plastics manufactured from biobased polymers and can potentially contribute to the circular plastics economy. In this direction, polylactic acid or polylactide (both abbreviated as PLA) is the most important commercially available polymer whose monomeric unit, lactic acid, can be produced from renewable resources. PLA has good thermal plasticity and mechanical properties and can be readily molded. During the manufacturing of PLA-based plastic products, the carbon footprint is approximately 75% lower than that of conventional plastic products. Moreover, in the industrial composting plant, PLA-based plastic products can be degraded after a few months. Therefore, the original building blocks of PLA return to nature and thus complete PLA's economic cycle. This presentation critically examines the advantages and challenges of PLA-based bioplastics in transitioning towards a circular plastic economy.

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# S20 – Circular Economy of Polymers

## S20 - 245

## The influence of composition on the characteristics of mechanically recycled polyolefins

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The most common recycling method used for commodity polymers such as polyolefins is the mechanical one, a physical process presenting the lowest energy consumption among conventional recycling techniques combined with low environmental impact [1, 2]. However, the overall quality of mechanically recycled plastics is usually limited. In essence, a post-consumer recyclate is a mixture of different compounds. Although the main fraction consists of the targeted plastic for recycling, undesired substances, i.e., contaminants, are commonly present. Predominantly, these contaminants comprise other types of plastics and, in lower quantities, both intentionally added substances (IAS) and non-intentionally added substances (NIAS) are present in the final composition [3, 4]. In addition, plastics undergo degradation during processing and lifetime, in which the macromolecules and polymer stabilizers undergo chemical modifications. The present study assesses the effects of the composition on the characteristics of recycled polyolefins. It is observed that the presence of polypropylene (PP) in high-density polyethylene (HDPE), as well as the formation of gels due to the degradation of HDPE macromolecules substantially affect long-term properties such as creep resistance. In recyclates consisting of laminated low-density polyethylene (LDPE) /linear low-density polyethylene (LLDPE) films, the composition of the adhesive interlayer affects their recyclability, especially the impact strength and aesthetic characteristics. In addition, the mechanical recycling of polyolefins showing insufficient thermal-oxidative stability can compromise the quality of the recycled material. In conclusion, to ensure the quality of recycled polyolefins is necessary to assess the composition of the recyclates and their thermal-oxidative stability.

[1] https://doi.org/10.1016/j.resconrec.2021.105633
[2] https://doi.org/10.1002/macp.202100488
[3] https://doi.org/10.1016/j.wasman.2017.07.044
[4] https://doi.org/10.1016/j.fpsl.2020.100553

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# S20 – Circular Economy of Polymers

## S20 - 272

## Graphene Synthesis through Recycling Lithium-Ion Battery Waste Polymers via CO2 laser

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Amid rising demands for electric vehicles (EVs) to meet global climate goals, sustainable management of the expanding EV battery market is crucial. Lithium-ion batteries (LIB) stand as the predominant energy storage technology in EVs, boasting an average lifespan of 8-10 years. Given their widespread implementation, the recycling of these batteries emerges as a critical facet for sustainability. Despite considerable strides in recycling anode and cathode materials, the efficient recycling of polymers from batteries presents a formidable challenge. Addressing this requires focused sustainable reclamation efforts, especially in polymer separation, hindered by limited information available from manufacturers. Another pivotal challenge involves the large-scale recycling of the entire component. In this paper we present a novel method eliminating polymer separation, prioritizing environmental sustainability, and showcasing adaptability for large-scale applications. The innovation in this study resides in the application of a CO2 laser in the graphene production process, specifically tailored to the distinctive composition of LIB waste materials. This initiative addresses challenges from chain-growth polymers in LIB waste, unexplored in Laser-Induced Graphene (LIG). Characterization tests using Scanning Electron Microscopy and Raman Spectroscopy affirm the successful conversion of low-char, chain-growth LIB waste polymer into graphene nanosheets. Additionally, our proposed method emphasizes its potential by achieving high-quality graphene production without recourse to post-processing steps involving harsh chemicals. Variations in graphene quality are observed with different laser parameters, notably multiple passes, contribute to high-quality flakes. This research advances sustainable EV battery production and waste reduction. Moreover, cost-effective metal-free graphene development holds potential for diverse industries, boosting commercial viability and sustainability.

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# S20 – Circular Economy of Polymers

## S20 - 281

## Graphene Synthesis through Recycling Lithium-Ion Battery Waste Polymers via CO2 laser

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Amid rising demands for electric vehicles (EVs) to meet global climate goals, sustainable management of the expanding EV battery market is crucial. Lithium-ion batteries (LIB) stand as the predominant energy storage technology in EVs, boasting an average lifespan of 8-10 years. Given their widespread implementation, the recycling of these batteries emerges as a critical facet for sustainability. Despite considerable strides in recycling anode and cathode materials, the efficient recycling of polymers from batteries presents a formidable challenge. Addressing this requires focused sustainable reclamation efforts, especially in polymer separation, hindered by limited information available from manufacturers. Another pivotal challenge involves the large-scale recycling of the entire component. In this paper we present a novel method eliminating polymer separation, prioritizing environmental sustainability, and showcasing adaptability for large-scale applications. The innovation in this study resides in the application of a CO2 laser in the graphene production process, specifically tailored to the distinctive composition of LIB waste materials. This initiative addresses challenges from chain-growth polymers in LIB waste, unexplored in Laser-Induced Graphene (LIG). Characterization tests using Scanning Electron Microscopy and Raman Spectroscopy affirm the successful conversion of low-char, chain-growth LIB waste polymer into graphene nanosheets. Additionally, our proposed method emphasizes its potential by achieving high-quality graphene production without recourse to post-processing steps involving harsh chemicals. Variations in graphene quality are observed with different laser parameters, notably multiple passes, contribute to high-quality flakes. This research advances sustainable EV battery production and waste reduction. Moreover, cost-effective metal-free graphene development holds potential for diverse industries, boosting commercial viability and sustainability.

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# S20 – Circular Economy of Polymers

## S20 - 321

## A transdisciplinary approach to solving some of New Zealand's plastic waste problems

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New Zealand sends approximately 380000 tones of plastics to landfill every year even though our system for collecting and recycling plastics is improving rapidly. New Zealand needs a functioning circular market for plastics which requires effective re-manufacturing methods, and widespread industry engagement in circular market behaviour. In this work we discuss a transdisciplinary approach to solve this problem, encompassing engineering, supply chain, marketing, and design, to create a new circular market system for plastics in New Zealand. Digital platforms are discussed as a possible solution to enable collaboration, knowledge sharing, circular resource flows, transparency, and accountability, which could lead to reduced information asymmetry and uncertainty in the plastics market. Embedded within this circular market system, the technological challenge is to develop new high performance polymer blends, extracted from waste plastics, that mimic and exceed the processing and mechanical properties of virgin resins. That is, we upcycle plastic that would otherwise end in landfill. To address these challenges, we use atmospheric plasma modification of plastics during extrusion to add functional groups to the materials. These functional groups can be altered by choosing the appropriate conditions in the plasma. We have shown that the properties of polyethylene, polypropylene and nylon can be altered using this extrusion-based technique. In addition, high performance composites can be manufactured by either modifying the recycled matrix or the fibers using the same plasma technique.

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# S20 – Circular Economy of Polymers

## S20 - 336

## Performance of post-consumer recycled polyolefins in rotational molding process

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In this study we evaluate the properties of post-consumer recycled (PCR) polyolefin-based material for the rotational molding process. Modifications must be applied to redefine the characteristics of those materials, relatively to their rheological, thermal, or physical properties, as PCR polyolefins were based on plastics coming from rigid parts produced by injection or extrusion blow molding. Sirblend R 00 040 CS AX was provided by SIRPLASTE company in powder form. The material was studied by MFI, DSC, TGA, FTIR, apparent density, dry flow, and granulometry. The processing conditions were varied in terms of mold internal air temperature (IAT) and cooling by air or forced air (fan). Despite the adequate properties of Sirbland for rotomolding, the parts had significant warpage and pinholes at the surface. As a result of that a study was carried considering the blend of PCR and virgin polyolefins. The proportions of 90/10 to 50/50 of recycled and virgin polyolefins were considered. At 50/50, good part quality was achieved with no warpage observe. Mechanical and morphological properties of the parts are still under study. It was concluded that PCR polyolefin was a blend of HDPE with a small portion of PP. The blend of 50% PCR HDPE with 50% virgin MDPE is important to avoid warpage. Colling by air is also a good strategy, but at the expense of a significant increase of cycle time.

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# S20 – Circular Economy of Polymers

## S20 - 34

## Effect of Jatropha Curcas Oil on Thermorheological Proprieties of Asphalt Binder Modified with recycled HDPE

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Polymer-modified asphalts (PMA) have been used for years to improve the performance of asphalt against premature pavement failures. However, polymer addition increases asphalt viscosity dramatically and reduces binder workability. Therefore, several types of additives have been proposed to recover the workability of PMAs. In this study, Jatropha curcas oil (JCO) was extracted and evaluated as an asphalt and PMA modifier. JCO-HDPE-modified bio-asphalt were prepared with JCO content from 1, 3 to 5 wt.%. Physical (penetration, softening point, and ductility), rheological (dynamic viscosity and Rolling Thin-Film Oven Test - RTFOT) tests and thermogravimetric analysis (TGA) were employed for evaluating the effect of JCO on rheological, aging, and thermal properties of the composites. Based on the conventional and basic rheological test, it was seen that the addition of JCO was effective in reducing the age-hardening of asphalt binders due to an increase in penetration and ductility, a decrease in softening point, and penetration index values. Aged asphalt binder, with a combination of JCO and recycled HDPE, showed improved resistance to thermo-oxidative aging by exhibiting lower oxidation and volatilization after RTFOT. TGA results indicated that JCO and HDPE have increased the thermal stability of modified binders by delaying the initial decomposition temperature of neat asphalt by 10 ºC. The incorporation of JCO leaded to a decrease in the viscosity of both virgin and HDPE-modified asphalt. Thus, JCO-HDPE-modified asphalt has better workability, which leads to a consequent reduction in fuel consumption and low harmful emissions at pavement service temperatures.

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# S20 – Circular Economy of Polymers

## S20 - 35

## Targeting recyclability in cross-linked bio-based polyurethanes through thermoreversible bonds

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Polyurethane (PU) finds extensive applications across various industries such as automotive, bioengineering, construction, and textiles1. Its widespread use is due to its adaptability, as it is available in two main categories: as a thermoplastic, which allows recycling, and as cross-linked networks that enhance mechanical properties but do not allow reprocessing. The substantial use of polyurethanes has raised concerns about the significant waste generated2. One approach to address the issue of polyurethane waste is to enhance its recyclability. This can be achieved by creating materials with thermo-reversible bonds, where these bonds break at a specific temperature and re-establish when the temperature decreases3. In this context, a promising solution is to incorporate dynamic covalent bonds into polyurethanes. One of the extensively researched thermally reversible covalent bonds is the furan-maleimide Diels-Alder adduct (DA). At elevated temperatures, a retro-DA reaction occurs, leading to the decoupling of the DA reactants. This process facilitates the reprocessing of cross-linked materials, effectively bridging the gap between thermoplastics and thermosets4. The objective of this study was to produce cross-linked polyurethanes, partially derived from bio-based sources, featuring dynamic covalent bonds based on the DA thermo-reversible reaction. To achieve this objective, a trifunctional crosslinker containing a DA adduct (DA-triol) was synthesized using maleimide and furfuryl alcohol, a component that can be obtained from plant-based sources. The polyurethanes were then produced using the DA-triol, a completely bio-based polyol and a partially bio-based isocyanate. Various formulations were assessed and recycled, resulting in polyurethanes with different mechanical properties and a bio-based content of up to 80%. These materials demonstrated outstanding recyclability due to the incorporation of the Diels-Alder Adduct.

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# S20 – Circular Economy of Polymers

## S20 - 369

## Mechanical recycling of multilayer plastics (MLP) from flexible food packaging

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Multilayer plastics (MLP) are extensively used in flexible packaging due to their exceptional properties, as each polymer layer provides specific characteristics that meet particular requirements, such as moisture barrier, mechanical strength, or protection against environmental factors. However, the thermodynamic incompatibility among the polymers within MLP, and the use of adhesives between them, complicates its recycling. Although mechanical recycling of MLP exhibits considerable scalability potential, it is known that the compounding of recycled multilayer films usually results in a blend with poor mechanical and physical properties. This work focuses on the mechanical recycling of MLP by blending them with a polypropylene (PP) matrix and using PP-graft-maleic anhydride (PP-g-MA) as a compatibilizer to improve the interfacial properties of the immiscible blend. Donated MLP from food packaging, consisting of layers of oriented PP (oPP), polyethylene terephthalate (PET) and linear low-density polyethylene (LLDPE), were grinded and blended with PP and PP-g-MA via extrusion and injection molding. Blends consisting of 5, 10 and 15 wt.% of recycled MLP were produced, all of them with 3 wt.% of PP-g-MA. Melt Flow Index (MFI), Shore D hardness, impact resistance, and tensile properties were evaluated. It was found that MLPs increase the MFI of PP, and that MFI decreases with MLP content. Also, MLP decrease Shore D hardness by approximately 3.5%, and no significant difference was found at different MLP content. Impact resistance for blends with 10 and 15 wt.% of MLP is significantly higher than that of PP, but for 5 wt.% it is reduced. Finally, tensile properties (elastic modulus, yield stress and tensile strength) are improved when adding 5 and 10 wt.% of MLP but are reduced at 15 wt.%. These results indicate that a blend of PP with 10 wt.% of recycled MLP could be used to manufacture components with better or similar mechanical properties than those of pure PP.

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# S20 – Circular Economy of Polymers

## S20 - 41

## Extrusion Pretreatment of Polyesters for Efficient Recycling Via Enzymatic Deconstruction

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Production and use of polyesters including PET are on the rise due to their versatile properties and good recyclability. Although it is presently the most successfully recycled plastic resin, its recycling rate is still only ~25%. The most widely recycled form of PET is rigid packaging used for water bottles, food trays and containers. However, this represents only about 55% of the PET end use in the U.S.; the remainder is heterogeneous film, sheet, and fibers, all of which present issues for the purity and quality of recyclates obtained through mechanical processing. In the last few decades, genetic engineering of specialized thermophilic enzymes has enabled industrially relevant rates of degradation of PET. While promising, this new paradigm in polymer deconstruction still suffers from low efficiency, slow kinetics, and is untested on real PET waste materials. We present mechano-chemical pretreatment processes to alter the molecular weight, crystal structure, and particle size of PET secondary feedstocks prior to enzymatic deconstruction. PET from both waste and prime sources was melt processed using single- and twin-screw extrusion as well as foaming, followed by melt quenching. High input of specific mechanical energy resulted in reduced molecular weight, which in turn encouraged crystallization in the solidification from melt. Mechanical grinding was also found to increase PET crystallinity. The effects of copolymer composition, pretreatment method, and reaction conditions on enzymatic depolymerization were studied using modified leaf compost cutinase enzymes expressed in E. coli. The production rate and yield of terephthalic acid were increased for the pretreated PET, especially when crystallinity was minimized. Results from this work will inform process intensification through coupling of the mechanical, chemical, and biological recycling strategies.

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# S20 – Circular Economy of Polymers

## S20 - 458

## Global Treaty Negotiations on Plastic Pollution

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This presentation will outline the current state and future directions of the global treaty negotiations for the elimination of plastic pollution, focusing on the outcomes of the latest Intergovernmental Negotiating Committee (INC-4). INC-4 achieved consensus on the urgent need for comprehensive measures addressing plastic production and waste management. Key negotiation points include defining "plastic pollution," control measures (including annexes), scientific and technical cooperation, knowledge awareness, ensuring treaty compliance, among others. Academia faces the challenge of advancing research in alternative materials and sustainable practices, enabling effective policy frameworks, and enhancing public awareness through education. This session aims to foster an understanding of the critical issues and collaborative opportunities that can drive international efforts towards a sustainable future free of plastic pollution.

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# S20 – Circular Economy of Polymers

## S20 - 95

## Advancing Sustainable Practices in Food Packaging: Investigating Liquid State Decontamination of Post-Consumer Polystyrene Recyclate

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With an increased global focus on environmental sustainability, the imperative for innovative solutions in plastic waste management has never been more critical [1]. This urgency is particularly pronounced in the food packaging industry, where stringent requirements for material quality, both in terms of mechanical and toxicological properties, necessitate advanced recycling methodologies [2]. This study addresses this pressing challenge by examining various liquid state decontamination processes and their impacts on mechanical and thermo-rheological properties [3]. Utilizing post-consumer waste, specifically white polystyrene yogurt cups, this research investigates the potential of liquid state decontamination processes. The feedstock was processed through a super-cleaning industrial-scale recycling machine and a twin-screw extruder equipped with a vacuum degassing system with two vacuum ports. A comprehensive array of tests, including melt flow rate measurement, plate-plate rheometry, high-pressure capillary rheometry, tensile testing, and Charpy impact testing, were conducted to discern the nuanced influences of the distinct decontamination processes on the thermo-rheological and mechanical properties of polystyrene. The outcomes of this research provide a detailed portrayal of the currently attainable properties of polystyrene derived from post-consumer waste. This insight is pivotal in establishing the feasibility of utilizing PCR in the production of food packaging materials. The study contributes valuable knowledge to the ongoing discourse on sustainable practices in plastic waste management, offering a pathway towards more environmentally responsible and quality-compliant food packaging solutions.

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# S20 – Circular Economy of Polymers

## S20 - 96

## Navigating Recycling Technologies in Circular Product Development

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As the plastics industry embraces circularity, Circular Product Development (CPD) is gaining increasing importance. Unlike conventional product development, CPD incorporates circularity as a key aspect alongside feasibility, viability, and desirability. An ongoing challenge in CPD lies in the redevelopment of existing products using recycled plastics that meet all the four dimensions of CPD. Previous studies have emphasized the necessity of employing different recycling technologies—mechanical, solvent-based, and chemical—in parallel, to maximize positive impact. While some research has compared the benefits of using materials from mechanical recycling versus chemical recycling, decision-making tools evaluating the feasibility of using these technologies from a product development perspective are scarce. Furthermore, the quality of recyclates increases from mechanical recycling to solvent-based recycling to chemical recycling. Nevertheless, the superior quality of chemically recycled materials might come with trade-offs such as increased environmental impact, complexity, and processing expenses compared to mechanically recycled materials. This study aims at assessing whether quality is the sole factor determining the preference for chemical recycling when redeveloping products. To support this, we explore the unrealized costs associated with mechanical recycling by evaluating the development costs incurred when substituting virgin material with mechanically recycled material. The complexity of a product and the trade-offs between constraints and objectives could also significantly influence the development costs. By comparing the cost of developing products with mechanically recycled material against the costs associated with chemically recycled materials, this work aims to provide insights into selecting between these technologies.

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# S21 – Degradation, Biodegradation and Composting

## S21 - 102

## Biodegradable polymer nanocomposites based on two-dimensional fillers: Strategies of processing

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Biodegradable polymers have been proposed as an alternative for minimizing the volume of plastic residues [1]. Nevertheless, their performance, mainly related to mechanical properties, needs to be improved for these materials to be more competitive. Some strategies have been used to try to solve these problems, from the use of particulate reinforcing fillers and natural fibers [2]. Natural fibers have several advantages, such as low price, abundance, biodegradability, and high toughness. Among the reinforcing fillers at the nanoscale, graphene has emerged as one of the promising components of polymer nanocomposites owing to its exceptional properties [3]. In this work, different formulations of graphene nanocomposites and Rami fiber composites based on biodegradable polymers Polyhydroxy(butyrate-co-valerate)-PHBV and poly (butylene adipate-co-terephthalate)-PBAT, were studied. The formulations were prepared by melt mixing strategy using a twin-screw extruder. Contents of graphene varied between 0.05 and 0.3%, and contents of ramie fiber ranged between 2.5 and 5%. The materials characterization was conducted using Electron Scanning Microscopy (SEM), Rheology analyses, Differential scanning calorimetry (DSC), Thermogravimetric analyses (TGA), and the determination of mechanical properties according to ASTM D638-14. The results indicated increasing of thermal stability and improvements in mechanical performance for both reinforcements, with better results considering graphene composites. SEM images revealed some discontinuous interface between the ramie fiber and polyesters matrixes, which is expected considering weak chemical interactions of these components. Even though it is important to highlight that this did not prevent obtaining composites with improved strength and toughness. In conclusion, both kinds of composites were successful in the mechanical reinforcement of biodegradable polymers.

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# S21 – Degradation, Biodegradation and Composting

## S21 - 190

## TGA derived activation energy and status of degradation for plastic jacket pipes in district heating

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For the European strategy of carbon dioxide reduction, district heating is a cornerstone to the transformation of green energy supply to buildings. In this context, the knowledge about lifetime and residual life of the existing district heating network is getting increasingly important. Since their invention polyurethane insulated plastic jacket pipes gained the major contributor the district heating net. Due to the complexity of the aging process, the simple Arrhenius based calculation was taken out of EN253 in 2019, leaving a gap for quality insurance and prediction. Although several factors influence the lifetime, a correlation between activation energies derived from TGA experiments seems feasible to describe the status of PUR-plastic jacket pipes. Success and limitation of a modified Chang method for the correlation of artificially and naturally aged polyurethane as the weakest part in plastic jacket pipes will be presented.

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# S21 – Degradation, Biodegradation and Composting

## S21 - 244

## Enhanced degradation of multi layered PBAT-starch films in home and industrial composting environments

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Since the 1980s, biodegradable mulch films (BMF) have been developed to be incorporated in soil and degrade in-situ [1]. Commercially available BMFs are typically manufactured as mono layered polymer blends. During winters in colder regions, the biodegradation of these films is affected by low soil temperatures, which leads to a long mineralization time of several years. For this study, it was hypothesized that a multilayered film with a thick starch core could accelerate mineralization of the other layers [2]. An experimental prototype three-layered film using poly-(butylene succinate-co-terephthalate) (PBAT) as the outer two layers and thermoplastic starch (TPS) as a thick center layer was created using a blown film line. A pure PBAT film was also manufactured to offer a baseline degradation scenario. To assess biodegradation of the prototype samples, a 50-gallon lab-scale composting, similar to a home compost environment (HC) apparatus was set up to test accelerated breakdown of BMFs. Mass loss in mono layered PBAT film was recorded to be only 9% in 365 days as compared to a multi-layered PBAT-starch-PBAT film with a significant mass loss of 64% over the same time period. A similar experiment was set up at an industrial compost (IC) facility with elevated temperatures between 60°C and 80°C during testing. The results showed 100% mass loss by fragmentation for all films in about 66 days. The prototype films showed a mass loss of 85±5% in 23 days as compared to the monolayer PBAT film with 63±9% mass loss. Further, multi layered starch film showed lower viscosity of the polymer, suggesting significant reduction in molecular weight in both HC and IC environments. For applications like mulching, where the only end-of-life scenario for films is biodegradation, the prototype multi layered film shows potential to replace slow degrading mono layered films in that are used today.

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# S21 – Degradation, Biodegradation and Composting

## S21 - 71

## Modelling Hydrolytic, Thermal, and Mechanical Degradation of PLA During Single-Screw Extrusion

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Maintaining a high-quality material during melt processing is challenging when working with poly(lactic acid) or PLA, due to its sensitivity to degradation. Random chain scission of the polymer chains is caused by hydrolytic, thermal, and mechanical degradation when exposing PLA to moisture, high processing temperatures and shear stresses. The aim of this study is to model degradation of a commercial PLA-grade during single-screw extrusion, which allows prediction of the molecular weight decrease during processing. First, an experimental study is performed to understand the effect of four processing parameters (moisture content in the granules, processing temperature, residence time, and shear stresses) on the molecular weight using a parallel plate rheometer and a single-screw extruder. Next, this data is used to model degradation kinetics, based on known hydrolytic and thermal degradation reactions in literature. [1-3] Third, the link between molecular weight decreases and a change of thermal, rheological, and mechanical properties is discussed. The results of this study allow PLA processors to effectively select processing conditions and thereby maintain a high-quality material, ultimately saving time and money during production.

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# S21 – Degradation, Biodegradation and Composting

## S21 - 88

## Upgrading recycled/oxidized ABS by multilayer coextrusion of PC/ABS blend

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Recycling polymers from Electric and Electronic Equipments (EEE) is a challenge. ABS is one of the most used polymers in EEE but loses part of its impact toughness as a result of oxidation during its lifetime. It is often used as a blend with PC. This work applies for the first time the technic of multilayered coextrusion to PC/ABS blends. Indeed, it is known to improve mechanical properties as shown in the literature for PC-SAN blends for instance. First, ABS pellets were exposed at 120°C to induce diffusion limited oxidation. ABS oxidation was studied through GPC and AFM coupled with FTIR. Then both [virgin PC/ABS] and [virgin PC/oxidized ABS] multi-layered films were extruded at 80/20 wt%. Such films present a microstructure of hundreds of layers ranging between 30 nm and 70 µm as illustrated in Figure (a). Finally, their mechanical properties were characterized and compared. While the drop in elongation at break property of 23% for unstructured samples was expected from oxidation induced ABS embrittlement, multilayered samples only lose 6 to 14% depending on the amount of layers as shown in Figure (b). This plot details the value of elongation at break unstructured blends of virgin and aged ABS with PC in horizontal lines. Each data point represents a specific multilayered film and its performance as a function of the number ABS layer thickness. The huge difference in properties drop during oxidation is attributed to the specific morphology developed during multilayer coextrusion. With this technic, recyclers could upgrade their recycled ABS and give it a second life.

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# S21 – Degradation, Biodegradation and Composting

## S21 - 99

## The use of chemiluminescence to assess the recyclability of polypropylene

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When it comes to mechanical recycling, oxidative degradation of polymer chains is one of the primary obstacles to closed-loop recycling. The oxidation of polymers is accompanied by chemiluminescence (CL), which can very sensitively be detected by CL analyzers, making it useful for monitoring the thermo-oxidative degradation of polymers [1]. Polypropylene (PP) is widely used in a variety of applications. However, PP can undergo thermo-oxidative degradation both during processing and service life even with the use of antioxidants. Small amounts of degraded material can induce degradation of unaffected PP fractions, limiting its recyclability [2, 3]. Therefore, it is necessary to have a thorough understanding of the impact of the degradation and stabilization levels of PP on its thermo-oxidative behavior during closed-loop recycling. In this study, CL was used to examine the thermo-oxidative degradation behavior and stability of two PP samples (PP1 and PP2) that were subjected to multiple processing cycles. CL measurements in air atmosphere were used to obtain the oxidative behavior of the polymers. For a comprehensive understanding of the CL outcomes, the auto-oxidation features were correlated with the chemical modifications of the polymer chains and with the active antioxidant concentration. Considering the CL results, a lower thermo-oxidative stability could be recognized by a reduction in the oxygen induction time (OIT), by a steeper slope during auto-oxidation, and by a decrease in time to reach the maximum rate of auto-oxidation. With these means, it has been shown that all antioxidants of PP1 were consumed after only one cycle of reprocessing whereas PP2 reached the same state after 5 cycles. Clearly, PP2 maintained a higher stability during reprocessing and is better suited for closed-loop recycling compared to PP1. This work shows that CL can be used to establish critical degradation and stabilization levels for the mechanical recycling of polymers.

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# S22 – Polymers in the Sustainable Development Goals of the United Nations

## S22 - 132

## WPC from Uruguayan industrial waste - A first approximation

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Wood–plastic composites (WPCs) are innovative wood-based composites manufactured using wood, thermoplastic, and additives through injection, extrusion, and hot-pressing molding processes. Due to their excellent weatherability, dimensional stability, and mechanical properties, WPCs are widely applied in many fields. The performance of a WPC is determined by the properties of its raw materials, wood content, and the interfacial bonding between the wood and the plastic. There is a lot of literature on these compounds, but no work on the species that are industrially planted in our country, Uruguay: Pine, and eucalyptus. As is known, even if it is the same species, the composition of the wood depends on the area where the tree grows. The aim of this work is compare the mechanical properties of mixtures of wood flours from both trees using two thermoplastic polymer matrix, polyethylene, and polypropylene, the two most used polyolefins. For this, we worked with four experimental designs factorial 24, using as variables the size of the wood particles, the wood-polymer ratio, and the rpm of the twin-screw extruder, at two levels, (high and low). The responses to these analyzed variables were resistance at breakage, hardness and water absorption using the corresponding ASTM test standards. We also analyzed the dispersion of the sawdust particles in the polymer using microscopy, also performing FTIR and DSC tests on some of the samples. In all cases, at the same load proportion, the properties of the samples containing eucalyptus were superior to the samples with pine wood flours. As a final conclusion we can say that this type of solutions allows us to give polymers a final solution with greater added value, in line with the sustainable objectives of the United Nations, in a country with a growing wood industry, in which more than 50% of the tree is wasted.

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# S22 – Polymers in the Sustainable Development Goals of the United Nations

## S22 - 149

## Effect of UV-C light on Oxygen Scavenging Kinetics of Green and Biodegradable Composite Films for Active Food Packaging

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Food safety and security are the burning issues of the modern world, which need to be addressed with environmentally benign approaches1,2. Green and sustainable synthesis and application of materials are essential to replace metal-based oxygen scavengers3. Recently focus has been shifted on developing plant-based materials that are sustainable and non-hazardous. This work explored natural rubber latex as a potential oxygen-scavenging material in combination with polyvinyl alcohol (PVA) to fabricate biodegradable films. Both materials were taken in different ratios for film formation and analyzed for their physical, mechanical, thermal, and moisture barrier properties along with oxygen scavenging capacity, rate, and biodegradability. Selectively, two parts of NRL film have exhibited the highest scavenging capacity and a rate of 1045 ml O2/g and 95 ml O2/g. day, at 60 ℃ and 120 s of UV-C exposure time, respectively, and a water contact angle of 65.18°. Alternatively, two parts, NRL and one part of PVA, have shown the lowest tensile strength of 10.36 MPa. Equal parts of PVA/NRL films have shown approx. 90% degradation within 90 days. The highest tensile strength of 24.32 MPa was achieved upon adding two parts of PVA. A higher water transmission rate of 24.2 g/m2.day was seen in film with equal parts of PVA and NRL. After oxidation, all the films have a significant color change when compared to the color before oxidation. The films turned light brown from pale yellow and had the highest total color change of 31.27. The results show that the fabricated PVA and NRL composite films can efficiently replace metal-based oxygen scavengers in active food packaging.

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# S22 – Polymers in the Sustainable Development Goals of the United Nations

## S22 - 374

## Ethylene Vinyl Alcohol (EVOH) for sustainable food production– Case Scenarios

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EVOH has been used for years in packaging because it prevents food waste. But beyond that, EVOH has helped the food supply chain become more sustainable, given the tendency for more environmental protection regulations. “Sustainable food production” with EVOH began with the commercialization of “Totally Impermeable [fumigation] mulch film (TIF)”, reducing the fumigant dose and fumigant emissions without sacrificing crop yield and quality. In another application, coined as hermetic bags, EVOH maintains the quality of the seeds like corn, rice, or green coffee allowing those crops to be exported around the world. In the more traditional food packaging for consumer use, flexible packaging continues to gain ground on rigid packaging due to the benefit of weight reduction. Indeed, three of the applications that have successfully overcome the challenges of the mono-material packaging are (1) fresh meat (in replacement of PVDC), (2) roasted coffee, and (3) organic ketchup (in replacement of aluminum foil). All these projects have been possible thanks to advancements in coextrusion equipment and the synergy of enhanced EVOH and enhanced polyolefin grades. One last piece that has posed even higher challenges has been the development of a retortable monomaterial flexible packaging: eliminating PET and PA while resisting the high thermal, pressure, and moisture stresses, maintaining the oxygen barrier. Last year Kuraray team patented special grades of EVOH that when used in the proper structure with PP can resist standard retort conditions (like cooking at 121C for 1.5h). All these improvements could open opportunities to sustainable packaging with better nutritional value for many types of food. Upon the available time, successful case-studies will be presented, comparing the properties and performance of the monomaterial flexible package versus conventional packaging in challenging applications.

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# S22 – Polymers in the Sustainable Development Goals of the United Nations

## S22 - 49

## A review on the presence of microplastics in drinking water distribution networks

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Microplastics (MPs) and other emerging contaminants coexist in the environment, and their simultaneous exposure is an escalating cause for concern. This is because microplastics have been observed to function as carriers of contaminants, owing to their high sorption capacity. When organisms ingest contaminated microplastics, it can intensify the release of contaminants, thereby raising their bioavailability and toxicity. In recent years, numerous investigations have highlighted the existence of this type of particulate matter in tap water. This has sparked inquiries and anxieties regarding the potential consequences of consuming water containing microplastics on human health. This concern is manifested in the increase of publications on this topic, which is relevant because it affects the quality of water drunk by people around the world. The study of microplastics in drinking water could contribute to the fulfillment of target 6.3 of Sustainable Development Goal 6 since it would demonstrate the need to improve the efficiency of treatment plants and the monitoring of distribution networks. In this article, literature related to the presence of microplastics in drinking water and their relationship with the materials used in the water distribution networks (WDN) was reviewed. Some of the studies found have focused on detecting the possible sources of contamination of the water reaching households. For example, the concentration of microparticles reaching consumers can increase depending on the source of water supply. In other studies, despite having a high removal of these solids, the water that reaches the homes has a higher concentration than that which left the treatment plant. Thus, it is assumed that the piping components, including the pipes, may release microplastics into the drinking water. After this review, free chlorine concentration, pH, pipe material, and time are parameters considered in the production of microplastics.

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# S22 – Polymers in the Sustainable Development Goals of the United Nations

## S22 - 387

## Mercury Contamination and PVC Production: Global Impact, Initiatives, and Sustainable Solutions

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The levels of environmental mercury (Hg) have experienced a significant increase since the onset of the industrial era, several anthropogenic activities emit elemental and ionic mercury. This pollutant circulates, deposits in soil, and transforms into methylmercury, adversely impacting human and wildlife health. Mercury impacts the nervous and cardiovascular systems, while methylmercury is neurotoxic, negatively influencing the development of children's brains [1]. PVC is produced through VCM polymerization using three methods: ethane oxychlorination, ethylene oxychlorination, and acetylene hydrochlorination [2]. This presentation aims to elucidate mercury emissions in VCM production via the acetylene-based method, which is used in the calcium carbide process (CCP) that use a mineral carbon source. In CCP-VCM, a mercury chloride catalyst causes emissions as temperatures (180 – 220 °C) volatilize the catalyst [3]. Estimated mercury release during acetylene processing is 0.098 kg per ton of PVC produced [4]. Currently, China, India, and Uzbekistan plants employ the acetylene-based process with a total capacity of around 22.16 million tons [5]. This method is estimated to release 40 tons of mercury annually, posing significant threats [2]. The Minamata Convention, effective since 2017, aims to reduce mercury emissions globally. One of the China's initiatives under this agreement, ongoing until 2025, focuses on reducing mercury in Vinyl Chloride Monomer (VCM) production, and has achieved a total reduction of 359.5 metric tons of mercury, approaching the proposed target [6]. Currently Some Chinese and Indian plants transitioned entirely to mercury-free methods, aiding global efforts [5]. In the past decade, numerous papers and patents on mercury-free catalysts emerged [5], signaling a swift transformation to eliminate mercury from PVC production. Also is crucial to explore alternatives to recover residual mercury from past emissions, fostering a more sustainable process.

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# Abstracts of PPS – 39

## Abstracts of Poster Presentations

# S01 – Additive Manufacturing (3D Printing)

## S01 - 104

## Development of recyclable metal-infused feedstock for low-cost 3D printing in the context of circular manufacturing

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Additive manufacturing, also known as 3D printing, of polymers such as PLA, ABS, PETG, and many others is a well-known technique to create very detailed, fully customized products with complex geometries. While plastics dominate this field, there's growing interest in exploring alternative materials such as metals, ceramics, and composites due to their unique properties. In particular, metal additive manufacturing via material extrusion which is known as fused filament fabrication (FFF) offers low-tooling costs, table-top systems, reduced metal powder handling needs and hazards and etc. In FFF for metals, a 'metal' filament consists of metal powder (high concentration, ~60 vol.%) and a binder system, including a polymer matrix and additives. The quality of the filament and subsequent processing for pure metal parts – 3D printing, debinding, and sintering – are significantly influenced by aspects like the size, shape, and dispersion of metal particles within the polymer matrix. In this context, the objective of this project was to develop metal-infused filaments with high concentration of metal powder (up to 60 vol.%), which can be used for standard (low-cost) FFF 3D printers. It sought to investigate how the size, shape, and dispersion of metal particles affect the processability of metal parts. The metal powders used for this project are fine spherical shaped carbonyl nickel and non-uniform shaped water-atomized iron. Fabrication of metal/polymer filaments involved a simple melting process using a single screw extruder. Two pre-mix approaches were employed before extrusion to study their impact on particles dispersion within the polymer matrix. Several polymers were tested as potential matrices for filaments fabricating. 3D printing of the metal/polymer filament was performed using a low-cost 3D printer. Mechanical property characterization of printed green parts was conducted to optimize the production of dense metallic 3D parts after debinding and sintering.

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# S01 – Additive Manufacturing (3D Printing)

## S01 - 160

## Biocomposite Filaments of Polylactic Acid/Nanocrystalline Cellulose Containing Carbon Nanotubes for Fused Deposition Modeling 3D Printing

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In this research, a bio-composite filament was prepared through melt-blending of polylactic acid (PLA) and various loadings of cellulose nanocrystals (CNC): 1, 5, 10, and 15 wt% so as to address high brittleness and low toughness of PLA. In order to enhance the compatibility of PLA and CNC during melt-processing, the surface of CNC was treated via grafting with trimethoxy silane. In the next step, prepared filaments were employed for 3D printing with Fused Deposition Modeling (FDM). The results of mechanical properties showed that the Young modulus increased upon rising CNC contents, while the elongation at break decreased. For instance, the Young modulus increased from 2.5 GPa for pure compression molded PLA to 2.8 GPa upon mixing with 10 wt% CNC. Similarly, the tensile strength for PLA and PLA/CNC (10wt%) was 56 and 59 MPa, respectively. By contrast, the elongation at break decreased from 3.7% to 2.7%. These outcomes clearly confirmed the reinforcing effect of CNC as a functional additive. A similar trend was observed in the case of 3D-printed samples. However, the corresponding values for 3D-printed specimens were lower than those of compression-molded ones. For example, 3D printed PLA had the Young modulus and tensile strength of 1.8 GPa and 47 MPa, respectively. This is a desired outcome as FDM 3D printing creates objects in a layer-by-layer approach, which can make a layered structure. In contrast, compression molding generally results in a more homogeneous structure. The layering in FDM can introduce weak points along the interfaces between layers, affecting overall strength. Moreover, as a result of the layering process in FDM 3D printing, we often have anisotropy, causing various properties in different directions, whereas compression molding, as a bulk-forming process, tends to produce more isotropic properties.

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# S01 – Additive Manufacturing (3D Printing)

## S01 - 242

## MSLA 3D Printing of Soft Networks Bearing Hindered Urea Groups

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The use of hindered urea bonds to provide dynamic reversibility in material systems that would otherwise not be recyclable has become of central interest to engineers and scientists over the past few decades. We present work regarding structure/property/processing relationships of networks prepared from a poly(urethane urea) prepolymer (PUUP). By varying composition, and thus the relative amount of reversible 1-(tert-butyl)-1-ethylurea (TBEU) moiety, we explore the mechanical, thermomechanical, and self-healing characteristics of prepared networks. Thermal and mechanical characterization of prepared polymer networks was completed by means of differential scanning calorimetry (DSC), tensile testing and rheological characterization. We find significant differences in thermal and mechanical properties, as well as the controllable reversibility of hindered urea moieties when preparing material networks with ladder architectures of various compositions. The tunability of these properties, dependent on composition, provides insight into the healability of select samples and application of printed materials. Moreover, the influence of material composition on processability for MSLA 3D printing is discussed. MSLA 3D printing allows for the rapid prototyping of complex geometries, where we focus primarily on the adjustment of parameters such as layer height and exposure time for multiple material compositions.

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# S01 – Additive Manufacturing (3D Printing)

## S01 - 261

## ABS 3D Printing Filaments Modified with SEBS and MWCNTs

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The objective of this study was to develop and morphologically and mechanically characterize 3D printing filaments of ABS modified with SEBS and MWCNTs. The adhesion between layers plays a crucial role in determining the properties of printed parts, as these interfaces often result in failure due to delamination. Therefore, we evaluated the hypothesis that SEBS could enhance layer adhesion owing to the higher molecular mobility of elastomeric segments. Tensile tests, Scanning Electron Microscopy (SEM), rheological behavior, and Infrared analysis were employed for filament characterization. Test specimens were printed and evaluated for impact resistance in two printer positions: the first with layers perpendicular to the crack propagation direction, and the second with layers parallel, indirectly assessing layer adhesion. From the tensile test of the filaments, a maximum tensile strength of 34.5 ± 4.1 MPa was observed for pure ABS. For the ABS-SEBS blend, the result was 31.6 ± 2.5 MPa, while for ABS-SEBS-0.25MWCNT and ABS-SEBS-0.5MWCNT, the results were 28.1 ± 3.3 and 26.3 ± 3.3 MPa, respectively. SEM analysis revealed that SEBS is immiscible in the ABS matrix. Samples printed with layers perpendicular to the crack propagation direction had an average impact resistance of 43.4 ± 2.8 J/m and 30.7 ± 3.4 J/m for ABS and ABS-SEBS, respectively. Printing with layers parallel to the crack propagation direction yielded values of 7.7 ± 1.8 J/m and 7.3 ± 1.1 J/m for ABS and ABS-SEBS, respectively, indicating no difference in layer adhesion. Therefore, the hypothesis that the presence of SEBS could enhance layer adhesion was not confirmed.

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# S01 – Additive Manufacturing (3D Printing)

## S01 - 360

## Individualized functional products through technology fusion

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In recent years, it has become apparent that technical components not only have to fulfil more demanding mechanical-structural properties, but that different functions and functional groups also have to be integrated into a hybrid system. For this purpose, it is necessary to combine a wide variety of materials and to dissolve the usual separation between structural and functional materials. This poses a great challenge when the different materials only form their functional structures on different size scales in different processing methods. Typically, neither the materials nor the technologies are compatible with each other. Against this background, hybrid systems must be conventionally and sequentially manufactured from the different materials component by component. This is followed by the assembly of the system. The aim of the presented work is to combine initially incompatible manufacturing processes such as injection molding and various additive manufacturing processes (FFF - Fused Filament Fabrication or FDM - Fused Deposition Modelling) and here to focus on projection micro stereolithography (PµSL) to generate hybrid systems that are characterized by the use of specific polymer materials on different length scales. This results in hybrid products for the first time that have a maximum degree of individualization as well as a multitude of structural and functional features at the same time.

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# S02 – Extrusion

## S02 - 315

## New Degassing Technology for Single Screw Extruders – Mechanics and Analysis

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This paper presents new degassing technology for single screw extruders. The technology is based on a new screw design with improved degassing capability – called the super degassing screw or SDS. The SDS technology offers several advantages over conventional degassing technology. • There is no requirement for a zero-pressure zone • There is no significant drop in pressure generating capability of the extruder • There is no reduction in length available for melting • There is no output penalty • 100% of the melt is exposed to the degassing action • Long degassing length and large surface area for degassing • The degassing action starts at the beginning of melting and continues to the end of melting • Venting can be done on standard extruders and reciprocating extruders • Chance of vent port plugging is remote This paper will discuss the design of the SDS and the physics behind it. A companion paper will describe test results of the super degassing screw with undried PET and ABS on a highly instrumented single screw extruder.

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# S02 – Extrusion

## S02 - 330

## On-Line Optical Monitoring of the Mixing Performance in Co-Rotating Twin-Screw Extruders

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The use of real-time techniques to evaluate the global mixing performance of co-rotating twin-screw extruders is well consolidated, but much less is reported on the specific contribution of individual screw zones. This work uses on-line flow turbidity and birefringence to ascertain the mixing performance of kneading blocks with different geometries. For this purpose, one of the barrel segments of the extruder was modified in order to incorporate four sampling devices and slit dies containing optical windows were attached to them. The experiments consisted in reaching steady extrusion and then adding a small amount of tracer. Upon opening each sampling device, material was laterally detoured from the local screw channel, and its turbidity and birefringence were measured by the optical detector. Residence time distribution curves (RTD) were obtained at various axial positions along three different kneading blocks and under a range of screw speeds. It is hypothesized that K, a parameter related to the area under each RTD curve, is a good indicator of dispersive mixing, whereas variance can be used to assess distributive mixing. The experimental data confirmed that these mixing indices are sensitive to changes in processing conditions, and that they translate the expected behavior of each kneading block geometry.

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# S02 – Extrusion

## S02 - 419

## Predicting Size and Shape Changes in Extrusion of Non-Circular Profiles

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It is well-known that the size and shape of an extruded profile is different from the shape of the die. However, prediction of this size and shape change has remained largely elusive. As a result, die design is often still a trial-and-error process and die manufacture requires multiple modifications before the profile shape and dimensions are correct. This process is often referred to as die tuning. Multiple die modifications increase the cost of die manufacture and reduce the profit margin for the profile extrusion company. This presentation will show how kinematic shape changes can be predicted from the velocity profiles in the die. Analytical expressions will be presented that allow prediction of size and shape changes. It will be shown how the degree of shear thinning of the molten plastic affects the shape changes of the extruded product. Examples of several extruded profiles will be presented.

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# S03 – Functional Additives and Reactive Processing

## S03 - 376

## Foaming Modified Poly(lactic acid) Obtained by Reactive Processing as a Sustainable Solution for Single-Use Packaging

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This study evaluated the foaming poly(lactic acid), PLA, a polymer obtained from renewable and compostable sources, to minimize the environmental impacts of generating microplastics, after chemical modification by reactive processing. For this purpose, the processing was carried out in a Haake torque rheometer, according to an experimental design 22, where the concentrations of dicumyl peroxide (DCP) and glycidyl methacrylate (GMA), were varied at two levels, 0.5 phr and 1.5 phr, and 1phr and 3 phr, respectively. The reactions were conducted at a temperature of 180°C, and the reaction time was 6.5 minutes. Analysis by size exclusion chromatography (SEC), acid group titration, % cross-linking by Soxhlet extraction, and nuclear magnetic resonance (NMR) were investigated. The results show that the samples processed only with peroxide at the lower and upper levels showed high cross-linking degrees, 67.8 % and 98.1 %, respectively. When GMA was added to the upper level of peroxide, the influence of the concentration of GMA was observed, which at the lower level still caused 91.8% crosslinking and at the upper level 1.2%. The other formulations in the experimental design, conducted at the lower peroxide level, showed percentages of 0.1% when peroxide and GMA were present. All the samples had higher molar masses than pure PLA, and the formulation with 1.5 phr of DCP and 3 phr of GMA had the highest molar masses and the lowest acidity. When the analyses were carried out at the lower peroxide level, 0.5 phr, the molar masses were lower than for the higher peroxide level and did not change with the variation in GMA concentration. This was attributed to the excess of GMA at the lower level. The NMR results indicate a modification by long branches in the PLA, resulting from the reaction of the GMA with the PLA with the subsequent reaction of the epoxy group at the end of the PLA chain. Samples were foamed to check the potential for producing PLA foams.

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# S03 – Functional Additives and Reactive Processing

## S03 - 83

## Reversibly Cross-liked Polyethylene

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Cross-linked polyethylene (PEX) is of particular technological interest for an extensive variety of applications like pipes or insulating material for electrical cables. While the cross-links inside the structure improve the polymer thermal stability, chemical resistance, and structural integrity, they complicate its recycling process since it cannot be melted down [2]. Traditionally, it is buried or cremated, causing it to degrade or burn rather than melt, leaving a high toxic carbon content (20-30%)[3]. The aim of the Redondo project is achieving a fully reversible cross-linking process that will enable the production of sustainable by design polymers. In this context, reversible carbon-dithio bonds (>C-S-S-) will be used to cross-link PE, while de-crosslinking will be implemented at moderate temperatures (200-270 °C) (reversibility), thus rendering cross-linked PE recyclable. In this work, the synthesis of cross-linked PE took place by reactive extrusion in the presence of tetramethylthiuram disulfide (TMTDS) and Perkadox 14S at 190 ºC for 20 minutes. FTIR analysis revealed no significant structural change on the samples, while the synthesized reversibly cross-linked PE (rPEX) was also characterized in terms of its cross-linking degree via gel content measurements. Tensile test was also performed in order to examine the mechanical properties, while DSC and TGA were applied for the investigation of rPEX thermal behavior. There was no shift detected in the melting and crystallization temperature of the samples. Acknowledgments This project has received funding from the European Union's Horizon Europe Framework Programme under Grant Agreement No 101058449. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or HADEA. Neither the European Union nor the granting authority can be held responsible for them.

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# S04 – Injection Molding

## S04 - 357

## Micro-Injection Molding: Crystallization of Polyoxymethylene and Influence of Molecular Weight

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Polyoxymethylene (POM) is a semi-crystalline polymer whose final structure and mechanical properties rely on the molecular weight and the applied processing conditions. This is pertinent to micro-injection molded components. A design of experiments (DoE) was conducted on POM materials with distinct molecular weights, controlling melt and mold temperatures and injection speed to investigate the correlations between processing and properties. A specially designed rod with a radially symmetrical cross section was utilized for the experiments as it has advantages in terms of flow and cooling behavior. To study the morphology, thin sections were extracted from the sample's center in the transverse direction and analyzed under a polarized light microscope. The crystallinity of the samples was examined through Differential Scanning Calorimetry (DSC). The micro-tensile test determined the mechanical properties. The study revealed that mold temperature is the primary factor affecting the final structure and mechanical properties of low molecular weight POM. Injection speed significantly impacts the mechanical properties of high molecular weight POM.

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# S04 – Injection Molding

## S04 - 392

## OPTIMAL NUMBER OF CAVITIES IN A MOLD AND BY EXTENSION OF FRAME TOOLS

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In addition to quality issues of the parts produced as well as those of the molds, the cost of the product is essential for any manufactured element. Therefore, establishing the optimal number of cavities, that is the one that leads to the lowest part cost, is always a must. This number is found using the traditional equations of economics, in particular those for minimum cost applied to thermo-plastics injection molds, in which several assumptions take part and lead to results that usually do not conform to reality. The aforementioned equations do not take into account a series of practical considerations that are decisive in such a decision. These considerations include the risk of operating a single large mold; the fact that increasing the number of cavities also means the length of the runner channels and therefore a higher injection pressure and material waste, with the consequent increase in energy consumption; the increase in the cost of each cavity and mold complexity as a result of the need for higher precision in tool construction; and the tendency for the hourly manufacturing cost of a plant to decrease when the amount of machines increases. On one hand, certain materials such as PVC do not allow hot-runner molds. And on the other, in the case of large production volumes, the result frequently indicates the purchase of a new larger machine when the plant already has injection molding machines of smaller size with idle capacity. By presenting several case studies and performing their graphical analysis, the relativity of the results of calculations, and the need to combine mathematical analysis with sound criteria from experience are well understood. The author´s forty-year experience and hundreds of molds constructed converge in this unique study.

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# S05 – Polymerization and Synthesis

## S05 - 166

## Polymerization Kinetics of a Bioproduct Epoxy by Means of Differential Scanning Calorimetry

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The diverse properties of epoxies contribute to their widespread importance in modern industry and technology. Understanding epoxy polymerization kinetics is crucial for tailoring the curing process to specific applications, achieving the desired material properties in the final product. The current work focuses on the inspection of a biobased epoxy-amine curing process through both dynamic and constant temperature experiments revealing the total heat of polymerization, the glass transition temperatures of cured and uncured network, as well as the effective crosslinking of the system under 25, 40 and 60 °C. Cyclical dynamic-dynamic and isothermal-dynamic DSC experiments were further performed, giving rise to the Di Benedetto equation, with glass transition values very close to the experimentally measured [1]. Applying the advanced isoconversional method proposed by Vyazovkin, the activation energy found to be constant with degree of conversion, implying a single step reaction [2]. A simple nth order with autocatalysis reaction model was utilized to reproduce the polymerization under dynamic conditions, while coefficients derived from that fitting were further evaluated for their ability to reproduce isothermal polymerization as well [3]. Results indicated that the selected reaction model was perfectly capable of tracking the evolution of conversion degree in the course of both dynamic and isothermal curing.

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# S05 – Polymerization and Synthesis

## S05 - 215

## Decellularized Extracellular Matrix-Derived Hydrogel Embedded with Reduced Graphene Oxide Bioink for the Electrical Stimulation of Human Adipose-Derived Mesenchymal Stem Cells

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The use of 3D bioprinting with cell-embedded inks has shown great potential in creating tissue and organ-like cellular models for in vitro study of pharmaceuticals and other potential bioactive compounds. Decellularized extracellular matrices (dECMs) combined with nanomaterials are commonly used in ink formulation since they could have chemical, thermal, electroconductive, mechanical, and biological properties that allow 3D bioprinting and a suitable microenvironment for cell growth, proliferation, migration, and differentiation. Our study proposes an electroconductive bioink for 3D bioprinting that allows cell electrostimulation, which consists of a reduced graphene oxide-embedded extracellular matrix-derived hydrogel from small intestine submucosa (SISMA-rGO). Several modifications to improve the hydrogel qualities were performed which include a methacryloyl modification to enhance the mechanical stability of dECM through photo-crosslinking reactions, protein absorption of GO to facilitate dispersion among the hydrogel and GO chemical reduction to confer electroconductive abilities. For this purpose, SISMA hydrogels were prepared, embedded with GO after protein absorption, and subsequently embedded with human adipose-derived mesenchymal stem cells (hAD-MSCs). Once bioprinted, the constructs were photo crosslinked to enhance their mechanical rigidity and underwent an in-situ reduction reaction to acquire electroconductive properties. SISMA-rGO composite hydrogels were successfully prepared with enhanced structural characteristics and adequate rheological properties as shown by a higher crosslinking degree and printability parameters. hAD-MSCs were successfully bioprinted within SISMA-GO with high cell viability and in situ reduction showed enhanced electrical conductivity of the bioink. This study demonstrates the potential of using SISMA-rGO for studying electrostimulation as a mechanism to promote and control stem cell differentiation, study currently underway.

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# S05 – Polymerization and Synthesis

## S05 - 22

## Analysis of novel polycarbonate-based materials Poly(thiourethane-urethane)s

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Polyurethanes (PUs) are an important group of polymers that have a number of unique properties. PUs is generally formed by reacting diisocyanates with polyols or diamines. New segmented poly(thiourethane-urethane)s (PTURs) was synthesized using a one-step melt polyaddition method, incorporating 1,10-methanediylbis(4-isocyanatocyclohexane) (HMDI, Desmodur W®), polycarbonate diol (PCD, Desmophen C2200), and (methanediyldibenzene-4,1-diyl)dimethanethiol. These PTURs were obtained with varying hard segment (HS) content within the range of 30-60 wt%, and their properties were systematically examined to understand the impact of hard segments content changes. A comprehensive characterization of the polymers was carried out through multiple techniques, including Fourier transform infrared spectroscopy (FTIR), gel permeation chromatography (GPC), and thermal analysis using differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA). Additionally, thermomechanical analysis (DMTA) was employed to assess mechanical properties Furthermore, the examination included various mechanical and optical properties, such as tensile strength, refractive index, UV-VIS characteristics, and color attributes. Surface properties, including contact angle and surface free energy, were evaluated, along with the adhesion of the PTURs to copper. FTIR analysis confirmed the intended polymer structure and revealed the complete conversion of isocyanate groups. TGA analysis supported the polymers' good thermal stability. However, DSC analysis indicated that the obtained materials were partially or completely amorphous, with a reduction in microphase separation as the hard segments content increased. Similar trends were observed from the DMTA data. Additionally, the PTURs displayed increased hardness, tensile strength, modulus of elasticity, storage modulus, adhesion to copper, refractive index, and total free surface energy as the hard segments content in the polymer was elevated.

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# S05 – Polymerization and Synthesis

## S05 - 267

## Study of the critical micellar concentration using different techniques for monomethoxy-poly(ethylene glycol)-poly(ε-caprolactone) block copolymers for the encapsulation of bioactive molecules

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Copolymeric micelles, formed by amphiphilic molecules, feature a hydrophobic core surrounded by a hydrophilic envelope, crucial for delivering water-insoluble drugs and controlled release. Their formation arises from attractive and repulsive forces, limiting macroscopic growth and favoring self-aggregation in the presence of a selective solvent. The CMC is an essential in these molecules, determining their self-aggregation. Fluorescence and dynamic light scattering (DLS) techniques were employed to measure the CMC. Pyrene fluorescence reveals emission spectrum changes from a polarized water environment to a non-polar one within the micellar core, while DLS detects fluctuations in light scattered by the micelles. The focus was on determining the CMC of monomethoxy-poly(ethylene glycol)-poly(ε-caprolactone) copolymers, like m-PEG56-b-PCL50, m-PEG55-b-PCL16, and m-PEG56-b-PCL50-Lin, for encapsulating bioactive molecules. The CMC values obtained by both fluorescence and DLS were respectively: 20.87 and 32.13 mg/kg for m-PEG56-b-PCL50, 0.80 and 10.69 mg/kg for m-PEG55-b-PCL16, and 1.00 and 11.00 mg/kg for m-PEG56-b-PCL50-Lin. These methods were validated with the Span-80 surfactant, resulting in a CMC of 18.72 mg/kg by DLS. Future plans include evaluating the temperature's effect on CMC and particle size using dynamic light scattering and how this affects encapsulation. Additionally, it is planned to estimate the CMC using TEM and SEM, allowing for the characterization of the shape and size of the micelles.

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# S05 – Polymerization and Synthesis

## S05 - 424

## Polyisobutylene reinforcement through multi-block chain exchange shuffling polymerization with isotactic Polypropylene

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Multiblock copolymers are of great interest in polymer chemistry research because of the resulting separate morphologies and differences in mechanical and thermal properties, which are not found in homopolymers. Polyisobutylene (PIB) and low cost-polyolefins (POs) are extremely important in the medical field. As macromonomers, they have gained attention due to their unique properties, biocompatibility, and recyclability in various applications. Specifically, we explored the crystalline reinforcement of PIB with isotactic Polypropylene (iPP) using the chain exchange shuffling technique developed in our laboratory as a potential tool to modulate the material's properties and optimize the desired morphology. We synthesized random semicrystalline/amorphous multiblock copolymers, by sequential depolymerization/repolymerization and optimized different reaction conditions such as solvent, temperature, and reaction time. The structure, molecular weight, morphology, and thermal and mechanical properties for the resulting polymers were investigated using NMR, GPC, AFM, DSC, and tensile test. Preliminary results showed that the incorporation of the units was successful, having an approximate average of 6.4 repeated units in the polymer. Random (PIB-b-iPP) with high molecular weight was obtained. The polymer showed different morphologies, crystalline and amorphous domains, and plastic deformation behavior. The successful incorporation of polypropylene with polyisobutylene blocks has not been reported before, so these results demonstrate exciting opportunities to synthesize a new class of polymers that will produce compatible elastomeric rubbers with improved mechanical properties and reduced response immune effects when used in biomedical applications.

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# S07 – Polymer Composites

## S07 - 172

## Influence of Melt Flow Rate on the Mechanical and Tribological Properties of Carbon Fiber Reinforced Polyoxamide Composites

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For the purpose of developing new polymeric tribomaterials for mechanical sliding parts such as bearing, cum, gear, and seal, this study aimed to experimentally the influence of melt flow rate (MFR) on the mechanical properties of carbon fiber (CF) reinforced polyoxamide (PA92) composites. PA92 has unique characteristics such as high melting point, high modulus, and low water absorption. Two types of melt flow rate (MFR): (a) MFR=11.05 g/10min (MFRm), and (b) MFR=18.89 g/10min (MFRh) were used in this study. CF/PA92 composites were extruded using a twin-screw extruder, and injection molded. Mechanical properties such as tensile properties and hardness were evaluated. Tribological properties were evaluated by ring-on-plate type sliding wear test. It was found that the mechanical properties of CF/PA92 composites based on MFRm are slightly higher than those of MFRh. The frictional coefficient, temperature of frictional surface and specific wear rate of CF/PA92 composites based on MFRm were lower than those of MFRh. These may be attributed to the change in the mode of wear mechanism according to the MFR of matrix polymer used.

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# S07 – Polymer Composites

## S07 - 176

## Rheological, Mechanical and Tribological Properties of Modified Cross Section Chopped Glass Fiber Reinforced Plant-Derived Polyamide 1010 Biomass Composites

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To develop new polymeric engineering materials based on biomass composites for mechanical sliding parts, this study aimed to investigate experimentally the rheological, mechanical and tribological properties of modified cross section chopped glass fiber (GF_m) reinforced plant-derived polyamide 1010 (PA1010) biomass composites. The cross section of GF_m has oval, and this GF_m's modification ratio, which is the ratio of horizontal length of an oval cross section to its vertical length, is 4. This commercial grade GF_m was surfaced-treated by silane-based sizing resin beforehand. For comparative evaluation, the conventional cross section type glass fiber (GF, round cross section) was used. GF_m/PA1010 and GF/PA1010 biomass composites were extruded using a twin-screw extruder, and injection molded. Rheological properties were evaluated by oscillatory flow testing using a parallel plate type rotational rheometer. Mechanical properties such as tensile properties and hardness were evaluated. Tribological properties were evaluated by ring-on-plate type sliding wear test. It was found that the rheological, mechanical and tribological properties of GF_m/PA1010 biomass composites are slightly improved. This may be attributed to the change in the internal microstructure formation such as fiber orientation and fiber network formation according to the different cross section of glass fiber.

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## S07 - 258

# EFFECT OF CATALYST ON BIO-BASED EPOXY VITRIMER

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Bio-based vitrimers are highly desired for the purpose of sustainable materials, as they combine renewable biobased raw materials and dynamic associative chemistry, to have polymers that possess both notable thermosetting properties that include mechanical and thermal, as and properties of thermoplastics such as malleability, reprocessability and self-healing, thus helping to improve issues such as durability, cost and performance, which still limit the applications of vitrimers in real life [1]. In this work, bio-based epoxy vitrimers were obtained from an epoxy derived from eugenol as a monomer and adipic acid as a hardener. The influence of the catalyst's concentration and type on curing kinetics and the dynamics of the bond exchange reaction of the obtained vitrimeric materials were studied. To evaluate the influence of the type and concentration of the catalyst (zinc acetate dihydrate, Zn(OAc)2·2H2O, and caffeine) at 5 and 10 wt.%, the obtained materials were characterized through Differential Scanning Calorimetry (DSC), Thermogravimetric Analysis (TGA), Fourier Transform Infrared Spectroscopy (FTIR), and Thermomechanical Analyzer (TMA). The results show characteristic bands of functional groups that confirm that poly(hydroxy esters) was obtained and also allow for analysis of the influence of the catalysts in the transesterification reactions. Likewise, our results suggest that the modification of the concentration and type of catalyst affects the speed of the transesterification reaction and allows the Tv of the epoxy-based vitrimers to be controlled. Interestingly, it was observed that even though the materials prepared with higher catalyst concentrations have lower thermal stability and Tg, all catalysts used were shown to promote rapid curing and network formation.

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# S07 – Polymer Composites

## S07 - 292

## Characterization of mechanical properties of composite materials of high-density polyethylene matrix reinforced with natural fibers for application in safety footwear toe caps

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Safety footwear has become an important aspect in manufacturing industries to protect feet from potential risks such as heavy objects, impact, cuts, penetration and compression, and other potential risks such as chemical, thermal, and electrical. Composite materials are used to obtain a combination of properties that cannot be achieved any other way; and thus, achieve unusual combinations of rigidity, weight, density, high-temperature performance, corrosion resistance, hardness, or conductivity. In this study, high-density polyethylene (HDPE) matrix composite materials reinforced with natural fique, pineapple, and banana fibers were used for application in safety footwear toe caps. The results show that the pineapple fiber provides mechanical properties such as tensile strength, Young's modulus, and bending resistance that are similar or high compared to the virgin material and the other fibers. Additionally, compression and impact tests were carried out on prototypes of toe caps reinforced with natural fibers following the specifications of international quality standards.

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# S07 – Polymer Composites

## S07 - 45

## HAEMOSTATIC DRESSINGS BASED ON CHITOSAN LOADED WITH POLY(BUTYLENE SUCCINATE) NANOPARTICLES AND HEPARIN WITH IMPROVED ANTIBACTERIAL ACTIVITY

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The initial stage of wound healing, hemostasis, is triggered by injury and results in the regulation of bleeding as well as the creation of a protective barrier. The use of hemostatic agents is required in cases of severe wounds to make up for the first stage of wound closure being hampered. Various hemostatic agents have been developed recently, but the majority of them are inefficient at stopping severe bleeding, expensive, or pose safety risks like causing additional thrombosis in undesirable locations. Chitosan is a cationic polysaccharide and was chosen because of its biological properties such as biocompatibility, non-toxicity, antibacterial activity, and hemostatic properties, and is widely used in wound healing applications. However, in order for an active ingredient heparin, to be released as an antithrombotic drug of the blood vessels following the action of the hemostatic patches, it was additionally encapsulated in poly(butylene) succinate (PBSu) nanoparticles and afterwards in the chitosan patch. The successful synthesis of material and the heparin-loaded nanoparticles was confirmed by FT-IR, its crystallinity was researched by XRD, and the morphology of patch and the size of the nanoparticles was analyzed with SEM images and DLS. In addition, biological studies confirmed the antibacterial properties and hemostatic activity of the chitosan dressing.

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# S07 – Polymer Composites

## S07 - 84

## Manufacture and Characterization of Polymer based Doped Silicon Phthalocyanine Polymethylmethacrylate Composite Organic Semiconductor Films

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The recent development of novel organic semiconductors has been substantially aided by their introduction in hybrid structures, such as polymer matrices. They provide greater mechanical properties as well as modifying optical and electrical behavior, widening their possible applications in diverse fields such as photovoltaics and optoelectronics. This work discloses the fabrication and characterization of two polymer composite semiconductor films based on a polymethylmethacrylate (PMMA) polymer matrix with embedded doped and undoped silicon phthalocyanine dichloride (SiPcCl2). The phthalocyanine was chemically doped with the (2E, 4Z)-5-(4-bromophenyl)-7-phenylhepta-2,4-dien-6-ynoic acid (BrDAc). The resulting doped semiconductor (SiPcCl2-BrDAc), as well as undoped SiPcCl2 were later dissolved alongside a PMMA matrix in chloroform solutions. The dissolutions were subsequently spread onto substrates, resulting in the polymer semiconductor composites as films. The composite films were characterized by infrared spectroscopy, in order to assess their characteristic functional groups. A topographical study was carried out via atomic force microscopy to analyze the morphological structure of the films and the mechanical properties stress, deformation, and Knoop hardness. The optical behavior, including the absorbance and transmittance parameters, was determined via ultraviolet-visible spectroscopy. Based on the obtained spectra, optical band gaps were obtained according to Tauc's method on indirect electronic transitions, with values of 1.601 eV for SiPcCl2-MeODAc/PMMA and 1.626 eV for SiPcCl2-BrDAc/PMMA. Finally, simple solar cell devices were manufactured with indium tin oxide and fluorine doped tin oxide anode layered substrates, composite films as active layers, and Ag cathodes; in order to assess photovoltaic behavior by external quantum efficiency and short circuit current, obtained in a solar simulator system.

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# S08 – Polymer Foams and Membranes

## S08 - 174

## Material Effects on Foam Evolution under Rotational Molding Conditions

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Rotationally molded foam moldings provide increased buoyancy and mechanical properties, which are beneficial for products such as lightweight marine structures. For optimal performance, appropriate material and process parameters must be used. However, establishing these for large products is challenging. Most optimization work is currently conducted using industrial scale equipment, meaning machines loose production capacity in order to complete this development work. Additionally, this method both wastes large amounts of material and energy. Recent work [1] developed a new bench-based procedure to facilitate the optimization of foam structures. The new procedure is particularly useful for the early product development stages of a large, foamed product, as it provides a means of identifying parameters to create a foam structure without using industrial scale rotational molding trials. In this work, the procedure was applied to study the effects of material parameters (such as polymer particle size, chemical blowing agent concentration, polymer melt flow index) and on developing foam structure.

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# S10 – Fibers and Films

## S10 - 121

### Polyacrylonitrile nanocomposite fibers with carbon nanotubes and carbon black to produce carbon fibers via direct electrical heating

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The carbon fiber market size as of 2022 was estimated at USD 6.5 billion and it is expected to grow to USD 21.7 billion by 20321. However, some commercial applications of carbon fiber and its composites are not feasible yet due to its high price: high and mid-performance carbon fiber's price ranges from 80 to 120 USD/lb and 10 to 20 USD/lb, respectively1. Approximately 13 % of the carbon fiber cost corresponds to stabilization and oxidation of polyacrylonitrile fibers and 19% to the carbonization and graphitization of these fibers2. Commercial carbon fibers available today are predominantly produced from PAN precursor fibers, which are stabilized and carbonized/graphitized in ovens at temperatures of ~530 and ~1600/2100 K, respectively. Conductive nanocomposite PAN fibers with carbon nanotubes can be heated via Joule Heating effect3 and stabilized in continuous configuration4. Following this approach, energy demand and cost of carbon fibers can be significantly reduced. Conductive PAN fibers with 15 wt.% carbon black and 2 wt.% multi-wall carbon nanotubes were produced via dry-jet wet-spinning5. The effect of the filler content on the polymer solution homogeneity and spinnability and on the precursor fiber structural and mechanical properties was studied. The fibers were successfully stabilized via direct electric heating in a batch-scale lab-built set-up; energy cost analysis is provided, as well as requirements for carbonization and graphitization5.

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# S10 – Fibers and Films

## S10 - 298

## Usage of Recycled Tetra Pak Substrates and Doped Vanadyl Phthalocyanine for the Manufacture of Semiconductor Films

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Organic semiconductors have seen great development with a special emphasis on applications such as field-effect transistors, photodetectors, and gas chemosensors. An important approach for organic semiconductors is the device manufacture, with substrates that can be recycled. Amongst the degradable and recyclable materials that have been used as substrates are, polyethylene terephthalate, polyvinyl alcohol, and naturally derived materials such as cellulose. Tetra Pak waste could be a good candidate because of its abundance and composition of around 71-75% cellulose, 5% aluminum and 20-24% polymer. In this work, the organic semiconductor behavior of vanadium (IV) phthalocyanine oxide (VOPc) films, doped with anthraflavic acid is studied. The films were deposited on recycled Tetra Pak with a high vacuum deposition system. Surface features and mechanical properties of the films were studied by atomic force microscopy. The resultant Root Mean Square roughness for the films is 124 nm and the maximum stress is 8.58 MPa. Infrared spectroscopy was carried out on KBr pellets and the films, to study the structure and composition of the doped VOPc-Anthraflavine. When comparing the spectra of the pellet and the thin film, the same signals are observed. This is an indication that there was no decomposition of the doped semiconductor during the deposition process. On the other hand, ultraviolet-visible spectroscopy was carried out on the films for the measurement of absorbance and transmittance; as well as to calculate its bandgap. The obtained values of fundamental bandgaps are 2.39 and 2.29 eV for the direct and indirect electronic transitions respectively. Finally, in order to evaluate the electrical behavior, simple solid-state devices were manufactured, using recycled Tetra Pak substrates. The electrical properties were examined in dark as well as under natural lighting conditions, exhibiting a current saturation of 10 mA which varies for the different lighting conditions.

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# S10 – Fibers and Films

## S10 - 342

## Effect of NIR fluorescence ceramic additives on structure evolution of poly(ethylene terephthalate) fibers in high-speed melt spinning

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Reducing global greenhouse gas (GHG) emission is recently becoming important by utilizing recycled materials in various industries. As the demand for the use of recycled materials increases rapidly, the issue of securing the identification of recycled materials is also needed. In this study, we investigated that fabrication of the PET fiber with the near-infrared (NIR) fluorescent additives for security characteristic. The security fiber was fabricated by various NIR particle concentrations (0, 0.3, 0.5, 0.7 wt.%) and take-up speed (1, 2, 3. 4 km/min) using melt-spinning. The thermal and mechanical properties of the recycle NIR/PET fiber was characterized by differential scanning calorimetry (DSC) and single fiber test. Rheological properties of NIR/PET fiber compared to that of neat PET were analyzed by in-line viscosity analysis during melt spinning process. The uniformity of the NIR/PET fiber was determined by FE-SEM cross-section diameter. The security property of NIR/PET fiber was characterized by photoluminescence (PL). From those results, it was confirmed that the NIR/PET fiber exhibits good spinnability, mechanical strength, and security performance as a security fiber for recycling PET identification.

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# S10 – Fibers and Films

## S10 - 355

## Effect of NIR fluorescence ceramic additives on structure evolution of poly(ethylene terephthalate) fibers in high-speed melt spinning

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High-speed melt spinning of the biodegradable poly(ethylene terephthalate) (PET) prepared by copolymerization with commercial regular PET (I.V. 0.64) and biopolymers (A, B, and C) was carried out to confirm the commercial potential of the copolymerized biodegradable PET and investigate the structure development of biodegradable PET fibers with various spinning conditions. Prior to the melt spinning, the basic properties, such as I.V. and thermal properties, of the biodegradable PET resins were analyzed to set the optimal processing conditions. The fabricated as-spun biodegradable PET fibers under various spinning conditions were analyzed in detail. The take-up speed was controlled from 1,000 to 6,000 m/min. Mechanical properties such as tensile strength, strain, and modulus of the biodegradable PET fibers were measured and compared between copolymerized biodegradable PET fibers with different bio-monomers. In addition, to confirm the characteristic structure development by crystallization and orientation of the biodegradable PET fibers, the thermal analysis (differential scanning calorimeter, DSC) and X-ray diffraction (XRD) were investigated. Finally, the correlation between the structure and properties of biodegradable PET fiber under various conditions was studied, and the possibility of commercialization of the copolymerized biodegradable PET fibers with different bio-monomers were confirmed.

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# S10 – Fibers and Films

## S10 - 363

## Preparation and Structure Control of Liquid Crystalline Aromatic Copolyester Fibers in Melt-spinning Process

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Melt spinning of liquid crystalline aromatic copolyester, composed of 4-hydroxybenzoic acid (HBA) and 2-hydroxy-6-napthoic acid (HNA) was conducted to investigate the structural control of the fiber under the various spinning conditions. Spinning temperature was controlled at 285 ~ 295℃, and the as-spun fibers were prepared by changing throughput rate (0.8 ~ 1.8 g/min·hole) and take-up velocity (550 ~ 2,200 m/min). Calculated apparent shear rate in the nozzle hole and draft ratio in the spinning line were approximately 30,000 ~ 70,000 s-1, and 10 ~ 25, respectively. The structure and properties of the as-spun fibers were analyzed using tensile test, SEM and 2D-WAXD. The mechanical properties such as tensile strength and modulus of the as-spun fibers showed a tendency to increase with the shear rate and the draft ratio, and 2D-WAXD analysis indicated that the mechanical properties increased with the crystalline orientation factor (fc) and the total fractions of highly oriented crystalline and non-crystalline anisotropic phases in the fibers.

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# S11 – Nanotechnology and Nanocomposites

## S11 - 167

## In-line modification of Ca-Al LDH with stearic acid

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Inorganic layered double hydroxides (LDHs) are often organically modified to improve their dispersion and distribution in polymers. In order to eliminate the need for a pre-treatment step, an in-line organic modification process has been developed. The direct compounding of Ca-Al LDH with stearic acid in polypropylene was investigated for this purpose. Polypropylene-grafted maleic anhydride was used to further improve compatibility. Electron microscopy, IR spectroscopy, and oscillatory plate rheology were used to assess the morphological properties of the resulting composites. The study successfully demonstrated that this method is a viable alternative for modifying LDHs and is easily transferable to large scales.

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# S11 – Nanotechnology and Nanocomposites

## S11 - 248

## Design of polymeric nanocapsules as carriers for controlled release of iron

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The encapsulation of various iron species and compounds has been studied as a strategy for the prevention and treatment of anemia. This approach has shown better results in reducing iron deficiencies than soluble salts [1]. Therefore, the design of a system of polymeric nanocapsules based on copolymers of monomethoxy-poly (ethylene glycol)-poly (ε-caprolactone) (mPEG-PCL) and monomethoxy-poly (ethylene glycol)-poly (ε-caprolactone)-poly (lactide) (mPEG-PCLA) is proposed for the controlled administration and release of iron. To obtain these block copolymers, synthesis was first carried out through ring-opening polymerization [2]. The resulting polymers were characterized by GPC, NMR 1H and FT-IR. Double emulsification/evaporation of solvent methodology was employed in this study to prepare polymeric nanoparticles [3]. To physically encapsulate Fe(II)-EDTA in polymeric nanoparticles, an exploratory phase was proposed to identify the working conditions required to obtain small nanoparticles. Additionally, to assess the stability of the nanoparticles over time, particle hydrodynamic diameter, polydispersity index, and ζ-potential were determined by dynamic light scattering (DLS). Encapsulation efficiency and Fe(II)-EDTA loading were determined by UV-Vis spectrometry using a 1,10-Phenanthroline-based method. The formulations were characterized by differential scanning calorimetry (DSC), transmission electron microscopy (TEM), and X-ray diffraction (XRD). Iron release from polymer nanoparticles was characterized by dialysis and quantification of the amount of Fe released by UV-Vis spectroscopy.

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# S11 – Nanotechnology and Nanocomposites

## S11 - 271

## Selective dispersion and compatibilizing effect of sepiolite nanoparticles in PLA/TPU blends

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In recent years, the interest in biobased and biodegradable polymers has been increasing and the use of poly(lactic acid), PLA, stands out. Although it has elastic modulus and tensile strength comparable to petroleum-derived polymers, its thermal behavior and brittleness are important disadvantages. Obtaining blends and/or nanocomposites are alternatives to overcome these drawbacks. Thermoplastic polyurethanes (TPUs) are excellent candidates to act as modifying agents in blends with PLA since they present a combination of high elasticity and toughness. PLA/TPU blends are immiscible and the use of nanoparticles as compatibilizing agents is an alternative that has been explored. In this work, the selective dispersion of sepiolite (SEP) and its effect as compatibilizing agent in PLA/TPU blends were evaluated. PLA/TPU blend (75/25 w/w) nanocomposites were obtained by 4 different routes, at a constant SEP content of 5 phr, in the molten state using an internal mixer operated at 100 rpm, 10 min of mixing and 180°C. The mixing protocols analyzed were: i) direct mixing of all components; ii) obtaining the PLA/TPU blend and subsequent incorporation of SEP; iii) obtaining masterbatches of one of the polymeric phases with SEP and subsequent mixing with the other polymeric phase. The influence of the presence of SEP and its selective dispersion in the blend was analyzed through small amplitude oscillatory shear rheology, DSC, TGA and SEM. In general, the presence of SEP led to considerable increases in G'and G'', with the highest values observed for the nanocomposite obtained through the PLA/SEP masterbatch route, indicating a possible preferential location of SEP at the blend interface. Neither the presence nor the mixing protocol had a significant effect on thermal transition temperatures or crystallinity, while the presence of SEP led to increases of more than 10°C in the thermal decomposition temperatures of the nanocomposites, compared to the PLA/TPU blend.

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# S11 – Nanotechnology and Nanocomposites

## S11 - 279

## Influence of coating structure of an SiOx barrier coating on a PET substrate on water vapor permeation activation energy

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The application of plasma polymerized silicon-based coatings on plastic substrates is an effective way to adjust the permeability of the substrate. However, the mechanisms of permeation are not yet fully understood. Here, the activation energy of permeation can offer valuable insights. In order to understand how the activation energy of permeation depends on the coating structure five silicon-based coatings with varying oxygen content were analysed, which led to properties modification ranging from silicon-oxidic to silicon-organic. Positron annihilation spectroscopy was performed to characterize the porosity and quartz crystal microbalance measurements were used to determine density and dissipation of the coating. These results were compared to chemical analysis and water vapor permeation measurements with a temperature variation in the range of 15 °C – 50 °C. As expected, the more silicon-organic coatings do not significantly impact the permeation rates, while the silicon-oxidic coatings exhibit a barrier effect. The porosity tends to increase for the more silicon-organic coatings, while interconnectivity increases for the more silicon-oxidic coatings. The pore wall chemistry is also affected, hinting at a phase shift from silicon-organic to silicon-oxidic, which will be analyzed in more detail. Here, quartz crystal microbalance measurements can offer valuable information. With this approach, we aim for an in-depth understanding of the chemical structure of silicon-based thin film coatings and its influence on gas permeation through those coatings.

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# S11 – Nanotechnology and Nanocomposites

## S11 - 326

## Forced Flow Processing of Highly Elastic Amorphous Polylactide and Its Applications

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As a solvent-free, simple, and efficient method, melt processing is preferred for fabricating polymer composites on an industrial scale. However, regulating the polymer condensate and the morphological structure of nanofunctional fillers at the nanoscale by melt processing is still a considerable challenge. Herein, we propose for the first time the effective regulation of the crystal structure of crystalline polylactide (cPLA) and the morphological structure of nanofunctional fillers by exploiting the strong shear stress and irreducible large deformation generated by forced flow processing of highly elastic amorphous PLA (aPLA) in two-roll milling. It was found that cPLA structure was broken from spherulites to nanocrystals (NCs) and uniformly dispersed and the PLA crystals were transformed from α-form to α'-form without undergoing melting and recrystallization, which endowed PLA blends with a higher shape recovery ratio and stronger recovery force (9 MPa at 80 °C). In addition, the dispersion of individual multiwalled carbon nanotubes (MWCNTs) with 1 and 10-15 μm long at a content of up to 30 wt.% in the aPLA matrix was achieved. Moreover, the in-situ exfoliation and dispersion of two-dimensional (2D) fillers (graphite and boron nitride) was realized, which had a 100% conversion rate from micrometer to nanometer dimensions and an ultra-high production rate (For example, the graphite nanoplatelets production rate exceeds 252 g h-1), by tuning two key parameters: processing temperature and number of passes through the rolls. Furthermore, by changing the content of CNTs and NCs, different nano-hybrid structures can be constructed, so as to control the thermal conductivity and dielectric properties of PLA composites effectively. This ultra-efficient, extremely simple, and solvent-free method provides new insights into the multi-level morphological structure regulation and performance studies of polymers and their nanocomposites.

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# S12 – Mechanical Properties and Fracture

## S12 - 181

## Impact of Nozzle Temperature on Failure Mode in Material Extrusion-Based Additive Manufacturing: A Study on Crack Deflection versus Crack Propagation

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Increasing demands on additively manufactured (AM) components in many engineering applications require increasing reliability up to a certain level. By now, there are numerous different AM processes for polymers, whereby especially extrusion-based techniques, like fused filament fabrication (FFF), have gained importance. Caused by an inevitable layer-by-layer setup, a large number of weld lines are created between individual strands and layers, which can possess vastly different properties, depending on the processing parameters (e.g. nozzle temperature) and the used material. Once a crack in such a structure has impinged on an interface, it has the opportunity to grow either into or penetrate the interface. In this work, two approaches, first published by Cook & Gordon (1964, strength-based) [1] and He & Hutchinson (1989, energy-based) [2], are investigated regarding their suitability for polymeric AM structures. In total, four different materials, a glycol-modified poly(ethylene terephthalate) (PETG), a polylactide acid (PLA), a rather compliant poly(methyl methacrylate) (PMMA), and a stiffer PMMA, further referred to as PMMA-s, were selected to determine whether the models are suitable for predicting the crack deflection/penetration problem in AM structures. The results uncovered that relying on the energy-based approach proved to be unreliable in predicting failure modes. Challenges included inadequacies in meeting the criteria of linear elastic fracture mechanics and complications with notch design. In contrast, the strength-based approach accurately predicted the crack path for all tested materials, establishing itself as a promising candidate for predicting failure modes in FFF materials [3].

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# S12 – Mechanical Properties and Fracture

## S12 - 182

## Effect of notches on the creep-fatigue performance of short fiber reinforced polypropylene

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Structural components made of short fiber reinforced (sfr) thermoplastics deliver lightweight potential due to their strength related to the density. Moreover, it is possible to manufacture very complex geometries by injection molding. The results are components with a lot of critical notches and radii. Since this area are very high loaded (for example in the screw connections) they needed to be considered in a lifetime assessment. To do this, models have been developed in the past and are used in the industry [1,2]. In the case of sfr polyolefins (here polypropylene) which are used above the glass transition, also the long-term viscoelastic behavior needed to be considered [3]. Especially, for fatigue loads interrupted by static loads, influence the lifetime and the notch (support) effect. In this researching work, a deeper look in the notch effect related to different load sequences are investigated. A focus here is the effect of static loads, or rather creep-fatigue loads. The results show an interaction between the notch sharpness and the constant load level. This interaction influences the resulting lifetime and can be considered with a developed model.

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# S12 – Mechanical Properties and Fracture

## S12 - 30

## Influence of network structure determined by Time-domain 1H DQ NMR on the creep properties of non-stoichiometric epoxy-amine resins aimed for chemical anchoring applications

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Chemical anchors, used to fasten (non-)structural components, are prone to creep under sustained loading, which significantly affects their long-term performance and service life. In this study, the molar ratio, that determines the ultimate network structure of an epoxy-amine resin system, is systematically modified to investigate the creep properties. Here, a diglycidyl ether of bisphenol A (DGEBA)-polyetheramine formulation, commonly used for chemical anchoring, is studied in ratios ranging from 100:60 to 100:130. The percentage of physical entanglement and defects (free and dangling chains) for each formulation is obtained by 1H-(Double Quantum) DQ nuclear magnetic resonance (NMR) measurements. Network density values from dynamic mechanical analysis (DMA) and network parameter from NMR measurements are found to be in good agreement. Tensile tests were performed to determine the impact on the mechanical properties and set the loading levels for tensile creep measurements (20, 40 and 60% of the individual ultimate tensile strength for up to 1000h) of the selected formulations. Epoxy-rich systems (Epoxy-Amine adduct) show the highest modulus and tensile strength, but inferior creep properties compared to stoichiometric and amine-rich (Amine-Epoxy adduct) compositions. This can be attributed to a higher content of free and dangling chains leading to lower deformation resistance. At high loads, the entanglement of the polymer chains seems to have an increasing impact on the creep behavior compared to defect-rich systems. Modelling using the Findley approach was carried out to link the obtained creep parameter with the material properties. Therefore, this work aims to deepen the understanding of the molecular-scale structures of epoxy resins which is required for material and design optimization by investigating the correlation between network structure and creep properties.

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# S12 – Mechanical Properties and Fracture

## S12 - 384

## Effect of the addition of postconsumer PP-recyclates on the performance of PP-pipes

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Engineering structures, such as operating plastic pipes, are often submitted to unexpected influences that may shorten their lifetime. An increasing understanding about the processes that govern these sudden failures has been attained in the last decades. This has led to a remarkable improvement of pipe performances by enhancing the material's slow crack growth (SCG) resistance (e.g. from PE63 to PE100RC). Still a great deal of uncertainty is associated with the use of non-virgin grades. This is mainly, because of the unknown effects of impurities that are found in recycled materials. The effects on lifetime relevant properties with regard to contaminants can be divided into three categories: i. polymeric contaminants of a different kind (e.g. PE in PP) ii. polymeric contaminants of the same kind (e.g. PE LD in PE HD, PP-R in PP-H) iii. non polymeric contaminants (e.g. inorganic particles) In that context, effects of non-polymeric impurities were studied in this work by mixing virgin polypropylene (v PP) grades with actual polypropylene recyclates (r PP) into different compositions (v PP/r PP in %: 100/0, 90/10, 75/25, 50/50 and 0/100). Subsequently, these materials were tested via internal pressure pipe tests. A profound dependency of contamination content on final failure time (tf) could be demonstrated, thereby. Additionally, a deeper analysis of fractured pipe samples revealed a clear correlation between the maximum size of incorporated inorganic impurities and tf. This indicates that two seemingly identical pipe samples, with regard to content of recycled material, can still have vastly different resulting failure times, based on the size of the introduced critical contaminant. Results show that it is not only necessary to understand the influence of the content and distribution of recyclates on the resulting lifetime of pipes, but more importantly the maximum introduced defect size as well.

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# S12 – Mechanical Properties and Fracture

## S12 - 388

## Optimizing Floral Industry Infrastructure: A Comprehensive Redesign Shifting from Wood to Wood-Plastic Composite (WPC) for Support Structures

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In the contemporary floriculture industry, the selection of materials for support structures, commonly known as "sleepers," holds paramount importance. Traditionally dominated by wood, this preference encounters mounting challenges due to fluctuating prices and increasing legislative constraints. To address this concern, our research proposes a shift from wood to a polymeric composite, specifically Wood-Plastic Composite (WPC). The technical evaluation of this transition entails a comprehensive assessment of structures, encompassing the determination of loads, bending moments, and shear stresses. Simultaneously, a detailed characterization of WPC is conducted, highlighting crucial mechanical properties such as modulus of elasticity, maximum rupture stress, yield stress, rheological properties, anisotropy constants, and the creep phenomenon. Given that the material will be exposed to temperatures around 35 °C, a meticulous analysis of its behavior under creep becomes imperative. We developed a design process for optimal beams, seeking to optimize material usage while meeting load requirements and ensuring an appropriate safety factor. Evaluation of pre-established geometries was conducted through simulations in Ansys Structural, with a focus on understanding the structures' response to the creep phenomenon. The Norton model of creep was employed, and the constitutive model's constants were determined through experimental measurements at different charges and temperatures (30°C 6N), (50°C 12N), (70°C 17N) and (105C° 17N). These findings were then juxtaposed with the anticipated lifespan associated with continued wood usage. This comparative analysis serves to elucidate the viability and advantages of transitioning to WPC. The research not only addresses immediate concerns within the floriculture industry but also contributes valuable insights into sustainable material choices and structural design optimization.

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# S14 – Modeling and Simulation

## S14 - 216

## Consideration of the Morphologic Structure in an Integrative Simulation Chain for the Fatigue Life Assessment of Short-Fiber-reinforced Polymers

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Components subjected to mechanical stresses are increasingly manufactured from short fiber reinforced thermoplastic polymers (SFRPs) owing to their elevated strength and cost-efficient manufacturing possibilities, meeting increasing demands in terms of emission reduction, efficient material utilization and lightweight construction. The material behavior of fiber reinforced thermoplastics under cyclic loading strongly depends on process- and environment related influence factors. Upon these, the process-induced emergence of local weak spots attributed to weld lines, as well as, in the context of semi-crystalline polymers, the formation of different crystalline structures due to varying process conditions exert the greatest impact on mechanical properties. Therefore, to account for a precise prediction of a component's fatigue life necessitates considering morphological properties already at an early design stage. Consequently, the present works objective is the development of a continuous workflow that integrates injection molding simulation results, specifically local fiber orientation and crystallinity, into a fatigue calculation scheme.

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# S14 – Modeling and Simulation

## S14 - 398

## Fiber Orientation Evolution Modeling in Thermoplastic Composites: Leveraging OpenFOAM and Symbolic Computation

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Accurately predicting the behavior of fiber-reinforced thermoplastic materials hinges on robust modeling of fiber orientation evolution. This study delves into the aim of utilizing OpenFOAM together with symbolic computation to tackle the complexities of modeling fiber orientation dynamics. To achieve this, a novel calculation open-source framework was meticulously crafted to function as a plug-in solver adaptable for integration with any incompressible flow solver within the OpenFOAM computational library. The new solver possesses the inherent capability to computationally unravel the evolution of the second-order orientation tensor. Integral to its functionality, several fiber orientation models and closure relations sourced from pertinent literature were embedded into this tool. The implemented calculation framework underwent thorough scrutiny, rigorously benchmarked against independent results derived from numerically integrating the governing equations associated with fiber orientation evolution. This robust verification process allowed assessing the fidelity and reliability of the developed tools. This pioneering endeavor represents a relevant step forward in fiber orientation modeling for thermoplastic composites, within the OpenFOAM environment. By leveraging symbolic computation and intricate computational methodologies.

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# S15 – Rheology and Characterization

## S15 - 135

## Modeling the crystallization kinetics of isotactic polypropylene (iPP)

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The crystallization of thermoplastics is strongly linked to their application properties. Depending on the material, the high cooling rates present in injection molding under simultaneous shear stresses can lead to the formation of different morphologies. To describe and model the α-crystallization process in isotactic polypropylene (iPP), isothermal and non-isothermal experiments by Fast Scanning Calorimetry (FSC) under process-relevant cooling conditions were done. Further experiments were performed on shear-induced crystallization by rotational rheometer to determine the accelerating effect of shear on crystallization. The determined values were used to evaluate the parameters of the extended Nakamura model, which is used in the injection molding simulation to improve the prediction of crystallization during processing and the final crystalline state of injection molded parts.

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# S16 – Morphology and Structural Development

## S16 - 20

## Investigation of isotactic polypropylene crystallization in processing conditions

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Flow and pressure applied during polymer transformation processes of semi-crystalline polymers can significantly affect the kinetics of crystallization, final morphology, and properties of the part. In polymer transformation processes, commonly used, the molten polymer is subjected to high pressure and thermal stress, as well as intense shear and elongational flow fields. The effect of pressure on crystallization kinetics is significant for both scientific and technological points of view since in important industrial processing techniques the polymer solidifies under high pressures. On the other hand, the high shear rates experienced during the polymer processing can lead to the development of a highly non-uniform morphology that is typically very different from what is observed for quiescent crystallization of the same polymer. An example is in injection molding, where the high shear rates experienced by a polymer melt close to the cold walls of the cavity can lead to a highly oriented layer ("skin" layer) whereas the low flow field close to sample mid-plane can lead to an isotropic layer ("core" layer) developing the so-called "skin-core" morphology. Thus, an understanding of polymer crystallization behavior with respect to the processing conditions is required to enable the rational design of materials and to optimize the final properties of the parts. In this work, the effects of the pressure and the flow field on the kinetics of crystallization of isotactic polypropylene (i.e., iPP) have been investigated. The study of the effect of pressure on the crystallization kinetics of iPP has been conducted using a dilatometer in the pressure range from 100 to 500 bar and different temperatures. Several isothermal flow experiments have been carried out using two different devices: the Linkam shear cell and the Multi-Pass Rheometer (MPR). To describe the evolution into isotropic structures and fibrillar structures, a Kolmogoroff–Avrami–Evans model has been adopted.

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# S17 – Rubber and Elastomers

## S17 - 170

## Influence of the Soft segment length on Physical Properties of Polyurethane Elastomers Crosslinked by Polyrotaxanes

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We have prepared polyurethane elastomers crosslinked by polyrotaxanes (PU-PRXs) with different soft-segment lengths to investigate the influence of the soft-segment length on the physical properties of PU-PRXs. As a result, the elongation of PU-PRX with a longer soft-segment length was two times larger than that of PU-PRX with a shorter soft-segment length while both PU-PRXs showed a similar tensile strength.

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# S17 – Rubber and Elastomers

## S17 - 300

## Effect of dispersed hard segments formed by low-crystallinity 2-hydroxypropyl-β-cyclodextrins as crosslinkers of PU/EP IPNs on damping properties

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Ideal damping materials require high loss factor (tanδ) over a wide range of temperatures and frequencies. Typically, a temperature range with tanδ > 0.3 is considered to be the effective damping temperature range. However, homopolymers have a very narrow effective damping temperature range of only 20K to 30K around the glass transition temperature [1, 2]. This shortcoming limits the application of polymers as damping materials. Here, we report a polyurethane (PU)/epoxy (EP) IPN damping material by taking low-crystallinity 2-hydroxypropyl-β-cyclodextrins (HP-β-CDs) as PU chain extenders. Both experiments and molecular dynamics simulations point to the fact that HP-β-CDs have hydroxyl groups with various degrees of reactivity to produce different motion units, and that unreacted hydroxyl groups can form hydrogen bonds with urethane groups. Various motion units extend the relaxation spectrum, and the damping temperature ranges, in addition to which the breaking and reconstruction of hydrogen bonds increase the tanδ value. Moreover, due to the low crystallinity of HP-β-CDs, unlimited cross-linking sites and highly dispersed PU hard segments can be obtained. Results show that IPNs cured by HP-β-CDs have a wide damping temperature range with 88.6K (tanδ > 0.3) and 74.7K (tanδ > 0.5).

Keywords: PU/EP IPNs; cyclodextrins; damping

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# S18 – Machine Learning in Polymer Processing

## S18 - 109

## Development of new advanced industry 4.0 technologies for SMEs and MSMEs for polymer processing to increase energy and production efficiency

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The incursion of MSMEs into Industry 4.0 contributes to reducing the technological gap and increasing competitiveness between them and large companies. The adoption of this technology has been slow due to the lack of affordable alternatives for this type of companies, which do not involve major changes in processing equipment and tailored to the needs of the sector, which is quite diverse. Another difficulty is that it is often a difficult or expensive task to measure all the variables involved in the processes. This is a very common problem that has been tried to be solved with very good results from the concept of estimation or observation in applications such as “sensorless”, inferential or virtual sensors that estimate variables from indirect measurements and mathematical models. , which implies a deep knowledge of the physical phenomena involved in the analyzed processes. Identifying this problem as an opportunity, this project seeks the development of a cyber-physical system for industry 4.0, based on the specific needs of MSMEs, useful for improving energy and productive efficiency in polymer injection and extrusion processing. which will allow the digital transformation of the plant and thus contribute to closing technological gaps, adding value to the product and, above all, improving competition in this market, since variables such as energy and mass flow are monitored, which impact directly in the energy cost of production and for each specific product. This through the development of a low-cost cyber-physical system that integrates Internet of Things, Edge and Cloud Computing technologies, mathematical modeling, analytics, and machine learning tools that allows real-time data analysis in MSMEs in the healthcare sector. plastic aimed at guiding control tasks to improve energy efficiency and productivity.

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# S19 – Machine Learning in Polymer Processing

## S19 - 118

## Modified thermoplastic starches (TPS) obtained by reactive melt mixing

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Starch is one of the most used polysaccharides to obtain biodegradable materials. Processing starch in the presence of a plasticizer, at high temperatures together with high shear stresses, allows for obtaining thermoplastic starch (TPS). TPS has disadvantages that limit its application such as brittleness, low ductility, poor heat resistance, and hydrophilicity. However, metal-organic coordination polymers can be obtained by taking advantage of the supramolecular interaction between the hydroxyl groups of the polymer chains with metal ions. A coordination polymer was developed by reactive extrusion of starch and zinc acetate and the resulting TPS showed improvements in mechanical performance, lower wettability, higher thermal and tensile strength, and higher hydrophobicity than unmodified one. On the other hand, crosslinking modification is also an efficient and commonly used approach to enhance starch properties. Particularly, borax acts as an intermolecular bond reinforcer, introducing covalent bonds that complement the natural hydrogen bonding, improving mechanical properties, solubility resistance, and thermal stability. The aim of this work was to thermoplasticize and modify corn starch by melt mixing in order to obtain modified TPS. Starch was thermally processed in the presence of water and glycerol as a plasticizers and using zinc acetate (0-7.5 % w/w) to obtain metal-organic coordination TPS and borax (0-7.5 % w/w) to obtain crosslinked TPS. Films obtained by thermocompression were characterized by thermogravimetric analysis and mechanical properties. Zinc acetate enhanced TPS thermal stability, increasing the maximum degradation temperature. Meanwhile, the presence of borax reduced this thermal parameter. Both additives reduced the flexibility of TPS films, decreasing the maximum tensile strain. Results demonstrated that is feasible to thermoplasticize and to modify starch by melt mixing, obtaining TPS with improved thermal and mechanical properties.

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# S19 – Machine Learning in Polymer Processing

## S19 - 119

## Biodegradable materials of poly(3-hydroxybutyrate) and thermoplastic corn starch

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Plastic pollution and its environmental impact have become growing concerns in recent years, inciting research into the development of biodegradable plastic materials. Among the promising biopolymers, poly(3-hydroxybutyrate), PHB, has emerged as a sustainable alternative due to its biodegradability and renewable resource origin. PHB shares physical properties related to traditional plastics like polypropylene, making it an attractive alternative for various applications, including agriculture, cosmetic, and medical fields [1]. However, the adoption of PHB has been hindered by its high production costs compared to synthetic plastics, thus limiting its current use primarily to medical applications. Efforts are currently addressing this cost barrier through strategies such as improving bacterial strains, optimizing fermentation and recovery processes, and utilizing cost-effective renewable resources as substrates. Additionally, researchers have explored blending PHB with other polymers to enhance its physical properties and reduce costs of the final materials. In this sense, blending PHB with thermoplastic corn starch (TPS) is an alternative scarcely investigated that could reduce the cost of the final materials without compromise the biodegradability. Blends of TPS with different synthetic and natural polymers have been studied greatly. In some cases, it was necessary to employ binding agents due to the low compatibility between both polymers [2]. The aim of this study was to investigate the miscibility of PHB and TPS obtaining films by melt mixing and thermocompression. Studied PHB:TPS blends were: 1:0, 0.25:0.75, 0.5:0.5, 0.75:0.25, and 0:1. Films were characterized by DSC and TGA. Melting and decomposition temperatures of TPS and PHB in the blends were observed as separate events. Blends based on TPS and PHB were able to be melt-processed at the chosen processing conditions, obtaining homogenous biodegradable films with good appearance and easy to handle. The presence of TPS and PHB in the composition of the blends were corroborated by melting and thermal degradation of both biopolymers.

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# S19 – Machine Learning in Polymer Processing

## S19 - 183

## Exploring Centrifugal Electrospinning: A Sustainable Approach Using Recombinant Spider Silk for Controlled Nanofiber Production and Filtration

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In the quest for sustainable materials, the emergence of biopolymers as promising alternatives to petroleum-based counterparts is rising. Notably, materials made out of eADF4(C16), a recombinantly produced spider silk protein[1], provide exceptional attributes such as biodegradability and sustainable production, accompanied by the possibility to processing them into e.g. hydrogels, films and coatings. Drawing inspiration from the mechanical stability inherent in spider silk fiber, the resulting recombinant fibers offer potential applications. Here, eADF4(C16) was used in centrifugal electrospinning, an innovative nanofiber production technique. Systematic variations in flow rates (up to several mL per minute), voltages, and spinning speeds of the center bell were employed aiming to customize fiber diameters for diverse applications. Integrating eADF4(C16) into an electrospinning-based process underscores its versatility and potential, offering a sustainable approach to nanofiber production. The commitment to sustainability is emphasized by the exclusive usage of water-based spinning dopes, replacing traditional organic solvents[2] and eliminating potential toxic elements associated with conventional electrospinning. The study extends beyond structural characterization to practical applications, particularly advanced filtration, specifically on bacteria filtering. The exceptional properties of eADF4(C16) fibers position them as an ideal candidate for developing efficient and sustainable filtration systems. In summary, this research highlights not only the beneficial use of spider silk-related biopolymers but also showcases their potential in the realm of centrifugal electrospinning.

1. Scheibel, T., Spider silks: recombinant synthesis, assembly, spinning, and engineering of synthetic proteins. Microb Cell Fact, 2004.
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# S19 – Machine Learning in Polymer Processing

## S19 - 183

## Exploring Centrifugal Electrospinning: A Sustainable Approach Using Recombinant Spider Silk for Controlled Nanofiber Production and Filtration

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# S19 – Machine Learning in Polymer Processing

## S19 - 193

## BIODEGRADABLE CONTROLLED-RELEASE POLYMER TO PROMOTE PLANT GROWTH

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Controlled release fertilizers (CRF) play an important role in agriculture since these are able to decrease nutrient dissipation due to volatilization and leaching, moreover, they offer a tailored nutrient release pattern conducive to optimal plant growth. However, a significant concern lies in the fact that the majority of these fertilizers are predominantly derived from petroleum-based synthetic products (Vejan et al., 2021). In this context, amino acids like L-aspartate and L-glutamate emerge as promising biopolymer precursors. L-aspartate contributes to the biosynthesis of proteins, the tricarboxylic acid (TCA) cycle and intermediaries of the glycolysis pathway (Han et al., 2021). On the other hand, L-glutamate plays a key role in the primary nitrogen assimilation pathway, TCA, carbon metabolism, energy production and biosynthesis (Liao et al., 2022). In this work, a biodegradable polymer was made using aspartic acid (Asp), glutamic acid (Glu) and ethylene glycol as monomers mixed with monopotassium phosphate via hot-pressing method to improve early plant-growth in a controlled manner. The polymeric matrix was studied by varying the ratios of Asp and Glu as poly (70% Glu-co- 30% Asp), poly (30% Glu-co-70% Asp) and poly (50% Glu-co-50% Asp), the obtained biopolymers were analyzed by infrared spectroscopy (ATR-FTIR), differential scanning calorimetry (DSC), X-ray diffraction (XRD), scanning electron microscopy (SEM) and transmission electron microscopy (TEM), degradation process, as well as phosphorus and potassium release were measured using the ammonium molybdate test and atomic absorption spectroscopy (AAS), respectively. The results shown the polymers were successfully synthetized and it was found that the release of potassium and phosphorus in deionized water relied on the structural composition of the polymeric matrix as seen in SEM, XDR, and TEM studies, which highlights the potential use of these biopolymers as a promising pathway to enhance plant nutrition.

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# S19 – Machine Learning in Polymer Processing

## S19 - 233

## Development of an active film made from alginate, nanocellulose and rutin nanoemulsions

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Active films have become one of the main research topics in food packaging, as they can be used in order to extend shelf life of food products by releasing antimicrobials, antioxidants, and other types of active molecules. Likewise, films made from biopolymers, such as alginate have generated great interest. Among the most promising active molecules is Rutin, a polyphenol extracted from several plants that is known for its antioxidant activity. However, rutin application in food packaging can be limited by its low water-solubility, for which alternatives like nanoencapsulation can be used. In this work, films made from alginate and reinforced with nanocellulose and different rutin nanoemulsion concentration. The effect of the rutin nanoemulsion concentration on the solubility, permeability, and structural properties. The addition of nanoemulsion presented a plasticizing effect, while reducing water vapor permeability. Finally, rutin release kinetics in several simulated media was studied.

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# S19 – Machine Learning in Polymer Processing

## S19 - 31

## Fully Bio-based Epoxy-Amine Resins from Circular Economy: Conception, Multiscale Structural and Mechanical Behaviour Characterization toward Low Carbon-footprint Composites

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Petrosourced epoxy/amine resins are widely used as matrices for composite materials by dint of their mechanical properties from day-to-day to highly technical applications. However, the use of Bisphenol A and the problems related to their recycling led us to propose new resins derived from biomass. In this context, matrices based on epoxidized resorcinol RE and several hardeners: aliphatic (HMDA), cyclic (limonenen DA-LIM) and aromatic (eugenol DA-AE), were studied. In-house chemical thiol-ene reactions introduced amine functions on the DA-LIM and DA-AE building blocks, leading to novel hardeners. Formulated bio-based resins (RE/HMDA, RE/DA-LIM & RE/DA-AE) exhibited glass transition temperatures Tg of between 95 to 110°C, 35°C higher than those of similar bio-based materials. These thermosets were compared to a petrosourced material (DGEBA/HMDA), to which the bio-based resins showed better flexural behaviour, fire resistance, as well as remarkable toughness (KIC), creep, and Fatigue Crack Propagation (FCP). To deepen the understanding between the materials structure and their functional thermomechanical properties, a multi-scale study combining DMA, static and dynamic mechanical testing, and 1H Time Domain Double Quantum (TD-DQ) solid state NMR was undertaken. This approach showed that the flexural moduli Ef of the studied samples depended linearly on the quantity of atoms between a repeating unit for each resin. It was also shown that the toughness, creep and FCP mechanical properties, as well as the Tg of the studied resins, derive not only from the chemical crosslink density, but also that physical entanglements quantified by 1H TD-DQ act as thermomechanical reinforcements. Finally, these resins were reinforced with recycled carbon fibers. Bio-based resins exhibited high gel temperatures and low processing viscosity, while their composites showed better tensile, compression, and flexural properties compared to the benchmark petrosourced material.

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# S19 – Machine Learning in Polymer Processing

## S19 - 335

## Compatibilization of polylactic acid (PLA) and thermoplastic starch (TPS) blends by reactive extrusion: characterization and evaluation of extrusion blown films

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Food packaging plays a crucial role in preserving the physical and nutritional qualities of products. To produce packaging films with specific properties, the approach often involves the production of multilayer films, which are not easily recyclable. Moreover, besides being multi-material, the polymers typically used are not biodegradable, which have a negative environmental impact. According to current environmental regulations it is required a significant reduction in the use of these polymers, therefore it is imperative to create alternative materials that, in addition to offer similar properties, can be biodegradable and sustainable. Polylactic acid (PLA) has been one of the most widely used biopolymers however some properties, such as low temperature resistance and low hardness limit its use in some applications. Thermoplastic starch (TPS) present poor mechanical and thermal properties, but its low cost makes it an interesting biopolymer at a commercial level. Several studies refer to the blend of these biopolymers, however due to their distinct nature, their incompatibility is a problem. To overcome this limitation, it's possible to apply chemical modifications, such as transesterification reactions and the use of coupling agents. The objective of this work was to develop new biopolymeric system based on PLA and TPS through reactive extrusion. Afterwards, films were produced by blown film extrusion. Chemical modifications were made on the PLA and/or TPS structures trough coupling agents, such as maleic anhydride, glycidyl methacrylate and a silane derivative. After the development of these materials, they were characterized as to their structural, morphological, thermal, mechanical (tensile tests) and barrier properties. The SEM results demonstrate that the addition of coupling agents, namely the starch_GMA, significantly increases the interfacial adhesion between PLA and TPS. Also, the hydrophilicity of the films was increased, alongside the young modulus.

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# S19 – Machine Learning in Polymer Processing

## S19 - 380

## A comparison of the properties of starch derived from various sources and their effects on cast polymeric films

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The food packaging industry actively pursues alternatives to conventional materials with environmental concerns, such as non-biodegradability, recycling challenges, and potential leaching of harmful chemicals. This urgency is underscored by environmental policies favoring eco-friendly, renewable resources. In this context, bio-sourced polymers, particularly starches, have gained prominence. As the second most abundant natural polymers after cellulose, their large-scale extraction is an established industry practice. However, despite their potential, challenges persist, including competition with food security and limitations in the competitive characteristics of starch materials in the plastics market. From a macromolecular perspective, starch is a polymeric material composed of two glucans: amylose, a linear macromolecule, and amylopectin, a highly branched polymer. Starch is also crystallizable, hydrophilic, edible, and biodegradable, making it desirable for designing novel and sustainable materials, including films for food packaging. Since these properties are often influenced by botanical origin, our research focused on characterizing seven different starches available in Colombia. We analyzed the inherent characteristics of seven different starches in Colombia, assessing films produced through solvent casting. This evaluation covered the mechanical behavior and permeability of the casted films to pinpoint the optimal starch source for bioplastic development. The results underwent further evaluation using the TOPSIS - Shannon Entropy method. The results show that films made with different starches can lead to materials with different applications, thus reducing the need to search for modifications in native starches when they already possess inherent characteristics that allow their application in a defined field.

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# S19 – Machine Learning in Polymer Processing

## S19 - 51

## Development of porous fibroin membrane for wastewater depollution applications

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The rapid growth of industry and human activity led to the generation of large amounts of wastewater contaminated with hazardous metals, such as Cu or Pb, which are a great threat to the environment and may have serious consequences for all living organisms [1]. In this work, a porous membrane material based on fibroin [2], a protein biopolymer which together with sericin (a sticky protein) form the cocoons of silkworms, Bombyx mori, has been developed. The structural hierarchy of hydrophobic and hydrophilic segments in B. mori silk fibroin displays unique self-assembly capability enabling to obtain substrates with exceptional and desirable physicochemical and mechanical features [3]. The fibroin porous membranes were tested, and, for comparison purposes, a regenerated dense fibroin membrane was tested under the same conditions for adsorption experiments. Characterization of the structure, morphology and binding sites of this material has been carried out. Adsorption experiments of Cu(II) and Pb(II) have been performed and showed maximum adsorption capacities of 0.10 mmolCu.g-1 and 0.12 mmolPb.g-1. These values are very similar to the literature findings for metal adsorption on pure fibroin matrices, and the method proposed in this work reduces the steps and cost involved in producing the membranes while maintaining metal adsorption similar to that of a dense membrane. The porous membrane also has a moderate permeability, essential characteristic for continuous systems. The fibroin membranes, therefore, are an interesting alternative in what concerns the adsorption of heavy metals and considering the adsorbent's biodegradability.

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# S20 – Machine Learning in Polymer Processing

## S20 - 187

## Recycling of multilayer film packagings and their industry application

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Multilayer films used in the food industry prolong the shelf life of food and help keep food products fresh. Two or more polymers are used in these films to reach this goal. In food packaging, EVOH or PA6 is often used as a barrier layer for gasses. PE or EVA provides low-temperature heat sealability [1]. The combination of different polymers offers flexibility in the multilayer film properties, which allows them to adjust to many applications. The drawback is a very short service life and poor recyclability on an industry scale. Chemical recycling, or chemical separation of the polymer layers, is resource-demanding and complex process, which leads to higher prices of recycled material. This makes chemical recycling unfavorable, even though the environmental impact is lower than that of virgin material [2]. Mechanical recycling of multilayer films is possible but is still widely considered unfeasible, leading to recyclate with poor mechanical properties [3]. This work shows that it is possible to recycle multilayer plastic films from food and bring them back into the packaging cycle. The recycling process and application of multilayer films were examined. The multilayer films in this study are from food packaging and consist of LDPE, PA6, and EVOH in different ratios. Together with multilayer films, polyethylene films from LDPE and LLDPE were recycled. Two different approaches were examined in the recycling process: i) using a compatibilizer and ii) adjusting polymer ratios without compatibilizers. As a first step, the analysis of the film composition was done. The following steps were shredding, washing, recycling and film making. The recycling was done in a kneader or extruder, and tensile test samples were prepared from pressed plates. The recycled material had to fulfil the criteria of tensile strength, strain at break, shrinkage, and transparency to be used again as a shrink film. Finally, the film was successfully tested within the company's production line.

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# S20 – Machine Learning in Polymer Processing

## S20 - 239

## Polymeric blends containing different carboxylic acids

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A single-screw extruder was used to produce polymeric blends composed of recycled high-density polyethylene (HDPE) and thermoplastic starch. Carboxylic acids with different sizes of carbon chains were used as compatibilizer agents in the blends. The carbon chain length of the acid was found to be an important factor in the morphology of the blends. In general, the higher the number of carbons, the more refined the morphology obtained. Nevertheless, that component did not have a substantial impact on the mechanical properties of the blends. The work was developed aiming at a possible application to HDPE from packaging, as this material is commonly found in aquatic environments worldwide.

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# S20 – Machine Learning in Polymer Processing

## S20 - 240

## Effect of clays in the mechanical properties of dynamically revulcanized blends composed of ground tire rubber/high-density polyethylene

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This study investigates the impact of adding Cloisite 20A and Halloysite clay on the mechanical properties of dynamically revulcanized blends composed of high-density polyethylene (HDPE) and ground tire rubber (GTR), which have been previously devulcanized via microwaves. Blends were prepared containing different concentrations of the phases. Halloysite clay seems to have acted as a compatibilizing agent between the phases of the blends, whereas Cloisite 20A clay seems to have acted as reinforcement in the revulcanized blends. Nevertheless, slight deviations were noticed concerning the variations in the concentrations of the phases. This study aimed to explore the possibility of utilizing end-of-life tires in polymeric blends.

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# S20 – Machine Learning in Polymer Processing

## S20 - 265

## Processing of rotomolded parts based on recycled plastics: Different case studies

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With the concept of circular economy and sustainable development, the plastics industry must find applications for its waste and residues. This includes both post-industrial and post-consumer origin. Although several processing methods are available, rotational molding (rotomolding) is a special case as the raw materials must be in a powder form (usually around 35 mesh). In this case, a pulverization step is required before molding. The latter can be seen as an extra step in the production, but it can also eliminate the extrusion step if the materials are not highly contaminated which is usually the case for post-industrial polymers. In this work, different resins were used (grades of polyethylene) to produce rotomolded parts based on 100% recycled content. The residues from different origin (cutting, sawing, buffing, etc.) are directly pulverized and used for specific applications. Typical examples will be presented and discussed in terms of processing conditions and limitations to obtain good parts (without defects) for commercial production.

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# S20 – Machine Learning in Polymer Processing

## S20 - 361

## Advances in PVC recycling: mechanical and chemical techniques from a sustainable approach

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PVC is a material widely used in many activities; however, the environmental problems associated with the production of this material are a global concern. Therefore, recycling techniques are highly valued. Mechanical recycling, despite is a traditional method, limits post-recycling applications because it preserves its natural structure. In contrast, chemical recycling allows the decomposition of polymers into pure or "virgin" substances, allowing for more valuable applications. Thanks to mechanical recycling of PVC has been widely implemented in PVC product development and its different variations, recycled PVC has gained value compared to virgin material. Several studies have demonstrated the viability of its use due to the mechanical properties obtained and the costs associated with its production. Historically, chemical recycling has been deemed an unviable technique. One of the most renowned cases is the Vinyloop process proposed by Ferrara, a company that had to shut down its plant because regulations classified the plasticizers of PVC as toxic substance which represents 40% to 50% of its weight, and R-PVC didn't economically compete with virgin material. Despite these challenges, studies have demonstrated that chemical recycling processes result in an approximate 46% reduction in energy consumption and a 72% reduction in water usage compared to virgin materials. Regarding the issue associated with plasticizers, researchers suggest that incorporating simple stages, such as transesterification, can effectively address the difficulties related with its management. This review could be implemented in future industrial and academic projects, which have as main purpose the generation of a value proposition for this material. Beyond the economic interest, behind this issue the right technique could lead to the reduction of the carbon footprint in the post-consumption phase of the life cycle. This would promote the sustainability of PVC.

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# S20 – Machine Learning in Polymer Processing

## S20 - 455

## Composite materials for the circular economy: tuning the biodegradability of materials through the use of spent coffee grounds as filler

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The accumulation of plastic waste in the environment is a massive environmental problem. 6.3 of the 8.3 billion tons of plastic produced in the years between 1950 and 2015 are considered having turned into waste. To avoid this, designing materials with tuneable degradation profiles is essential, and for this an in depth understanding of degradation mechanisms of polymers is necessary. Our work at Hereon focusses on A) the development of new sustainable biodegradable materials by upcycling of biomass waste, B) the investigation of degradation mechanisms of new and traditional plastic materials by microorganisms and chemicals. Lignocellulosic biomass waste has a huge and still largely untapped potential for the design of sustainable materials. Adding it as a filler to polymer formulations (e.g. based on polylactic acid or polyhydroxyalkanoates) can reduce the cost of the material, as well as its carbon footprint, by substituting parts of the synthetic polymers required. Additionally, it can add active compounds as stabilizers or plasticizers, or improve mechanical properties or affect the degradation of the material. Spent coffee grounds are one example of biomass waste, which is generated around the world in large quantities. In addition to the lignocellulosic material, they contain around 15 wt% of oil, which can be extracted and used as a plasticizer. Here, we show the use of the extracted spent coffee grounds as fillers, and the extracts as additives, to tailor material properties for different applications, including 3D printing, injection moulding and thermoforming. In addition, we show measurements of the accelerated degradation behaviour of biodegradable polymers, to select the most suitable candidates for composites for applications where degradation at the end of the life cycle is intended.

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# S20 – Machine Learning in Polymer Processing

## S20 - 57

## Recycling ability and enhanced mechanical performance of novel poly(lactic acid)-co-poly(ethylene azelate) copolyesters

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In recent years, there has been an increasing interest from both the academic community and industry for polymers derived from renewable resources, which are a response to the problem of depletion of fossil resources and the issue of environmental pollution, as they have a reduced carbon footprint in comparison to their homologues from fossil resources. Biobased and biodegradable polymers seem to be the ideal solution for the substitution of fossil-based polymers. Among all the bioplastics, poly(lactic acid) (PLA) has gathered the attention from packaging industry because it can be used as a disposable material. PLA can be used for multiple other applications: for instance, biomedical applications for bone or tissue engineering, in the automotive sector, for construction, electronic devices and agricultural uses [1]. The main reason for this attention is the fact that during its production process, the energy consumption can be reduced by 65% and the greenhouses emissions by 68% in comparison to conventional polymers. PLA's main production route is from starch, corn or even waste materials [2]. Some of limitations of PLA are the low degradation rate in a natural environment, and its brittleness [3]. The objective of the present work is to overcome the limitations of PLA by the synthesis of novel copolyesters from renewable resources. Novel poly(lactic acid)-co-poly(ethylene azelate) copolyesters were synthesized via ring opening polymerization (ROP) of L-lactide, and their properties were studied through various techniques. The mechanical performance of PLA-based materials was significantly enhanced compared to neat PLA, and preliminary results of chemical recycling by microwave irradiation indicated that lactic acid, azelaic acid and ethylene glycol could be recovered.

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# S21 – Degradation, Biodegradation and Composting

## S21 - 366

## Chemical Treatment for Industrial Rubbers to Recycle by Metathesis Degradation to Obtain Bio-based Compounds

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After their utility period or when industrial rubbers reach the end of life, these are disposed of in landfills or as microplastics. One of the methods to degrade industrial rubbers is via metathesis. This work reported the synthesis of diols, polyols, and polyesters, via metathesis degradation reaction from butadiene rubber (BR) using the fatty alcohol 10-undecen-1-ol and the fatty acid methyl 10-undecenoate as chain transfer agents (CTA). Unsaturated diols, polyols, and polyesters via metathesis degradation of butadiene rubber in a one-pot reaction were successfully achieved, and 95-98% yields were obtained for the different reactions. The degradation of BR and the polyesters and polyols synthesis was verified by FT-IR, NMR, GC/MS. The molecular weights before and after degradation and of the products obtained were characterized by GPC (Mn, Mw and PDI). To control the molecular weights, different mole ratios were used with respect BR and CTA, Mn obtained ranged from 360 to 3,000 g/mol. The elastomeric diols, polyols and polyesters can be used for the synthesis of engineering design polymers, intermediates, fine chemicals and in the polyurethane industry.

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# S22 – Polymers in the Sustainable Development Goals of the United Nations

## S22 - 241

## Plastics and the UN’s Sustainable Development Goals

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That plastics are everywhere in the global economy is a fact. However, we must consider the negative effects of our throwaway culture and poor waste management practices to balance out any benefits that plastics may provide. As an example, it's interesting to see how plastics have played a crucial role in ensuring public health and safety during the COVID-19 pandemic. However, we can't ignore the fact that the improper disposal of plastic waste has led to an increase in water pollution. It's a delicate balance that we need to maintain for the well-being of our planet. Recent literature concerning the role of plastics in achieving the UN’s Sustainable Development Goals (SDGs) was analyzed. Despite contributing to the accomplishment of at least 15 SDGs, pollution caused by plastics (mainly marine pollution) surpassed the sum of their positive contributions to the 2030 Agenda achievement. The study, however, emphasized the vital importance of the circular economy with practices such as reduction, recycling, and service life extension as viable solutions to the socio-environmental problems that plastics may create and a significant ally in attaining the SDGs.

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# S22 – Polymers in the Sustainable Development Goals of the United Nations

## S22 - 378

## Towards to sustainability in cosmetic packaging industry

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Despite the enormous effort in the cosmetic packaging industry, sustainability in this sector has proven to be challenging. Several solutions to be more sustainable, such as using polymers from renewable resources (bio-polyethylene and bio-polypropylene), or recycled or reusable packaging have been tested. Biopolymers from sustainable sources (PLA and TPS) have been seen to be a good alternative to conventional plastics, but their application in the cosmetic industry still faces some challenges. The effect from the long exposure between the biopolymer and the cosmetic cream is not well understood, which could influence the shelf-life and original characteristics of the product. Also, enhancing the interaction between the product and the customer is crucial to promote a more involving user experience. Therefore, this project aims to develop a fully functional biodegradable cosmetic package able to stablish communication with customers (spreading fragrance) and with sensorial elements (photochromic or thermochromic elements) thus making possible the transmission of sensations and messages. To achieve these objectives, several compositions made of biopolymers were developed with natural wastes and fragrances (using encapsulation methods), tested, and validated on their performance to meet the requirements for cosmetic industry.

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