PPS-40

40th International Conference of the Polymer Processing Society

April 22-25, 2025
Auckland, New Zealand

Abstract book

April 22 – 25, 2025
University of Auckland
Auckland, New Zealand

UNIVERSITY OF AUCKLAND
Waipapa Taumata Rau
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CENTRE FOR ADVANCED MATERIALS
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Welcoming Remarks

Dear Colleagues and Friends,

It is with great pleasure that I welcome you to the 40th International Conference of the Polymer Processing Society, held in the beautiful city of Auckland, New Zealand, from the 21st to the 25th of April 2025. This year marks a momentous milestone as we gather to explore the theme “The next 40 years of polymer processing.”

Hosted by the Centre of Advanced Materials Manufacturing and Design, in the Faculty of Engineering and Design at the University of Auckland, this conference continues to be one of the most prestigious meetings in our field. We remember our recent conferences in Colombia (2024) and Switzerland (2023), and we eagerly anticipate our upcoming 2026 conference in Italy.

This year, we are thrilled to host 20 different symposia alongside a special symposium on “Commercialization and Challenges in Shaping a Circular Economy for Plastics.” The response has been overwhelming, with 325 contributions encompassing 6 plenary talks, 42 keynote talks, 210 oral presentations, and 67 poster presentations, organized into 6 parallel streams over 4 days. We are proud to see representation from 34 countries, truly making this a truly global event.

Attending an international conference such as this is invaluable. It offers a unique opportunity to expand our knowledge, share innovative research, and hear about the latest advancements in polymer processing. Equally important, it provides a platform to build lasting networks and forge meaningful relationships with peers from around the world. These connections often lead to fruitful collaborations and friendships that transcend borders and propel our field forward.

Auckland, our host city, is a vibrant international destination renowned for its stunning landscapes, rich cultural heritage, and warm hospitality. As the largest city in New Zealand, Auckland offers a perfect blend of urban sophistication and natural beauty. Attendees will have the chance to explore its picturesque harbours, lush parks, and dynamic arts scene. With its diverse culinary offerings and welcoming atmosphere, Auckland promises an unforgettable experience for all.

In conclusion, I urge you to take full advantage of this conference, engage actively in discussions, and immerse yourself in the wealth of knowledge and expertise gathered here. Together, let us pave the way for the next 40 years of pioneering advancements in polymer processing. Once again, I extend my heartfelt welcome to each of you. May this conference be a testament to our collective dedication, innovation, and collaboration.

Warm regards,

Johan Verbeek
Conference Chair of PPS-40

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 Scientist 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 Committee

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Lih-Sheng Turng (United States)
Fardin Khabaz (United States)
Pablo Raimonda (Uruguay)
Phan Trung Nghia (Vietnam)

International Scientific Committee

Additive manufacturing

Anderson, Patrick David	Netherlands
Liu, Shih-Jung	Taiwan
Roman, Allen Jonathan	USA
Sun, Luyi	USA
Xia, Hesheng	China
Yourdkhani, Mostafa	USA

Biomedical applications

Didar, Tohid	Canada
Perret, Edith	Switzerland
Schauer, Caroline	USA
Turng, Lih-Sheng	USA

Biopolymers

Averous, Luc	France
Chan, Clement	Australia
Halley, Pete	Australia
Hong, Joung Sook	Korea
Machado, Ana	Portugal
Raquez, Jean-Marie	Belgium

Circular Economy for Plastics and Recycling

Dhooge, Dagmar	Belgium
Fiorio, Rudinei	Netherlands
Kenig, Samuel	Israel
Manas-Zloczower, Ica	USA
Puch, Florian	Germany
Ragaert, Kim	Netherlands
Raimonda, Pablo Alberto	Uruguay
Vlachopoulos, John	Canada

Degradation, biodegradation and composting

Ray, Suprakas Sinha	South Africa
Saha, Petr	Czech

Extrusion

Lee, Patrick	Canada
Rauwendaal, Chris	USA

Fibres and Films

Ajji, Abdellah Ajji	Canada
Kikutani, Takeshi	Japan
Kornev, Konstantin	USA
Ozden, Yenigun Elif	United Kingdom

Foams and Membranes

Altstädt, Volker	Germany
Foudazi, Reza	USA
Nofar, M. Reza	Turkey
Taki, Kentaro	Japan

Functional Additives and Reactive Processing

Jana, Sadhan	USA
Sobkowicz, Meg	USA

Industry 4.0 and AI

Hrymak, Andrew	Canada
Zhang, Jie	United Kingdom

Injection moulding

Candal, Maria Virginia	Spain
Coates, Phil	United Kingdom
Cruz, Camilo	Germany
Kuehnert, Ines	Germany
Pantani, Roberto	Italy
Van Bael, Albert	Belgium

Mixing and Compounding

Carmen, Rosales	Venezuela
Wiessner, Sven	Germany

Modelling and Simulation

Albuquerque, Rodrigo	Germany
Altan, M. Cengiz	USA
Costa, Franco	Australia
Gooneie, Ali	Netherlands
Mitsoulis, Evan	Greece

Morphology and Structural Development

Cakmak, Miko	USA
Yamaguchi, Masayuki	Japan

Nanotechnology

McNally, Tony	United Kingdom
Subdararaj, Uttandaraman	Canada

Polymer Blends and Alloys

Naskar, Kinsuk	India
Ougizawa,Toshiaki	Japan

Polymer Composites

Acosta-Sullcahuamán, Julio	Peru
Arnal, Maria	Venezuela
Bernal, Celina	Argentina
Dagreou, Sylvie	France
De Paoli, Marco Aurelio	Brazil
Kenny, Jose	Italy
Leon-Becerra, Juan	Colombia
Menceloglu, Yusuf	Turkey
Mueller, Michael Thomas	Germany
Zhang, Jinwen	USA

Polymerisation and synthesis

Jin, Jianyong	New Zealand
Rueda-Sanchez, Juan Carlos	Peru

Rheology and characterisation

Frontini, Patricia	Argentina
Grizzuti, Nino	Italy

Rubbers and elastomers

Alexandrova, Larissa	Mexico
Thomas, Sabu	India

Awards

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 characterisation 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 possitions. 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.

Award recipient 2025
Prof. Mohammad Arjmand

Dr. Mohammad Arjmand is recognized as a leading (and award-winning) researcher in the fields of nanotechnology and polymer engineering. His impact can be seen through his roles at the University of British Columbia (UBC) as a faculty member, a Canada Research Chair in Advanced Materials and Polymer Engineering, an Inductee of the Royal Society of Canada, and the Lead of the Plastic Recycling Research Cluster. Dr. Arjmand's research area is focused on the synthesis of multifunctional nanomaterials and the development of their polymer nanocomposites and assemblies. During his academic career, Dr. Arjmand has been honored with numerous awards and recognitions, such as UBC Okanagan Researcher of Year (2025), Charles A. McDowell Award for Excellence in Research at UBC (2025), Morand Lambla Award from Polymer Processing Society (2025), Elected Member of College of Royal Society of Canada (2024), Canadian Society of Chemical Engineering Lectureship Award (2024), Emerging Materials Chemistry Investigator from Canadian Society of Chemistry (2024), Journal of Nanoscale Emerging Investigator (2024), Journal of Materials Chemistry Emerging Investigator (2023), Killam Faculty Research Prize from UBC (2023), Canadian Society of Chemical Engineering (CSChE) Innovation Award (2022), Polymeric Materials: Science and Engineering (PMSE) Young Investigator Award from American Chemical Society (2022), Polymer Processing Society (PPS) Early Career Award (2021), and Canada Research Chair in Advanced Materials and Polymer Engineering (2019).

PPS Early Career Award

The 2025 PPS Early Career Award honors outstanding young researchers in polymer processing who received a Ph.D. degree (or equivalent) in the last 8 years. It aims to recognize and stimulate originality and potential for continuing creativity in the science and technology of polymer processing-related areas. The nominees may include tenured/tenure-track faculty members, post-doctoral researchers, and researchers working in industry or national laboratories. The award consists of a framed certificate and a cash prize of US$2000.

Award recipient 2025
Prof. Zhe Qiang (University of Southern Mississippi)

Dr. Zhe Qiang is the SSCT Endowed Chair and Associate Professor of Polymer Science and Engineering at the University of Southern Mississippi (USM). He earned his M.S. and Ph.D. degrees in Polymer Engineering from the University of Akron and subsequently completed a postdoctoral fellowship at Northwestern University. Dr. Qiang's research group focuses on the materials and manufacturing science of polymers and their derived functional materials, with an emphasis on sustainable development for the environment and society, including industrial decarbonization and waste recycling. Since beginning his independent career in 2019, Dr. Qiang has received many awards and honors, including being named to *Forbes* 30 Under 30 in Science (2022), the ACS PMSE Early Career Investigator (2023), SAMPE Young Professional of the Year (2023), NSF CAREER Award recipient (2023), AIChE 35 Under 35 (2023), RCSA Scialog Fellow, IUPAC Young Observer (2025), and the PPS Early Career Award (2025).

Award recipient 2024
Dr. Gace Gu (University of California, Berkeley)

Dr. Grace X. Gu is an Assistant Professor of Mechanical Engineering at the University of California, Berkeley. She received her PhD and MS in Mechanical Engineering from the Massachusetts Institute of Technology and her BS in Mechanical Engineering from the University of Michigan, Ann Arbor. Her research focuses on creating new materials with superior properties for mechanical, biological, and energy applications using multiphysics modeling and artificial intelligence, as well as developing intelligent polymer additive manufacturing processes to realize complex material designs. Recently, her group is working on in-situ monitoring and process optimization for additive manufacturing of sustainable materials such as biopolymers, recycled materials, and calcium carbonate-based composites, aiming to enhance their quality and reliability. Her work has been highlighted in various media outlets such as Popular Science, Smithsonian magazine, and 3D-Printing Industry. She is the recipient of several awards, including the PPS Early Career Award, Sloan Research Fellowship, TMS Early Career Faculty Fellow Award, PMSE ACS Young Investigator Award, ARO Early Career Program Award, LLNL Early Career UC Faculty Initiative Award, DARPA Young Faculty Award, Materials Today Rising Star Award, ASME Orr Early Career Award, ONR Young Investigator Award, and 3M Non-Tenured Faculty Award. She has given dozens of invited lectures and seminars, including TEDxBerkeley. Gu has co-organized symposiums at various conferences and serves on the advisory boards of several journals, including Composites Science and Technology, MRS Communications, and Materials Horizons.

Program overview

MONDAY 21 APRIL

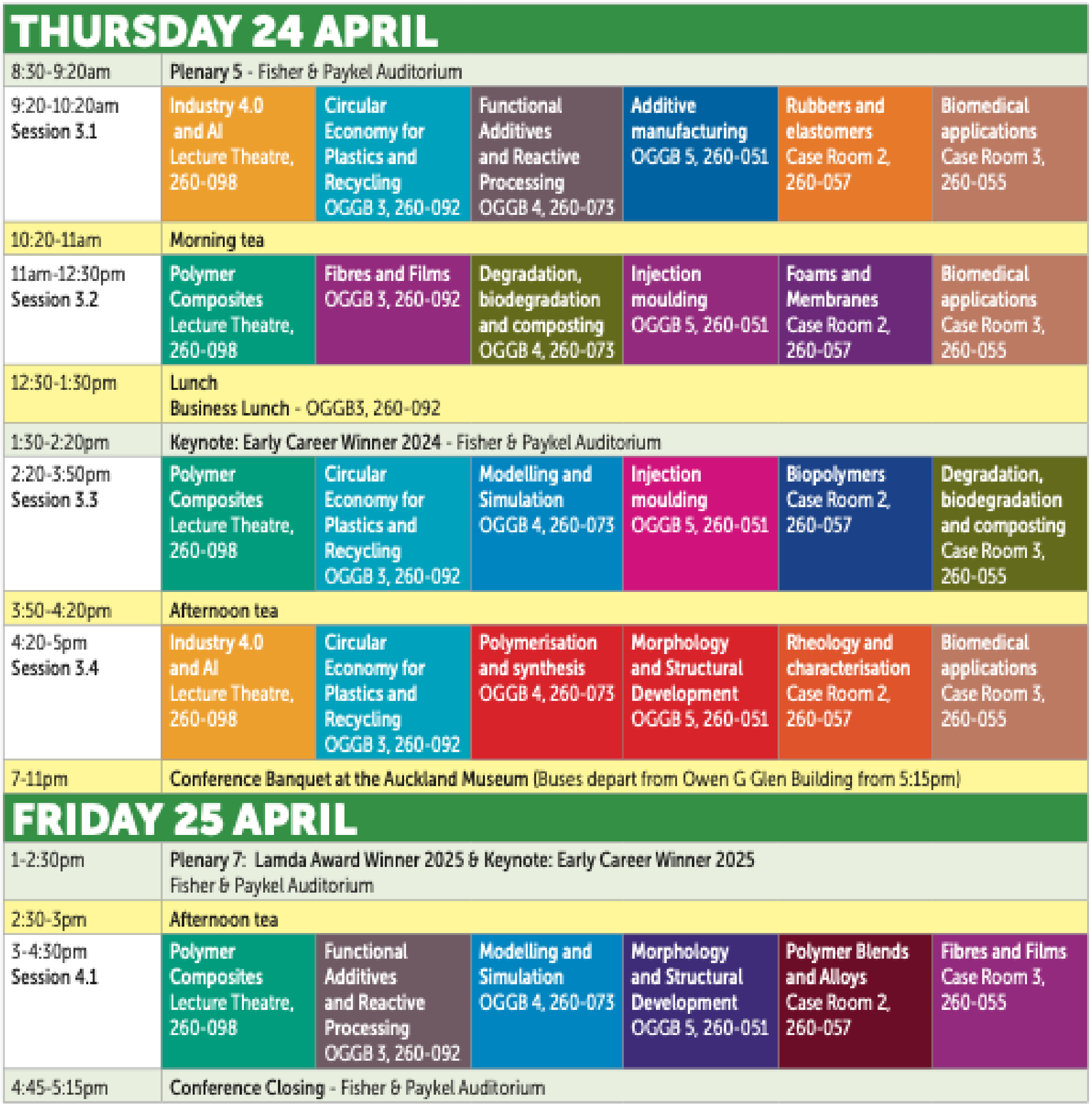
12noon	Registration					
1:30-2:30pm	**Executive meeting** - Decima Glenn Room (260-310)					
2:30-3:00pm	**Afternoon tea**					
3-4:30pm	**Executive meeting and International representatives** - Decima Glenn Room (260-310)					

TUESDAY 22 APRIL

8am	Registration					
9am-9:30am	**Conference opening** - Fisher & Paykel Auditorium					
9:30-10:20am	**Plenary 1**					
10:20-10:50am	**Morning tea**					
10:50am-12:10pm Session 1.1	**Polymer Composites** Lecture Theatre, 260-098	**Circular Economy for Plastics and Recycling** OGGB 3, 260-092	**Modelling and Simulation** OGGB 4, 260-073	**Additive manufacturing** OGGB 5, 260-051	**Biopolymers** Case Room 2, 260-057	**Morphology and Structural Development** Case Room 3, 260-055
12:10-1pm	**Lunch**					
1pm-1:50pm	**Plenary 2** - Fisher & Paykel Auditorium					
2-3:30pm Session 1.2	**Polymer Composites** Lecture Theatre, 260-098	**Circular Economy for Plastics and Recycling** OGGB 3, 260-092	**Modelling and Simulation** OGGB 4, 260-073	**Additive manufacturing** OGGB 5, 260-051	**Foams and Membranes** Case Room 2, 260-057	**Morphology and Structural Development** Case Room 3, 260-055
3:30-4pm	**Afternoon tea**					
4-5:30pm Session 1.3	**Polymer Composites** Lecture Theatre, 260-098	**Circular Economy for Plastics and Recycling** OGGB 3, 260-092	**Fibres and Films** OGGB 4, 260-073	**Additive manufacturing** OGGB 5, 260-051	**Foams and Membranes** Case Room 2, 260-057	**Injection moulding** Case Room 3, 260-055
6-8pm	**Welcome function and Poster Session**					

WEDNESDAY 23 APRIL

8:30-9:20am	**Plenary 3** - Fisher & Paykel Auditorium					
9:20-10:30am Session 2.1	**Special Symposia** Lecture Theatre, 260-098	**Nanotechnology** OGGB 3, 260-092	**Industry 4.0 and AI** OGGB 4, 260-073	**Rubbers and elastomers** OGGB 5, 260-051	**Biopolymers** Case Room 2, 260-057	**Rheology and characterisation** Case Room 3, 260-055
10:30-11am	**Morning tea**					
11am-12:30pm Session 2.2	**Polymer Composites** Lecture Theatre, 260-098	**Circular Economy for Plastics and Recycling** OGGB 3, 260-092	**Polymerisation and synthesis** OGGB 4, 260-073	**Extrusion** OGGB 5, 260-051	**Polymer Blends and Alloys** Case Room 2, 260-057	**Mixing and Compounding** Case Room 3, 260-055
12:30-1:30pm	**Lunch** **Editorial board meeting** - Case Room 2, 260-057					
1:30-2:20pm	**Plenary 4** - Fisher & Paykel Auditorium					
2:20-3:40pm Session 2.3	**Extrusion** Lecture Theatre, 260-098	**Circular Economy for Plastics and Recycling** OGGB 3, 260-092	**Modelling and Simulation** OGGB 4, 260-073	**Additive manufacturing** OGGB 5, 260-051	**Biopolymers** Case Room 2, 260-057	**Injection moulding** Case Room 3, 260-055
3:40-4:10pm	**Afternoon tea**					
4:10-5:20pm Session 2.4	**Polymer Composites** Lecture Theatre, 260-098	**Nanotechnology** OGGB 3, 260-092	**Modelling and Simulation** OGGB 4, 260-073	**Rubbers and elastomers** OGGB 5, 260-051	**Biopolymers** Case Room 2, 260-057	**Biomedical applications** Case Room 3, 260-055



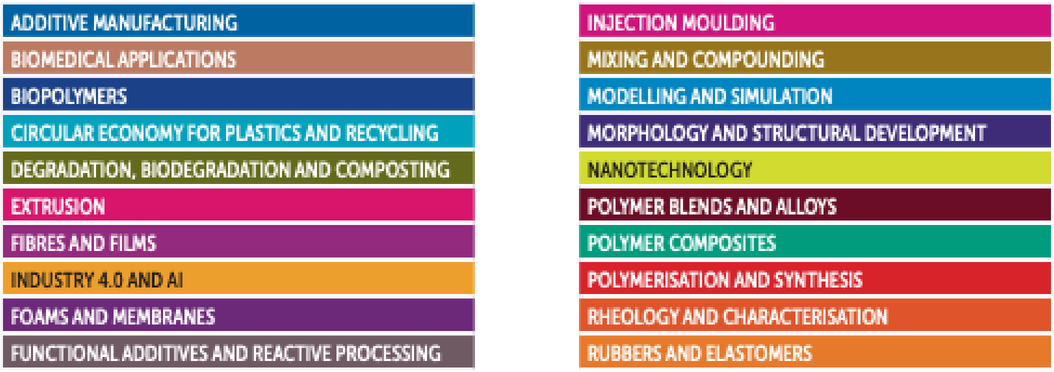
THURSDAY 24 APRIL

8:30-9:20am	**Plenary 5** - Fisher & Paykel Auditorium					
9:20-10:20am Session 3.1	Industry 4.0 and AI Lecture Theatre, 260-098	Circular Economy for Plastics and Recycling OGGB 3, 260-092	Functional Additives and Reactive Processing OGGB 4, 260-073	Additive manufacturing OGGB 5, 260-051	Rubbers and elastomers Case Room 2, 260-057	Biomedical applications Case Room 3, 260-055
10:20-11am	**Morning tea**					
11am-12:30pm Session 3.2	Polymer Composites Lecture Theatre, 260-098	Fibres and Films OGGB 3, 260-092	Degradation, biodegradation and composting OGGB 4, 260-073	Injection moulding OGGB 5, 260-051	Foams and Membranes Case Room 2, 260-057	Biomedical applications Case Room 3, 260-055
12:30-1:30pm	**Lunch** **Business Lunch** - OGGB3, 260-092					
1:30-2:20pm	**Keynote: Early Career Winner 2024** - Fisher & Paykel Auditorium					
2:20-3:50pm Session 3.3	Polymer Composites Lecture Theatre, 260-098	Circular Economy for Plastics and Recycling OGGB 3, 260-092	Modelling and Simulation OGGB 4, 260-073	Injection moulding OGGB 5, 260-051	Biopolymers Case Room 2, 260-057	Degradation, biodegradation and composting Case Room 3, 260-055
3:50-4:20pm	**Afternoon tea**					
4:20-5pm Session 3.4	Industry 4.0 and AI Lecture Theatre, 260-098	Circular Economy for Plastics and Recycling OGGB 3, 260-092	Polymerisation and synthesis OGGB 4, 260-073	Morphology and Structural Development OGGB 5, 260-051	Rheology and characterisation Case Room 2, 260-057	Biomedical applications Case Room 3, 260-055
7-11pm	**Conference Banquet at the Auckland Museum** (Buses depart from Owen G Glen Building from 5:15pm)					

FRIDAY 25 APRIL

1-2:30pm	**Plenary 7: Lamda Award Winner 2025 & Keynote: Early Career Winner 2025** Fisher & Paykel Auditorium					
2:30-3pm	**Afternoon tea**					
3-4:30pm Session 4.1	Polymer Composites Lecture Theatre, 260-098	Functional Additives and Reactive Processing OGGB 3, 260-092	Modelling and Simulation OGGB 4, 260-073	Morphology and Structural Development OGGB 5, 260-051	Polymer Blends and Alloys Case Room 2, 260-057	Fibres and Films Case Room 3, 260-055
4:45-5:15pm	**Conference Closing** - Fisher & Paykel Auditorium					

Colour coding by topic



ADDITIVE MANUFACTURING
BIOMEDICAL APPLICATIONS
BIOPOLYMERS
CIRCULAR ECONOMY FOR PLASTICS AND RECYCLING
DEGRADATION, BIODEGRADATION AND COMPOSTING
EXTRUSION
FIBRES AND FILMS
INDUSTRY 4.0 AND AI
FOAMS AND MEMBRANES
FUNCTIONAL ADDITIVES AND REACTIVE PROCESSING

INJECTION MOULDING
MIXING AND COMPOUNDING
MODELLING AND SIMULATION
MORPHOLOGY AND STRUCTURAL DEVELOPMENT
NANOTECHNOLOGY
POLYMER BLENDS AND ALLOYS
POLYMER COMPOSITES
POLYMERISATION AND SYNTHESIS
RHEOLOGY AND CHARACTERISATION
RUBBERS AND ELASTOMERS

Abstracts – Plenaries and Awards

Plenary

The ever increasing complexity of plastics innovation and manufacturing: A medical device manufacture's perspective.

Somervell Andrew*

Fisher and Paykel Healthcare, New Zealand
*Corresponding author: Andrew.Somervell@fphcare.co.nz

Abstract

Fisher and Paykel Healthcare is a leading designer and manufacturer of medical devices used for respiratory care applications. Success is based on ongoing product innovation aimed at improving patient care and outcomes. The use of novel polymers and development of unique high-volume manufacturing processes are an important part of enabling Fisher and Paykel to create unique, world leading products. We'll focus on how Fisher and Paykel approaches this in a highly regulated industry and how increasing quality, regulatory and environmental demands create further challenges and opportunities.

Plenary

Multi-Component Technology and Material Combinations: Past and Future

Kühnert Ines*

Institute of Polymer Materials & Leibniz-IPF, Germany
*Corresponding author: kuehnert@ipfdd.de

Abstract

The past of multi-component technology was characterized by the development and refinement of processes that made it possible to combine different materials during a single manufacturing process. This technique is particularly prevalent in injection molding, where multiple polymers or other materials are processed in a single step in a mold. It led to significant advances in the automotive, electronics and consumer goods industries. Whereas in the past the main challenge was to create connections with the highest possible adhesive strength, today the focus is on combining materials in such a way that products achieve a certain service life and their components can be easily separated and recycled after use.

The future of multi-component technology lies in the use of new materials, particularly sustainable and intelligent materials, as well as the expansion of the technology through additive manufacturing and functional integration. This will lead to even more efficient, more powerful and more environmentally friendly products. Multi-component technology has evolved significantly over time, and the future holds promising innovations and applications.

Plenary

Modelling Crack Propagation through Adhesives at Cryogenic Temperatures

Thompson Kim*

Rocket Lab, New Zealand
*Corresponding author: ks.thompson@rocketlab.co.nz

Plenary

Quality in Polymer Recycling: Science vs System

Ragaert Kim*

Maastricht University, Netherlands
*Corresponding author: k.ragaert@maastrichtuniversity.nl

Abstract

When discussing plastics recycling, we often speak of the importance of "high quality". Defining, measuring and predicting this quality, however, has proven to be one of the main scientific challenges in the field, which does not restrict itself to polymer science or even engineering alone. Quality is inevitably bound to application - the same recycled plastic maybe excellently suited for a film but not at all for a bottle. More recent quality models have incorporated this and allow us to score recyclates on substitutability towards different applications. For implementation in policy, non-technical aspects like longevity of the new product, waste availability and market demand are equally important. Systemic choices - such as should we send a certain waste stream to mechanical or chemical recycling - are dependent on a holistic understanding of quality.

Remarkably, from a social sciences perspective, different stakeholders along the value chain have been found to perceive the meaning of quality entirely differently, with some remarkable discrepancies among them.

Finally, if we truly want to predict quality, we need to understand and model the full recycling process - from collection over sorting and washing to extrusion or pyrolysis - to be able to make any type of valid assumption on final quality of a bale after recycling.

The lecture will discuss the development of the understanding, quantification and prediction of quality in recycling, and how it is affected by progressing policies and insights, as well as the maturation of chemical recycling.

Plenary

Sustainable plastics - Case study on developing high performance bioplastics

Halley Peter

University of Queensland, Australia
*Corresponding author: p.halley@uq.edu.au

Abstract

Plastics waste presents a major global environmental issue, in part due to the usefulness and popularity of plastics packaging and products. Over 403 tonnes of plastics was used globally in 2023 [1], and of this amount only around 9% was recycled successfully. The solution to using plastics sustainably is a complex, and will be developed by using a holistic approach of product design, sustainable processing, management of waste collection, recycling and chemical recycling, and use of more sustainable plastics options.

This talk will examine as a case study the research and development of high value bio-based polymers products at UQ and through our start-up company. This will include initial work on starch biopolymers through to a range of biopolymer blends and biomaterials. The paper will examine major improvements in material and performance properties that led to wider applications for starch and other biopolymer materials via materials chemistry, polymer blending, tailored processing and cradle to cradle analyses. A strong case for linking fundamental research discoveries with product development will be highlighted. Application areas include food packaging, agricultural films, injection molded products and high functionality products.

References:

[1] Global plastic production 1950-2023, Published by Statista Research Department, Feb 17 2025 (https://www.statista.com/statistics/282732/global-production-of-plastics-since-1950/)

Keynote

Learning from nature, mathematics, and artificial intelligence for sustainable materials design and manufacturing

Gu Grace (1)*

(1) University of California, Berkeley - California - USA
*Corresponding author: ggu@berkeley.edu

Abstract

The growing demand for sustainability in materials design and manufacturing is driving breakthroughs that reduce environmental impact while enhancing performance and efficiency. In this talk, I will present our research at the intersection of bioinspired design, mathematical tiling, and artificial intelligence (AI) to address key sustainability challenges. First, I will discuss a novel aerodynamic design inspired by owl feathers and cicada wings, leading to a sinusoidal serration propeller that improves flight efficiency and reduces noise. Next, I will explore composite structures based on aperiodic monotiles, which offer superior mechanical properties and durability compared to conventional patterns, promoting sustainability in materials. Finally, I will introduce an AI-driven monitoring system for polymer additive manufacturing that detects and corrects defects in real-time, enhancing component quality and reducing waste. Together, these innovations can transform a wide range of applications, paving the way to create more resilient structures, design more sustainable materials, and develop greener manufacturing technologies along the way.

Plenary

Flexible 3D-Printed Cellulosic Constructs for Electromagnetic Interference Shielding and Piezoresistive Sensing

Arjmand Mohammad*, Amini Majed

University of British Columbia, Canada
*Corresponding author: mohammad.arjmand@ubc.ca

Abstract

Advances in materials science and sustainability have established cellulose nanofibers (CNFs) as a pivotal nanomaterial for constructing complex 3D architectures using innovative 3D printing techniques. However, the practical application of 3D-printed CNF-based materials in next-generation electronics remains constrained by their inherent limitations, such as low electrical conductivity and limited mechanical flexibility. Our research addresses these challenges by integrating ion-seeded CNF-based 3D-printed frameworks with a conductive polymer through a streamlined process known as "cold chemical vapor polymerization" (CCVP). The method begins with the precision direct ink writing (DIW) of a specially formulated 2,2,6,6-tetramethylpiperidine-1-oxy-oxidized (TEMPO-oxidized) CNF hydrogel. This hydrogel is subsequently saturated with $Fe3^{+}$ ions and freeze-dried to create ion-embedded CNF frameworks. Interconnected conductive pathways of poly(3,4-ethylenedioxythiophene) (PEDOT) are then developed within these frameworks using CCVP. This approach allows for precise tuning of electrical conductivity, yielding highly conductive (546 S/m) and mechanically flexible (70% compressible) patterned constructs. The advancement is exemplified by grid-based structures designed for absorption-dominant electromagnetic interference (EMI) shielding. These innovative shields exhibit an absorbance (A) of 0.71 and an exceptional specific EMI shielding effectiveness (SSE/t) of 3406.45 dB·cm2·g⁻1. The aerogels demonstrate outstanding stability and durability, retaining their EMI shielding performance after exposure to various solvents and 100 compression cycles. Remarkably, DMSO treatment enhances their shielding effectiveness by 4 dB, likely due to improved PEDOT conductivity. Furthermore, these aerogels also function as highly sensitive piezoresistive sensors, underscoring the versatility of this sustainable approach for advancing wearable electronics and multifunctional technologies.

Keynote

Polyolefin innovations for clean air and water

Qiang Zhe*

University of Southern Mississippi, USA
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Abstract

Securing clean air and water is crucial for fostering a sustainable and prosperous future, where economic equity is closely linked to technological accessibility. This talk will explore how the transformative potential of commodity plastics, among the most cost-effective and widely accessible materials, can be harnessed to drive industrial decarbonization and water remediation. In the first part of the talk, I will address the challenge of process heat in the chemical and materials industries, a significant contributor to energy consumption and greenhouse gas emissions. I will delve into the additive manufacturing of carbon-based Joule heaters derived from polyolefins and their recycled counterparts, demonstrating how the structure and properties of these complex carbons can be precisely tuned by altering filament composition and processing conditions. This approach enables the electrification of heating processes, thus facilitating the decarbonization of chemical and energy production. The second part of the talk will focus on the development of functional mesoporous materials from low-cost thermoplastic elastomers and their efficient application in removing micropollutants from water, particularly per- and polyfluoroalkyl substances (PFAS). This presentation will highlight the transformative role of polyolefins in advancing a sustainable future for our planet and society.

Abstracts – Keynotes and Oral Presentations

Session 1.1: Additive manufacturing
Paper ID: S22-43

Scarless support removal in vat photopolymerization: towards enhanced surface and dimensional control

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Abstract

The study investigates methodologies for enhancing surface resolution and dimensional accuracy in vat photopolymerization-based additive manufacturing (VPP AM) by optimizing support structures. In VPP, support structures are essential for achieving complex geometries; however, their removal frequently results in surface imperfections and compromised dimensional accuracy. This research focuses on understanding the surface interactions between photopolymer parts and support structures at the contact interface, intending to enable scarless support removal. The study proposes a framework that incorporates computational and mechanical analyses of tensile behavior across various support structure configurations to explore force distribution during detachment, complemented by indentation-based methods to evaluate localized mechanical responses. The investigation considers optimization strategies specific to VPP, including adjustments of process parameters, layer-by-layer projection techniques, and tailored geometric configurations for support structures to enhance ease of removal without impacting surface quality. This study aims to develop a universal methodology for scarless support removal while preserving the mechanical strength and surface quality of the final parts. This approach lays a foundation for experimental validation, advancing VPP capabilities for mass customization in applications that demand precision in dimensional control and high-quality surface finishes.

Session 1.1: Additive manufacturing

Paper ID: S22-46

Development of Recyclable and Halogen-Free Flame-Retardant Powders for Laser-Sintering: Material Evaluation and Performance Enhancement

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Abstract

The application areas for laser-sintering (LS) are still limited due to the lack of material diversity. In particular, the high flammability of standard polyamide-based powders is a significant challenge. The demand for flame-retardant (FR) components, especially in the electrical and electronics industry or mobility sector, is constantly increasing and can only be met to a limited extent by commercial powders. These available LS-FR powder materials are neither sustainable nor economically viable, as the use of halogenated FRs is severely restricted due to health and environmental concerns, while halogen-free FR powder alternatives are not recyclable. The focus of this study is to provide the basis for the future development of a recyclable and halogen-free LS powder with flame retardancy. Therefore, different halogen-free FRs are evaluated with respect to their use in LS. First, their decomposition behavior and mode of action are examined. Subsequently, the additives are dry blended with polyamide 12 to investigate properties relevant for LS, such as particle morphology, thermal behavior and melt viscosity. In the next step, the blends are used to produce test specimens for the UL94 vertical flame retardancy test in the LS process. In addition, the process stability of the aged powder blends is investigated by re-examining their thermal behavior and melt viscosity. Finally, the two most promising additives identified in the preliminary screening are subjected to a more comprehensive investigation following the same procedure. The primary objective is to optimize the flame retardancy, while simultaneously analyzing the mechanical properties and recyclability.

Session 1.1: Additive manufacturing

Paper ID: S22-83

Additive-Free Aqueous-Based Graphene Ink for 3D Printing Functional Aerogels

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Abstract

Refining graphite and its derivatives, such as graphene, holds immense potential in various fields, from electronics to biomedical applications. However, conventional processing techniques often hinder their full utilization. This research introduces an innovative approach: an all-graphene, aqueous-based ink for direct ink writing (DIW), enabling the 3D printing of functional aerogels tailored for electronics and electromagnetic interference (EMI) shielding. Our method involves a two-step electrochemical synthesis, including a meticulously designed intercalation step to regulate the surface properties of graphene nanosheets. Through comprehensive characterization, we highlight the profound influence of graphene nanosheets' physicochemical attributes on ink homogeneity, rheology, electrical conductivity, and EMI shielding effectiveness. Notably, we observe that rheology alone cannot predict the printability of 2D particulate systems; instead, ink homogeneity, influenced by inter-sheet interactions, emerges as a critical factor. By optimizing intercalation conditions, we demonstrate that phosphoric acid treatment enhances both printability and conductivity, achieving remarkable electrical conductivity (158 S/cm) and electromagnetic shielding effectiveness (50 dB at 50 μm thickness) without necessitating post-processing reduction steps. This innovative approach facilitates rapid, continuous, and large-scale manufacturing of lightweight, porous materials, circumventing environmentally harmful reductant chemistries or high-temperature processing. Our work opens up promising avenues for employing graphene and other nano-based inks in advanced manufacturing technologies.

Session 1.1: Additive manufacturing

Paper ID: S22-78

Metal Nanoparticle Coating of 3D Printed PLA Structures

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Abstract

Traditional electronics are often fabricated using planar PCB, while many applications require on-demand, multi-material, and three-dimensional products. The potential ability to incorporate electronic circuits into 3D printed structures opens up many possibilities in the creation of multifunction structural sensors. However, one of the main challenges in achieving this is to deposit conductive patterns onto uneven and complex surfaces. While some techniques have been developed to address this issue, such as using micronozzles, micromolding in capillary and multi-process printing, these methods can be time-consuming, costly, and rely on line of sight for deposition. Additionally, they are generally limited to deposition on one 3D-printed structure at a time. Herein, we propose a method for depositing conductive patterns on 3D-printed structures using a combination of plasma treatment and bulk solution deposition. A silver nitrate solution, formulated without polymer binders, is introduced into microchannels via capillary flow to form the desired patterns. The silver nitrate is then reduced to silver nanoparticles through plasma treatment, eliminating the need for any heat-based post-processing. This low-temperature process is energy-efficient and environmentally friendly. We successfully deposited conductive silver onto flat 3D-printed surfaces. It was found that nitrogen plasma is an optimal choice for experiments compared to oxygen and hydrogen plasma as it requires less power and does not generate non-conductive by-products. Our future work will involve the creation of microchannel patterns that can facilitate silver ink flow along the microchannels via capillary effect to create a conductive path. This research offers a potentially more economical and time-efficient solution to make conductive patterns on complex surfaces, especially for large-scale production. The method demonstrates promising applications in areas such as sensors, antennas, and robotics.

Session 1.1: Additive manufacturing

Paper ID: S22-59

Additive Manufacturing of Polymer Covalent Adaptable Networks

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Abstract

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 and sintering, 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. The novel dynamic cross-linked polymer CANs, including polydimethylsiloxane with pyrazole urea bond, polyurethane with Diels-Alder bond, polyurethane with halogenated bisphenol carbamate were synthesized in a kilo scale and were used for SLS 3D printing. The obtained PU-CANs 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. 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. Furthermore, The electrically conductive PDMS composite parts with self-healing lattice structures were printed. Ingeniously utilizing the quasi-static processing characteristic of SLS printing, the conductive segregated carbon nanotubes (CNTs) networks are in-situ formed in PDMS-CANs during the printing process, showing an ultra-low percolation threshold of 0.007 wt%. Due to the photothermal and electrothermal effects of CNTs, the composites possess multifunctions including crack diagnosis and self-healing triggered by heat, electricity, or light. References: 1. S.J. Sun, X.P. Gan, H.S. Xia, et al, Additive Manufacturing, 2020, 33, 101176. 2. S.J. Sun, G.X. Fei, H.S. Xia, et al, Chem. Eng. J. 2021, 412, 128

Session 1.1: Biopolymers

Paper ID: S25-95

Influence of spirulina biomass addition on the polymer properties

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Abstract

Microalgae culture systems can be used to treat wastewater and recover nutrients. They can also fix CO2, and the biomass can be reutilized as a biofertilizer or in the obtention of bio-based polymer, making it an eco-friendly wastewater treatment process. This work aims to evaluate the addition of cyanobacteria Arthrospira platensis biomass, known as spirulina, in the properties of different polymer matrices, such as polypropylene (PP) and ethylene vinyl acetate (EVA). Composites containing 20 wt% spirulina biomass were prepared by melt mixing using a torque rheometer. The morphology was analyzed using optical microscopy and scanning electron microscopy. Mechanical properties were evaluated through bending (ASTM D790), and toughness (ASTM D5045) tests and thermal characterization was performed by differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA). A better dispersion and adhesion of the biomass in the PP matrix was observed. A 53% reduction in Young's modulus was observed, however, and no rupture occurred in the specimens containing Spirulina during the toughness tests, indicating the effectiveness of Spirulina in increasing the toughness of the matrix. Despite the low adhesion between Spirulina and the EVA matrix and poor biomass particle dispersion, no significant differences were observed in the mechanical properties compared to pure EVA. This research highlights the feasibility of using Spirulina as an additive in polymer matrices, with implications for developing sustainable and efficient materials.

Session 1.1: Biopolymers

Paper ID: S24-40

Alternative biobased polymer additives – a comparison of the stabilization efficiency of conventional antioxidants, biobased alternatives derived from existing biomass, and their extracts

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Abstract

Additives are often neglected when it comes to the investigation of sustainable materials. Especially the use of stabilizers requires closer examination, as conventional antioxidants have been criticized for being harmful to the environment and human health. Recent studies have shown that crucial additives could be replaced by by-products from winemaking like wine pomace (WP). It was shown that WP and its extracts (WP-E) can improve the thermo-oxidative stability of plastics, offering an alternative to conventional antioxidants like Irganox 1010 (I-1010). However, extraction is laborious and stabilization of polymers by WP-based bio-additives has barely been compared to conventional antioxidants. In this study, WP-based bio-additives are compared to I-1010 to analyze whether there is a performance gap between alternative and conventional antioxidants. In addition, WP-Es, produced by environmentally friendly extraction, are used to investigate whether the effort of extraction is worthwhile to improve the performance of bio-additives. Investigations of the different antioxidants (WP, WP-E, and I-1010) were performed with poly(butylensuccinate) (PBS) and poly(lactic acid) (PLA) as matrix materials. Stabilized biocompounds with additive concentrations of 0.3–5% by weight were initially produced with a material-efficient miniaturized single-screw extruder to assess the general applicability, followed by investigations with a lab-scale twin-screw extruder. The resulting biocompounds were analyzed in terms of thermal and mechanical properties and thermo-oxidative stability. A moderate performance gap between WP and I-1010 was found, which could be closed by extraction, demonstrating that both WP and WP-E can be used as biobased alternatives to I-1010. Compared to WP, lower concentrations of I-1010 and WP-E were required to achieve a comparable stabilization. Thus, extraction might not be mandatory but could be beneficial to avoid affecting other properties of the matrix.

Session 1.1: Biopolymers

Paper ID: S25-9

Compounding Of High Heat Service Temperature Poly(Lactic Acid) For Hot Fill Food Packaging Applications

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Abstract

Heat distortion temperature (HDT) exceed 100oC of the bioplastic compound based on poly(lactic acid) (PLA) for hot fill food packaging applications was the main aim of this research work. By using the statistical approach, 2k factorial design of experiment (DOE), the optimization of silane, polyols and glycerol in PLA compound formula was found. Further exploring, glycerol was evidenced for enhancing the flow ability and tensile properties of the compound in comparison with neat PLA and the PLA compound without glycerol addition. Adding the reactive polymerization of poly(urethane) (PU) system; isocyanate, polyols and glycerol, in the PLA compound found that thermal properties was slightly increased with inferiority in mechanical properties. The vinylsilane/peroxide crosslink systems were also investigated. It was found that the MFI was decreased but HDT, tensile and impact properties were increased upon increasing the DCP concentration. In the talc filled PLA compound exploration, the results showed that higher heat resistance PLA compound was achieved by the addition of talc filler. In the study of PLA/PU compound systems, the results reviewed that lower in MFI, HDT and tensile properties but fractionally higher in impact strengths were observed when the amount of polyols in PLA/PU system was increased. Vacuum drying in order to remove the moisture residual risen from the sauna treatment of the compound samples showed the positive effect to MFI and HDT of the obtained material at the given PU content. But it had the negative effect on the mechanical properties. Final verdict of the study concluded that the vacuum dried of the silane/DCP induced crosslinked PLA blended with polyols manifested the outstanding HDT at 106oC without scarifying of other properties.

Session 1.1: Biopolymers

Paper ID: S25-8

Development of plant polymers-based bioplastics/biocomposites for industrial applications

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Abstract

Plant polymers-based plastic is a new generation of material that is able to significantly reduce environmental impact, to perform like traditional plastics when in use, and to completely biodegrade within a composting cycle through the action of living organisms. However, starch- and protein-based bioplastics have limited commercial applications due to several drawbacks such as poor processability, brittleness, moisture sensitivity, and inferior mechanical and thermal properties. First, we developed several new technology to make plant starch-based bioplastic and developed several novel bioplastic products with potato pulp, plant fiber and Poly(lactic acid) (PLA) using extrusion technology. We developed an improved processing technology for potato starch-based bioplastic using glycerol and tri-ethyl citrate as co-plasticizer without water. We then expanded our research from potato starch-based bioplastic to pulse starch-based bioplastic. Second, we developed several new technology to make plant protein-based bioplastic for food packaging applications. We designed a water resistant surface by immobilizing hydrophobic copolymers (PSG) with functional groups on soy protein isolate (SPI) films. We then introduced different amounts of guanidine-based antimicrobial polymers (PHGH) on the resulting hydrophobic surface to adjust water resistance of the modified films. The introduction of hydrophilic PHGH on the resulting surface generated many micropores, which potentially increased the water uptake of the modified protein-based films. The modified protein-based film with a multi-functional surface including anti-microbial property showed potential for applications in the packaging and medical fields. Third, we used canola meal (CM) as feed stock to develop novel bio-composites for industrial applications such as disposable trays and containers. Since canola meal is difficult to be plasticized, we developed a reactive extrusion technology for CM composites.

Session 1.1: Circular Economy for Plastics and Recycling
Paper ID: S28-75

Enabling the Recyclability of Industrial Waste EPDM via Twin Screw Extrusion

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Abstract

The global demand for sustainable materials is driving the need for more efficient recycling processes, particularly in the rubber industry. Ethylene-propylene-diene monomer (EPDM) rubber is widely used in various applications due to its excellent material performance, and plays a critical role in sectors such as automotive [1]. However, its recyclability is inherently limited due to the cross-linked network. Mechanical recycling fails to restore the beneficial properties and therefore waste EPDM is often incinerated or landfilled [2]. We have therefore investigated the use of continuous extrusion as an economically viable and scalable method to improve the recyclability of EPDM. We aim to reduce the cross-linking density by varying the barrel temperature, identifying the limits of processability during the extrusion process. Chemical analysis allows detecting the main mechanisms of degradation, which are then linked to the processing conditions. Moreover, we explore the possibility of re-cross-linking the extrudates as well as blending into virgin EPDM. Based on thorough analysis, the promising restoration of properties will be discussed. These findings pave the way towards sustainable, closed-loop recycling of EPDM at industrial scale, while addressing a critical gap in rubber recycling. References: [1] S.O. Movahed, A. Ansarifar, S. Estagy. Review of the Reclaiming of Rubber Waste and Recent Work on the Recycling of Ethylene-Propylene-Diene Rubber Waste. Rubber Chemistry and Technology, 2016, 89, 54–78. [2] E. Roetman, J. Joustra, G. Heideman, R. Balkenende. Does the Rubber Meet the Road? Assessing the Potential of Devulcanization Technologies for the Innovation of Tire Rubber Recycling. Sustainability, 2024, 16, 2900.

Session 1.1: Circular Economy for Plastics and Recycling

Paper ID: S28-76

Innovative Recycling of Crosslinked Polyethylene: Regeneration and Reincorporation for Enhanced Circularity in Cable Industry

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Abstract

Due to remarkable insulation properties, lightweight and simple manufacturing, crosslinked polyethylene (XPE) is frequently used in electrical cables. Nevertheless, secondary recycling, commonly employed for commodity thermoplastics, cannot be applied to XPE due to its crosslinked nature. The majority of industrial waste is then either incinerated or landfilled [1]. Within this context, exploring new pathways to recycle XPE represents a compelling but yet unsolved issue. While thermo-mechanical decrosslinking has been extensively studied for rubbers [2], its application in recycling XPE still requires an in-depth investigation of the correlation between process parameters and final material properties. In this work, XPE waste was regenerated by flash extrusion at high temperature and shear. A thorough characterization (e.g. gel content, NMR, SEC, rheology…) of the so-obtained polyolefins (rXPEs) will provide a comprehensive picture of the mechanisms involved in the regeneration process depending on the extrusion temperature. Moreover, when rXPEs are reincorporated into virgin linear polyethylene, the resulting blends acquire unique and distinct features. We will address in particular the viscoelastic properties of the reincorporated compound, combining and comparing extensional and shear rheology as well as capillary rheometry. Depending on the regeneration temperature of rXPEs, the blends exhibit a wide range of elongational and shear viscosities, which paves the way for innovative applications of XPE waste. References: [1] Selvin, M. et al. 'Review on Recycling of Cross-Linked Polyethylene'. Ind. Eng. Chem. Res., 2024, 63, 1200–1214. [2] Bockstal, L. et al. 'Devulcanisation and reclaiming of tires and rubber by physical and chemical processes: A review'. J. Clean. Prod., 2019, 236, 117574.

Session 1.1: Circular Economy for Plastics and Recycling

Paper ID: S28-80

Sintering and Densification Behaviour of Virgin/Recyclate Blends for use in Rotomoulding

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Abstract

The incorporation of recyclate is becoming essential due to various legalisation and directives from policymakers, this is no different for the RM industry. Recycled rotational moulding material, which has good sintering behaviour, can be very difficult to source and transport due to large hollow products and long service life, as a result to is essential other sources of post-consumer recyclate (PCR) are of interest in research. Consequently, it is necessary to consider other feedstocks from well-established, sophisticated recycling technologies like the packaging industry and other PCR streams. Despite this, such materials were never intended for RM and do not have the appropriate characteristics leading this has led to significant challenges. Rotomoulding (RM) is a unique polymer processing method which adopts a low shear environment for manufacturing large hollow products. The RM process is underpinned by key process such as sintering and densification of polymers. Powdered materials, typically polyethylene, are used in the biaxial processing method, where upon heating coalescence occurs and formation of a polymer melt is achieved from the particles. This referred to as sintering and densification. During the process, some air can be trapped in the molten polymer leading to formation of voids or bubbles. The characteristics of the polymer significantly influence sintering and bubble removal, for example; molecular weight, viscosity, presence of additives and fillers. In addition, the physical form of the material such as particle size, particle size distribution and shape can affect the process. This study investigates the sintering behaviour of polyethylene powders designed specifically for rotational moulding, with key focus on how the sintering and densification process is affected with the addition of recycled materials. In recent studies, porous structures were produc

Session 1.1: Circular Economy for Plastics and Recycling

Paper ID: S28-70

Transforming E-Waste into Flame-Retardant Fillers for Recycled LLDPE: A Path to Sustainable Innovation

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Abstract

E-waste, comprising discarded electronic devices, is the fastest-growing solid waste stream globally. E-waste contains valuable materials like metals and plastics, but also hazardous substances that pose significant environmental and health risks if not properly managed. The improper disposal and recycling of e-waste can release toxic chemicals, including lead and mercury, into the environment. Among the various components of e-waste, Random-Access Memory (RAM) modules are particularly noteworthy. RAM, a critical component in computers and other electronic devices, contains flame retardant additives during its manufacturing, which can be repurposed as flame retardant additives. By utilizing RAM chips powder from e-waste, we can transform these discarded materials into value-added fillers that enhance the flame retardancy of polymers, for example, recycled Linear Low-Density Polyethylene (LLDPE). Recycled LLDPE is known for its flexibility, strength, and resistance to chemicals, making it suitable for a wide range of applications. By incorporating RAM powder into recycled LLDPE, we aim to enhance its flame retardancy while maintaining its desirable mechanical properties. Recycled LLDPE samples were compounded with varying concentrations of RAM powder, and their thermal stability, flame retardancy, and mechanical properties were evaluated. The results demonstrated that the optimal concentration of RAM powder not only enhanced the flame retardancy of recycled LLDPE but also maintained its mechanical integrity, making it a viable material for applications requiring stringent fire safety standards. This study highlights the potential of using electronic waste to develop high-performance, flame-retardant polymer composites. By repurposing e-waste and recycled LLDPE, this research contributes to environmental sustainability, reduces the ecological footprint of polymer production, and adds value to waste materials that would otherwise contribute to landfill.

Session 1.1: Modelling and Simulation
Paper ID: S33-68

Improvement of a Numerical Two-Phase Simulation Model for the Melting Process in Single-Screw Extruders Based on Experimental Investigations

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Abstract

Most extruders in the plastics processing industry are plasticizing extruders, fed with pellets or powder that must be melted within the extruder. In many processes, the extruder's melting performance represents the throughput-limiting factor. If the material melts too late along the processing length, it may not be sufficiently thermally and materially homogenized. Conversely, if it melts too early, it can degrade due to thermal and mechanical stress along the screw after melting. Therefore, accurate prediction of the melting length is crucial in designing single-screw extruders. While the numerical simulation of fluid flows has become state-of-the-art in many applications—owing to increasing computational power that allows models to avoid simplifications inherent in analytical models—the simulation of plasticizing extruders has not yet reached this level. This is because traditional computational fluid dynamics (CFD) simulations represent only fluids and cannot model bulk solids. To address this, a simulation approach has been developed where the solid material is described as a highly viscous fluid. In this study, this approach was adopted, and the simulation results were compared with experimental data—especially regarding throughput and melting behavior—for various process parameters, screw designs, and for both a semi-crystalline and an amorphous thermoplastic. The melting behavior in the experimental investigations was examined using Maddock's screw pull-out tests, allowing for a comparison of the melting rate and the kinematics of the melting process. Using statistical experimental design, the effects of various model parameters on the simulation results were investigated and successively adjusted through comparison with experimental data. This iterative process enabled the generation of a set of parameters that can be utilized in future simulations.

Session 1.1: Modelling and Simulation

Paper ID: S33-47

Detailed Boundary Layer CFD-Microsimulation of Mineral-Filled Polyamid 6 using ANSYS Rocky

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Abstract

Low production costs are essential in modern automotive design while having complex shapes and function integration in parts and components. To achieve these new challenges, while maintaining high quality parts for customers, injection molding of polymers is used. Interior and exterior chrome parts are made of ABS or PC/ABS and subsequently electroplated. Therefore, high surface qualities with the cool-touch-effect can be ensured. If the designated part has to withstand higher mechanical loads, these materials can be substituted by mineral-filled polyamide 6 (PA6). The surface quality after the electroplating process depends mainly on the particle distribution and orientation in the boundary layer. Unfortunately scrap rates of nearly 30 % are not uncommon for using PA6. Therefore, a simulation methodology was developed to predict the morphology of the boundary layer of parts. To investigate this microscopic area, macrosimulations for the whole part were performed in a first step to derive the boundary settings for microsimulations, such as the inlet velocity function. The calculations were performed not isothermal and with approximated real particle shapes using ANSYS Rocky. To improve the representation of the particle behavior, an optimized inlet area and particle interactions were implemented. Additionally, injection molded parts were electroplated and investigated via optical classification, peeling tests and micrographs of cross-sections. This surface characterization of real parts should be used in the future to validate the developed simulation methodology. The impact of the operation conditions on the electroplating process is shown in this paper and a detailed simulation methodology for the surface near area is derived.

Session 1.1: Modelling and Simulation

Paper ID: S33-36

Deriving equivalent shear viscosity of polymer melt under non-isothermal state using digital twin model of slit rheometry

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Abstract

In plastic injection molding, the melt temperature increases dramatically as a result of the viscous dissipation caused by the shear-thinning behavior of thermoplastic polymers. This phenomenon degrades the accuracy of traditional viscosity models (η_(orig.)), which assume isothermal conditions. This leads to significant errors in the pressure gradients and pressure drops computed in molding simulations. To address this issue, the present study employs a digital twin model of a slit rheometer to conduct non-isothermal simulations of the rheological measurement. The simulations focus particularly on the effects of viscous heating on the melt flow and temperature distribution of the polymer melt within the die. The characteristic temperature at the slit wall, rather than the bulk temperature of the melt, is used to correct shear heating effect to derive an equivalent shear viscosity model (η_(eq.)) under non-isothermal conditions. The findings show that the slit rheometry provides more accurate melt viscosity information across a broader range of shear rates compared to traditional capillary rheometry. In addition, the simulations employing the equivalent shear viscosity model (η_(eq.)) successfully capture the effects of viscous heating in slit rheometry. In particular, the value of n in η_(eq.) increases under non-isothermal conditions, indicating that the slope of the viscosity curve in the shear-thinning region becomes less steep. In other words, the equivalent shear viscosity increases compared to that predicted under isothermal conditions. The experimental measurements confirm that the pressure gradient and pressure drop predicted using the equivalent model (η_(eq.)) are more accurate than those predicted using the original model (η_(orig.)).

Session 1.1: Modelling and Simulation

Paper ID: S33-30

Predicting the orientation of flake pigments in injection-molded metallic polymer using smoothed particle hydrodynamics

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Abstract

Injection molding of polymers containing metallic flake pigments is a production method that decorates plastic products without a painting process. The quality of the metallic appearance strongly depends on the orientation of flake pigments in the surface layer of the product. While aligned orientation is desirable for achieving a good metallic effect, disturbed orientation can occur during molding due to flow disturbance caused by obstacle structures such as holes, thin-walled areas, and bosses. Regions with disturbed orientation exhibit weaker or different metallic effects, resulting in appearance defects (referred to as flowlines in this study). To design and manufacture products without defects caused by disturbed flake orientation, numerical simulation for predicting flake orientation is useful. In this study, we investigated the applicability of Smoothed Particle Hydrodynamics (SPH), a mesh-free method, for predicting flake orientation in the surface layer. The non-Newtonian fluid motion during injection molding was calculated using a fully implicit SPH scheme to handle highly viscous flow, while temperature and flake orientation were simulated using an explicit scheme. Additionally, the solidification of polymers was considered to reproduce the formation of the frozen layer and the resultant surface orientation. The effectiveness of the developed SPH methodology was examined by simulating the injection molding of a plate with a thin-walled area. The simulation predicted a linear distribution of regions with disturbed flake orientation downstream of the thin-walled area. The width of the simulated flowline increased downstream, while its visibility (flake angle) decreased. These trends were found to be in qualitative agreement with experimental observations using X-ray computed tomography.

Session 1.1: Morphology and Structural Development

Paper ID: S14-312

Observation of Scratch Behavior of Polystyrene with Fluorescent Molecular Probe

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Abstract

Plastics are widely utilized in diverse applications, including automotive and consumer electronics, where functionality and appearance are crucial. Due to the susceptibility of plastic products to scratching, understanding scratch characteristics is essential. While the scratch properties of polymers have been studied in many cases, reports on polymer chain scission remain limited. In recent years, there has been active research on mechanochromic materials, which exhibit luminescence or color changes in response to mechanical stimuli. These mechanochromic properties enable the visualization of mechanical stresses or damaged areas, making them promising for applications in stress distribution analysis, material lifespan prediction, and damage-detection sensors. The application of the fluorescent molecular probe Diarylacetonitrile (DAAN) has been reported to enable the visualization and quantitative evaluation of polymer chain scission. DAAN functions to detect polymeric mechanoradicals generated by homolytic cleavage of polymer chains under mechanical stimulation and transforms into DAAN radicals that emit yellow fluorescence under UV light. In this study, we blended DAAN into polystyrene (PS) and visualized the chain scission events in PS during scratching. To reveal the relationship between scratching behavior and molecular chain scission, we conducted morphological observation, fluorescence imaging, retardation measurement, and scanning 3D profile of scratch path. Scratch tests were conducted at a fixed testing speed of 10 mm/s, while varying the test load at 10, 15, and 20 N to evaluate load dependency. As the test load increased, cracks progressed, resulting in deeper fractures. Both scratch width and depth tended to increase with the load. An increase in test load also led to greater fluorescence intensity, suggesting that more molecular chain scission of PS occurred.

Session 1.1: Morphology and Structural Development

Paper ID: S14-88

Visualization of Polymer Chain Scission during Melt Processing Using a Mechanochromic Probe

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Abstract

Stimuli-responsive polymers have been extensively studied and widely utilized in a variety of fields. They can change their physicochemical properties and adapt structural conformations upon applications in response to external stimulation, including heat treatment, light illumination, and electrical current. Mechanochromic materials are also used as material force sensors to sensitively detect the mechanical stress distribution, and intuitively reflect the occurrence or propagation of the structural materials. This research focuses on the effect of screw rotational speeds, kneading temperatures, and feeding rates on mechanoradical generation when mechanochromic polymer was stimulated by heat and stress using mechanochromic materials to visualize the defection of polymer. The mechanoradical generation is higher with the increase of screw rotational speed, the more rotational speed, the higher fluorescence intensity was obtained. This could be due to the H+ of diarylacetonitrile (DAAN–triOMe/triOMe) (DAAN) withdrawn by the radically defective polystyrene (PS) nearby. It is supposed that the higher the screw rotational speed, the more polymer chain was broken down because of high shear, therefore DAAN mechanoradical was more generated and provided higher fluorescence intensity when compared to lower screw rotational speeds. In contrast, the mechanoradical generation decreased with the increase in kneading temperature. This is assumed the higher temperature the more kinetic energy of the polymer occurred, therefore mechanoradical has more possibility to react with each other or H+ nearby to form a stable and then become non-radical adduct DAAN resulting in less mechanoradical generation. Furthermore, as the result of complex viscosity, the melt viscosity of the kneaded PS was lower than unkneaded PS, suggesting that the kneading process caused the scission of the polymer chains. Similarly, the higher screw rotational speed affected lower melt viscosity. As these results, DAAN could be applied to visualize stress and defection of polymers.

Session 1.1: Morphology and Structural Development

Paper ID: S14-50

Crystallization behavior of polypropylene blends after shear flow

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Abstract

The crystallization behavior after shear history was studied using polypropylene (PP) blends with various materials such as talc, polymethylmethacrylate (PMMA), and polyethylene. It was found that the talc having a long aspect ratio enhanced the crystallization temperature. Furthermore, PMMA with low molecular weight also enhanced the PP crystallization because deformed PMMA droplets acted as fillers with long aspect ratio at low temperature. Finally, low-density polyethylene (LDPE) accelerated the shear-induced crystallization of PP during cooling, although such phenomenon was not detected by the high-density polyethylene addition. Since the Rouse-Weissenberg number increased with decreasing temperature even at a constant shear rate, LDPE showed strain hardening under shear flow during cooling, leading to excess deformation of PP between prolonged LDPE droplets. The blends showing marked shear-induced crystallization exhibited a high level of molecular orientation of PP due to the well-developed shish-kebab structure.

Session 1.1: Morphology and Structural Development

Paper ID: S14-42

Suppression of the Skin-Core Structure of Poly(vinyl alcohol) Films to Improve the Mechanical and Optical Properties

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Abstract

As the core material to realize the polarization function, the microstructure of poly(vinyl alcohol) films formed during the solution drying process significantly influences their tensile ductility and optical transmittance. However, due to the rapid volatilization of solvents in the actual production process, the phase transition occurs in a very short time, and there is not enough time to attain the equilibrium state, which will cause a gradient structure in the thickness direction. Herein, we proposed a strategy to suppress the skin-core structure by shifting the drying process of PVA solution from evaporation-induced dominance to diffusion-induced dominance to slow down the drying rate. We observed that the drying rate of PVA solutions can be effectively slowed when the double hydrogen-bonded water and multiple hydrogen-bonded water were predominant as PVA aqueous solution concentration is higher than the critical concentration and the homogeneous film was obtained[1]. In order to suppress the "skin-core" structure in the lower concentration, we further propose a strategy to reduce the evaporation rate through the incorporation of plasticizer-type additives. Herein, we added the urea/diethanolamine (DEA) compound additive to the solution with concentration of 10 wt%.[2] When the content of the compound additive exceeded 10%, the PVA film became flat and free of bubbles and the “skin-core” structure. The compound additive also enhances the tensile ductility and optical transmittance. The fracture strain of the modified PVA film reaches 448.2%, and the average light transmittance in the visible range reaches 97.8% when the content of the compound additive is 20% of the PVA mass. REFERENCES [1] Yinghan Li, Xinhong Yu, et al. Inhibition of the Skin-Core Structure in Poly(Vinyl Alcohol) Films by Increasing the Diffusion-Induced Dominated Drying Process. Macromolecules, 2023, 56(22): 9175−9188. [2] Yinghan Li, Xinhong Yu, et al. Suppression of the Skin-Core Structure of Poly(vinyl alcohol) Films by Adding Urea/Diethanolamine to Improve the Mechanical and Optical Properties. Macromolecules, 2024, 57 (13): 6109-6122.

Session 1.1: Polymer Composites
Paper ID: S35-32

Self-reinforced thermoplastic polyurethane composite with excellent mechanical properties, heat resistance and sustainable recycling

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Abstract

The traditional reinforcement and toughening approaches of thermoplastic polyurethane (TPU) fail to adequately address the mechanical properties, compatibility and recyclability of TPU composites. In this study, the self-reinforced TPU composite was successfully prepared by introducing self-reinforced fiber structure, and their heat resistance, service life and recyclability were significantly improved. The reinforced fibers and matrix phase had the same chemical composition, and the reinforced fibers could be uniformly distributed in the TPU matrix. The network structure formed by reinforced fibers enhanced the rheological properties of self-reinforced TPU composites. The hydrogen bond interactions between reinforced fibers and TPU matrix improved the micro-phase separation structure. When the reinforced fiber content was 7 wt.%, the degree of hydrogen bond and degree of micro-phase separation of TPU7 increased from 0.693 and 40.93 % to 0.713 and 41.63 %, respectively. The network structure and excellent interfacial interactions significantly enhanced the strength and toughness of TPU matrix. Compared to TPU, the tensile strength, elongation at break and tensile toughness of TPU7 were increased by 58.2 %, 107.1 % and 210.3 %, respectively. The introduction of reinforced fibers increased the heat resistance of self-reinforced TPU composites by 20-30 °C. After ten-times closed-loop recycling process, TPU7 still exhibited excellent tensile properties and elongation at break, i.e., the loss of tensile strength and elongation at break was only 15.9 % and 11.0 %, respectively. This work provides a solution strategy for preparing TPU composites with ultra-high mechanical properties, thermal stability and sustainable recycling-reprocessing.

Session 1.1: Polymer Composites

Paper ID: S37-86

High aspect ratio carbon nanotubes as tire tread rubber reinforcement toward improved fuel efficiency

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Abstract

Our group has recently synthesized high aspect ratio (100 μm L x 15 nm D; L/D > 6,000) carbon nanotubes (CNTs) on unconventional, thin-layered catalyst supports, leading to high yields and low costs compared to most commercial CNTs. This could be a first step toward industrial adoption of CNTs as viable alternatives to traditional carbon-based fillers like carbon black (CB) and carbon fiber. A possible application of these CNTs could be partial or full replacements of CB in tire tread rubber. While CB is a necessary component of tread rubber primarily for mechanical reinforcement, the total carbon content is typically quite high (≥ 30 wt%). CNTs generally impart a higher degree of composite mechanical reinforcement than CB due to morphological differences. Our preliminary work on short (L/D ≈ 100), commercial CNTs in tread rubber has shown improvements in ultimate strength and toughness compared to traditional CB. We also found synergistic CB-CNT effects with simultaneously improved ultimate strength and ductility. Improvements in abrasion resistance, rolling resistance, and wet/ice traction have also been reported. Because the aspect ratios of the CNTs synthesized here are much greater than most commercial CNTs, we hypothesize the carbon content could be significantly reduced to achieve similar or improved composite properties. Initial results show that high aspect ratio CNTs impart similar degrees of mechanical reinforcement at nearly an order of magnitude lower carbon loading compared to the CB control (≤10 phr CNT vs. 72 phr CB). These improvements in tire tread rubber properties could result in a notable automobile lightweighting effect and improved fuel efficiency.

Session 1.1: Polymer Composites

Paper ID: S37-54

Processing of polymer based ionogels and their applications in flexible sensors

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Abstract

Skin-like sensors have gained tremendous attentions due to their potentials in body motion monitoring, healthcare monitoring and human–machine interaction. In general, the flexible sensors are normally constructed by integrating rigid electronic particles and flexible polymers, which exhibit poor transparency and low long-term stability. As combing ionic liquids (ILs) and flexible polymer together, we can generate the ironically conductive ionogels, exhibiting high stretchability, sensitivity, and optical transparency. Based on the electrical signals of ionogels (such as resistance, current, as well as capacitance), they can be used to design flexible tactile sensors to detect pressure and strain. Herein, we combine thermal-plastic poly(urethane) (TPU) and ILs together to generate the TPU@IL ionogels, which can be fabricated into membranes, fibers, as well as nanofiber membranes. These different shaped ionogels were designed into flexible strain/pressure sensors with high transparency, outstanding sensitivity as well as good stability for long-term usage. Keywords: Flexible sensors, ionogels, e-skins, wearable electronics.

Keynote

Session 1.2: Additive manufacturing
Paper ID: S01-113

3D polymer powder printing by SAS: Selective Acoustic Sintering

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Abstract

A new 3D printing technique, Selective Acoustic Sintering (SAS), is introduced that fuses polymer powder particles together using focused ultrasound transducers. This technology creates volumetric scan paths or holographic shapes, reducing printing times and producing fully dense products. A mathematical framework is proposed to determine the feasibility of this method, which optimizes the printing process and determines the appropriate process parameters for different materials and applications. The analysis of a diverse dataset of printable materials shows that selective acoustic sintering has potential for various applications, including printing metals, ceramics, and polymers. To further extend the modeling framework, numerical simulations are presented that model the coupling between acoustic wave propagation and acoustic thermal heating. With the numerical toolbox, the temperature increases at off-center focal positions are studied and quantified, and the feasibility of off-center volumetric scanning in SAS is shown. A model-based ultrasound characterization method for powder-based materials is realized, which accurately measures the speed of sound, impedance, and attenuation of the materials. The results show that coupling media used in these setups can significantly impact the accuracy of the measurements, especially for powder-based materials. Additionally, the degree of compaction and the type of filler used in the polymer powder compacts affect the acoustic properties of the materials. The findings have implications for the design of the selective acoustic sintering 3D printer, as mainly attenuation determines the acoustic energy transmitting and, thus, printer dimensions. Therefore, it is concluded that reducing the porosity of the powder by compaction or filling is necessary to reduce attenuation and enable sufficient heating inside the powder build volume in SAS 3D printers.

Session 1.2: Additive manufacturing

Paper ID: S01-105

Online Rheological Measurement in Screw Extrusion Additive Manufacturing for Improved Process Modelling

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Abstract

Screw extrusion based fused granulate fabrication (FGF) is a growing technique in material extrusion (MEX) additive manufacturing (AM). Compared with filament-based techniques, FGF offers a more cost-effective, versatile alternative with improved environmental sustainability and enabling a circular economy. Despite its advantages, there is no available information on the rheology of the materials being processed in published literature. The aim of this study was to improve understanding of the rheological behaviour of the thermoplastic as it is being extruded. To achieve this, the apparent melt viscosity was obtained by using two pressure sensors integrated right after the metering section of a small scale FGF extruder with an 85 mm long, 14 mm diameter screw. The study was conducted using ADFLEX X 100 G thermoplastic polyolefin granules. The results indicated that even with small scale FGF extruders, there exists a pressure periodicity which is equivalent to the extrusion screw speed. The 3D printing process was found to operate at a shear rate ranging from about 0.05 s-1 to 0.32 s-1 with the viscosity varying from about 180 kPa.s to 30 kPa.s respectively. Printing at 190°C using a 0.4 mm nozzle resulted in a melt pressure of about 1.8 MPa at 2.5 screw RPM and about 3.2 MPa at 10 screw RPM. Increasing screw speed led to increased extrusion rates and pressure generation. Smaller nozzle diameters caused elevated pressure generation for the same extrusion rate output, irrespective of screw speed. While the die swell increased with pressure and screw speed, it decreased with increasing temperature. The study provides conclusive and valuable information on the pressure generated by small-screw extruders, thus, also on the rheological behaviour of the material being extruded, combined with the die swell experienced by the melt when exiting the nozzle. These results are essential for the development of better models for extruder development of small scale FGF.

Session 1.2: Additive manufacturing

Paper ID: S22-79

Optimal Design of Soft Gripper Mechanisms Combining Finite Element Analysis and Machine Learning

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Abstract

Metamaterial mechanisms are micro-architectured flexible structures that operate through the elastic deformation of specially designed components. This study introduces an optimal design approach for a compliant metamaterial mechanism, utilizing machine learning (ML) technology. The design space is segmented into finite cells with varied hinge configurations, and finite element (FE) analyses are employed to assess how these different configurations deform. The FE analysis results are integrated with ML models to optimize the design of a soft gripper mechanism based on specific functional requirements. Deep reinforcement learning with deep a deep Q-learning framework is utilized in ML-based optimization, exploring how tiling direction and penalization strategies for disconnected hinges influence performance. ML-optimized designs exhibit substantial improvements, showing a 56.3% increase in rotational compliance when compared to traditional human-guided designs. The optimized soft gripper is fabricated using additive manufacturing, and its performance is validated through experimental tests on objects of varying sizes. The results demonstrate that ML-based design optimization is a highly effective and efficient method for creating soft metamaterial mechanisms, presenting a practical and versatile approach centered on digitized cell structures.

Keynote

Session 1.2: Circular Economy for Plastics and Recycling
Paper ID: S04-138

The conformational preference of dynamic crosslinker modulates the ‘closed-loop’ circular economy in polypropylene vitrimer

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Abstract

In the plastics industry, a significant challenge to achieving a circular economy is the upcycling and revalorization of post-consumer recycled (PCR) thermoplastic polyolefins (TPOs). Untreated PCR polyolefins generally have poor mechanical properties compared to virgin materials, making them suitable only for low-value applications. In this context, covalent adaptable networks (CANs), a unique class of dynamic crosslinking structures, offer a promising solution by combining the benefits of thermosets and thermoplastics. However, often, the conformational preference of the crosslinkers is overlooked and the resulting performance of the vitrimer is believed to be originating from the crosslinking during synthesis/processing. Our study begins to suggest, that depending on the spatial arrangement and flexibility of the crosslinker, it can either promote or hinder the network formation (gelling) process, as understood from DFT. The DFT simulations, by adjusting molecular coordinates to minimize the total energy, offered the most stable structure at room temperature and the molecular dynamics (MD) simulation helped in gaining detailed insights into the oscillatory behaviour and structural dynamics of the CAN, possibly taking place during the extrusion process in the melt at higher temperatures. It is now understood that the gelling is controlled by the conformational preference and should be considered as an additional design parameter for designing PP vitrimer. Maleic anhydride (MA) was employed as a reactive agent to promote crosslinking, while styrene served as a grafting enhancer by reducing the surface energy of MA-grafted PCR PP. Additionally, MA alone was tested as a grafting agent. The resulting vitrimer, formed by integrating different classes of dynamic crosslinkers with equivalent chain lengths, enable the direct upcycling of PCR PP into high-performance materials. Keywords: PCR. PP, Vitrimer, Closed-loop circular economy, Upcycling

Session 1.2: Circular Economy for Plastics and Recycling

Paper ID: S04-108

Uncertainty in Reported Cost (Prediction), the Case of Plastics Recycling

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Abstract

The transition to a circular economy for plastics requires attention in various domains, i.e. combinations of the technological aspects with economic, environmental and social aspects. Steps are being made to combine the technological and economic (i.e. cost) aspects of plastics recycling as part of this transition. An important perspective is that of operators of sorting and recycling facilities, i.e. the business economic perspective. The cost associated with a specific technology is an important parameter that has to be predicted and taken into account. Yet, current costing models use single-point cost estimates, which do not take into account uncertainty. Such deterministic models ignore the underlying variability of the input parameters, and hence ignore uncertainty, which yields results that can be erroneous or create the perception of certainty. By not including all relevant information, the quality of the subsequent decisions based on these results is questionable. Cost uncertainty is especially relevant in (technologically) complex settings, such as plastics recycling, notably in combination with its long-term tender-oriented structure which emphasises the need for thorough understanding of the (origins of) costs. Cost information and its associated uncertainty are eminent to facilitate informed decisions. This interdisciplinary research presents and discusses a framework, which is based on established methodologies from life-cycle analysis, to incorporate uncertainty in business economic costing models linked to specific technologic steps. Furthermore, the framework includes a selection of stochastic parameters which yield a certain level of overall uncertainty, i.e. a level of representativeness. The top selected variables, ranked on contribution to the total uncertainty, allows for the inclusion of sufficient information to have broad enough confidence intervals while remaining narrow enough to be informative.

Session 1.2: Circular Economy for Plastics and Recycling

Paper ID: S28-92

Addressing the global plastics problem – value added adhesives derived from recycled plastics

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Abstract

Plastics are useful materials and will continue to be used for the foreseeable future. However, 400 million tonnes of waste plastics are generated every year. In addition, 15 million tonnes of urea formaldehyde, a recognised carcinogen, is used in the manufacture of wood fibreboard products every year. NILO is well progressed in the development of an innovative process technology to address both these challenges by converting plastic waste into an adhesive to replace urea formaldehyde in the production of wood fibreboard. The patented Nilo technology can utilise all polyolefins (polyethylene and polypropylene) encompassing almost 60% of all plastic waste, including difficult to process soft plastic (film). The waste plastic derived adhesive produced via the NILO process has been tested at commercial scale and demonstrated to comply with the applicable engineering and quality standards. In this presentation we will describe the journey of a small NZ-based start-up company, and the development of the plastics-to-adhesives process. Results of prototypical fibre-board properties be presented, alongside NILO's future challenges.

Session 1.2: Circular Economy for Plastics and Recycling

Paper ID: S28-91

Characterization and recycling potential of partially cross-linked EVA-foam scrap for orthopaedic insole manufacturing

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Abstract

The shoe industry is significant due to its global market prospects, economic impact, and role in consumer behaviour. Footwear has evolved from a basic necessity to luxury, with consumers spending more on shoes than ever. Companies in the shoe industry increasingly focus on customized shoes to meet consumer demands for style, fit, and comfort, highlighting the sector's competitiveness and need for innovation. Comfort and durability are crucial for customized footwear, and that's where EVA soles come in Ethylene-vinyl acetate (EVA), is a lightweight, flexible, and shock-absorbent material that has revolutionized the shoe industry. This copolymer is commonly used as an expanded thermoplastic foam, and contains about 18 - 28% vinyl acetate (VA). The shoe industry generates significant waste, and a considerable proportion comprises poly[ethylene-co-vinyl acetate] (EVA). Unfortunately, there are no practical solutions for recycling or disposing of EVA waste because EVA foams are cross-linked to provide improved cushioning, shock absorption, and durability, ensuring that the material maintains its shape and performance under repeated impact and stress. This is essential for comfort and longevity in shoes. This research to be presented explores potential recycling solutions for EVA foams. This process involves analysing each ingredient (crosslinking agents and blowing agents) that goes into the foam formulation and thermal and mechanical characterisation. It is aimed to develop an innovative biobased EVA-foam containing high fractions of recycled EVA foam. Foam extrusion and compression moulding are the chosen processing methods to manufacture EVA-foam insoles.

Session 1.2: Foams and Membranes

Paper ID: S30-29

Multi-scale studies on CO_2 bubble nucleation mechanism at polymer/metal interface for material recycling

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Abstract

In this presentation, we describe the mechanisms of bubble nucleation and delamination at the polymer-metal interface based on multiscale simulations. First, we report bubble nucleation of CO2 gas in polymers near the glass transition temperature (Tg) by coarse-grained molecular dynamics simulation, which allows detailed visualization at the molecular scale. We then present the simulation of inhomogeneous nucleation using the phase field method and the simulation of delamination using the finite element method. Finally, these simulations are compared with experimental results and the mechanisms of bubble nucleation and delamination at the interface are summarized.

Keynote

Session 1.2: Foams and Membranes

Paper ID: S30-327

High Surface Area Polymer Gels For Oil-Water Separation

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Abstract

This work examines the functional dependence of efficiency of separation of oil-water emulsions on surfactant adsorption abilities of high surface area polymer gels. The work also develops understanding of the factors and steps that are involved in emulsion separation processes using polymer gels. The work considers four polymer gels offering different surface energy values, namely syndiotactic polystyrene (sPS), polyimide (PI), polyurea (PUA), and silica. The data reveals that surfactant adsorption abilities directly control the emulsion separation performance. The gels of sPS and PI destabilize the emulsions due to significant surfactant adsorption. The surfactant-lean oil droplets are then absorbed in the pores of sPS and PI gels due to preferential wettability of the oil phase. The PUA and silica gels are more hydrophilic and show lower surfactant adsorption ability. These gels cannot effectively remove the surfactant molecules from the emulsions leading to poor emulsion separation performance.

Session 1.2: Foams and Membranes

Paper ID: S08-28

A novel semi-continuous preparation mode of ultra-low density thermoplastic polyurethane foam

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Abstract

The production of elastomer foam commonly faces challenges like low production efficiency, limited controllability, uneven foaming, and inherent shrinkage characteristics, especially in manufacturing thick foam sheets. Addressing these, an innovative “semi-continuous foaming with ultra-low-pressure” (SFU) strategy that integrates low-temperature gas-locking, conduction-microwave heating, and N2-assisted gas-exchange was proposed, aimed at optimizing the entire process of TPU foam production, from manufacturing and storage to post-processing. The low-temperature air-locking approach ensures that saturated TPU can be stored or transported for extended periods before foaming, thereby enabling the semi-continuous production of TPU foam. The innovative heating method combined conduction and microwave (C-M) heating to ensure a uniform temperature increase and distribution within the TPU foam throughout the entire foaming process. The N2-assisted gas-exchange process involving N2 saturation and a secondary foam treatment using C-M heating effectively achieves anti-shrinkage properties of TPU foam, facilitating the creation of high expansion ratio foam.. SFU strategy offers the flexibility to adjust initial cell sizes (5–30 μm after shrinkage) and expansion ratios (1–24 times) by manipulating parameters such as microwave radiation time, power, and saturation time. Furthermore, the foam was prepared under ultra-low pressure (<7 MPa), resulting in a final expansion exceeding 14.2 times TPU thick sheet (5 mm thickness before foaming) foam with excellent resilience (energy loss coefficient ~ 10 % and ball resilience ~ 68.8 %). This study explores the mechanism by which TPU can self-absorb during microwave heating and extends this process to TPU materials with varying thicknesses (16.5 mm thickness before foaming) and chain compositions, as well as different types of elastomeric materials or materials with elastomer-like properties (e.g., PBAT, etc.).

Session 1.2: Foams and Membranes

Paper ID: S08-27

Green Preparation of Biodegradable Polyester Foams with Supercritical Fluid

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Abstract

The preparation of low-density biodegradable polyester foams with uniform fine cell morphology and dimensional stability is very challenging. The foaming behavior of biodegradable polyesters with different chain structures and different blends was investigated by using supercritical fluid as the blowing agent. The interactions between biodegradable polyesters and CO2, as well as the rheological properties of biodegradable polyesters, were explored. The effect of chain expansion and blending modification on foaming process was carefully studied. Then the key influence factors on cell morphology and shrinkage performance of foamed biodegradable polyesters were analyzed. Based on insights into the interaction between polymer and supercritical fluid, we carried out a series of explorations on suitable raw materials and additives. Introducing a suitable aromatic content obtained higher strength to improve the cell stability on the premise that the strong degradability can be maintained, which provides an effective strategy to prepare PBAT and PBST foams with good degradability and favorable mechanical properties. Combines the advantages of tunable molecular structure of in-situ copolymerization with the high efficiency of melt blending, it also provides an effective strategy for the preparation of biodegradable functionalized foams. These findings can serve as valuable insights for the large-scale production of lightweight biodegradable foams.

Keynote

Session 1.2: Modelling and Simulation
Paper ID: S33-64

Leibniz Collaborative Excellence Project ML4SIM: AI and Digital Material Characterization Revolutionize Composites Process Simulation

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Abstract

This presentation addresses the challenge in simulating fiber-reinforced polymer composites (FRPCs), where conventional finite element models struggle to capture the multiscale nature of FRPC manufacturing processes. These materials, which are essential in wind turbines and aircraft, present computational challenges due to the diverse physical phenomena occurring at different geometric scales. The traditional reliance on physical experiments for material characterization is time-consuming and costly, requiring extensive testing to determine parameters such as permeability and capillary pressure. A breakthrough approach integrates artificial intelligence (AI) with conventional numerical simulations to overcome these limitations. The Leibniz Collaborative Excellence funded project, "Machine Learning for Simulation Intelligence in Composite Process Design, (ML4SIM) K377/2021" aims to revolutionize process simulations by automating the generation of input data and developing data-driven surrogate models. These surrogates, trained on over 6500 simulated models, allow for the prediction of material properties with high accuracy. Two AI-based methods—feature-based and geometry-based neural networks—predict permeability with mean relative errors of 11.35% and 11.21%, respectively. A combined approach using these two methods further improves the accuracy to 8.33%. The AI-based methods are also used in a scale-bridging algorithm to determine the mesoscopic permeability. For this purpose, the local structure in meso-scale models is analyzed and the micro-scale permeability is determined on the basis of the derived properties using AI-based methods. These properties are then assigned to the meso-scale models prior to their

numerical permeability determination. The work also highlights the latest advances in physics-aware machine learning, and the development of a hybrid solver that aims to unite data-driven surrogates, conventional numerical solvers, and physics-informed neural networks into a single simulation framework operating across multiple scales.

Session 1.2: Modelling and Simulation

Paper ID: S33-87

Investigation the Influence of the Melt Rotation on the Fiber Orientation Variation in FRP Injection Molding Parts

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Abstract

In this study, two sets of four-cavity systems in one mold are utilized as a platform. One set is a balanced runner (BR) system and the other is a non-balanced runner (NBR) system. Those four-cavity systems have an ASTM D638 standard specimen with 63.5 mm x 9.53 mm x 3.5 mm in each cavity. Both CAE simulation (Moldex3D) and experiment (Arburg machine) are applied to conduct. The results show that the filling pattern of the simulation analysis are quite matched with that of experimental study for both BR and NBR systems. Furthermore, through observation and comparison of the geometric shrinkage changes of the injected parts, it can be found that the dimensional deformation of the injected parts in three directions (x, y, and z) of the NBR compared to BR system has a significant difference. Specifically, in the end of filling region (EFR), the difference in shrinkage changes in the flow direction of the injected part is not obvious, but that in the cross-flow and thickness directions is reduced. In addition, based on the same cavity (1C) for the BR and NBR systems, the melt rotation effect significantly reduces the shrinkage of the injected parts in both the cross-flow and thickness directions. These phenomena are enough to prove that the appearance of the melt rotation can effectively revise the dimensional shrinkage of the injection parts. Furthermore, the fiber orientation analyses of 1C cavity have been performed using CAE simulation for both BR and NBR systems. The results show that in the NBR system the orientation of fibers influenced by the melt rotation effect are quite different. Specifically, the fiber orientation tensor in flow direction (A11) exhibits an increasing trend. Conversely, the fiber orientation tensors in both of cross-flow (A22) and thickness directions (A33) demonstrate a decreasing trend. It can be speculated that the overturning of the melt causes changes in the flow field, which further changes the fiber orientation due to diminish the flow-fiber coupling effect, thereby reducing the upstream-to-downstream asymmetry of the injected parts in the cross-flow direction and thickness direction.

Session 1.2: Modelling and Simulation

Paper ID: S13-81

Identification of a kinetic model for thermal oxidation of stabilized polypropylene

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Abstract

Understanding the physicochemical aging of polymers is key for guaranteeing a proper design, use and recycling of a polymer-based component. This understanding should be translated into suitable simulation models, which account for aging processes. One modeling approach consists in considering the system of elementary reactions taking place in the material system. Those chemical reactions can be related to relevant material descriptors, which at the same time can be used to model a target material property. Under this framework, the evolution of the chemical reactions can describe the change of a given material property, i.e., the material aging. This work deals with the thermal oxidative aging of polypropylene (PP). Neat PP is extremely sensitive to thermal oxidation. For industrial applications, PP is standardly formulated with a stabilization package for extending its lifetime. During use-phase, the stabilizers are ideally consumed under thermal oxidative conditions, thereby hindering or slowing-down the degradation of the PP matrix. Parameters such as the initial concentration of the stabilizers present in a PP compound have an impact on the progression of aging. In this context, the aim of this work is to establish a method to identify these parameters and finally simulate the thermal oxidation of stabilized polypropylene. We propose a method based on analytical techniques combined with inverse analysis of the proposed kinetic model. The kinetic model covers phenolic and phosphite-based stabilization . We employ Differential Scanning Calorimetry, Liquid Chromatography – Mass Spectrometry, Inductively Coupled Plasma - Optical Emission Spectroscopy and Oxidative-Induction Time measurements on thin films (~150 μm) as experimental base for the identification. We discuss the strategy for the inverse analysis as well as the challenges related to the kinetic model, as for example, the determination of the initial concentration of hydroperoxide in the PP material.

Session 1.2: Modelling and Simulation

Paper ID: S33-73

Assessing solids conveying in injection moulding machines using coupled numerical simulations based on the Discrete Element Method (DEM) and Multibody Systems (MBS)

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Abstract

Design of single screw machines for polymer processing often focuses on the melt dominated areas of the screw. However, solids conveying is a key aspect for processes with high screw speeds, grooved feed sections, small screw diameters and material with low bulk density. In injection moulding, throughput limitations are relevant in packaging applications as due to low cooling times, dosing affects the cycle time. In addition, insufficient solids conveying is a primary cause for air residue in the melt and final product. Therefore, well-designed feed sections are required, especially as recycling processes with direct processing of regrind become more attractive. Due to the low pourability and bulk density, regrind intensifies intake issues, amplifying the importance of an accurate calculation of solids conveying. Existing models for injection moulding are based on analytical equations and do not allow for assessing new feed section and intake designs, adapted to high screw speeds or regrind. In this paper, numerical simulations based on the Discrete Element Method (DEM), previously used in the field of extrusion, are carried out. In order to replicate the cyclic rotation and translation of the screw, a coupled approach of DEM and Multibody Systems is pursued. To verify the accuracy of such coupled simulations, a special test rig is added to a conventional injection moulding machine. Pure solids conveying is investigated, as the DEM does not accommodate for large plastic deformations or melting. Different screws and intake designs as well as smooth and grooved barrels are investigated. Different resins, pellet shapes and regrind are processed, varying the processing parameters and comparing the results to the simulation. The coupled approach replicates the reality well in terms of dosing time and drive torque, confirming the DEM can be utilised to further investigate process phenomena and develop calculation models for solids conveying in injection moulding.

Session 1.2: Morphology and Structural Development
Paper ID: S14-181

Morphological understanding and Comparative Analysis of HDPE/Starch-Based Blends

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Abstract

The morphological analysis of mechanically recycled high density polyethylene (HDPE) and polypropylene (PP) blends is a key topic in recycling research [1], [2]. Our previous work [1] examined the effect of strong differences in melt flow index (MFI) on material properties. While compatibility is required, biopolymers, in particular starch, offer a sustainable alternative to mechanical recycling for plastic waste. Native starch, however, cannot be thermally processed [3], [4]. By adding a plasticizer, heating, and applying shear, starch undergoes gelatinization, creating thermoplastic starch (TPS) [4]. While TPS alone lacks mechanical strength, blending it with HDPE and adding a compatibilizer can enhance this. Building on our previous findings, HDPE with a low MFI was selected, to match the MFI of starch, enhancing the compatibility [1]. HDPE/starch blends are evaluated through a multi-phase approach. Firstly, HDPE is mixed with native starch up to 10 wt%. Secondly, starch is first gelatinized, then blended with HDPE up to 50 wt% TPS. In a final phase, a compatibilizer is added to the system. The morphological, thermal, and mechanical properties are assessed using polarized optical and scanning electron microscopy, differential scanning calorimetry, melt flow index, and tensile and impact testing. Mechanical testing indicates that gelatinization improves tensile strength, with a significant increase compared to blends with native starch. For elongation at break, the addition of a compatibilizer was unnecessary, as blends with TPS achieved optimal elongation, while blends with native starch were brittle. This trend aligns with morphological analysis. [1] A. Verberckmoes et al., Macromol Mater Eng, vol. (SCI-IF 2021: 4.367), 2023. [2] A. V. Van Belle et al., Polymers (Basel), vol. 12, no. 5, May 2020. [3] P. F. Muñoz-Gimena et al., In Polymers (Vol. 15, Issue 13). [4] T. Jiang et al., In Adv Ind and Engineering Polymer Research (Vol. 3, Issue 1, pp. 8-18).

Session 1.2: Morphology and Structural Development

Paper ID: S14-175

New Processing Methods and Applications for Fluorinated Polymer Functional Membranes

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Abstract

Fluorinated polymer materials, such as polytetrafluoroethylene (PTFE), polyvinylidene fluoride (PVDF), and polychlorotrifluoroethylene (PCTFE), are crucial for various industries due to their exceptional properties, including heat resistance, chemical corrosion resistance, low friction, low moisture absorption, and strong oxidation resistance. These materials play a crucial role in sectors such as energy conservation, environmental protection, information communication, aerospace, and high-end manufacturing. However, due to their high melting viscosity, traditional plastic processing methods are often unsuitable for most fluorinated polymers. As a result, various techniques are employed to process these polymers into the required film products. During this processing, precise control over the multi-level structure of the materials is very important. The film-forming processing involves complex scientific challenges, such as the evolution of crystal structure under multiple thermal-mechanical coupling conditions, the rheological behavior of solid particles and melts, molecular creep relaxation, and enhancement of surface interfaces. Focusing on the above problems, the multi-level structure, rheological properties, and the structure-property relationship of fluorinated polymers are systematically studied. Additionally, the mechanisms behind performance enhancement are extensively explored to address the challenges of achieving both high transmittance and high strength in PTFE microporous membranes, as well as balancing high particle filling with low dielectric loss in PTFE composite membranes. The goal is to enhance and develop new manufacturing technologies and principles for high-performance fluorinated polymer membranes. This research provides significant theoretical support for the development of key materials, such as fuel cell proton exchange membranes and high-frequency communication PCB semi-cured flakes.

Keynote

Session 1.2: Morphology and Structural Development

Paper ID: S14-133

Revisiting structure-property relations in PP/HDPE blends: From processing to performance with recycled polyolefins

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Abstract

The United Nations predicts that plastic waste could reach 23-37 million tonnes by 2040, with only 9% currently recycled. Around 60-70% of this waste consists of polyolefins such as LDPE, HDPE, LLDPE, and PP. These materials are challenging to separate due to their similar densities, leading to mixed PP/HDPE waste streams. Recycling these blends results in downgraded mechanical properties compared to virgin materials. While thermal and rheological characterizations of these blends have been partially addressed, the effects of impure material compositions on melting behavior and structure formation under controlled processing conditions are largely unexplored. Typically, only melt-state properties are considered, but these fail to account for the solid-to-melt transition. In this study, we demonstrate that the dominant heat source during this transition is plastic deformation, specifically from compression, with negligible contribution of shear. Heat generation is governed by the yield stress in the solid state, which varies between different polyolefins, complicating the recycling of mixed plastic waste and often leading to partial melting or degradation. Our investigation extends to thermal and rheological properties of controlled PP/HDPE blends, utilizing extended dilatometry to simulate near-processing conditions, including pressure and shear. Microstructural analysis through X-ray diffraction and mechanical testing reveals that under quiescent conditions, increasing polyethylene concentration reduces strength and elongation-at-break. However, under shear, polyethylene enhances the yield stress due to increased flow strength, especially when rapid melt solidification occurs, leading to more oriented polypropylene structures. This research advances the understanding of melting and crystallization behaviors in polyolefin blends, providing key insights for optimizing polymer recycling processes through precise control of processing conditions and blend composition.

Session 1.2: Morphology and Structural Development

Paper ID: S14-51

Smart materials processed by spatial-temporal programming of polymer crystalline structures

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Abstract

Most of polymer materials can be crystallized at suitable conditions and their physical properties (such as mechanical, optical properties, solvent responsiveness) can be tuned by altering the crystalline structures. Also, the diversified crystalline structures of polymers can be controlled by the post-processing conditions. Due to the high spatial-temporal selectivity of light, it is possible to achieve the spatial and temporal arrangements of various crystalline structures at the different scale levels by combining the methods such as photothermal effects and photo cross-linking. This provides potential ways for the functionalization of traditional crystalline polymers. In this work, we have controlled the regional crystalline phase structures of polymers by the light-triggered photothermal effects and thus prepared the shape morphing, self-evolvable, and self-stiffening polymer materials. First, we introduced the stable and metastable crystalline phases in isotactic polybutene-1 by using the photothermal effects, and the metastable-to-stable phase transition renders the polymer materials self-evolvable ability. Additionally, the melt-recrystallization process of polymers was spatially regulated by cross-linking density, and thus the shape morphing and self-stiffening materials was prepared. This study demonstrates that the spatial-temporal programming of polymer crystalline structures is an effective way to develop the new functional materials. References [1] Yuan, W., Yu, C., Xu, S., Ni, L., Xu, W., Shan, G., Bao, Y., Pan, P. Mater. Horiz. 2022, 9(2): 756. [2] Yuan, W., Xu, S., Yu, C., Ding, M., Zheng, Y., Zhou, J., Shan, G., Bao, Y., Pan, P. Chem. Eng. J. 2022, 446(4): 137346. [3] Ding, M., Yuan, W., Xu, S., Yu, C., Zheng, Y., Zhou, J., Shan, G., Bao, Y., Pan, P. ACS Macro Lett. 2022, 11(6): 739. [4] Zhang, X.; Zhou, Y. C.; Han, M. Z.; Zheng, Y.; Liu, J. F.; Bao, Y. Z.; Shan, G. R.; Yu, C. T.; Pan, P. J. Chem Bio Eng. 2024, Doi: 10.1021/cbe.4c00058

Session 1.2: Polymer Composites
Paper ID: S17-117

Thermoelectric materials based on carbon nanoparticles for the utilization of process waste heat during photocatalytic reactions

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Abstract

The EU project GlaS-A-Fuels aims to generate energy from the environment and from the photocatalytic reaction of bioethanol to bio-butanol and bio-hydrogen using optimised catalysts. It is therefore necessary to develop a highly efficient thermoelectric (TE) generator that will be incorporated into a special glass reactor for the energy harvesting during photocatalytic processes. For the development of the TE generator new materials based on carbon nanoparticles (CNPs) such as single-walled carbon nanotubes or graphene are studied. This work focuses on the investigation of thermoelectric properties, including electrical conductivity, Seebeck coefficient and the resulting power factor of CNP-based buckypapers or composite films. The impact of polymer and solvent selection as well as the processing procedure on the TE behaviour of the CNPs is demonstrated. The present study compares the polymer melt processing and solvent mixing procedures for different polymer materials. Furthermore, the influence of the solvents on the CNP-based buckypaper is demonstrated. Finally, the electrical and thermoelectric properties of these composites are subsequently analysed and compared. The target value is a high electrical conductivity of more than 100 S/m. For the development of p- and n-conductive materials, a Seebeck coefficient of around + 50 μV/K and - 50 μV/K is required. The efficiency of TE generators is also demonstrated using various designs and the influence of different material compositions is analysed. In addition, the first results of the post-glass melting encapsulation of the developed TE polymer composite inside typical inorganic oxide glass are presented. In this process, the functional layers of the TE element are feasibly integrated into a transparent 'soft' phosphate glass with a glass transition temperature of 192 °C. Thanks for the financial support of the EU Commission project GlaS-A-Fuels (Grant Agreement No. 101130717, HORIZON-EIC-2023-PATHFINDEROPEN-01)

Session 1.2: Polymer Composites

Paper ID: S17-140

Double-layer electromagnetic interference shielding materials with microcellular structure for low reflection

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Abstract

With the rapid advancement of information and communication technologies, electromagnetic (EM) pollution has become a major issue affecting both human health and the operation of precision electronic devices. Therefore, the development of efficient, broadband, lightweight shielding materials with an emphasis on electromagnetic wave absorption is of great significance. Traditional single-layer material designs face challenges such as limited absorption potential and issues of reflective pollution. To address the issues, we constructed a double-layer composite structure consisting of a microcellular CNT/CIP/PVDF absorption layer and a highly conductive solid CNT/PVDF (20/80) layer. By controlling the composition of CNT/CIP and void fraction (VF) using supercritical CO2 foaming, the impedance and the EM attenuation capability of the absorption layer was effectively adjusted. A maximum reflection loss of -60.0 dB and an effective absorption bandwidth of 3.44 GHz was obtained for CNT/CIP/PVDF (5/10/75) at 75% VF. Furthermore, we demonstrated that, with the combination of the absorption layer and the shielding layer, an average total shielding effectiveness (SE) of 41.75 dB across the X-band with an average reflectivity (R) of 0.12 was achieved at the total composite thickness of just 3 mm. The excellent absorption-dominated EMI shielding performance is attributed to the multi-scale structure (nanoscale MWCNT, microscale CIP, and microporous structures), polarization effects at the interfaces between different materials, dielectric loss induced by the pores, and multiple scattering within the structure extending the path. Overall, the double-layer design allowed for the decouple of impedance match, attenuation, and shielding, resulting in a “absorption-reflection-reabsorption” pathway to dissipate EM energy. The lightweight double-layer EMI shielding composite with excellent shielding efficiency and low reflection characteristics presents a promising strategy for the dev

Session 1.2: Polymer Composites

Paper ID: S37-96

Mechanical Recycling Strategies for Waste Sandwich Panels with Glass Fiber-Reinforced Polypropylene Outer Layers: Process Optimization and Fiber Length Preservation

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Abstract

The increasing use of glass fiber-reinforced polypropylene in sandwich panels has created significant production and end-of-life waste, which requires efficient recycling strategies. This study aims to develop a process chain for recycling waste sandwich panels into fiber-reinforced pellets for injection molding, focusing on maintaining fiber length to enhance mechanical properties. The initial step involves cutting and shredding the panels, followed by processability assessment and definition of boundary conditions for size reduction. Recycled pellets are produced through twin-screw extrusion, with variations in input flake size, screw speed, and processing temperature based on a design-of-experiments approach. Fiber length and energy consumption are measured at each step to determine optimal processing conditions. The recycled pellets are then molded into test specimens and the effect of fiber length, back pressure, and screw speed on the mechanical properties is evaluated. The results highlight key correlations between processing parameters and fiber length and provide insights for improving the recycling of fiber-reinforced thermoplastics in lightweight construction applications.

Session 1.2: Polymer Composites

Paper ID: S37-84

Boosting Flame Retardancy of Polyolefin/CaCO3 composites reinforced with Halogen-Free Flame Retardants for Construction Materials

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Abstract

Polyvinyl chloride (PVC) is the most widely applied in the construction industry (flooring and pipes). However, PVC use is restricted because of environmental concerns involving volatile organic compounds (VOCs) used in PVC as additives. Thus, polyolefins such as polypropylene and polyethylene, are being explored as substitutes for PVC, i.e., in pipes and flooring production. These polymers are easy to process, and they have relatively high mechanical properties, great recyclability, and low cost, which make them an excellent alternate material. However, one of the principal concerns in the construction industry is flammability, which very often limits wider application in this industry. In this study, to reduce flammability of these polymers, the halogen-free flame retardants such as zinc borate, magnesium hydroxide, and intumescent flame-retardant melamine polyphosphate were added to polypropylene/ and polyethylene/calcium carbonate composites. Additional properties such as thermal, morphological, and mechanical of thermoplastic polymers based on calcium carbonate composites reinforced with halogen-free flame retardants were also investigated. Two approaches were considered in this work. Firstly, we developed polypropylene/calcium carbonate (50 wt.%) materials containing 5 and 10 wt.% of zinc borate and magnesium hydroxide with the aim to obtain the optimum formulation with enhanced properties to be used in fabrication of sheet materials for flooring application. The second approach explored recycled linear low density polyethylene (rLLDPE)/calcium carbonate (10 wt.%) materials containing 5 and 10 wt.% of zinc borate and melamine polyphosphate (MPP) to be applied in fabrication of flame retardant pipes. The results demonstrated enhanced thermal stability, flame retardancy with increased of higher char content, leading to significant increases in the Limiting Oxygen Index (LOI) value.

Keynote

Session 1.2: Polymer Composites

Paper ID: S37-7

Empowering Polymers with Multifunctionality: The Role of Graphene Nanoplatelets in Advanced Nanocomposites

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Abstract

Initially isolated from graphite by Geim and Novoselov in 2004, graphene is composed of a single layer of sp2-hybridized carbon atoms configured in a hexagonal lattice. When oxidized through potent oxidizing agents and acids, the resultant graphene oxide becomes an electrical insulator but can regain conductive properties upon reduction. Few-layer graphene can be classified as graphene nanoplatelets (GNPs), each with a thickness below 10 nm. Unlike GNPs, graphene nanosheets possess larger lateral dimensions and are generally less preferred in polymer processing for two reasons: they present challenges in dispersion within polymer matrices, and their large dimensions are not fully exploitable for enhancing mechanical properties. Over the last five decades, polymers have surpassed metals and ceramics in industrial applications due to their superior specific strength and cost-effectiveness. Despite these advantages, polymers often suffer from inadequate stiffness and multi-functionality, such as electrical conductivity. Although carbon nanotubes and silicates have been extensively explored to mitigate these limitations, graphene stands as a more potent alternative, offering exceptional mechanical, electrical, and thermal properties. Jun Ma's research team has been pioneering the utilization of GNPs since 2008 for the processing of various polymers, including epoxy, elastomers, and conductive polymers, resulting in nanocomposites with enhanced mechanical strength, electrical and thermal conductivity, fire resistance, and other functionalities. Recent innovations focus on solvent-free methods for synthesizing polymer/GNP composites.

Keynote

Session 1.3: Additive manufacturing
Paper ID: S22-420

Design automation of 3D printed polymer products

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Abstract

The recent advent of computational design software has created opportunities that give users the ability to automate the design of complex products. If these software technologies are combined with good design for additive manufacturing practices, it can become a tremendous catalyst for increased innovation. This talk attempts to impart some practical guidance on how to design parts and use automated design software to gain the maximum benefit from what AM can offer. Additive manufacturing (AM) is one of the most expensive manufacturing methods in the known universe. Therefore, for it to be commercially viable for production applications, it must add enough value to overcome those high costs. This talk will focus on the main factors that affect AM cost and how to design around these so that they can be transformed into value adding features. It will demonstrate how, with automated product design and good design for AM (DfAM) practices, AM can be transformed from a slow and expensive technology into one that can transform products into success stories. It will present numerous real-world examples of how AM can be used to add significant value to products. This includes products in aeronautical and transport applications, prosthetics and healthcare, heat exchangers, and artistic applications.

Session 1.3: Additive manufacturing

Paper ID: S21-299

Isotropic cellular structure design strategies based on triply periodic minimal surfaces

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Abstract

Isotropy is a desired characteristic in cellular structures for load bearing and energy absorption applications that must respond uniformly under external loads in all orientations. Triply periodic minimal surface (TPMS) cellular structures are attracting much attention for such applications due to their demonstrated high performance, tailorable properties, and open cell architecture. However, TPMS structures usually display stiffness anisotropy. In this work, new design strategies are presented for isotropic TPMS-based cellular structures, revealing a large available design space in terms of relative density and relative stiffness. The first design strategy arranges TPMS-based cells in a Simple-Cubic/Face-Centred Cubic inspired pattern, resulting in reduced elastic anisotropy. Two parametric optimisation approaches involving level-set mid-surface offsetting and the functional grading of relative density are then applied in a second step to eliminate any residual elastic anisotropy. Anisotropy is characterised through finite element analysis using the Zener ratio. Four families of cells are optimised, each based on a different TPMS unit cell, and then additively manufactured using the material extrusion process with polylactic acid. Finally, experimental quasi-static compressive tests are conducted to characterise stiffness, strength, and energy absorption properties. Optimised designs are tested in three crystal orientations ([001], [101] and [111]) and manufactured in three orthogonal print orientations. The Primitive TPMS-based design is the stiffest of the four designs reaching 64.4% of the Hashin-Shtrikman upper bound of bulk modulus at 20% relative density. Experimental results validate all four optimised cell designs for elastic isotropy and indicate that all the cell designs are also isotropic in terms of crushing strength and energy absorption.

Session 1.3: Additive manufacturing

Paper ID: S01-129

Organic Neuromorphic Transistors Fabricated by Direct-Ink-Writing

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Abstract

Organic electrochemical transistors (OECTs) are widely studied as neuromorphic devices due to the hybrid ionic/electronic conduction capability which can mimic the working mechanism of synapses. Traditional OECT fabrication techniques, such as photolithography, are costly, material-restrictive, and lack the ability to create three-dimensional (3D) architectures, thus limiting the development of OECTs. Direct-ink-writing (DIW) presents a versatile and cost-effective alternative for fabricating OECTs with complex geometries. However, few studies have been carried out to control the rheological properties of the ink and thus achieve desired channel architecture which is essential in modulating transconductance and ion retention. In this study, we developed a polymer electrolyte-modified poly(3,4-ethylenedioxythiophene):poly styrene sulfonate (PEDOT:PSS) ink for fabrication of OECT channels. The ink demonstrated a storage modulus six times higher and a thixotropy index three times greater than unmodified inks, ensuring improved printing shape fidelity. This allowed the facile fabrication of neuromorphic OECTs with channel thicknesses exceeding 10 μm, significantly greater than those fabricated with 2D patterning techniques, which are typically on the nanometer scale. Despite PEDOT:PSS comprising only 50 wt% of the channel film, our DIW-fabricated OECTs exhibited performance comparable with conventionally fabricated devices, achieving normalized transconductance (G) of up to 2.45 mS μm^{-1} at low voltage (Vg = 0.6V) and a μC* of 38.32 F $cm^{-1}V^{-1}s^{-1}$. Additionally, the devices demonstrated advanced synaptic functionalities, including dynamic filtering, sensory adaptation, long-term plasticity, and stable long-term depression and potentiation behaviors. With the development of novel DIW-compatible inks and their capability to fabricate complex structures, DIW-fabricated OECTs are well-positioned to advance the next generation of 3D-integrated neuromorphic transistors.

Session 1.3: Additive manufacturing

Paper ID: S01-106

Influence of Filler Type and Volume Fraction on the Electrical Conductivity and Shore Hardness of TPU Composites in Fused Filament Fabrication

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Abstract

Thermoplastic polyurethane (TPU), known for its flexible properties, is typically non-conductive, limiting its use in electrical applications. To address this, conductive fillers, such as spherical metallic and plate-like mineral fillers, can be compounded into the TPU matrix. This study examines the influence of filler type and volume fraction on the electrical conductivity and Shore hardness of TPU composites produced via Fused Filament Fabrication (FFF). The research focuses on how these fillers affect both the electrical conductivity and Shore hardness of printed samples. The addition of conductive fillers aims to improve the electrical properties of the material, making it suitable for applications requiring sufficient electrical conductivity to safely dissipate Electrostatic Discharge (ESD). However, the mechanical properties, particularly hardness and flexibility, are also influenced by the type and amount of filler. Varying the filler volume fraction allows optimization of the balance between conductivity and hardness. Using a lab-scale twin-screw extruder, TPU-based compounds were produced. Two matrix materials were combined with the fillers at different volume fractions. These compounds were processed into test specimens via FFF. Electrical conductivity was measured using both low- and high-resistance methods, including four-point probe measurements for low-resistance materials and ring electrode measurements for high-resistance samples, where both volume and surface conductivities were assessed. Shore hardness tests were conducted to evaluate the mechanical properties of each compound. The results demonstrate a positive correlation between the filler volume fraction and electrical conductivity, with a notable improvement in volume conductivity as the filler content increases. In contrast, the influence on Shore hardness is less pronounced, though a slight increase in hardness is observed.

Keynote

Session 1.3: Circular Economy for Plastics and Recycling
Paper ID: S26-289

Enhancing Plastic Waste Compatibilization: Universal dynamic crosslinkers for optimized recycling

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Abstract

The mounting plastic waste crisis demands innovative recycling solutions, particularly ones that address the fundamental incompatibility between different plastic types, which often compromises the integrity of recycled materials. This project introduces a proof of concept for universal dynamic crosslinkers (UDCs) designed to improve compatibility and stability across incompatible polymers. These UDCs create reversible bonds within diverse plastics, thereby reducing phase separation and enhancing critical material properties such as processability, mechanical properties, and thermal stability. We explore compatibilization and thermal stability studies on model polymer systems and plastic waste recovered from the automotive industry to provide evidence of how dynamic crosslinkers serve as a universal approach for adding plastic waste and ensuring that these bonds between these polymers enhance long-term thermomechanical stability as these materials undergo reprocessing and recycling, all in the presence of impurities. Each crosslinker chemistry interacts uniquely with different polymers, influencing key characteristics such as rheological, viscoelastic, and thermal responses, as evidenced in our compatibilization studies involving amorphous and semicrystalline polymer blends.

Session 1.3: Circular Economy for Plastics and Recycling

Paper ID: S26-206

Mild chemical recycling of fiber reinforced epoxy composites and utilization of the recyclate for preparation of new composites

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Abstract

Owing to their remarkable overall performance, glass and carbon fiber reinforced polymer (GFRP & CFRP) composites have gained widespread adoption across various industries. However, their inherent stability, stemming from the crosslinked structures of thermoset polymers which account for more than 80% of matrix resins used in FRPs, poses a significant challenge in managing the growing volume of FRP waste generated from both manufacturing scrap and end-of-life products. Consequently, there is a pressing need for an eco-friendly upcycling method that effectively recovers and reuses both the valuable fibers and the polymer matrix from FRP waste. This study presents a novel approach for upcycling FRP waste based on amine cured epoxy matraces under mild reaction conditions. Decomposition of amine cured epoxy matrix took place effectively in an aqueous 20% zinc acetate solution at a moderate temperature of 250 °C. Addition of acetic acid further improved the efficiency and lowering the reaction temperature, resulting in complete decomposition of the matrix resin. The resulting decomposed matrix polymer (DMP) is insoluble in the aqueous reaction medium, facilitating the effortless recovery of the catalyst solution, DMP, and fibers. In one case, chemically recycled GFRP without separation of fiber and DMP was used to blend with thermoplastics (PA6, PP and PE) to produce quality fiber reinforced thermoplastic composites. In another case, DMP was employed to transform conventional epoxy resins into recyclable epoxy vitrimers which was used as the matrix for recovered carbon fibers. The new composites prepared this way can be hydrothermally recycled. This work showcases a novel strategy for achieving a circular economy within the FRP industry.

Session 1.3: Circular Economy for Plastics and Recycling

Paper ID: S04-141

Innovative Processes to Improve Polymer Properties - From Mechanical Recycling to Virgin Product Production

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Abstract

From 2020 to 2024, a research team led by Fukuoka University conducted innovative mechanical recycling research. Based on the “Physical Degradation and Physical Regeneration Theory”, the team developed various processes to control the number of entanglements during molding, and found that the physical properties of recycled plastic can be dramatically improved. This process can also be applied to improving the physical properties of plastic products made from virgin materials, and can realize not only durability of plastic products but also multi-recycling.

Session 1.3: Circular Economy for Plastics and Recycling

Paper ID: S04-132

Breaking the Unbreakable Bond: Towards Adhesives' Sustainable Future

Jarach Natanel (1), Avshalomov Rachel (1), Sasson Tair (1), Kenig Samuel (1), Dodiuk Hanna (1)*, Dodiuk Hanna (1)*

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Abstract

Thermoset adhesives, such as epoxies, polyurethanes, and silicones, offer high mechanical properties and exhibit relatively high chemical and thermal resistance. However, thermosets are infusible and insoluble and cannot be removed or reused without damaging the substrate. Consequently, there is a need for thermoset adhesives that can be debonded on demand. One potential solution is to incorporate reversible and\ or dynamic bonds into the adhesives, turning them into covalent adaptable networks (CANs) or vitrimers. These polymers can fully dissociate or soften under specific stimuli, making them promising candidates for addressing the need for debonding/reuse capabilities and sustainability. Our group has studied several dynamic and reversible bonds systems that can be used in adhesives. The first encompasses the reaction between boric acid and alcohol moieties based on polysaccharides and reactive plasticizers like glycerol, forming boronate esters, which are pH responsive. The second is based on thiol-disulfide bonding-debonding by radiation and heat, respectively. In this lecture, our main results will be presented, demonstrating the potential of this approach for sustainable circular economy in adhesives and matrices for fiber composites. References (1) Jarach, N.; Golani, D.; Naveh, N.; Dodiuk, H.; Kenig, S. Thermosets Based on Reversible Covalent Bonds (Vitrimers). In Handbook of Thermoset Plastics; Dodiuk, H., Ed.; Elsevier, 2021; pp 757–800. (2) Jarach, N.; Dodiuk, H. Debondable, Recyclable and/or Biodegradable Naturally Based Adhesives. In Biobased Adhesives: Sources, Characteristics and Applications; Dunky, M., Mittal, K. L., Eds.; Scrivener Publishing LLC, Wiley, 2023; pp 427–462. (3) Avshalomov, R.; Jarach, N.; Dodiuk, H. Breaking the Unbreakable Bond: Towards Sustainable Adhesives' Future. Eur. Polym. J. 2024, 209 (February), 112920.

Session 1.3: Circular Economy for Plastics and Recycling

Paper ID: S04-132

Breaking the Unbreakable Bond: Towards Adhesives' Sustainable Future

Jarach Natanel (1), Avshalomov Rachel (1), Sasson Tair (1), Kenig Samuel (1),
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Abstract

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Session 1.3: Fibres and Films

Paper ID: S07-222

Passive Daytime Radiative Cooling film based on Sustainable biomaterial composites

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Abstract

The utilization of chlorofluorocarbons (CFC) in cooling systems and air conditioners causes ozone depletion and contributes to rising global temperatures. Sustainability cooling technologies such as passive daytime radiative cooling (PDRC) are a good demonstration of eco-friendly cooling systems due to zero energy consumption, environmentally friendly, low maintenance, and cost-effective. Typically, PDRC film consists of polymeric material as a substance combined with reflective and emissive particles, including metal oxide nanoparticles like titanium dioxide (TiO2) or zinc oxide (ZnO). In this work, the films were fabricated employing low-density polyethylene (LDPE) and polydimethylsiloxane (PDMS) as substance parts with modified microcrystalline bacterial cellulose (MCBC) with TiO2 and ZnO to nanoparticles. The incorporation of metal nanoparticles improved solar reflectivity and thermal emissivity, enhancing the cooling performance of the PDRC films. The surface temperature decreased by 3.7ºC due to combining TiO2, ZnO, and MCBC composites with LDPE. Additionally, the MCBC composite increased the tensile strength by 80% compared to pristine PDMS. These results highlight the potential of this eco-friendly cooling technology for energy-efficient applications and climate-resilient agricultural practices.

Session 1.3: Fibres and Films

Paper ID: S07-195

Efficient circularly polarized luminescence with dual-sided opposite chirality of polar liquid crystal template-induced perovskite nanofiber composites

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Abstract

The circularly polarized luminescence (CPL) containing chiral feature is regarded as an essential component of advanced visual perception and hold significant applications in fields of information encryption and anti-counterfeiting security. The CPL emission of lead halide perovskites（LHPs）have attracted considerable attention due to their excellent optical properties. Chiral liquid crystal (LC) template induction has been demonstrated as an effective approach to achieving efficient CPL in LHPs. However, due to the inherent environmental instability of LHP, it can currently only be assembled with a few non-polar LCs through quantum dot doping or layer by layer stacking, resulting in immutable photonic bandgaps (PBG) and a single CPL emission mode. Herein, a method of in-situ self-assembly of chiral LCs on the surface of perovskite nanofibers was presented, achieving a high dissymmetry factor (glum) of CPL of 1.1. Encapsulation of perovskite nanocrystals (PNCs) with a polymer matrix effectively isolates the polar LC environment, while the porous structure of the fibrous membrane facilitates the in-situ self-assembly of nanoparticles. Based on the integrated heterostructure formed by nanoparticle self-assembly, the composite exhibits CPL with dual-sided opposite chirality, alongside tunable PBG and mechanical properties. Anti-counterfeiting application is demonstrated on various substrates by exploiting multimode optical characteristics of the created composites. The developed multimodal polarized luminescence strategy provides a platform for the advancement of chiral functional materials and optical encryption devices.

Session 1.3: Fibres and Films

Paper ID: S07-196

Enhanced Hydrogen Spillover on Oriented PEDOT:PSS Fibers for Highly Sensitive Detection of H2 Mixed CO via Tunable Adsorption Sites

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Abstract

Hydrogen (H2) is considered a key component of future green energy solutions. However, its production and utilization are often accompanied by carbon monoxide (CO), making the development of sensors that not only exhibit high sensitivity to pure H2 but also can accurately quantify the individual components in H2 and CO mixtures crucial. Owing to the similar chemical and adsorption kinetics properties of H2 and CO, the adsorption of these gas molecules onto sensing materials, along with the subsequent charge transfer, results in similar electrical signal responses. This similarity makes quantifying individual components in gas mixtures extremely challenging for conventional chemiresistive gas sensors, which rely on single-signal outputs. In this study, we developed a highly oriented PEDOT:PSS/PEO fiber structure loaded with Pt for enhanced hydrogen spillover, achieving excellent H_2 responsivity at room temperature (Rs ~100% @ 800 ppm H2) and an ultralow detection limit (~75 ppb). Furthermore, by leveraging the competitive adsorption of CO and H2 at adsorption sites, the sensor exhibited not only direct differences in the signal amplitude across various CO concentrations but also significant differences in the adsorption kinetics, which allowed precise extraction of the kinetic time constant τ. By constructing a standardized map correlating the gas mixture concentration and ratio with τ, we accurately quantified individual components in H2 and CO mixtures. This work demonstrates a significant advancement in gas sensing technology by enabling simultaneous detection and quantification of H2 and CO in mixed gases, providing a new pathway for expanding the dimensionality of the signal output of resistive gas sensors.

Keynote

Session 1.3: Fibres and Films

Paper ID: S07-65

Bio-mimic hydrogel fiber: Design of Spinning process and Construction of high performance

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Abstract

Hydrogel fibers have attracted substantial interest for application in flexible electronics due to their ionic conductivity, high specific surface area, and ease of constructing multidimensional structures. However, universal continuous spinning methods for hydrogel fibers are yet lacking. Based on the hydrophobic mold induced regional heterogeneous polymerization, a universal self-lubricating spinning (SLS) strategy for the continuous fabrication of hydrogel fibers from monomers is developed. The obtained W-PAMAA/Fe3+ hydrogel fiber exhibited excellent mechanical properties (tensile stress > 4 MPa, tensile strain > 400%) even after 120 days of swelling in the pH of 3–9. For the more, Inspired by the multilevel adjustment of spider silk network structure by ions, bionic hydrogel fibers with elaborated ionic crosslinking and crystalline domains are constructed. Bionic hydrogel fibers show a toughness of 162.25 ± 21.99 megajoules per cubic meter, comparable to that of spider silks. The demonstrated bionic structural engineering strategy can be generalized to other polymers and inorganic salts for fabricating hydrogel fibers with broadly tunable mechanical properties. In addition, the introduction of inorganic salt/glycerol/water ternary solvent during constructing bionic structures endows hydrogel fibers with anti-freezing, water retention, and self-regeneration properties. This work provides ideas to fabricate hydrogel fibers with high mechanical properties and stability for flexible electronics.

Keynote

Session 1.3: Foams and Membranes
Paper ID: S08-447

Advancing Polyimide Aerogels for Energy and Thermal Management Applications with AI-Enhanced Design

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Abstract

Polyimide (PI) aerogels represent a versatile class of advanced materials with exceptional thermal insulation, mechanical flexibility, and lightweight properties, making them ideal for applications in microelectronics, aerospace, thermal management and energy sector. These aerogels exhibit ultralow thermal conductivity (as low as 19 mW/m.K), high service temperatures (over 550 °C), and customizable properties through structural and chemical modifications. Recent advancements include thin-film PI aerogels with controlled thickness and enhanced drapability, aerogel fiber bundles for improved mechanical robustness, and aerogel composites incorporating additives such as carbon nanotubes (CNTs) and graphene nanoplatelets (GNPs) for superior electrical conductivity and dimensional stability. Innovative fabrication techniques, such as sol-gel processing and supercritical drying, enable scalable production of these multifunctional materials with tailored nanostructures. Demonstrating excellent flexibility, ultralow density (below 0.1 g/cm^3), and high specific surface areas, these PI aerogels address critical challenges in thermal management, structural integrity, and energy efficiency, opening pathways for their integration into next-generation electronic devices, aerospace systems, and energy storage solutions. Emerging artificial intelligence (AI) techniques are further revolutionizing the development of aerogels by optimizing the synthesis process and accelerating the discovery of novel formulations. By leveraging machine learning (ML) algorithms, it is possible to predict the effects of compositional and process parameters on aerogel properties, enabling rapid screening of potential candidates with desired characteristics. AI-driven approaches are particularly promising for designing aerogels with reduced thermal conductivity, enhanced mechanical flexibility, or targeted dielectric properties. These tools not only facilitate the identification of optimal solvent systems, crosslinking agents, and nanofillers but also contribute to sustainable materials development by minimizing experimental waste and energy consumption. The integration of AI into aerogel research paves the way for the creation of next-generation materials tailored for increasingly complex and demanding applications.

Session 1.3: Foams and Membranes

Paper ID: S08-223

Phosphorylated Bacterial Cellulose-Poly(vinyl alcohol) Membrane for Enhanced Water Purification with High Efficiency Methylene Blue Adsorption

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Abstract

Bacterial cellulose (BC)/polyvinyl alcohol (PVA) composite membranes were modified using a diammonium phosphate (DAP) solution to enhance the capability to remove methylene blue (MB) from wastewater. Bacterial cellulose was extracted from nata de coco waste and the formation of composite membranes was achieved by casting aqueous mixtures containing the BC and PVA in a concentration of 1.5% w/w related to the BC. The membranes were then phosphorylated with DAP solutions, whose concentration was varied from 0.05 to 0.3 M to investigate the influence of the charge density on the adsorption capacity. The morphology, chemical structure, crystallography, and thermal degradation of the composite membranes were investigated. The phosphorylation reduced the thermal stability, which is lower than that of the unmodified membrane, and improved the MB adsorption capacity from 1057 to 1932 mg/g on account of chemisorption with monolayer and multilayer adsorption behaviors. Desorption and regeneration experiments confirm the high reusability of the membranes over 3 times of testing and low MB leakage during the regeneration process.

Session 1.3: Foams and Membranes

Paper ID: S08-167

Microcellular foaming of high-hardness TPU/MOF nanocomposites through combined heterogeneous nucleation and gas enrichment effects

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Abstract

High-hardness thermoplastic polyurethane (HD-TPU) are utilized in advanced engineering applications due to their superior strength, flexibility, and abrasion resistance. However, the high content of hard segments reduced the gas solubility, making it difficult to generate uniform microcellular foams. In this study, the metal-organic framework (MOF) zeolitic imidazolate framework-8 (ZIF-8) was employed as both a heterogeneous nucleating agent and a gas enrichment “nano-reservoir” to enhance HD-TPU foamability. Dopamine modification was applied to greatly improve ZIF-8 dispersion in HD-TPU. ZIF-8 significantly enhanced the CO2 solubility in the TPU/MOF composites. The dual effects of MOF facilitate the preparation of microcellular HD-TPU/ZIF-8 foams with uniform cell size distribution after low-pressure saturation (3-5 MPa). Cell density and expansion ratio were increased by 50 and 1.5 times, respectively. The cyclic compression performance of HD-TPU/ZIF-8 foams was significantly enhanced. This study presents a novel method for preparing high-performance HD-TPU microcellular foams by introducing porous nanoparticles.

Session 1.3: Foams and Membranes

Paper ID: S08-121

The Effects of Ultra High Molecular Weight and CO2 Solubility on the Structure of PMMA Nanocellular Foam

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Abstract

Nanocellular foam has received much interest recently due to its superior properties to microcellular foams. Previous studies have shown that molecular weight and carbon dioxide (CO2) solubility are critical factors in obtaining nanocellular foams from commercial-grade polymers. It has been believed that a solubility exceeding 30 wt% is key to generating a nanocellular PMMA foam. This study demonstrated the production of nanocellular foams from reagent-grade PMMA at a significantly lower solubility under moderate saturation conditions (13.8 MPa and 20°C). Experiments with reagent-grade PMMA of 136 kg/mol weight-average molecular weight showed that nanocellular PMMA with an average cell size of 140 nm and cell density of 1.72×1015 cells/cm3 could be successfully fabricated at a CO2 solubility of 25.89 wt%. The glass transition temperature of CO2-saturated PMMA (Tg-mix) was significantly lowered due to the plasticizing effect of CO2. Interestingly, various prediction models for Tg-mix exhibited different degrees of accuracy when applied to reagent-grade versus commercial-grade PMMAs, highlighting the complex interplay between polymer grade, CO2 solubility, and foam formation dynamics.

Session 1.3: Injection moulding

Paper ID: S11-179

Cavity balance improvement via automated gate location and flow leader optimization

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Abstract

Better injection moulded part quality can be achieved with a balanced cavity. However, improving cavity balance for complex moulds is often a challenging task. The designer must consider a wide range of possibilities, including common design changes such as gate location and cavity geometry. With the goal of helping designers reduce overall flow resistance within the cavity, two simulation methods were developed: one for automatically repositioning gates and another for adjusting cavity thickness distribution via flow leaders. The gate location method is based on the response surface methodology (RSM) described in Porcher, F. et al. (2024) while the flow leader generation method is inspired by the work of Lam, Y. and Seow L. W. (2000). To validate both methods, an injection moulding tool for a demonstrator part was manufactured and experiments were performed. Two different gate locations were selected for the experiments. The locations selected were the best and worst gate locations resulting from the RSM metamodel, respectively. For each gate location, we manufactured one unmodified cavity as reference and one cavity with flow leaders generated with our simulation method, thus totalling four mould cavities. The results show a significant improvement in cavity balancing with the added benefit of a substantial reduction in the maximum injection pressure. Porcher, F., Gruber, G. F., Borger, P., Piotrowski, B., Rohnstock, F. and Auhl, D. W. (2024) 'Simulation-based optimization approach for the gate location optimization of injection molded plastic parts', PROCEEDINGS OF THE 38TH INTERNATIONAL CONFERENCE OF THE POLYMER PROCESSING SOCIETY (PPS-38). St. Gallen, Switzerland, 22-26 May 2023, AIP Publishing, p. 110004. Lam, Y. and Seow L. W. (2000) Cavity balance for plastic injection molding, Polymer Engineering and Science, 40, 6, 1273-1280.

Keynote

Session 1.3: Injection moulding

Paper ID: S11-169

Comprehensive Cause Analysis of Injection Molding Anomaly by Integrated Capacitance-Pressure-Temperature Sensor

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Abstract

Batch-to-batch variations in injection molding product quality arise not only from fluctuations in manufacturing conditions but also from material inconsistencies. In-mold sensors play a critical role in detecting these process anomalies and identifying their root causes. However, conventional in-mold sensors typically focus on measuring cavity conditions (such as pressure and temperature) rather than the intrinsic properties of the materials, making it challenging to distinguish between changes in material composition and variations in mold conditions. This gap can be addressed with a capacitance sensor capable of characterizing the dielectric properties of in-mold materials in real time, thereby monitoring their status throughout the molding process. In this work, an integrated capacitance-pressure-temperature(C-P-T) sensing probe is proposed for comprehensive identification of injection molding anomalies. Initially, we obtained and interpreted the capacitance signals from injection molding experiments, demonstrating how these signals reflect changes in material status within the mold. Subsequently, molding experiments with various process fluctuations, including variations in injection/packing pressure, mold/melt temperature, and material impurities etc., were conducted using the integrated C-P-T sensor. The results reveal that by analyzing the variation patterns of C-P-T signals at different stages, people can effectively identify the source of anomalies — whether they arise from pressure, temperature, or material variations. In addition, it was found that analyzing the capacitance and pressure signals together (specifically, detecting the abnormal correlation between capacitance and pressure integral) allows for the identification of injection molding part flash and check ring leakage.

Session 1.3: Injection moulding

Paper ID: S11-16

Transfer learning to predict part quality for injection molding

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Abstract

Polymeric materials are known for being cost-effective, lightweight, and easy to process. Utilizing injection molding technology, these materials can be mass-produced into complex geometric products. While virtual quality measurement systems are effective in preventing defects, they often fall short when applied to recycled polymers. Recycling is essential for sustainable production, but it can significantly alter material properties. To address this challenge, we propose leveraging transfer learning (TL) to adapt quality models originally developed for virgin materials to recycled materials. Key features from cavity pressure sensor data were extracted as quality indices, and a neural network was trained to predict part weight and geometric dimensions. TL was then employed to fine-tune this pretrained model using data from recycled materials. This approach requires minimal data collection and could substantially lower the costs associated with improving quality when using recycled materials. Our findings confirm that TL is highly effective in predicting the quality of injection-molded products made from recycled materials, offering superior predictive accuracy and reduced training time compared to conventional methods. The proposed process could significantly reduce the costs of implementing process quality inspection systems, thereby encouraging the adoption of recycled materials. In addition, new molds typically require a trial molding process before they are deployed to production machines. However, variations in machine performance make it difficult to maintain consistent molding quality, necessitating adjustments to machine parameters to account for these differences. Thus, cross-machine product quality prediction is crucial for accurately forecasting product quality across different machines within a manufacturing process, ensuring consistent quality, minimal defects, and optimized production. To enhance production efficiency and avoid the substantial time and

Session 1.3: Injection moulding

Paper ID: S32-6

Development and Analysis of Novel Freeform Conformal Cooling Channels in Additively Manufactured Injection Moulding Tools

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Abstract

Injection moulding (IM) is the most used manufacturing process worldwide to produce plastic parts. The cooling phase is the longest of the five injection moulding stages since it can take up to 80% of the total cycle time. The cooling phase is highly responsible for both the efficiency and effectiveness of the moulding process i.e., it determines the total cycle time and the quality of the parts respectively. Straight-drilled cooling channels are still the most used type of cooling channel in industry, and they often result in non-uniform cooling of plastic parts, causing long cooling times and part defects such as sink marks and warpage. Therefore, designing new cooling channels has been the focus of numerous studies in recent years, aiming at creating a more efficient and effective IM process. Studies have been devoted towards the development of conformal cooling channels (CCCs), channels which follow the contours of the plastic part being manufactured, resulting in a more effective and efficient IM process due to more uniform cooling. While CCCs have helped reduce the shortcomings of traditional cooling channel designs, they still have their own limitations, which include the inability to effectively cool tight spaces and a lack of uniform cooling caused by the circular profile of the cooling channel. This study aims to overcome these limitations by developing novel CCCs, termed freeform CCCs (FCCCs), which are of a freeform shape. The FCCCs abandon the concepts of a single flow path or branching pipes and they make full use of the geometrical freedom offered by (metal) additive manufacturing. The FCCCs were compared against benchmark cooling channels through a simulation study and moulding experimentation. The metrics used in these comparisons include the cooling time, average temperature, and warpage of the case study part, among others. The results of this study will be presented at the conference.

Session 1.3: Polymer Composites

Paper ID: S34-210

Mechanical performance of in-line plasma bulk modified PA6 and PP reinforced with plasma surface treated flax fibre

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Abstract

Natural fibre-reinforcement is primarily studied as an alternative to glass fibre for polymeric matrix composites. Environmental metrics suggest that flax fibre, as a glass fibre replacement, is favourable when stiffness is the primary design criterion. Other design aspirations may contribute to the use of flax fibre reinforcement, including, low cost, biodegradability, and non-toxicity. Waxy substances on the natural fibre surface do not allow intermolecular and covalent bonding between the reinforcement and the polymeric matrix. Focusing on flax fibre as a reinforcement, removal of waxy substances has been shown to enhance composite strength. However, wet chemical methods are not favourable when considering environmental metrics. A continuous air plasma surface treatment at atmospheric pressure was introduced in the present work to remove weak layers and waxy residues from the flax fibre to improve interphase performance. The mechanical properties of flax fibre reinforced polypropylene and polyamide 6 were enhanced by plasma treating the (i) fibre, (ii) matrix, and (iii) both simultaneously in an extrusion process. The flax degradation was carefully minimised by inspecting the plasma surface treatment process with a infrared camera and by thermogravimetric analysis. The plasma modification of the polymer bulk took place during twin-screw extrusion through the sampling port in the pumping/mixing-zone. The bulk polymer plasma treatment did not increase the mechanical properties as significantly as the flax fibre surface plasma treatment. However, the bulk plasma treatment elegantly demonstrates the importance of tailoring both the reinforcement surface and the bulk matrix to maximise mechanical performance.

Session 1.3: Polymer Composites

Paper ID: S34-221

Non-destructive fiber-matrix adhesion measurement of glass fiber reinforced thermoplastic composite laminates using ultrasound

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Abstract

With the growing demand for lightweight solutions to reduce emissions, especially in the automotive and aerospace sectors, recyclable continuous fiber-reinforced plastic composite laminates with a thermoplastic matrix, also known as “organo-sheets”, are of rising interest. To achieve their maximum mechanical properties, the fiber-matrix adhesion is critical. In this work, organo-sheets with a polypropylene (PP) matrix and twill woven glass fiber fabrics are produced by film stacking in an autoclave process. The films used contain different amounts of maleic anhydride grafted PP (MAH-PP) as a coupling agent to produce organo-sheets of different mechanical strength. To analyze the fiber-matrix adhesion the organo-sheets are subjected to tensile and three-point bending tests. The research shows that MAH-PP has a low impact on the mechanical properties if the force is applied parallel to the warp and weft threads. However, applying the force at an angle to the warp threads (e.g., 45 degrees) shows a significant improvement in the mechanical properties of the laminates as the amount of coupling agent is increased. The non-destructive measurement uses a laser to excite acoustic waves that propagate through the laminate and are detected by a piezoelectric transducer. A viscoelastic acoustic waveguide simulation model is then used to fit the obtained measurement data set and thereby inversely quantify the damping behavior of the laminate. The data show a correlation between the measured damping and the mechanical properties, allowing the fiber-matrix adhesion to be evaluated by measuring the damping. Therefore, this non-destructive method could be used in process and quality control.

Session 1.3: Polymer Composites

Paper ID: S17-172

Interfacial enhancement and properties of the PTFE-based composite films

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Abstract

Polytetrafluoroethylene (PTFE) features an ultralow dielectric constant and loss, excellent chemical stability, and high weather resistance, making it highly promising for high-frequency communication applications. However, the highly symmetry and weak intermolecular interactions among PTFE chains allow for easy chain movement and slippage, which leads to a high coefficient of thermal expansion and poor dimensional stability over its service life. To address the issue of dimensional stability in PTFE materials, compositing with functional fillers is a crucial approach. The interface between the PTFE matrix and these fillers presents key scientific challenges. In this study, the structural evolution of the gas-liquid-solid phase interface during the film-forming and drying process of PTFE/functional fillers composite emulsions were systematically studied. And the issues of filler uniformity and film cracking by adjusting the interfacial capillary forces were addressed. Additionally, to reduce the slippage of PTFE chains and optimize the distribution of fillers, a class of rigid macromolecules was introduced to form “rivet” structures. This innovation resulted in an increase in yield strength and Young’s modulus by 59.4% and 122.3%, respectively, while reducing the creep strain by 42.4%. The study presents a novel method for enhancing the interface and improving creep resistance of PTFE composites, paving the way for the development of high-performance PTFE composite films.

Session 2.1: Biopolymers
Paper ID: S03-190

Unlocking the Potential of Bio-Refinery Waste Humins for Functional Material Development: Esterification and Diels-Alder Reaction Strategies

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Abstract

Biorefineries are crucial in advancing sustainability by utilizing renewable feedstocks to convert biomass into valuable chemicals and materials while reducing reliance on fossil fuels and minimizing environmental impact. A representative process involves the acid-catalyzed treatment of polysaccharides from biomass to produce platform chemicals such as furfural, 5-hydroxymethylfurfural, levulinic acid, and formic acids. However, a major challenge hindering the widespread adoption of this technology is side reactions such as aldol condensation and transesterification leading to the formation of humins - black, tar-like by-products that can account for up to 50% of total carbon loss. At the same time, these humins are chemically rich and possess dense poly furanic structures substituted with hydroxyl, aldehyde, and ketone groups. Recognizing the economic and sustainability importance of humins side streams, this study proposes multiple strategies to transform humins into new materials via chemical modifications. On the one hand, using esterification reactions with various reagents, we functionalize hydroxyl groups in the humins, selectively converting them into fine powders and low-viscosity liquids. We further show that significant fractions of humins, up to 50 wt.-%, can be incorporated into polyester matrices such as polylactic acid, enabling the preparation of high-strength elastomers with peculiar foam morphologies. On the other hand, we explore the use of the furan rings, abundant in humins, as dienes in the Diels-Alder reaction – a well-known and extensively studied cycloaddition reaction, by using 75 wt.-% humins and bismaleimide, we prepare covalently adaptable networks that can be manipulated through temperature and shear. These materials exhibit self-healing properties with the added capability to vary electrical conductivity. All obtained materials are thoroughly investigated using a comprehensive set of analytical techniques, including FTIR and NMR spectroscopy, differential scanning calorimetry, gravimetry, rheometry, and dielectric rheometry. Keywords: biorefineries, humins, diels alder,rheology, esterefication, waste valorisation

Session 2.1: Biopolymers

Paper ID: S03-103

Influence of fibre characteristics on PHA-based biocomposites properties

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Abstract

The addition of fibres from biomass in PHA-based biocomposites offers several advantages, including reducing raw material cost and environmental impact, enhancing biodegradation, and providing a natural appeal to the final products, which all contribute to a circular economy. However, incorporating fibres increases brittleness of the biocomposite, diminishing its market uptake. To address this challenge and improve our biocomposites properties, we focused on identifying key fibre characteristics, such as shape, dimension, and composition, which influence overall properties. Queensland fibres derived from over ten different organic waste agricultural sources were investigated. In addition to mechanical properties, the evolution of thermal and rheological properties was also examined. This study was conducted collaboratively with the Materials & Energy Research and Innovation Centre of Southern Brittany University (UBS) and the National Research Institute for Agriculture, Food and the Environment (INRAe) in France. They Conducted accurate fibre biochemical composition and shape analyses which were essential to understanding their impact. Through this data, we developed a reproducible methodology to assess fibre composition (extractives, hemicellulose, cellulose, lignin ratios) using common laboratory tools as TGA, NMR, and FTIR. The results from this study can be used to predict and effectively select the most suitable fibres for developing PHA-based biocomposites, which is crucial given the diversity of available biomass. This research is part of a broader holistic approach to enhance the toughness of PHA-based biocomposites, including investigating PHA chemical structure, thermal degradation, fibre dispersion and distribution and crystalline microstructure. The aim is to establish a comprehensive platform to support long term development of advanced biocomposites.

Keynote

Session 2.1: Biopolymers

Paper ID: S03-21

Reactively processed poly(butylene adipate terephthalate) composite-based multilayered films for sustainable packaging applications

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Abstract

In this study, we attempt to enhance the properties and biodegradability of poly(butylene adipate terephthalate) (PBAT) using nanocomposite technology to meet the demand for sustainable packaging applications. Two nanoclays containing PBAT composites are reactively processed and integrated into the multilayered films. Reactive processing facilitates the dispersion and distribution of nanoclay particles in the PBAT matrix. The multilayered films comprising reactively processed PBAT composites exhibited a 24.5%–31.5% reduction in the oxygen transmission rate and improved dimensional stability and tensile properties. Moreover, the degradability of the multilayered film comprising reactively processed PBAT composites reached 82% in 180 days. In contrast, a neat PBAT film of similar thickness attained only 53% degradation in the same period. The biodegradation mechanism is proposed based on the topology of the disintegrated films studied using scanning electron microscopy, chemical bond vibrations determined by Fourier-transform infrared spectroscopy, and structural evolution by small- and wide-angle X-ray scattering (SWAXS). The SWAXS analysis is used to understand the changes in the degree of crystallinity, long-range periodic order, and crystalline and amorphous layer thickness of the multilayered films before and after degradation. Such multilayered films can find applications where packaging or biomedical devices cannot be recycled.

Keynote

Session 2.1: Industry 4.0 and AI
Paper ID: S10-257

Digital Technologies: Catalysts for Advancing Polymer Research

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Abstract

The rapidly evolving field of plastic processing is experiencing significant advancements, fueled by the integration of digital technologies. This presentation will examine how the synergy between thermoplastic polymers, processing technologies, and digital tools can accelerate research and facilitate industrial applications. By leveraging processes such as extrusion, compounding, injection molding, and foaming, alongside digital technologies like machine learning (ML) modeling, Bayesian optimization, digital twins, and cloud-based data management tools, we are achieving unprecedented levels of material performance and process efficiency. We will discuss the application of ML algorithms for accurate predictions of material properties, which enhance material selection and design decisions. Additionally, Bayesian optimization techniques are proving crucial for optimizing thermoplastic compounds and resin formulations. These methodologies enable precise fine-tuning of process parameters, maximizing critical properties such as thermal stability while minimizing factors like material density. These advancements not only lead to superior product performance but also support sustainability goals by promoting the use of bio-based materials, reducing the number of required experiments, and minimizing the carbon footprint. We will provide an overview of the synergies between digitalization and plastic processing, showcasing their potential through specific examples.

Session 2.1: Industry 4.0 and AI

Paper ID: S10-18

Can you listen to the sound of polymer melts?

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Abstract

All resins have their own constitutive equations and respond to external environments in their own unique ways. The problem is that we do not know those equations. In well-defined, simple flow environments, we have a considerable amount of understanding on how they respond to environments, but in complex flow environments, similar to real-world conditions, we know virtually nothing. Despite numerous studies on constitutive equations and extensive research on rheometry, we still know very little about the inherent response patterns of resins in complex flow environments. Polymer processing still remains within the framework of the power-law model. However, resins react to external environments in their own unique ways. Perhaps they are constantly trying to tell us about their experiences. What if that is the case? What if their voices are drowned out by excessive noise, preventing us from hearing them? What if we could hear their voices? What if we could understand what they are saying? If we could understand what resin is communicating, not through a three-dimensional constitutive equation, but simply through some real-time signals that propagate, polymer processing could be reinterpreted from a new perspective. In this presentation, I will show that different resins send different signal patterns based on real-time signals obtained from an extruder. Although the method is not yet fully refined, I aim to demonstrate that different resins emit different signals, and discuss the theoretical basis for this observation as well as its potential applications.

Session 2.1: Industry 4.0 and AI

Paper ID: S10-11

Use of Machine Learning to Predict the Product Properties in the Cable Manufacturing Process

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Abstract

This paper investigates the feasibility of using machine learning models to predict product properties in cable manufacturing processes, specifically focusing on the continuous vulcanization (CV) process for XLPE power cables. Traditionally, the properties of cables manufactured through CV processes have been predicted using analytical models that involve heat transfer and chemical reactions. The primary process parameters include temperatures in the crosslinking tubes and cooling zones, while key properties of the cable during the process are the temperatures at different locations within the cable, the degree of peroxide decomposition, and the amount of crosslinking byproducts. The study was conducted as follows: First, sets of process variables (primarily temperature conditions for crosslinking) for XLPE cables were prepared. Second, a dataset was generated by calculating the cable properties based on the process variables prepared in the first step. Third, multiple machine learning models were trained using the dataset, and the best-performing model was selected. The evaluation of the model's performance revealed overall good agreement between the analytically calculated properties and those predicted by the machine learning model. This study offers valuable insights into the capabilities and limitations of machine learning in predicting complex industrial processes.

Session 2.1: Nanotechnology
Paper ID: S14-237

Magnetic Field Assisted "Z" orientation of Nickel Particles along Microcolumns to Produce Thickness Functionalized Piezoelectric films on a Roll-to-Roll Manufacturing Platform

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Abstract

Flexible pressure sensors are a class of advanced transduction devices that are highly valued across diverse fields, including healthcare rehabilitation, advanced human-machine interface (HMI) electronics, and automotive safety, owing to their lightweight and ability to conform to complex surfaces. In this work, we demonstrate the scalability of the advanced technique of magnetic field-assisted alignment on a continuous roll-to-roll manufacturing line by exploring a series of processing parameters to establish an optimal operating window. Quasi 1-3 composite films with low particle concentrations of ferromagnetic nickel (Ni) particles aligned within a silicone-based elastomer. External magnetic fields are used to engineer the columnar microstructure based on the difference in magnetic permeabilities of the binary system. This directed self-assembly of Ni particles results in anisotropic films with enhanced conductive performance in the Z-axis or thickness direction. Since the polymer-microparticle system is subjected to a spatiotemporal evolution of temperature and magnetic fields. Offline measurements, including in-plane alignment, through-thickness light transmission, and viscosity evolution, are used as a framework to determine the influence of these transient processes on final column morphology. Real-time visualization in the X-Y plane quantified by image analysis provides the kinetics of morphological evolution where columns are formed with particle-depleted zones, leading to optical transparency. This characteristic is used to determine the kinetics of column formation via out-of-plane light transmission during Z-alignment. Isothermal and non-isothermal rheokinetics identify the gel point required to "freeze" the column structures. The scalability of the process is demonstrated by producing 17ft x 6in piezoresistive film with columns in the thickness direction. The resulting anisotropic film is quantified for its piezoresistive performance under uniaxial comp

Keynote

Session 2.1: Nanotechnology

Paper ID: S15-188

Ethylene methyl acrylate copolymer (EMA) assisted dispersion of graphene nanoplatelets (GNP) in poly(ethylene terephthalate) (PET)

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Abstract

Composites of polymers and graphene-based materials having enhanced electrical conductivity continue to attract intense research interest. Significant enhancement in electrical conductivity of such composites is limited by poor dispersion and distribution of the nanomaterial in the polymer matrix, limiting the formation of a conductive filler-filler network at low percolation thresholds [1]. In this study, composites of PET and GNP at loadings up to 10wt% were prepared by melt mixing in a twin-screw extruder and the role of ethylene methyl acrylate copolymer (EMA) in assisting dispersion of GNP within the PET matrix investigated. Inclusion of EMA enhanced GNP dispersion such that reduced electrical and rheological percolation threshold values and, improved filler-filler (GNP-GNP) network formation were achieved. Rheological percolation thresholds were measured at 2.3 vol% and 1.1 vol% GNP in the absence and presence of EMA, respectively. Similarly, the electrical percolation threshold decreased from 1.7 vol% to 0.5 vol% GNP. The AC conductivity of PET changed from completely insulating behavior to semi-conductive with a value of 10-4 S/cm on inclusion of EMA. EMA facilitates the formation of a GNP-GNP network by increasing the melt strength of PET due to a crosslinking reaction with PET, which in turns assists exfoliation of the GNP. This is due to ester groups of the acrylates in the co-monomer unit of EMA reacting via transesterification with PET in the extruder creating cross-linked structures. This reaction was confirmed from oscillatory rheology, FTIR and solid-state 13C NMR experiments [2].

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Session 2.1: Nanotechnology

Paper ID: S15-109

Integrative material characterization of crystalline nanocellulose reinforced filaments for fused-filament fabrication

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Abstract

Recently Crystalline nanocellulose (CNC) has received increased attention in the scientific community following a universal push for more environmentally conscious engineering and increased sustainability. Due to the combination of high stiffness and low density of CNC, a high specific modulus of approximately 90 MPa/(kg*m^3)[1] is achieved. However, during processing via fused filament fabrication (FFF), the material is exposed to a series of thermal and mechanical loads. Therefore, the load history has to be considered when characterizing and predicting the composite's properties in the final 3D-printed construction part. A recycled 3D-printable polypropylene modified with CNC up to 15 vol% content was examined in this study. Since the CNC's reinforcement effect is mostly determined by the interactions between the cellulose and the matrix[2], a maleic-acid-anhydride-based compatibilizer was used. To characterize the novel composite shear rheological investigations, dynamic-mechanical analysis (DMA) and measurements regarding shrinkage were performed. An unexpected decrease in viscosity with increasing filler content was observed. This decrease was attributed to (I) the increased use of low viscosity compatibilizer with increased filler content and (II) the thermal degradation of the compatibilizer manifesting in a color change of the tested material. This hypothesis was verified by differential scanning calorimetry (DSC) measurements. This enabled a reliable material characterization, which can help to predict the properties of the final printed part.

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Keynote

Session 2.1: Rheology and characterisation
Paper ID: S19-264

Elucidating the effect of strain hardening on contraction flow of coextruded polymer melts using visualization and simulations

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Abstract

Multilayer films combine distinct characteristics of different materials to create products possessing novel and unique properties. Coextrusion is an excellent method for producing multilayer films. The main drawback is the occurrence of interfacial roughness under certain conditions even when two layers of the same polymer are coextruded. Previous experiments and simulations have indicated that strain hardening under uniaxial elongational flow plays a role but the underlying mechanism remains unclear. In this study, we focused on coextrusion flows undergoing a 4:1 contraction where the fluid experiences considerable stretching. We employed particle image velocimetry (PIV) using a confocal microscope to measure the velocity distribution in the contraction region through a quartz window. Additionally, we measured flow birefringence with a polarized high-speed camera. The results from these experiments were systematically compared with finite element viscoelastic simulation using the Phan-Thien/Tanner constitutive equation. Using the above, we investigated two types of polypropylenes: exhibiting (SHPP) and not exhibiting (noSHPP) strain hardening. As a first step, we investigated the flow characteristics in the contraction during the single-layer extrusion of the two polymers at different volume flow rates. The simulated velocity distributions adequately reproduced the measured flow velocity profiles. Experiments and simulations showed that in the contraction region, the increase in the first normal stress differences is more pronounced for SHPP than for noSHPP. This provided some validation of the constitutive equation used in the simulations. During the presentation, we will discuss insights gained from comparing the preliminary experimental results with the simulations, as well as some thoughts on the relationship to interfacial instability.

Acknowledgement: This work was supported by JSPS KAKENHI Grant Number JP24K17730.

Session 2.1: Rheology and characterisation

Paper ID: S19-267

Rheological behavior of nanostructured polymeric fluids with two-dimensional (2D) materials

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Abstract

The synthesis, characterization, modification, and application of two-dimensional (2D) materials, including graphene and its derivatives (such as graphene oxide - GO), and hexagonal boron nitride (hBN), are currently receiving much attention due to their unique properties derived from its nanostructure. These characteristics lead to innovative and disruptive applications, such as multifunctional nanocomposites, smart materials through 3D/4D printing and conductive inks. However, for these materials to be produced on a large scale, several challenges still exist, namely the fundamental understanding of the rheological behavior of these materials dispersed in different dispersant matrices. In this sense, we have been working on the functionalization of graphene and hBN, dispersed on different model fluids (Polyethylene glycol – PEG, Carbopol and xanthan gum) with the main objective to study the rheological properties during shear flow. It was shown that higher oxidation times increase the functional groups, which leads to a higher dispersion and exfoliation of GO sheets in the PEG. Moreover, the addition of GO in a PEG solution results in significant growth of the suspension viscosity, and a change of the fluid behavior from Newtonian to pseudoplastic. This effect is related to the concentration and oxidation level of the obtained GO particles. When the GO was dispersed in Carbopol, promoted a decrease in viscosity, yield stress and elasticity, mostly due to chemical interactions between the 2D material and the model fluid. More recently, the rheological properties of oxidized hexagonal boron nitride (hBN-Oxi) were investigated, and the results revealed that the increase of hBN-Oxi concentration led to a yield stress, well described by the Herschel-Bulkley model. These results provide fundamental insights into rheological response of this 2D materials in complex fluids which is critical for the development of various solution processing and manufacturing techniques.

Session 2.1: Rheology and characterisation

Paper ID: S19-177

Challenges in the Rheological Characterization of Heterophasic Thermoplastic Elastomers

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Abstract

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 most TPE pose manufacturing challenges because it affects their flow behavior significantly. On the other side, the characterization of process-relevant rheological behavior 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 in literature or databases 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 with comparable 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. Special emphasis is given to the effect of the experimental boundary conditions for the meaningfulness of rheological data.

Session 2.1: Rubbers and elastomers
Paper ID: S38-72

Defect Detection in Silicone Sealants via Ultrasonic Non-Destructive Testing and Data Analysis

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Abstract

This study investigates the use of ultrasonic non-destructive testing techniques for evaluating silicone sealants. During the scanning process, a three-axis motion control system was employed to move the probe vertically along the tube at a constant speed, enabling B-scan imaging. The tube was rotated in 5-degree increments for sequential scanning until the entire sample was thoroughly examined. The collected dataset was segmented based on the scanning intervals and divided into two categories—transverse and longitudinal—depending on the segmentation direction. Principal Component Analysis (PCA) was employed to exam the inspection data in a low-dimensional space. In the PCA score plot, the distribution of data was more dispersed in the presence of defects, while defect-free data exhibited a tighter clustering. A detailed analysis of the transverse cross-sections revealed a marked shift in the score plot as the data approached defect areas, correlating with the actual defect locations identified during testing. Moreover, calculating the determinant of the covariance matrix for the principal components showed that the determinant of defective data was larger than that for defect-free data. This approach demonstrates the ability to detect both the presence and location of defects in silicone sealants, eliminating the need for destructive testing methods.

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Session 2.1: Rubbers and elastomers

Paper ID: S38-48

Design Strategies to Improve Thermo-mechanical Performance of TPUs

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Abstract

Thermoplastic polyurethanes (TPUs) are versatile elastomers widely used in various applications due to their strong mechanical properties and good chemical resistance. However, their limited thermal stability and reduced mechanical performance at high temperatures present a challenge, restricting their application in a broader range. This presentation looks at various strategies aimed to overcome these limitations, including the incorporation of nanofillers (CNS), thermal treatment (annealing), and structural modifications through controlled crosslinking. Combining CNS addition with annealing resulted in a synergistic enhancement in thermo-mechanical properties. Morphological assessments revealed the formation of a secondary network of hard segment domains on top of the primary network of nanofiller responsible for the observed synergistic improvements in properties. Structural modifications through introducing a limited number of crosslinks into the soft segments of TPU by replacing diols with triols could also enhance thermomechanical properties while preserving processability and transparency. Notably, annealing of samples with no crosslinks or lower crosslink content (2.5% triol) can enhance properties at temperatures near the annealing temperature, due to increased chain mobility and phase separation. However, in samples with higher crosslink content (5% and 10% triol), the effect of annealing is less pronounced due to limited phase segregation achievable through annealing in systems with denser crosslink networks. The introduction of crosslinks into the soft segments of TPU improves TPU thermal stability and creep properties.

Session 2.1: Rubbers and elastomers

Paper ID: S38-33

Review on FEM-based Fatigue Life Prediction Models for Dynamically Stressed Elastomers

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Abstract

Elastomers are often used to reduce vibration and influence the vibration behavior of dynamically loaded systems due to their dampening properties. To reduce costs, Finite Element Method (FEM)-based designs are used in the early stages of the development process. To date, there is no universal material and fatigue model because the mechanical properties and service life of elastomers depend on many different factors, such as material composition, stress, and external influences. This review provides an overview of FEM-based models for predicting the fatigue life of dynamically stressed elastomers. It summarizes existing FEM-based fatigue life prediction models, focusing on the different methodological approaches. In addition, the strengths and weaknesses of each model and their industrial applicability are discussed. The research was conducted using Google Scholar, Scopus and ScienceDirect databases. Despite the use of FEM-based approaches, the challenge of accurately representing the complex, hyperelastic behavior of elastomers remains. In addition, the universal applicability of the models is still a critical hurdle.

Keynote

Session 2.2: Circular Economy for Plastics and Recycling
Paper ID: S27-405

Time-Dependent Mechanical Enhancement of Polylactic Acid Through Biaxial Cold Rolling

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Abstract

Polylactic acid (PLA) is a renewably-sourced, biodegradable polyester known for its high mechanical strength, optical transparency, and good barrier properties. Despite its many benefits, widespread adoption is limited by PLA's intrinsic brittleness. One way to address ductility concerns is through roll milling–a solid-state processing method that utilizes shear and compression to produce oriented workpieces of uniform thickness. Roll milling has been shown to increase ductility and mechanical strength in commodity polymers without the need for fillers or reinforcing fibers. The current work examines the time-dependent mechanical enhancement of biaxially oriented, low crystallinity PLA using roll milling at room temperature. In addition to low crystallinity PLA, the effects of annealing to induce moderate crystallinity after rolling are also being explored. Early findings reveal increased toughness, tensile strength, and 1% secant modulus with a strong dependency on the timeframe between rolling and mechanical testing. The effects of roll milling on impact strength and flexural properties are also being investigated. The results of this study will guide the reduction of unsustainable, expensive, and complex fillers traditionally used to toughen PLA products. As global demand for more sustainable materials grows, roll milling presents an opportunity to expand the use of PLA in the packaging, medical, and consumer products industries.

Session 2.2: Circular Economy for Plastics and Recycling

Paper ID: S26-270

Research on Recycling and Utilization of Waste Polymer Materials Difficult to be Regenerated by Solid State Shear Milling (S3M)

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Abstract

Plastic is indispensable and widely used, resulting in a sharp increase in waste plastic. The recycling and utilization of thermoplastic single waste plastic has become relatively mature, but for waste plastics difficult to be regenerated, such as mixed, cross-linked, and thermosetting waste plastics, it is still a big challenge. At present, the treatment of these waste plastics are still limited to incineration, burial, or disposal in the natural environment, causing great harm. To realize the high-value and effective recycling and utilization of these waste plastics, in this paper, a green and low-carbon recycling equipment and the related technologies were established based on the novel solid state shear milling (S3M) technology invented in our research group. By controlling the particle size and domain of commingled waste plastic powders, solid state mechanochemical de-crosslinking at room temperature of cross-linked waste plastics, and surface functionalization of thermosetting waste plastic powders, the existing problems of waste plastics difficult to be regenerated were successfully solved. And by combining other novel polymer processing technologies including hyperbranched surface modification-high filling, interface co-crosslinking, micro crosslinking, and powder extrusion-solid state stretching, etc., high-value utilization of these waste plastics was further achieved.

Session 2.2: Circular Economy for Plastics and Recycling

Paper ID: S26-242

From PP Waste to High-Quality Products – Comparing Contamination Levels of Different Waste Streams in Mechanical Recycling Processes

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Abstract

In high-quality plastics recycling, the effectiveness of recycling processes relies on the quality of the input, which is waste. This study examines the contamination levels of the plastic material throughout the entire mechanical recycling chain for two different post-consumer polypropylene (PP) waste streams. One stream was collected from mixed waste in the Netherlands while the other was sourced from separate plastic waste collection in Austria. The objective is to compare the mechanical recycling processes conducted with these two waste streams, focusing on their contamination levels at various recycling stages. To achieve this, advanced analytical techniques, specifically Analytical Thermal Desorption Gas Chromatography coupled with Flame Ionization Detection and Mass Spectrometry (ATD-GC-FID/MS), were employed to assess the composition and concentration of volatile organic compounds (VOC) released from the material. Variations in waste composition and sorting practices can lead to different levels of VOC emissions and contamination affecting the material quality. The findings highlight the impact of cross-contamination on the overall efficiency of the mechanical recycling process. This emphasizes the need for improved waste sorting and collection methods to enhance the quality of recycled materials in common recycling processes and mitigates the risk associated with contaminants. Additionally, the study shows the highest quality of recycled post-consumer PP which is currently achievable through mechanical recycling with state-of-the-art technologies. Thus, this research identifies potential adjustments to improve the mechanical recycling process of PP from the initial waste collection to the final product, ensuring compliance with regulatory and product requirements.

Session 2.2: Circular Economy for Plastics and Recycling

Paper ID: S26-219

Closing the Loop: University-Industry Collaboration for a Circular Plastic Economy

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Abstract

In the shift toward a circular economy for plastics, closing the loop between plastic production, use, and recycling is essential to address the pressing challenges of plastic waste and resource efficiency. This presentation explores the critical role of university research and industry collaboration in accelerating circular solutions for plastics. Universities are uniquely positioned to advance innovative materials, processes, and technologies that can redefine the lifecycle of plastics, with an emphasis on sustainable design, enhanced recyclability, and effective upcycling. By working closely with industry, our research team has focused on developing scalable approaches designed for real-world applications, addressing both economic and environmental priorities. Our research spans several key areas: modification techniques that improve the processability and performance of recycled plastics, development of sustainable polymers, and mechanical recycling methods that enable the transformation of plastic waste into valuable resources thus broadening their applicability across diverse sectors. Case studies will highlight successful projects achieved through academic-industry partnerships demonstrating the potential for collaborative research to catalyse sustainable practices within the plastic sector.

Keynote

Session 2.2: Extrusion
Paper ID: S06-354

Reactive extrusion of biomass for value chemicals and solid biofuels

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Abstract

Twin-screw, co-rotating extruders have been widely employed for the processing of thermoplastics. In this research, we propose to escalate their potential by purposefully modifying a twin-screw extruder to mechanochemically convert biomass, the most abundant natural polymer, into valuable products. A LabTech co-rotating, twin-screw extruder was used to torrefy Pinus radiata bark to produce solid biofuels and liquid biochemicals. Torrefaction was performed under an inert atmosphere at temperatures between 275 and 375 °C. The effects of temperature, screw speed, and screw design on the distribution and characteristics of solid and liquid products were investigated. The higher temperatures increased the yield of biochemicals. The high shear had an opposing effect on the chemicals, their amount decreased but enhanced the torrefaction performance. Up to 30 compounds were identified and 9 were quantified in the torrefaction liquid using gas chromatography and mass spectrometry (GC-MS), such as furfural, phenol and vanillin. These compounds were decomposition products of the cellulose, hemicellulose and lignin. The yield of individual biochemicals was affected by the processing temperature, screw speed and screw design. This study demonstrated that polymer extruders can be modified and used to extract chemicals from biomass which could allow companies to use obsolete but still operational polymer extruders after minimal modification to introduce another income stream for companies.

Session 2.2: Extrusion

Paper ID: S06-194

The Design and Validation of Shape Forming Elements for Architected Composites

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Abstract

This research investigates the design and validation of Shape Forming Elements (SFEs) that transform a basic, coextruded input cross section of two concentric circles, into complex architected output geometries, where the coextruded materials mechanically interlock. The mechanical interlocking of two materials, liquid crystalline polymer and another high performance polymer, prevents the materials from delaminating. The SFEs achieve this transformation through strategically designed flow channels that manipulate the distribution of the materials. Each SFE can perform one or more outlined operations: cutting, rotating, shifting, combining, and reshaping the materials within the flow. The validation process for these SFEs includes both physical and computational methods. Polymer clay samples, coextruded via 3D printed dies, serve as a hands-on visualization of how the material flow changes within the SFEs. In parallel, simulations using ANSYS Polyflow provide a detailed analysis of flow dynamics and material deformation, offering more accurate predictions on how the material will behave. These preliminary validations will be followed by coextrusion trials, where polymers are processed through metal 3D printed SFEs to produce actual composite structures. Key geometric attributes, such as area, perimeter, perimeter to area ratio, moment of inertia, section modulus, and radius of gyration – are quantitatively analyzed across all stages of validation. This work not only explores the design principles behind SFEs, but also provides a comprehensive evaluation of how the different methods – clay modeling, simulation, and polymer coextrusion – compare. Understanding these relationships helps optimize the SFEs for producing complex architected composites with higher precision and consistency, ultimately advancing the development of tailored composite materials for advanced engineering applications

Session 2.2: Extrusion

Paper ID: S06-180

Experimental determination of the degassing performance of twin screw extruders for the material system Methylmethacrylate in PMMA

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Abstract

Degassing processes are usually placed downstream of a virgin polymer reactor an the solvent laden melt is send to the devolatilization extruder. This setup is mimicked in laboratory scale in this study to investigate the degassing efficiency of the monomer methylmethacrylate (MMA) and toluene from Polymethylmethacrylate (PMMA) melt using a twin screw extruder (TSE). The experimental setup was conducted using a two-stage extrusion process. In the first stage, PMMA was melted and 13%(w/w) MMA and 2%(w/w) toluene was incorporated into the melt with a Berstoff ZE60UT TSE. This solvent-laden melt was then transferred to the second TSE a KraussMaffei ZE65BP, where the degassing process took place. Successively, the polymer was granulated and the MMA and toluene content was determined by GC-MS. Here, the influence of the polymer viscosity, temperature, vacuum pressure, throughput and specific filling degree was investigated. The process window was tested in with a throughput of 68-296 kg/h with two different raw polymer grades (Grade 1: MFI: 1.5 g/10 min; 230°C, 3.8 kg; Grade 2: MFI: 12.2 g/10 min; 230°C, 3.8 kg). Through the vacuum degassing the volatile content was reduced by cout/cin = 0,006 to 0,028. A strong influence of the polymer viscosity on the degassing performance as was observed. Grade 2 showed a better devolatilization performance which is attributed to the higher mobility of the volatiles in the low viscous melt. Furthermore, it was shown that the specific throughput plays a mayor role for degassing applications. The devolatilization improves at lower specific throughput in general but for MMA a sweet spot at 1,5 kg/h/rpm was observed at which an optimum of low toluene and low MMA concentration was observed due to the back reaction of PMMA to MMA at lower specific throughputs. Our results demonstrate that the twin screw extruder is highly effective in reducing the solvent content in PMMA melts.

Session 2.2: Extrusion

Paper ID: S06-100

Real-time prediction of melt pressure in polymer extrusion process integrating physics-informed neural networks and random forest

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Abstract

Accurate control of melt pressure in the polymer extrusion process is critical for product quality and consistency. Real-time prediction of melt pressure is key to optimizing the extrusion process and improving product uniformity. Traditional methods, like finite element simulations, are too computationally expensive for real-time use, while polynomial models struggle to capture the complex, nonlinear dynamics of extrusion, leading to suboptimal predictions. Machine Learning (ML) technologies have recently shown promise in modeling complex manufacturing phenomena. However, purely data-driven models often lack interpretability and struggle to maintain accuracy under varying conditions. On the other hand, Physics-Informed Neural Networks (PINNs) embed physical laws into the learning process, leading to more physically consistent predictions. Despite this, PINNs alone cannot account for disturbances in the extrusion process that are difficult to model theoretically. This creates a gap in achieving robust, real-time predictions by either method alone. To address this, we propose a novel framework that integrates PINNs with Random Forest (RF) models for real-time melt pressure prediction in polymer extrusion. In this approach, melt pressure is divided into two components: the theoretical component, driven by screw speed changes, is modeled using PINNs, while the fluctuation component, caused by historical temperature disturbances, is predicted using RF. Additionally, sliding window technology is applied to update the RF models in real-time, allowing the system to adapt to environmental changes during the extrusion process and maintain prediction accuracy. This hybrid framework overcomes the limitations of purely data-driven or physics-based models, offering a real-time prediction tool that can be deployed in industrial settings. It enhances computational efficiency and opens opportunities for more efficient, sustainable polymer processing.

Keynote

Session 2.2: Mixing and Compounding
Paper ID: S12-347

Study on Carbon Fiber Breakage in Blending Process Using Twin Screw Extruder

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Abstract

Carbon fiber reinforced thermoplastics (CFRTP) are used in a variety of applications due to their light weight and high mechanical properties. It is known that the properties of molded CFRTP depend on the length of the remaining fibers and increase until the fibers reach a certain length. However, it is difficult to maintain the fiber length that leads to excellent properties due to fiber breakage during the kneading and molding processes. The objective of this study is to develop a prediction model of fiber breakage when polypropylene and carbon fiber are kneaded in a twin-screw extruder. The kneading is mainly performed in the kneading section, and since the flow is very complex, a prototype apparatus that can represent simple shear flow was built and tested. In developing the model, fibers were assumed to break due to shear stress, and a criterion equation for fiber breakage was assumed based on the shear stress data obtained. Next, shear stress was calculated from the results of particle tracking using Ansys Polyflow, and a predictive model of fiber breakage was created using the assumed breakage criterion equation. Comparison of the analysis and experimental results showed that the average fiber length tended to shorten as the kneading block in the kneading section increased, but there was a difference in absolute values. Therefore, to improve the accuracy of the prediction model, an experiment was conducted in which the gap at the material feeding section of the machine was changed. The results of the prediction model using the rupture criterion equation for the shear stress data obtained by changing the gap are shown below

Session 2.2: Mixing and Compounding

Paper ID: S12-276

Tunning Mechanical Properties of Acid-grafted Polyethylene Using Ionic Interaction

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Abstract

Plastics, particularly in packaging applications, contribute significantly to environmental waste, highlighting the urgent need for more effective and sustainable recycling methods [1,2]. One promising strategy is the introduction of thermo-reversible ionic crosslinks into polymer matrices to enhance mechanical and thermal performance [3,5]. In this study, ionomers were generated by melt neutralization of poly(ethylene-co-methacrylic acid) (PEMAA) containing only 4 wt% acid groups, using various metal bases—MgO, ZnO, $Ca(OH)_2$, and K_2CO_3—and systematically evaluated to understand the influence of metal cation type and neutralization level on material properties. Notably, the neutralization of such a low acid content during extrusion presents a significant technical challenge. Fourier-transform infrared spectroscopy (FTIR) revealed shifts in carboxylate peak positions and intensities, confirming ionic bond formation and changes in electrostatic environments. Differential scanning calorimetry (DSC) showed that increased neutralization led to a reduction in crystallinity and melting point, consistent with ionic disruption of crystalline domains. Time sweep rheology demonstrated that gelation time decreased with rising temperature, and the crosslinking rate varied significantly by metal cation, with Zn^{2+} initiating the fastest ionic clustering and Mg^{2+} producing the most thermally stable networks. Frequency sweep tests indicated that ionic interactions enhanced the complex viscosity and storage modulus (G'), particularly at lower frequencies. Dynamic mechanical analysis (DMA) revealed clear shifts in β and β' relaxation peaks to higher temperatures with increasing neutralization, indicating restricted chain mobility due to stronger ionic crosslinks. MgO exhibited the greatest effect on raising the α-relaxation temperature, reflecting improved stiffness and thermal stability. Tensile testing confirmed that cation type also affected mechanical behavior, with divalent cations contributing to enhanced modulus and tensile strength compared to K^+. Overall, these findings establish a strong link between metal cation chemistry and the structure–property relationships in PEMAA ionomers. This work provides a foundation for designing recyclable, high-performance materials through tailored ionic interactions and melt processing strategies.

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Session 2.2: Mixing and Compounding

Paper ID: S12-236

Ultrasound-assisted extrusion of nanoparticles reinforced HDPE: Cavitation impact

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Abstract

Ultrasonics is widely used to enhance the dispersion of nanoparticles in polymer solutions, a process known as sonication. The phenomenon driving agglomerate breakage is cavitation. It occurs when solvents in the polymer solution form bubbles that rapidly collapse, producing large shock waves that improve nanoparticle dispersion and, for layered nanoparticles, exfoliation. Given the effectiveness of this method, some researchers have incorporated ultrasonics directly within extruders to improve dispersion within molten polymer matrices. However, cavitation dynamics in molten polymers, both with and without layered particles, remained underexplored, necessitating a deeper understanding to improve process control. While some studies suggest that cavitation continues to play a role in molten systems, shock waves do not propagate as they do in solutions. Alternatively, water cavitation or air excitation between particle layers may play a greater role in enhancing exfoliation in molten polymers. To investigate the effects of ultrasound in extrusion, we carried out two types of experiments. Initially, clay and graphene-reinforced polymers were processed using a co-rotating twin-screw extruder, Process 11, equipped with an ultrasound tip, Q700 Sonicator. Two sets of batches were prepared for clay-based composites: one with dried clays and another with wetted clays. This was done to assess the impact of water cavitation on particle exfoliation. For comparative purposes, graphene was also examined, as smaller interlayer spacing precludes water or air particle penetration. Concentrations ranging from 2 and 17 wt% were prepared and characterized. Rheology was used to access particle dispersion, X-ray diffraction (XRD) to evaluate particle exfoliation, and Scanning Electron Microscopy (SEM) to measure agglomerate size. To gain further insight into the underlying physics, additional experiments were conducted in degassed and non-degassed polydimethylsiloxane (PDMS) of varying viscosities, with the focus on examining fluid behavior induced by ultrasound using particle imaging velocimetry (PIV).

Session 2.2: Mixing and Compounding

Paper ID: S12-102

Dispersive and distributive mixing effect of screw elements on the co-rotating twin-screw extruder

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Abstract

Compounding is the process of incorporating various additives into base polymers to modify their properties and performance. This is crucial for producing materials that are customized for specific applications. Incorporation is achieved through distributive and dispersive mixing, typically on co-rotating twin-screw extruders equipped with special screw elements. If the mixing quality is insufficient, the screw configuration can be adjusted along with the process parameters, requiring precise knowledge of the mixing properties of the screw elements. However, the exact mixing properties of these elements have not been thoroughly researched and quantified. In this study, the mixing behavior of individual screw elements is analyzed in terms of dispersive and distributive mixing using 3D CFD flow simulations with particle tracking and comparative experimental investigations with a special twin-screw extruder design. The experimental investigations are conducted to validate the simulation results, enabling future screw element evaluations to be based on simulations. Therefore, mixing behavior is analyzed in the simulation with the particle distribution in a plane perpendicular to the screw element, the maximum shear stress on a particle's path, and the shear stress integral. Experimentally, particle size distribution is measured, and particle distribution is analyzed using polished samples. The results show that the geometry of the screw element significantly influences the quality of both distributive and dispersive mixing and that the simulation results match the experimental findings. These results make it possible to evaluate the screw element regarding its mixing properties based solely on simulations, thereby optimizing the mixing zone of a twin-screw extruder without extensive experimental investigations.

Session 2.2: Polymer Blends and Alloys
Paper ID: S16-199

Anchoring Ties: Improving Environmental Stress Crack Resistance in recycled HDPE with a Styrenic Triblock Copolymer

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Abstract

Environmental Stress Cracking Resistance (ESCR), a vital material property for high-density polyethylene (HDPE) bottles, is limited in products containing post-consumer recycled (PCR) HDPE. This study investigates the effect of a styrenic triblock copolymer, Styrene-b-Ethylene-b-Ethylene/Propylene-b-Styrene (SEEPS), on the properties of HDPE. By adding SEEPS, the ESCR of virgin and recycled HDPE improved up to 130%. Scanning Electron Microscopy (SEM) revealed well-dispersed SEEPS domains within HDPE spherulites, with rigid polystyrene (PS) domains connected by flexible polyolefin mid-blocks that act as "anchoring ties." It is postulated that SEEPS forms a network within the crystalline structure of HDPE, where the PS domains of SEEPS act as rigid anchors and prevent the disentanglement of HDPE tie chains during environmental stress cracking. The evaluation of the Strain Hardening Modulus (SHM) revealed that ESCR enhancement is temperature-dependent, with SHM values decreasing when PS domains reach or exceed their glass transition temperature (TgPS ≈ 100 °C). Results of in-situ Fourier-Transform Infrared (FTIR)-Tensile tests further confirmed that the styrene domains were under stress during strain hardening below the TgPS. This study provides substantial evidence of the anchoring ties hypothesis as a plausible mechanism for enhancing ESCR in HDPE by adding styrene triblock copolymers, presenting a promising approach to improving the recyclability of HDPE.

Keynote

Session 2.2: Polymer Blends and Alloys

Paper ID: S16-197

Journey from Processing to Recycling of Multilayer Waste Films: Main Challenges and Prospects with innovative approaches

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Abstract

In a circular economy context with the dual problems of depletion of natural resources and the environmental impact of a growing volume of wastes, it is of great importance to focus on the recycling process of multilayered plastic films. This talk provides an overview of recent advances in the processing and recycling of these multilayer polymers, addressing manufacturing processes, common materials, and the complexities of recycling and reuse. The first part of this study focuses on recycled flexible films, such as those used in packaging and agricultural bale wraps, which often contain sticky additives that migrate to the surface during recycling. To understand this migration, experiments were conducted using model blends of polyethylene with varying molecular architectures and branching levels, both with and without mineral fillers. Innovative methodologies, including tribo-rheometry and surface "tack" monitoring, were developed to study the kinetics of additive migration and its influence on rheological behavior under shear and elongation. The second part examines multilayer films based on polypropylene and polyethylene, which pose additional recycling challenges due to their complexity. Model blends with physical compatibilizers were created to simulate these materials, allowing for an in-depth evaluation of their rheological, morphological, and mechanical properties. These findings were then applied to post-consumer, multiphase systems to assess real-world recycling applications.Finally, this study explores a forward-looking approach to eco-design, aiming to develop recyclable multi-micro/nanolayer films by forced assembly layer coextrusion. This approach minimizes the number of components, controls layer thickness, and eliminates the need for tie layers, facilitating easier recycling. The rheological, morphological, and mechanical properties of these films were evaluated across multiple mechanical recycling cycles to determine their durability and performance

Session 2.2: Polymer Blends and Alloys

Paper ID: S16-124

Formation of rigid core-soft shell structure of polymer blends by reactive processing

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Abstract

We here reported a viable and universal approach to elaborate supertoughened nanoalloys with significantly depressed yielding behaviors by virtue of elastomeric nanobelts to replace conventional rubber droplets in a glassy matrix by a simple reactive processing strategy. Stereocomplex crystal (SC)-immobilized EGMA, prepared by cocrystallization of enantiopure PDLA-/PLLA pairs respectively pregrafted onto EGMA chains, is used to toughen PLLA. Therefore, the structure of the elastomer, from droplets and shells to nanobelts in the PLLA matrix, can be achieved. Such controllable morphology allows for the corresponding nanoalloys with significantly enhanced notched impact strength while keeping the high strength. Furthermore, tricontinuous morphology integrates penetrative elastomeric nanobelts (EGMA), glassy polymers (PLLA), and SC phases, which are achieved by adjusting SC moieties. The authors demonstrate that the resulting nanoalloy integrates superior performance (toughness, heat resistance, and crystallization rate) and stress leveling-off without fully undergoing real yielding, surpassing most elastomer-toughened PLA alloys. The morphology development and underlying origin of the impact/deformation mechanism are elucidated.

Session 2.2: Polymer Blends and Alloys

Paper ID: S16-10

Enhancement of Vibration Damping and Viscoelastic Properties of MABS Through Novel Polymer Blends with VDT and SEBS-g-MAH Compatibilizer

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Abstract

This study investigates the development of novel polymer blends aimed at enhancing the mechanical and vibration damping properties of Methyl Methacrylate Acrylonitrile Butadiene Styrene (MABS). A multi-phase binary polymer blend was formulated using melt mixing in a twin-screw extruder with varying weight ratios (10, 20, and 30 wt.%) of a styrene-based thermoplastic elastomer (trade name VDT). Additionally, the impact of a Maleic Anhydride-grafted Styrene Ethylene Butylene Styrene (SEBS-g-MAH) was used as a compatibilizer at different concentrations (2, 4, and 6 wt.%) and the effect was evaluated. Compatibility and performance were characterized using differential scanning calorimetry (DSC), Dynamic Mechanical Analysis (DMA), Fourier Transform Infrared (FT-IR) spectroscopy, Nuclear Magnetic Resonance (NMR), and microscopy techniques. The results demonstrated significant improvement in the damping properties with the incorporation of the elastomeric phase into the MABS matrix. The best results were given by the 4 wt.% SEBS-g-MAH which exhibited the highest enhancement in both damping performance and tensile strength. Morphological analysis revealed the underlying reasons for the enhanced compatibility between MABS and VDT. Further insights from NMR and FT-IR analyses corroborated the superior interaction within the MABS-VDT blend. These findings suggest that the strategic incorporation of VDT, coupled with the optimal concentration of SEBS-g-MAH compatibilizer, effectively enhances the viscoelastic properties of MABS, making it a promising candidate for applications requiring advanced vibration damping materials.

Session 2.2: Polymer Composites
Paper ID: S35-284

Synergistic Anchoring Strategy of Liquid Metal with CuS and CNTs to Achieve Homogeneous Dispersion in Silicone Rubber for Efficient Solar Energy Harvesting and Motion Sensing

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Abstract

Gallium-based liquid metal (LM) has obtained considerable attentions in materials science due to its unique multifunctionality. However, the high surface tension of LM makes it difficult to effectively compound with polymer materials, and it is prone to leakage during use causing safety hazards. Here, we based on the coordination bindings mechanism between lone-pair electrons and vacant orbitals, utilizing mechanochemical methods to achieve rapid anchoring of LM with CuS, thereby effectively overcoming the inherent interfacial non-wettability between CuS and LM. Meanwhile, carbon nanotubes (CNTs) were introduced as an outer layer structure, enhancing the anchoring stability of LM on CuS and effectively preventing LM leakage within the polymer matrix. The prepared CuS-LM/CNT can be easily mixed and processed with silicone rubber (SR) to form the desired composites. The resultant SR composite exhibits excellent photothermal conversion ability, long-term structural stability, and superior mechanical properties. Furthermore, the SR composite possesses highly sensitive strain sensing characteristics, making it suitable for monitoring movements in various parts of the human body. Finally, the feasibility of applying the SR composite in solar thermoelectric generator (STEG) system is further validated, and the SR composite showed significant solar-heat-electricity conversion potential in real environment. This work provides valuable guidance for the development of high-performance solar harvesting materials and clean energy collection and conversion technologies in the future.

Session 2.2: Polymer Composites

Paper ID: S34-254

Linking Chemical Structure to Performance: Acrylates as a Styrene Replacement in Unsaturated Polyester Resins

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Abstract

Styrene is widely used in unsaturated polyester resins (UP) as a reactive diluent and crosslinker, enhancing processability and mechanical properties, with up to 40 wt% significantly increasing the glass transition temperature (Tg). Incorporated into the UP backbone, Styrene forms AB-crosslinked graft copolymers, where increased Styrene content widens the network via longer B-chains. The steric hindrance of styrene's aromatic structure raises Tg up to an optimal styrene content, specific to the UP resin. Beyond this point, the effect of increased free volume becomes dominant, leading to a subsequent decrease in (thermo-)mechanical properties. Despite these benefits, Styrene's carcinogenic nature, respiratory risks, along with its low vapor pressure, render it unsustainable from economic, ecological, and health perspectives. To address this, alkene-functional monomers, e.g. methacrylates (MA), offer promising alternatives due to their high market relevance, lower toxicity, and good mechanical performance. The mechanisms governing network formation and architecture are similar to those of styrene-UP blends, yet research on UP-MA crosslinked graft copolymers remains limited. In our study, monofunctional MAs with different molecular weights (Mw) (MMA, 2-HEMA, THFMA, BNMA) were cured with a biobased UP resin to evaluate their impact on network and mechanical properties. To assess the influence of Mw for bifunctional MAs, EGDMA, 1,4-BDDMA and 1,6-HDDMA with increased repetition unit number were introduced into the network. Lastly, the effect of altered functionality was determined using the trifunctional TMPTMA. Utilizing those well-known MAs as co-monomers in a cold-curable UP-system, the author presents findings regarding the relationship between structural features of MAs and their impact on network architecture and corresponding (thermo-)mechanical properties to further enhance sustainability in composite applications by linking chemical structure to performance.

Session 2.2: Polymer Composites

Paper ID: S34-233

Hierarchically ordered structure in thermally conductive polymer composites and its application

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Abstract

Currently, how to regulate the morphological structure of anisotropic fillers in thermally conductive polymer composites (TCPC) during polymer processing is a key issue to achieve high performance and multifunctionality of TCPC. Herein, the weak magnetic field and the unique stretching & shearing force fields field were used to effectively control the distribution and orientation of the anisotropic functional fillers, and further construct different types of hierarchically ordered structures in the TCPC. On the one hand, vertically aligned (VCS), horizontally aligned (HCS) and scaffolds fishbone-shaped (FCS) CF scaffolds were constructed via the weak magnetic field-assisted Tetris-style stacking and carbonization process. It was found that the thermal conductivity of VCS-7/PDMS and HCS-7/PDMS reached to 45.01 W/(m·K) and 42.18 W/(m·K) in fiber alignment direction, respectively. FCS/PDMS exhibited heat transfer differences in different directions, allowing efficient heat transfer in the fiber alignment direction. On the other hand, the silicone rubber (SR) composites with a highly vertically aligned network of hexagonal boron nitride (h-BN)/CF was constructed via the combination of multistage stretching extrusion (MSE), layer-by-layer stacking and hot-pressing procedures, which exhibited a high through-plane thermal conductivity of 9.5 W/(m·K) and breakdown voltage of 7.7 kV/mm. Moreover, co-extrusion developed based on MSE was used to arrange highly Gt-CNTs and h-BN layers in an alternating manner to construct hierarchically ordered structure in the 4-layer SR composites, which enables the composites multifunctional integration including anisotropic thermal and electrical conductivities with frequency-selective EMI shielding. Our works provide new insights into the rational design, simple preparation and multifunctional integration of TCPC for advanced electronic devices. Keywords: hierarchically ordered structure; polymer composites; processing; thermal conductivity; electromagnetic interference shielding

Keynote

Session 2.2: Polymer Composites

Paper ID: S17-116

(Dis)advantage of melt-mixed thermoplastic polymer composites for energy generation through the thermoelectric effect

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Abstract

In the context of the current urgent energy problems, one approach to improve the energy efficiency of equipment or systems is waste heat recovery. Waste heat is a by-product of many production processes and, if not reused, is released into the atmosphere or water. By using the Seebeck or thermoelectric (TE) effect, a net zero emission of energy transfer from heat to electrical energy can be achieved if suitable electrically conductive materials are used. This paper presents results on the development of novel, energy-efficient and environmentally friendly thermoelectric materials based on electrically conductive polymer/carbon nanotube (CNT) composites that can be used as TE generators to directly convert waste heat into thermoelectric power. The factors influencing the thermoelectric properties of melt-mixed thermoplastic composites with multi- and single-walled CNTs were investigated. The influences of carbon nanotube types and grades, polymer matrix materials, filler content and processing conditions on electrical conductivity, the Seebeck coefficient, the power factor and the thermoelectric figure of merit of the nanocomposites are investigated. In order to produce composites with n-type transport behavior, we show ways to obtain materials with negative Seebeck coefficients, especially by adding suitable additives during the melt mixing process. Finally, thermoelectric demonstrators were built consisting of p- and n-type polymer composite strips and their performance was evaluated. Even though the TE values achieved are still significantly below those of conventional materials, the results show that such conductive polymer composites are promising and can in principle be used for TE applications.

Session 2.2: Polymerisation and synthesis
Paper ID: S18-207

Hydroxyester mediated epoxy vitrimer systems with improved recyclability

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Abstract

Traditional glycidylether epoxy-amine and epoxy-anhydride resin systems form stable crosslinked network structures upon curing, and the cured products cannot be reprocessed like thermoplastics and are challenging to be recycled chemically. In recent years, researchers have made tremendous endeavors employing various dynamic covalent principles to impart certain degrees of malleability and easy recyclability to crosslinked polymers. Our group has also made a substantial effort on developing epoxy vitrimers based on both glycidylether epoxy-anhydride and glycidylester epoxy-amine resin systems. Our approach is to introduce self-catalysis into the reaction system, so both the curing of epoxy resin and subsequent dynamic transesterification in the crosslinked network polymers can take place without external catalysts. It is critical to maintain sufficient hydroxyls and ester linkages in the system to enable adequately fast transesterification and hence decent adaptability. We have demonstrated applications of hydroxyester mediated epoxy vitrimers for composite matrix, room temperature coating and elastomeric materials. We have also investigated the simple and eco-friendly recycling of epoxy vitrimers via hydrolysis or alcoholysis. The approach and method developed can be conveniently applied to commercial epoxy resin systems to achieve new adaptable and recyclable properties while mostly retaining their application performance.

Session 2.2: Polymerisation and synthesis

Paper ID: S18-187

MOF/Photopolymer Composites for Selective Adsorption of Cationic Dyes

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Abstract

Metal-organic frameworks (MOFs) represent a class of highly versatile and customizable materials known for their exceptional properties and wide-ranging applications. Despite their superior properties, MOFs come with inherent challenges, primarily owing to their powder-like nature. Their susceptibility to moisture absorption, coupled with a lack of malleability and poor processability, compromises their stability when exposed to aggressive chemicals. Consequently, their industrial potential remains limited. To address these limitations, MOFs are frequently integrated with polymer matrices to develop composite materials that harness the advantages of both constituents. Nevertheless, challenges persist, such as the compatibility between polymers and MOFs, and the dispersion of MOFs in polymer matrices. To address the relevant issues, we introduce a novel strategy for the rapid assembly of MOF/photopolymer composites utilizing visible-light-triggered photopolymerization. A series of commonly used MOFs, alongside functionalized variants, are employed in fabricating polymer nanocomposite materials under the irradiation from various visible LEDs. Notably, certain MOFs investigated, such as UiO-66-NPYG and UiO-66-Tz, exhibit remarkable photoinitiation abilities and significant potential for thick curing, thereby accelerating the production of corresponding composite materials. UiO-66-Tz based polymer composite reveals exceptional selective adsorption of cationic dyes over anionic dyes. This study paves the way for the further advancement of MOF-based photoinitiators and their integration into photopolymerization methodologies, showcasing their potential utility across a spectrum of industrial and environmental contexts.

Keynote

Session 2.2: Polymerisation and synthesis

Paper ID: S18-162

Improved mechanical properties of bioderived and biodegradable polymers via block-copolymer synthesis from polyhydroxyalkanoates (PHAs)

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Abstract

With the consistently rising demand for plastics and the increasing problems being faced worldwide regarding plastic pollution, finding environmentally friendly alternatives is a pressing issue. Polyhydroxyalkanoates (PHAs) are materials of high interest due to being bacterially synthesised and biodegradable in a variety of environments such as soil, marine, or fresh water, as well as common household composting. Yet the most commonly available PHAs still lack the mechanical properties needed to truly replace a wide range of non-degradable plastics. Poly(3-hydroxybutyrate) (P3HB) and its copolymer poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV) exhibit high tensile strength and modulus. However, their high crystallinity leads to a lack in toughness and especially elongation, resulting in a relatively stiff and brittle material. While the copolymerisation product of 3-hydroxybutyrate (3HB) and 4-hydroxybutyrate (4HB) - poly(3-hydroxybutyrate-co-4-hydroxybutyrate) (P3HB4HB) - shows a considerable improvement in elongation at break at higher 4HB contents, it lacks in tensile strength and toughness, leading to an elastic but weak material. It has been demonstrated that block-copolymer synthesis via well-established chemical synthesis routes can produce PHA-based copolymers that are not easily accessible through bacterial synthesis, displaying mechanical properties that might exceed those of their random copolymer counterparts or simple blends of the employed block materials. In our work we demonstrate the synthesis of block-copolymer materials based on low-3-hydroxyvalerate content PHBV and P3HB4HB via isocyanate chemistry, resulting in materials exhibiting significantly improved toughness and elongation at break compared to the block materials or comparable blends.

Session 2.2: Polymerisation and synthesis

Paper ID: S18-144

Synthesis and characterization of PEG-based hydrogels for pollutant sequestration

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Abstract

Due to the rapid growth of industrial activities in developed and developing countries, water pollution is rapidly advancing as a major challenge for humanity. Today, an emerging solution for wastewater treatment is based on the use of hydrogels for absorbing pollutants, with focus on metal ions, dyes and drugs. In order to facilitate large-scale implementation, it will be important to rely on natural and abundant sources to obtain hydrogel that can be subsequently functionalized with green absorbing agents. This work is centered on the first step stage of the above process, consisting in the preparation of photocatalytic PEG-based hydrogels, and on their 3D printability. To this end, hydrogels composed of Poly(ethylene glycol) diacrylate (PEGDA), chain-extended by means of poly(ethylene glycol)-methacrylate (PEGMA) or 2-hydroxyethyl acrylate (HEA), are prepared by UV-activated photopolymerization. The crosslinking sol-gel kinetics and the final gel properties are characterized by Small Amplitude Oscillatory Shear (SAOS) measurements. The effect of oligomer chemistry, molecular weight and composition, and photo-initiator concentration on the final mechanical properties, mesh size (porosity) and water swelling ability are presented and discussed. Preliminary 3D printability tests are also proposed. This work is funded by the European Union – Next Generation EU.

Session 2.3: Additive manufacturing
Paper ID: S01-365

Improved FGF 3D printing using biocarbon additive

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Abstract

3D printing for large products using FGF technique is gaining a lot of interest compared to standard 3D printing. Within the current research, an additive was developed for a standard 3D printing material used on large scale printing. This additive allows faster 3D printing speeds combined with smooth 3D printing surface, good printing stability, good overhang possibilities, good interlayer adhesion combined with satisfying impact properties. Rheological characterisation combined with microscopy allowed to explain the improvement for the printing and mechanical performance. In this research, a comparison is made between 3D printing with and without the additive for a simple box geometry allowing to quantify the most important printing parameters as there are printing speed, printing temperature, final mechanical properties (in print direction and perpendicular to printing direction), overhang possibilities (increasing widht of the box) and shrinkage of the 3D printed part. Using the developed additive in a proper concentration, allows to get towards faster 3D printing with similar or better performance compared to standard materials. It also has the advantage to be a biobased material with low price.

Session 2.3: Additive manufacturing

Paper ID: S21-359

Characterisation of process-induced defects in strut-based polymeric lattice structures

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Abstract

Lattice structures, known for their high strength-to-mass ratio and ability to absorb impact energy, have gained significant attention in sectors like aerospace and bioengineering. These complex geometries are created using additive manufacturing (AM) technologies. While AM offers advantages such as reduced material waste and the ability to produce highly complex objects at lower costs, workpieces often contain defects and irregularities. These defects can degrade the desired mechanical properties, highlighting the need to incorporate their impacts into analyses. Though many studies have explored the relationship between topology-related factors and the mechanical properties of lattice structures, few have addressed the impact of printing irregularities, particularly in polymeric materials. This research aims to report on the process-induced defects in polymeric lattice structures. Using X-ray CT techniques, the study scans the printed lattices to identify defects, revealing two categories: geometry-related defects (strut waviness, thickness variation, and deviations in cross-sectional geometry) and internal voids. Image processing methods are employed to analyze the X-ray CT images and extract defect data. An algorithm is developed to automatically capture the morphology and distribution of defects from the datasets. Detailed characterisation of internal voids, including their geometry, volume, aspect ratio, orientation, and distribution within the strut, is a key novelty of this research. Unlike previous studies, which have considered internal voids as spheres, this work explores the effect of void shapes on the mechanical properties of lattice structures. In future studies, the results will be incorporated into finite element models to assess how these imperfections affect the mechanical performance of lattice structures.

Session 2.3: Additive manufacturing

Paper ID: S21-324

A Low-cost Pellet Extruder for Material Extrusion-based Additive Manufacturing

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Abstract

In the plastic industry, extrusion is the basic process for converting polymers from granular raw material, or pellet, into a homogeneous melt. This melt is delivered at high pressure and at a uniform rate and temperature to the mould for forming into the final shaped part. With the advent of additive manufacturing, this process has been adopted as one of the seven ASTM-defined processes known as material extrusion (MEX). The most commonly used MEX systems are filament-based due to their relatively simple construction. However, these systems are limited in the flexibility of motion and feature slow extrusion speeds. This project aimed to design and manufacture a low-cost, lightweight, high-flow rate pellet extruder integrated with an ABB robotic arm for 3D printing. Three thermoplastic polymers, PLA, PP and LDPE, were selected for this system. From extrusion tests, the extruder achieved mass flow rates of 243 g/h, 362 g/h and 446 g/h for PLA, PP and LDPE, respectively. Under the right conditions, this extruder could run as high as 25 times faster than a typical filament-based desktop system. This robotic-driven, low-cost MEX system demonstrated enhanced performance, stability, and versatility for additive manufacturing applications.

Session 2.3: Additive manufacturing

Paper ID: S21-304

Macro/Micro Synergistic Construction of Three-Dimensional Porous Piezoelectric Materials and Devices

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Abstract

Achieving efficient electrical conversion and energy storage from abundant, discrete, and often underutilized environmental pressure energy is a critical need and a key area of research in renewable energy development worldwide. Piezoelectric materials, known for their excellent mechanical and piezoelectric properties, have been used for decades to harness high-entropy energy and power electronic devices. By building on macro/micro structural synergy, this research has introduced a series of innovative methods and technologies for the efficient, large-scale fabrication of piezoelectric composite materials and devices. The study explores the principles underlying piezoelectric performance enhancement in frame-structured components, resulting in a range of new three-dimensional frame structure piezoelectric devices with diverse configurations and output properties; Assisted by a template method, piezoelectric devices with multi-level pore structures were prepared, confirming the synergistic effect of electrets; Furthermore, by coupling micro-foaming with 3D fused deposition modeling (FDM) technology, a novel in-situ foaming-assisted FDM approach was developed to harmonize macro and micro structures, offering a simple and rapid technique to enhance piezoelectric output. This study presents a new approach for optimizing output performance through simultaneous macroscopic and microscopic structural design, paving the way for piezoelectric nanogenerators to achieve their potential in large-scale applications.

Session 2.3: Biopolymers
Paper ID: S03-313

Impact of electron beam irradiation on blends made from P3HB and P3HB4HB

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Abstract

Biopolyesters like Polyhydroxyalkanoates (PHAs) are of great interest for sustainable polymer engineering due to their biodegradability and biocompatibility, making them promising candidates for various applications. However, their mechanical and thermal properties often require modification. Blending and electron beam irradiation are two methods to modify these properties. By blending two different PHAs, material characteristics can be combined, and via electron beam irradiation, the polymer's molecular structure can be changed, altering both thermal and mechanical characteristics. In this study, we investigate the thermal and mechanical properties of blends from poly(3-hydroxybutyrate) (P3HB) and poly(3-hydroxybutyrate-co-4-hydroxybutyrate) (P3HB4HB) and the effect of electron beam irradiation on these blends, with a focus on the compatibilization of the two different phases. The high crystallinity of P3HB causes brittle mechanical behavior and generally prevents crosslinking during irradiation [1]. In contrast, P3HB4HB is amorphous and therefore a ductile polymer crosslinking easily under electron beam irradiation due to the absence of crystalline phases. These different properties of P3HB and P3HB4HB present a unique opportunity to investigate how blending and subsequent irradiation can influence the overall behavior of the material. We investigate alterations in molecular structure and correlate these with changes in characteristic temperatures and crystallinity, as well as mechanical properties, aiming to characterize the particle-matrix interaction between the two polymer phases and the changes in these interactions as a result of irradiation. It is assessed whether the presence of both a crystalline and an amorphous phase can lead to beneficial synergistic effects.

[1] Krieg, David, et al. "Additive Free Crosslinking of Poly-3-hydroxybutyrate via Electron Beam Irradiation at Elevated Temperatures." Polymers 15.20 (2023): 4072.

Session 2.3: Biopolymers

Paper ID: S03-294

Antioxidant biopolymers for prolonging food shelf life utilizing tannins derived from grape marc

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Abstract

Research directions for sustainability in the food sector include replacement of oil-based plastics with biopolymers. In addition added functionality such as antioxidant properties are of interest to prolong product shelf-life. We have established antioxidant properties in biopolymers such as ethyl cellulose, starch and gelatin, including lessening the rancidity of fish and vegetable oils in contact with the biopolymers. Grape marc is a promising source of antioxidant tannins that can be applied to food packaging applications. Most recently, tannins present within a commercial grape seeds powder, or a grape skins solution were added into gelatin to create biopolymer films with active and intelligent properties. Both tannin extracts displayed differences in colour in solution as the pH was changed, which provided an intelligent function with the use of skin tannins. The films released a proportion of the tannins into a 50% ethanolic food simulant, and exhibited antioxidant activity, given by the DPPH radical scavenging by the same food simulant. [Etxabide, Y. Yang, J.I. Mate, K. de la Caba, P.A. Kilmartin, Food Packag. Shelf Life 2022, 33, 100896]. This project will continue as part of a New Zealand MBIE-funded programme, “Waste to treasure: using novel chemistry to valorise residual plant materials”, involving researchers from the University of Auckland, Scion, University of Canterbury and Auckland University of Technology. The programme will use grape marc waste fractions that have received little attention in the past, including grape proteins, bioactive polyphenols, fine chemicals and surfactants, along with high-value paper products with fire-retardant and antimicrobial properties and paper-based electronics. The research is directed to eliminating a problem horticultural waste stream and will help to establish economically and environmentally sound local biorefineries. [https://www.waste2treasure.co.nz/]

Session 2.3: Biopolymers

Paper ID: S03-263

Development of starch film for food packaging

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Abstract

Starch-based films have attracted significant interest in food packaging, as their biodegradability offers a sustainable alternative to conventional petroleum-based films, addressing the growing demand for environmentally friendly packaging solutions[1]. Despite these advantages, a key challenge in developing starch-based films with high-barrier properties is achieving a balance between mechanical strength, water resistance, and gas permeability all while maintaining biodegradability [2]. To address these limitations, researchers have focused on improving starch-based films by incorporating additives and utilizing advanced processing techniques [3]. One promising approach involves the use of polyvinyl alcohol (PVOH) in combination with other property enhancers in starch-based formulations. These additives enhance the material's overall performance such as mechanical strength, water resistance, and gas barrier properties. This study investigates the potential of these enhanced starch-based films through two methods: extrusion casting and solution coating. To assess the effectiveness of these novel formulations, a series of tests were conducted, including evaluations of rheology, film-forming ability, water vapor transmission rate (WVTR), and mechanical properties. These tests aim to determine the suitability of these formulations for practical food packaging applications, while maintaining their biodegradable characteristics. The findings from these evaluations will contribute to the development of more sustainable packaging solutions that align with industry requirements.

References

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Session 2.3: Biopolymers

Paper ID: S03-238

Thermoplastic polyesters in packaging applications: Tribute to furan-based polyesters

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Abstract

The aim of this study was to obtain environmentally friendly bioplastics suitable for beverage packaging by developing furan-based polyesters and studying their properties intended for packaging applications, utilizing mechanical and gas barrier properties. All materials were synthesized employing a two-step melt polycondensation reaction using dimethyl furan 2,5-dicarboxylate (DMFDCA) and different diols including 1,2-ethylene glycol, 1,3-propylene glycol, 1,4-butylene glycol, 1,5-pentylene glycol, and 1,6-hexylene glycol. 1H nuclear magnetic resonance (NMR) and Fourier-transformed infrared spectroscopy (FTIR) analyses were applied to confirm the molecular structure of the polyesters. Differential scanning calorimetry (DSC), dynamic mechanical measurements (DMTA), and X-ray diffraction (XRD) allowed for characterizing the supramolecular structure of the synthesized polymers. Moreover, oxygen transmission rate (OTR) measurement, TGA analysis, along tensile tests confirmed the utilitarian performance of the obtained bio-based polyesters. Despite the fact, that the most developed renewable polyester with an already confirmed industrial potential is polylactide (PLA), herein one will emphasize the potential of furan-based materials, also as poly(ethylene terephthalate) (PET) replacements. Replacing PET with alternatives like PEF, PTF, or PLA can promote sustainable growth. However, addressing the environmental impact of polymers also requires a shift in social behavior, with a focus on reducing consumption as a central part of our daily routines.

This study was financed by the National Science Centre within project OPUS (no. 2023/51/B/ST8/00775).

Session 2.3: Circular Economy for Plastics and Recycling
Paper ID: S26-311

Assessing the degradation level and stability of recycled polypropylene via chemiluminescence analysis

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Abstract

Understanding the degradation level and remaining stability of polymers intended for recycling is crucial for obtaining high-quality recycled materials. This study explores chemiluminescence (CL) analysis as an analytical technique for monitoring the degradation level and stability of two polypropylenes with different stabilization systems (PP1 and PP2). These polymers were extruded consecutively up to seven times to simulate recycling and lead to different degradation levels. After each processing cycle, CL measurements were performed under air (CL-air) and nitrogen (CL-N2) atmospheres. Measurements obtained under air indicate that the oxygen induction time (OIT), the rate of change in CL intensity during auto-oxidation (RCL), and the time at the maximum CL intensity (tmax) are suitable indicators of the oxidative stability of PP. Melt processing of PP leads to a decrease in OIT and tmax, and an increase in RCL. The antioxidants (AO) present in PP1 are consumed substantially faster than those in PP2. PP1 shows the lowest OIT and tmax and highest RCL values after a single melt processing step while PP2 requires five processing cycles to reach the same situation. CL-N2 measurements show that the total luminescence intensity (TLI-N2) and the temperature of the TLI peak (TTLI) reflect the degradation level of PP. Increasing the number of processing cycles of PP leads to an increase in TLI-N2 and reduces TTLI. In CL-air analysis, a peak related to the thermal history of the polymer (TLI-air) is observed and its area increases with the number of processing cycles. TLI-air and the TLI-N2 correlate linearly for both PPs, demonstrating that the TLI-air can also indicate the degradation state of PP. Therefore, CL-air measurements can effectively assess PP's degradation level and stability, providing essential insights for evaluating material recyclability.

Session 2.3: Circular Economy for Plastics and Recycling

Paper ID: S27-348

Post-consumer recycling of PA66-GF Composites from Electrical Waste: Performance Retention through Accelerated Aging Models

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Abstract

The recycling of post-consumer glass fiber-reinforced polyamide 6,6 (PA66-GF) composites from electrical equipment poses significant challenges due to material degradation after prolonged use and high-temperature exposure. This study investigates the recyclability and performance retention of PA66-GF composites simulating end-of-life (EoL) waste from low-voltage circuit breaker components. A simplified accelerated thermal aging model, based on an Arrhenius-type equation, was developed to examine the relationship between aging time, temperature, and the material's mechanical properties. This model was then used to age virgin PA66-GF specimens to a state representative of post-consumer waste after a 20-year ser-vice life in low-voltage circuit breakers. Comparative analyses were conducted on virgin, aged, and recycled PA66-GF samples to assess mechanical, thermal, electrical, and structural changes through various characterization methods, including tensile and flexural tests, Charpy impact tests, Comparative Tracking Index (CTI), glow wire tests, vertical flame burning tests, and SEM-EDX measurements. Testing revealed measurable declines in mechanical properties in aged samples, accompanied by changes in crystallinity and oxidation levels. Recycled aged samples, when incorporated back into new formulations at varying proportions, demonstrated that up to a specific threshold, recyclate could be reintroduced with minimal impact on key material properties. These results suggest an optimal percentage of aged/recycled content in new PA66-GF formulations that balances performance and sustainability goals, providing a practical approach for recycling EoL plastic components from electrical waste. This study underscores the feasibility of incorporating post-consumer recycled compo-sites into circular material flows and offers a framework for recycling similar high-performance polyamide composites in industrial applications.

Session 2.3: Circular Economy for Plastics and Recycling

Paper ID: S04-333

Circular bio-based polymers for the construction industry

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Abstract

The entire construction industry in general, but also building services engineering and supply technology in particular, have a great potential for optimization in terms of their greenhouse gas emissions and waste generation, as they are responsible for more than a third of the global greenhouse gas emissions. One way in which this proportion can be reduced is by replacing petrochemical raw materials in polymer components with bio-based base materials. Bio-based plastics can make a significant contribution to resource efficiency and the circular economy, especially if they are produced regionally, used and reused or recycled sensibly. In the CircularBioMat project we want to minimize the environmental footprint by substituting petroleum-based polymers with bio-based polymers for building services engineering. First, we evaluated the used oil-based materials and together with the project partner suitable bio-based polymers were selected. In a further step we characterised the oil- and bio-based polyethylene PE with High Pressure Capillary Rheometer for viscosity, Differential Scanning Calorimetry for thermal properties and pvT measurements. One bio based material CBM 1 matches the viscosity of both PE IM for injection moulding and PE EX for extrusion quite well, while the CBM 2 is expected to have a lower zero shear viscosity. The DSC shows similar melting behaviour, only the degree of crystallinity differs, especially CBM 1 shows a lower normalized enthalpy. The specific volume is different in all polymers, only the CBM 1 matches the PE Ex in the solid region, while in the melting it has a higher specific volume. In a further step we made recycling trials by injecting molding and grinding the materials ten times and we analysed the viscosity with a cone and plate rheometer to observe changes in the zero shear viscosity and especially the cross over point. The mechanical behaviour is tested by tensile testing for different recycling steps by a partner.

Session 2.3: Circular Economy for Plastics and Recycling

Paper ID: S27-331

Controlling Silicone Degradation - A First Step in Circularising the Silicone Economy.

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Abstract

Silicones, or polysiloxanes, have revolutionized modern industrial processes, medical applications and construction industries. However, no current commercially-scaled recycling solution exists for this ubiquitous polymer, making it a major source of plastic waste. Hydrolysis is the main natural degradation process that degrades silicones, and can be replicated under controlled laboratory conditions. We have begun to explore strategies for the hydrolysis of bulk crosslinked polydimethylsiloxanes as a route towards the closed-loop recycling of waste products into useful silicone feedstocks. Paramount to the development of a successful closed-loop recycling pathway is method development for analysing complex mixtures of inorganic polymers and their degradation products, which is largely absent from the literature. Here we will discuss the methodology and challenges of analysing complex heterogeneous mixtures, and provide insight into the composition of recycled silicone feedstocks and their downstream products. Additionally, we will discuss our exploration of silicone waste composition and its impact on the degradation product mixtures, an important factor in developing broadly applicable recycling solutions.

Session 2.3: Extrusion

Paper ID: S06-446

Producing TPU-TPU/SWCNT multi-layered composites using melt multipliers

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Abstract

Forced assembly multilayer co-extrusion is a continuous and flexible melt processing route that can create layered structures based on the baker's transformation by repeatedly stretching, cutting, and stacking the melt flow. This processing technique may bring advantages in the design of polymer nanocomposites through the selective localisation of fillers and enhancement of their dispersion. This work describes the use of a prototype device composed of small-scale melt multipliers, using DentIncx mixing channels [1]. A pre-dispersion of single-walled carbon nanotubes (SWCNT) in polypropylene glycol was melt-extruded with thermoplastic polyurethane (TPU) to produce composite filaments. The selected composition was fed to the prototype device together with neat TPU, resulting in the extrusion of tapes with alternate layers of the different melts. We show that layered tapes display electrical conductivity and keep the ductility of TPU.

Session 2.3: Extrusion

Paper ID: S06-296

Design and Modelling of an Advanced Filament Extrusion Die with In-line Rheological Analysis

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Abstract

High-quality filaments are crucial for fused filament fabrication (FFF) to ensure components with strong structural integrity and good surface finish. Filament defects like inconsistent diameter, ovality, or poor fibre dispersion in fibre-reinforced filaments reduce print quality, compromising the performance and reliability of 3D-printed parts. This paper delineates the conceptual design and development process of an advanced extrusion die that enables precise temperature control and real-time rheological analysis of polymeric flow with an aim to enhance filament quality. The die design, shown in Figure 1, was inspired by the approach proposed by Gancheva et al. [1] as well as the operational principles of capillary rheometers, which evaluate material flow and rheological properties by observing pressure variations across zones with different diameters. Parallel to the design development, computational fluid dynamics (CFD) simulations were conducted using ANSYS PolyFlow to analyze the flow dynamics within the die prior to empirical testing. The emphasis of this analysis is to predict the temperature and pressure profile essential before stepping into the processing stage of the material of interest. A generalized Newtonian non-isothermal flow problem was solved iteratively for a polymeric material that follows Arrhenius Law and Cross model for the temperature and shear rate dependency of viscosity, respectively. This approach demonstrates the potential of combining flow modelling with unconventional die designs to address polymer extrusion challenges and broaden material portfolio of additive manufacturing.

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Session 2.3: Extrusion

Paper ID: S06-212

Extrusion-based processing of cellulosic feedstocks for thermoformed packaging applications

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Abstract

Cellulosic biopolymers require processing to be suitable for use in paper packaging. Typically this is carried out at very large scales and requires substantial water and chemical use. Twin screw extrusion is a potential alternative, which could be applied at much smaller scale (several thousand tonnes per year) enabling small scale agri-waste feedstocks which are currently composted or landfilled to be converted to pulp suitable for moulded fibre production. Such items could substitute for difficult to recycle plastics. This investigation tested the hypothesis that extrusion pulped hemp hurd could be substituted for mechanically pulped pine in thermoformed moulded fibre products. A LabTech twin screw extruder (26 mm diameter, 40 LD) was used to process hemp hurd chips soaked overnight in a proprietary low-hazard chemical solution (10:1 liquor: wood ratio). The peak extrusion temperature was 120°C, chosen to improve chemical activity and generate steam without causing excessive drying or degradation of the pulp. Different screw configurations were trialled to assess influence on fibre and pulp properties. Pulp was moulded into trays using a Kiefel Natureformer pilot scale thermoformer. It was blended with chemically processed commercial pulp as appropriate to ensure sufficient material properties, quantified via tensile and burst testing. All configurations caused breakdown and pulping of the hurd chips. Conveying elements retained the greatest fibre length but required screening of pulp. More intensive processing via different element types increased the amount of useful pulp but reduced the fibre length; optimal configurations produced fibres around 0.5 mm in length. Blending the hurd pulp with wood pulp ensured that material performance was broadly equivalent to typical moulded fibre made from commercial pine pulp. This confirms that extrusion processing could in principle be used to produce pulp from suitable biobased feedstocks, enabling distributed manufacturing approaches.

Session 2.3: Extrusion

Paper ID: S06-230

Applications of Twin-Screw Extruder with Ultra-High Length-to-Diameter Ratio in Polymer Mixing

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Abstract

The twin-screw extruder is a critical tool for the mixing and granulation of materials, extensively utilized in the processing of plastics, rubber, food, and pharmaceutical products. It operates by generating pressure and shear force through the rotation of the screws, enabling materials to be fully plasticized, uniformly mixed, and molded via a die. For certain polymer material systems, utilizing a twin-screw extruder with a substantial length-to-diameter (L/D) ratio is often essential to achieve longer residence times and ensure uniform mixing. Presently, the L/D ratio of commercial twin-screw extruders can reach up to 60, but this may not always suffice. In some cases, dual stages of twin-screw extruders or repeated mixing and extrusion processes are necessary to attain homogeneous mixing, which significantly increase both equipment costs and manufacturing complexity. We have developed screw support elements that facilitate the use of twin-screw extruders with ultra-large L/D ratios (greater than 100). This report will present the findings of our research regarding the application of these extruders with ultra-large L/D ratios across three domains: the gel spinning of ultra-high molecular weight polyethylene, the dry-jet wet spinning of polyacrylonitrile nascent fibers, and the blending of graphene/polyamide 6. These advanced extruders have shown significant advantages in mixing material systems and enhancing product performance. They hold great potential for the development of new polymer and composite materials, as well as for advancements in polymer recycling and sustainability.

Session 2.3: Injection moulding
Paper ID: S32-57

Evaluating Purgeability in Additive and Conventional Manifold Systems: An Experimental and Numerical Approach

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Abstract

In the injection molding process, manifold systems are essential for distributing the melt from the injection unit to the cavities of the mold. The increasing use of additive manufacturing enables the production of complex systems with optimized geometries that would be challenging or impossible to manufacture conventionally. These novel geometries not only promise improved flow distribution, but also more efficient purging during color and material changes, which is essential for minimizing waste and reducing energy consumption. The efficiency of these purging processes depends on several factors, including the geometry of the distribution system, the flow velocity and the rheological properties of the materials used. A number of simulative and experimental evaluation criteria are available to quantify the purgeability. In this paper, the purgeability of two additively manufactured manifold systems and one conventionally manufactured manifold system is analyzed both experimentally and numerically. For this purpose, experimental color change tests are first carried out and evaluated at six different operating points. These operating points are then transferred to the ANSYS Fluent simulation environment, and the results are compared with the experimental data. The additively manufactured manifold systems exhibit better purging behavior overall, with lower temperatures resulting in the fastest purging times. It is shown that not every quality criterion is equally suitable for the evaluation of purgeability, even if there is a high transferability of the simulation results to the experimental data.

Session 2.3: Injection moulding

Paper ID: S11-122

Determination of pVT data of thermoset moulding compounds for the simulation of the warpage behavior

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Abstract

The development of the FEA interface for injection moulding simulation programs has enabled the transfer of a range of results, including temperature distribution, pressure gradient, fibre orientation, residual stress and warpage, directly to structural analysis software such as ANSYS. This allows the prediction of the expected properties of the part. The accuracy of this software is therefore dependent on the quality of the predictions made by the injection moulding simulation. Inadequate material data sets, particularly with regard to pVT data and the lack of systematic warpage studies, have a negative impact on the prediction quality of injection moulding simulation and structural analysis of thermoset moulding compounds. As a result, the potential of these materials, such as low creep, good chemical resistance and high strength and stiffness even at higher temperatures, cannot be realized. Therefore, more expensive high-performance thermoplastics or energy-intensive aluminium are used to realise potential technical applications. In order to obtain the necessary pVT data, it is essential to employ an appropriate test method. This will allow the creation of a more comprehensive dataset for thermoset material. A series of comprehensive tests on the high-pressure capillary rheometer are employed to characterise this material behaviour under isothermal and isobaric test conditions. Subsequently, warpage simulations are conducted. To validate the simulative work, systematic injection moulding tests are performed, varying different processing parameters and component geometries to obtain different warpage properties.

Session 2.3: Injection moulding

Paper ID: S11-107

Improvement of injection molding simulation by application of modeled pressure-dependent viscosity data

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Abstract

The accuracy of injection molding simulations is largely dependent on the quality of the material data on which the flow calculations are based. Viscosity, as a measure of flow resistance in plastic melt, is a key material property that significantly affects simulation results, especially the simulated injection pressure. The melt viscosity of a polymer is largely dependent on three factors: temperature, shear rate and pressure. A conventional high-pressure capillary rheometer (HPCR) can be used to measure viscosity in a shear rate range relevant for injection molding as a function of temperature and shear rate. However, conventional HPCR cannot determine the pressure dependence. Special devices, such as back pressure viscometers or back pressure chamber extensions, are required for this, but they are rarely available. Additionally, these measurements are time-consuming and expensive, which is why pressure-dependent viscosity data are rarely available. In this study, pressure-dependent viscosity data are calculated via a correlation between conventional viscosity data and pressure dependent melt density, utilizing the free volume approach based on the Simha-Somcynski equations of state. The advantage of this model calculation is that it is based on existing material data and is therefore particularly cost-effective. Subsequently, injection molding simulations of a mold with a hot runner manifold were carried out for both amorphous and semi-crystalline thermoplastics, using two different widely used software solutions. The simulations were carried out using conventional viscosity data and model-calculated pressure-dependent viscosity data. Injection pressures were compared at different injection speeds, revealing significantly higher injection pressures for amorphous polystyrene based on pressure-dependent data. Additionally, experimental injection molding tests were performed at simulated operating points to evaluate improvements in simulation accuracy.

Session 2.3: Injection moulding

Paper ID: S32-82

Data-driven optimization of part quality and energy consumption during injection molding

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Abstract

To preserve energy and resources, the use of in-line embedded sensors to monitor product quality is becoming a growing field of research. In this investigation several defects common to injection molded parts are purposely forced by choosing the process parameters accordingly. This is followed by an analysis of common injection molding process parameters (cylinder wall temperature, mold wall temperature, clamping force, holding pressure, injection speed) to eliminate the forced defects through a design of experiments (DoE). Furthermore, the quality of the molded parts, the energy input per cycle and the components of the total cycle energy (heating elements, main drive, and periphery) are evaluated. These experiments are carried out with two different molds and with three materials (Polypropylene (PP), Polyamide 6 (PA6), and Polycarbonate (PC)) in order to determine whether mold geometry or the used material have any influence on the total cycle energy. Initial investigations for PP showed only a slight increase in the total energy of the cycle at high cylinder wall temperatures, as the reduced viscosity simultaneously reduced the consumption of drive energy. The results for PA6 and PC are shown in the final presentation.

Session 2.3: Modelling and Simulation
Paper ID: S13-150

Development of physics-informeability measurement in resin transfer molding and process surrogate modeling

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Abstract

Resin transfer molding (RTM) is an essential process for manufacturing fiber-reinforced polymer (FRP) materials, where thermoset resin is infused into a closed, fiber-preloaded mold under a pressure drop. Accurate prediction of resin flow behavior is critical to prevent defects that can compromise product quality. In practice, computer-aided engineering (CAE) simulation software is commonly used to simulate resin flow and optimize RTM processes. Resin flow through porous media in RTM is typically governed by Darcy's law and continuity equations, with permeability as a key parameter. However, conventional permeability measurement requires specially designed devices, which can incur significant material and labor costs. Additionally, optimizing the RTM process directly through CAE simulations is challenging due to the heavy computational demands involved. This study aims to develop a surrogate model for RTM by leveraging physics-informed neural networks (PINNs), a deep learning technique integrating physical laws into neural networks. The PINN model aims to predict resin flow behavior and estimate critical parameters like permeability using historical operation data, eliminating the need for experimental measurements. CAE-simulated data was used to train the PINN model, allowing it to establish reliable permeability estimates. The model's results were then compared to simulation data to assess accuracy. Future work will incorporate real-world process data to further refine and validate the model's predictive capabilities. Ultimately, this PINN-based model is designed to be a computationally efficient tool for RTM process optimization, addressing the complex challenges encountered in industrial applications.

Session 2.3: Modelling and Simulation

Paper ID: S13-126

Development of a model for the temperature response of melting surfaces in ultrasonic heating systems

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Abstract

The heat-sealing operation is completed by heating the melting surfaces to the temperature range at which they become melted and immediately cooling them. This heat seal utilizes the thermoplastic properties of plastic to produce adhesion through intermolecular forces that occur between molecules. For proper implementation of heat sealing, it is essential to consider operating conditions that take the melting surface temperature into account. On the other hand, ultrasonic sealing has many unclear aspects to its technology, despite expectations for contaminated sealing and other factors. In this study, we attempted to simultaneously measure the output power and melting surface temperature in the ultrasonic heating method, as well as to construct an estimation model. The model assumes that heat transfer is only in one-dimensional direction, and the boundary conditions for the horn and anvil are semi-infinite solids with a thin region of temperature transfer. The melting surface temperatures were numerically calculated using the heat conduction equations, considering internal heat generation for the melting surface. Numerical calculations were performed using the time variation of the output. A Teflon sheet (0.2 mm) and a retort pouch (material composition: PET 12㎛/ONY 15㎛/CPP 60㎛) were used as the model materials. Different values for energy efficiency were given for each temperature range in case of a retort pouch. This is due to the lower viscoelastic modulus associated with the melting of the PP layer, which makes it harder to generate frictional heat. As a result, the calculation results were found to capture the experimental results well. Therefore, in the ultrasonic heating method, it is now possible to study the operating conditions considering the melting surface temperature response.

Session 2.3: Modelling and Simulation

Paper ID: S13-111

Packing Frustration and Polymer Glass Formation

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Abstract

The generalized entropy theory (GET) of polymer glass formation combines the lattice cluster theory for polymer thermodynamics with the Adam-Gibbs relation between the configurational entropy and the structural relaxation time. The GET enables explaining many important problems in the study of polymer glass formation and makes a long list of predictions on the influence of multiple physical factors on the glass formation of polymeric materials, such as monomer structure, rigidities of backbone and side chains, lengths of backbone and side chains, cohesive energy, pressure, spatial dimension, etc. From a molecular perspective, a key prediction from the GET is that packing efficiency determines many characteristic properties of polymer glass formation. Polymers with more complex structures and more irregular shapes exhibit more packing frustration and have a stronger temperature dependence of the configurational entropy, so these polymers have larger fragilities and higher glass transition temperatures. By contrast, polymers with relatively simple structures can pack more efficiently in space and the variation of the configurational entropy with temperature is relatively weak in these materials, so these polymers have larger fragilities and lower glass transition temperatures. In recent works, we showed that the degree of packing efficiency can be tuned by adjusting the arm number in star polymers and the knot complexity in ring polymers, and we utilized molecular dynamics simulations to systematically investigate the glass formation of these polymers, with a particular focus on the role of packing efficiency in determining polymer glass formation. This talk discusses these results in detail.

Session 2.3: Modelling and Simulation

Paper ID: S33-98

Advanced Fan-Out Packaging Interface Strength Measurement and Hygro-Thermal Coupling Delamination Investigation

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Abstract

Advanced Fan-Out packaging is susceptible to thermally induced warpage due to the mismatch in coefficients of thermal expansion (CTE) between different materials. Additionally, thermally induced stresses often concentrate at the interfaces. Some materials, such as molding compounds, underfill, and polyimide, also tend to absorb environmental moisture, leading to expansion. This can result in delamination or popcorn failures at the interfaces during thermal processes. To mitigate these risks, this study is divided into two parts. The first part investigates the interface strength of the redistribution layer (RDL) under temperature-humidity conditions. Double cantilever beam testing was conducted on bi-material specimens under temperature-humidity preconditions to explore the interfacial strength between copper and polyimide, as well as to observe the influence of moisture sensitivity level (MSL) test conditions. The experimental data were combined with analytical formulas to determine the mode I critical strain energy release rate and to observe the effect of different temperature-humidity conditions on interface strength. In the second part, Fan-Out wafer-level chip scale packaging (FO-WLCSP) is used as a test vehicle and modeled using the finite element method (FEM), validated against actual packaging warpage measured by shadow moiré. This model is then applied to analyze coupled stress under a hygro-thermal environment, and the virtual crack closure technique is employed to evaluate the energy of opening mode at the crack tip of the interface between copper and polyimide. This allows for an assessment of the risk of interfacial delamination after post-mold curing processes and MSL testing. Finally, the Taguchi experimental design method is used to assess the impact of geometric design and material selection on the strain energy release rate at the crack tips.

Keynote

Session 2.4: Biomedical applications
Paper ID: S23-349

Double-Expanded Polytetrafluoroethylene (PTFE)-Hydrogel Vascular Grafts with Enhanced Mechanical and Biological Properties

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Abstract

Expanded polytetrafluoroethylene (ePTFE) is commonly used for vascular grafts. However, its application as small-diameter grafts has been hampered due to problems such as thrombosis and restenosis stemming from lack of endothelialization and mis-matched mechanical properties. Recently, a novel manufacturing technique for ePTFE has been developed. Through modifications to the ePTFE processing by adding one additional expansion step at lower temperatures, highly compliant double-expanded PTFE (dePTFE) with enhanced mechanical properties and a desirable toe region akin to natural blood vessels can be produced. In this study, an inner layer of P(AAm-co-NaAMPS)-xanthan-alginate hydrogel was synthesized and introduced onto the luminal surface of both ePTFE and dePTFE vascular grafts. In these polymer-hydrogel vascular grafts, the outer polymer layer provided mechanical stability, while the inner hydrogel layer enhanced cytocompatibility, endothelialization, and burst pressure resistance. Among the four types of vascular grafts studied, namely, ePTFE, dePTFE, ePTFE-P(AAm-co-NaAMPS)-xanthan-alginate, and dePTFE-P(AAm-co-NaAMPS)-xanthan-alginate, the dePTFE-P(AAm-co-NaAMPS)-xanthan-alginate hydrogel vascular graft exhibited the most desirable attributes. It had the highest longitudinal and circumferential tensile strengths with a desirable "toe region," highest burst and leakage pressures, and highest suture retention strength. Additionally, this vascular graft also demonstrated the best endothelialization capabilities. Overall, the dePTFE-P(AAm-co-NaAMPS)-xanthan-alginate hydrogel vascular graft was founded to be a promising candidate for PTFE-based vascular grafts, showing potential for future applications in vascular graft transplantation.

Session 2.4: Biomedical applications

Paper ID: S02-22

Towards a new generation of medical fibers for local drug delivery

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Abstract

Traditional local drug delivery methods often face challenges such as sudden release of medication, limited drug storage and poor mechanical properties. Here, we introduce a novel approach to local drug delivery employing melt-spun drug-loaded liquid-core filaments (LiCoFs). LiCoFs, composed of a drug-containing liquid core enveloped by poly(ε-caprolactone) (PCL), offer a promising solution to these issues. We conducted experiments incorporating fluorescein sodium salt as a model drug dissolved in various liquid cores. For some fibers, the liquid was also exchanged with different drug-containing solutions using a pumping device. We evaluated the thermal, mechanical, and structural characteristics of LiCoFs and conducted extensive drug diffusion trials. The intactness of various anti-inflammatory drugs were assessed after the melt-spinning trials using mass spectroscopy. The anti-inflammation property of drugs after spinning was also verified using Cyclo-oxygenase (COX) inhibitor tests. These drug-loaded LiCoFs pave the way towards a new generation of medical fibers/textiles enabling precise and localized drug delivery.

Session 2.4: Biomedical applications

Paper ID: S02-12

New Forms of Electrospun Nanofiber Materials for Biomedical Applications

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Abstract

Electrospinning is an enabling nanotechnology which is capable of producing a rich variety of novel structured materials in many biomedical applications. New forms of electrospun nanofiber materials were recently developed in our lab including nanofiber foams/sponges, short nanofibers, nanofiber aerogels, nanofiber microspheres, and porous nanofiber microspheres. These developed materials have been demonstrated in several biomedical applications (e.g., hemostasis, tissue regeneration, and cell delivery). The compressed nanofiber foam is capable of re-expanding to its original shape in atmosphere, water and blood within ten seconds. Such nanofiber foams exhibit greater capacity of water/blood absorption compared to current commercial products and high efficacy in whole blood clotting assay, in particular for thrombin-immobilized samples. These nanofiber foams are capable of being packed into a syringe for injection. The in vivo tests indicated the effectiveness of nanofiber foams for hemostasis in a porcine liver injury model. In summary, the newly developed electrospun nanofiber materials show great promise in biomedical applications.

Session 2.4: Biopolymers
Paper ID: S24-386

Tailoring of lignin based biopolymer to polyelectrolyte for dye removal in textile effluent

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Abstract

Sivasakthi Raghavendar1,2, Satyapaul A. Singh1, K. M. S. Rao2, D. Purnima1 1Department of Chemical Engineering, BITS-Pilani, Hyderabad, India 2Ion Exchange (India) Ltd., Research & Development Centre, Hyderabad, India Abstract The rapid depletion of non-renewable resources necessitates a shift towards a bio-economy, focusing on the sustainable use of renewable bio-resources. Careful resource management is crucial for sustainable development and future progress. Sustainable wastewater treatment involves low energy consumption and minimal environmental impact. Biopolymer-based coagulants and flocculants are prospective alternatives for synthetic organic flocculants and inorganic coagulants as they are abundant, environmentally friendly, easily degradable, and extremely safe. The objective of this research work was to develop a lignin-based biopolymer as coagulant for dye removal from textile effluent which is a significant cause of illness in humans and the degradation of the environment. Upon coagulation the sludge generated should be environmentally friendly and safe for disposal. Lignin was tailored to lignin polyamine and characterization techniques such as FTIR, NMR, XPS, XRD, TGA, and SEM with EDX were performed. Lignin polyamine showed promising results in the treatment of a synthetic effluent containing known concentrations of Reactive Red and Reactive Blue dyes. Furthermore, the lignin polyamine was found to be effective in removing dyes from real textile effluent, which contains a mixture of dyes of unknown concentrations. Therefore, alternative green synthesis of lignin biopolymers can contribute to achieving the World Sustainable Development Goals (SDGs).

Session 2.4: Biopolymers

Paper ID: S24-385

Rheological and thermal evaluation of modified thermoplastic starch/poly (butylene succinate adipate) blends with tartaric acid and dicumyl peroxide as coupling agents

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Abstract

The pollution of the oceans with plastic waste is a major environmental challenge that calls for the development of sustainable materials. Biopolymer blends, particularly modified thermoplastic starch (TPSA) and poly(butylene succinate adipate) (PBSA), have emerged as promising alternatives. Previous studies have focused on improving the compatibility of these polymers, which possess contrasting hydrophilic and hydrophobic properties, by incorporating coupling agents such as tartaric acid (TA) and dicumyl peroxide (DCP). While DCP showed limited effects, TA was found to significantly improve the mechanical properties, processability and microstructure of TPSA/PBSA blends by increasing ductility and homogeneity. Based on these results, the current study investigates the rheological and thermal performance of these blends, focusing on their potential for foaming in biodegradable packaging applications. Rheological properties were evaluated using a parallel plate geometry to investigate melt flow behavior, viscosity and processability. Thermal properties were evaluated using differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA), focusing on thermal stability and processing conditions. The rheological results indicate that the modified blends have reduced viscosity, which improves their suitability for foam processing. Thermal analysis shows that the presence of both TA and DCP in the blends results in closer thermal transitions with lower transition temperatures compared to unmodified blends. These results suggest that TPSA/PBSA blends modified with TA and DCP could be processed at lower temperatures and exhibit improved compatibility, making them more efficient for foam production. Overall, the study highlights the potential of these blends as environmentally friendly alternatives for foam-based packaging, with further optimization of processing conditions and mechanical properties required to fully realize their commercial viability.

Keynote

Session 2.4: Biopolymers

Paper ID: S03-245

Plastification of dialcohol cellulose for stable melt processing

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Abstract

The growing awareness of the negative environmental impact of non-biodegradable and fossil-based plastics, particularly in the context of disposable packaging, is driving an increasing interest in renewable and biodegradable alternative solutions. Cellulose and its derivatives appear good alternatives due to their biobased origin, biodegradability, and unique physical-chemical properties. However, when considering production methods, cellulose has some limitations. The strong intermolecular interactions between cellulose chains produce good mechanical properties at relatively low densities. Those interactions remain largely intact as the temperature rises, resulting in cellulose having a melting temperature higher than its degradation one. This hinders the exploitation of certain production methods used for conventional plastics, e.g. melt processing, advantageous in energy and solvent consumption. Chemical modification of cellulose fibres to dialcohol cellulose (DAC) lowers the crystallinity opening a processability window between the decreased glass transition and the degradation temperatures. DAC was successfully melt-processed using only water as a processing aid. If only water is added, the material's mechanical properties are strongly influenced by its water content, which varies depending on the environmental conditions (temperature and relative humidity). Therefore, less volatile plasticizers with different functional groups and molecular weights were added. The selected plasticizers are urea, glycerol, sorbitol, isosorbide and their combination with choline chloride to obtain deep eutectic solvents. The addition of a plasticizer enables to control processability and physical properties of DAC-based materials by decreasing their sensitivity to external conditions. This work aims to investigate the effect of different plasticizers and plasticizer content on the melt processability, with the support of rheological, morphological and thermomechanical analyses.

Session 2.4: Modelling and Simulation
Paper ID: S33-225

Enhancing the synthesis of polyurethanes: controlling side reactions and solvent dependencies

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Abstract

One of the most commonly produced polymers are polyurethanes, because of their wide range of applications. Nonetheless, there is not much clarity on their kinetics and level of side reactions, harming property design. Despite that it is shown that both reactants and products work as a catalyst, these effects are mostly lumped in one overall rate coefficient for the polyurethane reaction [1]. However, the knowledge of the rate coefficients for each reaction route, and thus each catalytic pathway, is essential to create accurate models that enable predictions of the reaction outcome at any set of conditions [2]. To tackle this knowledge gap, we performed the reaction between 1-butanol and phenyl isocyanate towards butyl phenyl carbamate at varying initial conditions to define rate coefficients for the non-catalyzed and the alcohol-, isocyanate- and carbamate catalyzed reaction. It should further be stressed that not only catalytic effects take place, but also the solvent has significant effects on the reaction rate. In order to develop a solvent dependent model, experiments were performed in three conventional solvents: dichloromethane, tetrahydrofuran and toluene; as well as in two promising 'green' solvents: limonene and cyrene. This enables linking the Arrhenius parameters of all four reactions to the solvent's properties, being the dielectric constant and hydrogen bonding ability. Our results show that the alcohol and carbamate catalyzed route are the main contributors to the overall reaction rate. Higher dielectric constants and the possibility to form hydrogen bonds both decrease the rate of reaction. Lastly, both green solvents showed to have a good applicability, however when cyrene is used, one has to be aware of its high viscosity compared to the conventional solvents [3].

[1] Cheikh et al. Polymers 2019 11(10), p.1543

[2] Trossaert et al. React. Chem. Eng. 2023 8(10), p.2408

[3] Trossaert et al. 2024 in preparation

Session 2.4: Modelling and Simulation

Paper ID: S33-243

Ultrasonically aided extrusion: a CFD and experimental analysis of polymer chain scission

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Abstract

The inconsistent composition of recycled polymer materials leads to significant variations in their viscosity, causing flow imbalances that reduce product quality during extrusion. Ultrasonically Aided Extrusion (UAE) presents a potential solution by using localized ultrasonic vibrations to reduce viscosity locally, allowing for dynamic flow balancing in the extrusion die during the extrusion process. However, designing dies for UAE is challenging due to the complex interactions of ultrasonic waves within the extrusion die. These interactions can be addressed using Computational Fluid Dynamics (CFD) to aid die design, ensuring more effective handling of ultrasonic wave effects. One significant concern is the potential for polymer scission due to ultrasonic vibrations. In this study, we compared CFD simulations with small scale lab tests to assess the impact of ultrasonic parameters—such as amplitude and exposure time—on polymer degradation. An experimental setup was developed to expose polymer samples under controlled conditions to ultrasonic wave effects. CFD simulations were then employed to model the resulting acoustic stresses. Our findings highlight the potential of a polymer degradation model combined with CFD simulations and experiments to enhance die design for minimal chain scission while maximizing flow balance. This approach could lead to more sustainable and efficient extrusion processes and a much faster die design process.

Keynote

Session 2.4: Modelling and Simulation

Paper ID: S13-176

Fiber Spinning Simulations with Integral Constitutive Equations

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Abstract

The fiber-spinning process is an important industrial operation to manufacture synthetic fibers. This process occurs under free-surface conditions, and the final properties of the fiber are characterized by the extensional properties of the polymer. Specifically, the non-isothermal response of the polymer in uniaxial extension dominates the process. The fiber-spinning process is analyzed by means of a unidirectional approach since the thickness of the fiber is very small with respect to its lateral dimension. The analysis accounts for the prehistory of the material inside the die based on purely extensional strains. For viscoelastic polymer melts, the constitutive equation must be able to describe adequately the rheological behaviour of the polymer in extensional flow. A good candidate for such modelling is the K-BKZ integral constitutive equation, with a spectrum of relaxation times, which captures well the non-linear viscoelastic response of polymer melts. The non-isothermal response is taken into account with a temperature shift-factor utilizing the Morland-Lee hypothesis. The present work includes effects due to gravity, inertia, and air drag, where applicable. Simulation results are compared with experiments on poly(ethylene terephthalate), polypropylene, and low-density polyethylene at low and high speeds. Results are also compared with previous simulations. It is shown that in some cases the extrudate swell at the spinneret exit must be taken into account to accurately predict the drawing forces, which makes a fully two-dimensional analysis a necessity for such operations.

Keynote

Session 2.4: Nanotechnology
Paper ID: S15-419

Multifunctional Biomimetic Nanocoatings

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Abstract

Large-scale biomimetic organic/inorganic hybrid nanocoatings with a nacre-like microstructure were prepared via a facile co-assembly process. Different from conventional polymer nanocomposites, such nanocoatings contain a high concentration of nanosheets, which can be well aligned along the substrate surface. Moreover, the nanosheets and polymer matrix can be chemically co-crosslinked. As a result, the nanocoatings exhibit exceptional mechanical properties, barrier performance, and dielectric strength, but meanwhile they are highly transparent. Because of their excellent performance and high versatility, such nanocoatings are expected to find widespread application.

Session 2.4: Nanotechnology

Paper ID: S15-319

High-Performance Polymer Processing via Integration of Nanostructured Carbon Scaffolds

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Abstract

In this study, we developed high-performance polymer composites by integrating nanocarbon-based porous fillers, using single-walled carbon nanotube (SWCNT) aerogels as a key example. These nanostructured fillers enhance the thermal and mechanical properties of polymer matrices, expanding their use in advanced polymer processing by addressing limitations inherent to conventional polymers. Among the applications, we fabricated flexible SWCNT aerogels uniformly coated with polyimide (PI), resulting in a high-surface-area structure that supports both processability and stability. This nanocarbon/PI composite provides a consistent PI layer on nanocarbon surfaces, forming a stable, high-surface-area interface suitable for energy applications. Its structure facilitates efficient charge storage, making it ideal for applications requiring high specific capacity and reliable charge-discharge cycles. In addition, we incorporated nanocarbon aerogels into high-temperature polymer matrices, including PI and other high-performance resins, used in carbon fiber reinforced plastics (CFRP). This integration raised the glass transition temperature (Tg) of the composite by 50–100°C, significantly improving high-temperature stability and mechanical robustness. The distributed nanocarbon network aids thermal dissipation and reinforces structural integrity, supporting CFRP applications demanding superior thermal performance. These findings underscore the versatility of nanocarbon-based porous fillers in polymer processing, paving the way for next-generation composites with enhanced thermal, mechanical, and energy-related properties. This work contributes to the advancement of durable, high-performance materials suitable for extreme conditions and multiple applications.

Session 2.4: Polymer Composites
Paper ID: S35-290

Characterization of Plasma-Treated Glass Fibre-Reinforced Polypropylene and Polyamide-6 Blends

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Abstract

Recently, the importance of recycling materials has gained significant global attention due to the increasing accumulation of landfill and industrial waste. Among these waste materials, thermoplastic polymers are particularly significant because they can be easily softened by heating and moulded into various useful products due to their excellent physical and mechanical properties. However, many of these polymers are immiscible and non-biodegradable, posing significant disposal challenges. In this work, the useability of the recycled thermoplastic polymer blends has been enhanced through an innovative plasma treatment approach. These blends have been then incorporated into fibre-reinforced thermoplastic composites. The novel technique introduces bulk functionalities to promote better bonding within polymer blends. The resulting modification of their miscibility and the dispersion of phases enhances interfacial bonding at the fibre/matrix interphase. Glass fibres have been added into plasma-treated polymer blends of polypropylene (PP) and polyamide-6 (PA6) during twin screw extrusion. The topology of the polymer blends, as measured with atomic force microscopy, has become rougher following plasma treatment, indicating improved adhesion between the polymers. Furthermore, there was an increase of about 8.5% and 8% in the tensile strength of the plasma-treated glass fibre-reinforced composites with 90-PP/10-PA6 and 10-PP/90-PA6 polymer blends, respectively. The SEM micrographs also revealed that the dispersion of phases improved within the polymer blends, and a stronger interfacial bonding developed between the glass fibres and blend matrix after plasma treatment. Moreover, there was no significant change when comparing the complex viscosities of the treated and untreated polymer blends; however, they were higher than their respective pure polymers (PP or PA6), indicating a synergistic effect of improved miscibility and dispersion of the minor phase.

Session 2.4: Polymer Composites

Paper ID: S35-303

Designing Microstructural Architecture in Butterfly-Inspired Hybrid Composites with Hierarchically Structured Fibrous Assemblies

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Abstract

Stringent environmental policies and sustainability targets are driving the adoption of lightweight materials in high-performance transportation and defense sectors. Inspired by nature's unparalleled engineering, this work introduces butterfly-inspired hybrid composites that emulate the multifunctional performance of natural architectures. Specifically, these composites are reinforced with hierarchical fibrous assemblies comprised of nano-sized graphene nanoplatelets (GnPs) covalently bonded onto micro-sized glass fibers (GFs), emulating the hierarchical architecture of butterfly legs. This work presents a novel approach to control the self-assembly behavior of hierarchically structured fibrous reinforcements by tailoring the surface chemistry of the GFs to optimize the density of covalently bonded GnPs. It is demonstrated that tailoring the microstructural architecture significantly enhances the mechanical properties of these hybrid composites, primarily due to improved stress transfer at the interface, facilitated by trans-crystallization, which induces a gradient interphase. Compared to the current industrial composite substitute for metallic structural components, these hybrid composites are tailorable to achieve improvements up to 17%, 23%, and 221% in tensile strength, flexural strength, processability (melt-flow index), respectively, with an 18% weight reduction. These advancements stem from the detailed structure-property designs, spanning across multiple length-scales, formulating a fundamental understanding of how to tune performance to meet stringent requirements. Ultimately, these cost-effective butterfly-inspired materials produce lightweight structural components that showcase the potential of biomimicry in advancing sustainable engineering solutions.

Keynote

Session 2.4: Polymer Composites

Paper ID: S35-279

Development of Induction-Heating-Assisted Direct Joining Technology for Fabricating Polymer-Metal Hybrid Structures

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Abstract

In recent years, the use of high-performance polymer composites, such as carbon fiber-reinforced thermoplastic composites (CFRTP), has expanded rapidly in sectors like automotive, electronics, and aerospace. Following this trend, polymer-metal hybrid structures have become increasingly attractive due to their combined advantages of light weight, flexibility, and high strength. To bond these dissimilar materials effectively, advanced direct joining technologies are needed over traditional adhesive or screw-based methods. A key challenge in polymer-metal joining is preventing damage to the polymer matrix or fibers. This study introduces an Induction-Heating-Assisted Direct Joining (IHDJ) technique, developed with self-designed equipment. This non-contact method enables rapid heating while avoiding damage to both the metal surface and the polymer's internal fibers. The equipment integrates both the heating and pressure systems through programming, allowing for automated monitoring and control of the temperature and pressure necessary for joining. The process utilizes localized electromagnetic induction to heat the metal, causing the polymer to melt. Under applied pressure, the molten polymer penetrates the fine structures on the metal surface, forming strong mechanical interlocks (anchoring effect). In this study, CFRTP-metal hybrid joints were successfully produced using the IHDJ equipment, meeting the application requirement (tensile-shear strength >20 MPa). An interaction between processing parameters, such as interface temperature and pressure, and joint strength was observed. Parameter optimization was explored through a combination of experimental testing and Response Surface Methodology (RSM) prediction. Additionally, joint quality and bonding mechanisms were examined. This work validated the feasibility, reliability, and industrial scalability potential of the IHDJ technology for fabricating polymer-metal hybrid structures.

Keynote

Session 2.4: Rubbers and elastomers
Paper ID: S38-256

Processing and Properties of Electrospun Rubber-Rubber Composites

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Abstract

This study aimed to create tougher, more elastic anisotropic rubber-rubber composites by reinforcing a silicone (PDMS) matrix with oriented, electrospun thermoplastic polyurethane (TPU) fibers. Such materials mimic the properties of natural tissues, holding promise for biomedical and biomimicry applications. The composites were made by electrospinning fibrous webs from TPU (Pellethane) solutions and saturating them with PDMS (Sylgard 184). Morphological analysis using SEM and porosity measurements revealed that orientation increased with drum rotation speed, though not in direct proportion. Thermal analysis with DMA showed that the composites retained the phase transitions of each component, with Sylgard glass transition and melting occurring around -116 °C and -70 °C to -40 °C, and Pellethane glass transitions at -118 °C and -30 °C, plus a melting onset around 90 °C. Mechanical testing indicated that the TPU-silicone composites were 10-20× more fracture-resistant than Sylgard 184, particularly in highly oriented samples. The Young's modulus showed lower stiffness in unoriented composites versus either Sylgard or unoriented TPU, with transverse-oriented (90°) samples having less stiffness than longitudinally oriented (0°) samples. Overall, these electrospun TPU-PDMS composites demonstrated enhanced toughness and controlled anisotropy based on fiber orientation achieved by adjusting collector speed.

Session 2.4: Rubbers and elastomers

Paper ID: S20-143

Effect of High-Pressure Fluids Mixing on Development of Carbon or Silica Nano-filler Rubber Composites

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Abstract

Rubber products with excellent strength and elongation characteristics by dispersing carbon black (CB) or silica nanoparticle (SiO2) in elastomers and vulcanizing them are used in tires and other tough products. In recent years, studies have been conducted to increase mechanical strength by increasing the filler content, however, high concentration of fillers causes increased heat generation during mixing, which leads to material degradation, and performance improvement has reached a plateau. In this study, we have developed a high-pressure twin-screw batch mixing machine and investigated whether it is possible to achieve higher strength and elongation of rubbers by mixing with high-filled fillers under a high-pressure CO2 field that causes swelling and plasticization of the elastomer component and improves the wettability of nanofillers while suppressing heat generation. The resultant CB/natural rubber (NR) composites achieved a superior tensile strength and elongational strain at break than mixing atmospherically. On the other hand, SiO2/NR and SiO2/SBR composites show similar mechanical properties to those of normally mixed rubber. These results would have come from the development of the size of the bund rubber region around filler particles under a high-pressure CO2 field that makes the network structure of filler particles. These results were confirmed by the observation of AFM and SEM of cut samples and the measurements of the extraction ratio of the fillers of the uncured sample.

Session 2.4: Rubbers and elastomers

Paper ID: S20-135

High-Performance and Recyclable Silicone Rubber based on Hybrid Cross-linked Networks

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Abstract

The recycling of thermosetting silicone rubber has seen significant advancements through the elaborate design of molecular structures. However, challenges persist in achieving effective recycling via industrially viable methods. In this work, we developed high-performance and recyclable polydimethylsiloxane (PDMS)-based elastomers using industrial silicone rubber processing technologies. Hybrid bonding networks were constructed combining dynamic covalent boronic ester bonds and permanent cross-links. The reconfiguration of dynamic boronic ester bonds under elongation not only introduces additional energy dissipation mechanisms but also allows the chains with permanent bonds to be more effectively aligned before scission, thereby significantly enhancing the mechanical properties. Furthermore, the presence of dynamic bonds enables rapid network reconfiguration at elevated temperatures, resulting in efficient recycling of silicone rubber. Notably, the tensile strength increased from 4.3 MPa to 7.0 MPa, and the elongation at break improved dramatically from 200% to 1000%. These values significantly outperform commercial counterparts that rely solely on permanent cross-linking. By controlling the density of dynamic cross-links, the material demonstrates the ability to undergo multiple reprocessing cycles with minimal loss of performance, maintaining a tensile strength of 5.0 MPa and an elongation at break of 900% after 1 times of reprocessing. This strategy offers a promising pathway to simultaneously enhance the mechanical properties and recyclability of silicone rubber.

Session 3.1: Additive manufacturing
Paper ID: S01-435

High-Speed MEX Additive Manufacturing of High-Performance Polymers – Process and Parts' Quality Analysis

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Abstract

Two main material extrusion (MEX) additive manufacturing (AM) technologies are fused filament fabrication (FFF) and fused granulate fabrication (FGF). Up to date, there exist a few literatures on the effects of high-speed additive manufacturing using FFF systems, while no work can be found for FGF systems especially for high-performance polymers. The printing speed used in FFF systems is usually between 20 and 100 mm/s, where the lower range is commonly used to achieve a higher resolution. Several attempts had been made to increase the printing speed in FFF system up to 150 mm/s, which, however, resulted adversely in the layer adhesion and overall print quality [1-4]. This study investigates the correlation between the printing speed and the melting and extrusion performance of both FFF and FGF systems using a high-performance polymer, namely polyetheretherketone (PEEK). Both systems have the same motion system with a maximum printing speed of 500 mm/s which is greatly higher than the one of standard FFF systems. While the FFF system is equipped with a standard filament extruder, the FGF system works with a pellet- or screw-based extruder which is built in-house. The experiments are carried out by gradually increasing the printing speed of both printing systems up to their maximum printing speed, while both melting and extrusion rates are monitored and might be adjusted accordingly. To be compared and analysed is the highest printing speed can be achieved by both systems which still results in an acceptable printing quality. Furthermore, polymer testing is to be carried out to investigate the effect of high-speed 3D printing on the thermo-mechanical properties of the parts.

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Session 3.1: Additive manufacturing

Paper ID: S01-431

Buckling-stretch-buckling dominated hybrid mechanical metamaterials for improving mechanical properties

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Abstract

Lattice structures have undergone significant changes due to the advancement of additive manufacturing, and more recently, hybrid lattice structures have provided opportunities for numerous future applications. The goal of this study is to introduce a novel method for conceptualizing and designing hybrid lattice structures that specifically addresses the issue of global buckling in lattice frameworks. The present methodology effectively integrates the unique mechanical characteristics of lattice structures dominated by stretch and bending. Here, we partition the structures into three layers, positioning the bending dominant structures at the upper and lower ends, and the stretch dominant structures in the middle layer to mitigate the impact of global buckling at the center. The BCC, FCC, and Kelvin lattices are employed as uniform lattice structures, and the Octet, Iso-Truss, and Truncated Cube lattices as intermediate layers in hybrid laminate structures. The stereolithography process fabricates three homogeneous and hybrid lattice structures, using epoxy resin as material. The peak load, force-displacement response, compressive strength, and energy absorption of all lattice structures have been studied. It is observed that the hybrid structure combining FCC and Truncated Cube (HS-FTF) outperforms both uniform and hybrid lattice structures and exhibits superior peak load, compressive strength, and energy absorption properties. The hybrid structure combining Kelvin and Iso-truss structure (HS-KIK) exhibits superior performance in terms of load-bearing capacity when compared to its Kelvin uniform lattice topology. The hybrid structure of BCC and Truncated Cube (HS-BTB) exhibits superior energy absorption and compressive strength in comparison to the BCC uniform structure. All structures fall within the range recommended by the Gibson-Ashby model, and HS-FTF has surpassed the maximum compressive modulus limit.

Session 3.1: Additive manufacturing

Paper ID: S22-408

Melting and crystallization phenomena in 3D printing

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Abstract

Additive manufacturing, namely 3D printing, is attracting increasing interest in the industrial field since it allows obtaining parts with complex shape that are challenging to obtain with conventional processes. In particular, 3D printing of polymers is able to construct the object through the deposition of extruded bead on a deposition plate. Although interesting, 3D printing of polymers is challenging due to several phenomena that are not completely understood. For instance, the presence of seeds of crystallization due to an incomplete melting induces a faster crystallization with consequent effects on the adhesion between adjacent beads. If the crystallization is faster than the reorganization of molecules at the interface between adjacent beads, the molecules will not interact and the adhesion will be poor. Otherwise, if crystallization occurs later in the process, it will increase the interaction at the interface, and the adhesion will be strong. This work aims at assessing the effect of previous crystallization on the mechanical performances of 3D printed parts. A PLA filament has been obtained by extrusion and annealed at different temperatures to achieve desired crystallization degree. The filament has been used during the process conducted with different extrusion ratios to obtain the parts. The higher the extrusion ratio, which means flow rate, the higher the crystallinity and the orientation of the part are. The crystallinity degree and the orientation achieved during the process are correlated with the residence time of polymer inside the extruder.

Session 3.1: Biomedical applications

Paper ID: S02-163

High Elastic PTFE-based Dressing with Wound Microenvironment Management Ability for Outdoor Wound Care

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Abstract

Harsh outdoor environmental factors including scorching sun, heavy rain, dust and bacteria, seriously restrict the wound healing. The ideal dressing for outdoor wound care should not only possess comfort, but also the ability to optimize wound microenvironment. Expanded polytetrafluoroethylene (ePTFE) film fabricated by solid phase stretching fibrosis possess good biocompatibility, excellent waterproofness and breathability, coupled with the ability to block pollutants, making it an ideal material for medical devices. Nevertheless, the per-fluoride and highly regular molecular structure of ePTFE also exist the problems of intolerance to creep and poor interfacial bonding, which limits its application in the field of medical dressing. In this research, ePTFE was superposed with fluororubber (FR) and polyurethane (PU) by electrospinning to create an elastic protective layer, and then compound with the wound-touching layer composed of the antibacterial drug loaded hydrogel to fabricated an innovative dressing. The microstructure images showed that the introduction of FR transition layer and the interlocking of adjacent layers endowed the compound dressing with good interfacial bonding. The elastic recovery rate of the compound membrane was more than 90%, which did comply well with the skin deformation during joint movement. The compound dressing could achieve excellent passive cooling through a reflection-scatter-evaporation synergy to reduce the impact of the scorching sun. The in vivo experiments simulating dressings against the effects of rain and bacteria was made to compare the efficacy of PTFE-based dressing and commercial dressings in promoting the healing of infected wounds; The results determined PTFE-based dressing possess the ability to optimize the inflammatory microenvironment within wound, making it a promising outdoor wound dressing. This research offers a novelty solution and has a great significance for the wound care under harsh environments.

Session 3.1: Biomedical applications

Paper ID: S23-52

Adhesive hydrogel patches fabricated from the design of polymer network for the wound dressing

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Abstract

Hydrogel exhibits a favorable similarity in modulus and water content to soft human tissues, making it an excellent material for medical wound dressings. However, current hydrogel wound dressings face several challenges, including low mechanical strength, complex synthesis processes, toxicity from chemical reagents, high swelling ratios, and poor adhesion properties. Among these, the most critical issue is the adhesion of hydrogel dressings in wet environments. Developing highly adhesive polymer patches for wound dressings in such conditions remains both challenging and rare. In this work, we have enhanced the adhesion performance of hydrogel materials in wet environments by controlling the functional group content during polymer functionalization and effectively constructing the hydrogel network. We provide a detailed illustration and analysis of the fabrication process, structural morphology, performance mechanisms, and application cases of the prepared hydrogel patches. Additionally, we propose strategies for creating soft polymer patches with strong adhesive properties for use in wet environments, offering both experimental insights and a theoretical foundation for the future clinical application and medical validation of these soft polymer patches.

Session 3.1: Biomedical applications

Paper ID: S23-37

Degradable drug-eluting mesh/nanofibers for therapy of muscle injury

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Abstract

A new bioresorbable polycaprolactone (PCL) mesh scaffold, designed to deliver drugs, was developed using a solvent-cast additive manufacturing technique to enhance muscle injury treatment. The mesh's degradation rate and mechanical strength were assessed after immersion in a buffer solution over varying periods. The in vitro release profiles of vancomycin, ceftazidime, and lidocaine from the mesh were analyzed using high-performance liquid chromatography (HPLC). Additionally, the in vivo effectiveness of the PCL mesh in muscle repair was examined in a rat model through histological analysis. Results indicated that the PCL meshes degraded by 13% after four months in buffered solution. All mesh samples, regardless of pore size, demonstrated higher strength than rat muscle and withstood 10,000 cyclic loadings. Furthermore, the mesh provided sustained release of antibiotics and pain relievers for more than three days in vitro. The findings suggest that drug-loaded PCL meshes significantly outperform pure PCL meshes in promoting muscle repair in rat models. Histological analysis confirmed the biocompatibility of the resorbable meshes. These biodegradable, drug-releasing meshes hold promise for future applications in human muscle injury therapy.

Session 3.1: Circular Economy for Plastics and Recycling

Paper ID: S27-409

Assessing Closed-Loop Recyclability of Polyethylene Films in Food Packaging Applications

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Abstract

The increasing demand for sustainability in food packaging has pushed the industry into the need to use recyclable materials in their products. Polyethylene is the elected polymer for single-used packaging due to their characteristics such as flexibility, mechanical, optical, processability properties and cost. However, the use of recycled polymers as an alternative to virgin materials is still viewed with huge concern. In particular, the use of recycled from unknown sources could be a potential cause of contamination that can be harmful for human health. This study investigates the closed-loop recyclability of PE films specifically for food packaging applications, focusing on the study of mechanical and rheological properties of recycled low-density polyethylene (LDPE), its safety in direct contact with food, and its suitability for thermoforming processes. The use of a closed-loop source ensures a high level of control of contaminants (like different polymers or inorganic/organic material) present in the recycled plastic. Mechanical and rheological tests show a normal deviation in properties compatible with polymer with additional processing cycle, with no significant loss in performance. Additionally, migration tests followed food safety standards, assuring that no potential contaminant migrated to the food. To access the thermoformability, sheets were extruded with recycled material. The results showed a fair capability to produce thermoformed products. These findings provide insights into the possibility of using recycled LDPE for sustainable food packaging solutions, supporting the practices in line with circular economic principles.

Session 3.1: Circular Economy for Plastics and Recycling

Paper ID: S27-378

Towards the circularity of thermoformed parts for packaging industry

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Abstract

Polyethylene is one of the most used materials to produce blown film for protection in packaging pallets in a business to business system (B2), between producers and distributors. Therefore, the collection and recycling of this raw mate-rial waste is easier, generating a recycled material with less contamination and with characteristics to be reused in blown film production. The aim of this work is to explore the potential of using recycled PE to produce extruded sheet and thermoforming reusable PE packaging, for transporting dried fruits with shell, in the context of B2B business. Were evaluated seven different batches of recycled PE and relevant properties related with processing and the packaging performance, where measured. The melt flow index, MFI, was evaluated in a range of temperatures, the melting temperature measured by DSC and the as mechanical properties, using previously injected specimens. The results showed the suitability of all tested materials for sheet extrusion and thermoforming, while the mechanical properties remain similar to virgin LDPE. Regarding the product design, was considered a secondary packaging to be used in rigid and stackable boxes. The packaging includes a lid fixed with a sticker that contains the nutritional information in accordance with legal requirements and a code that contains information about the com-position of the material used to manufacture the part, allowing recording the number of reuses. The ribs, geometry of the ribs and extraction angles were designed to minimize deformation of the part when subjected to the maximum weight of contents. The finite element method was used to simulate deformation considering several initial sheet thicknesses. The T-SIM software was al-so used to simulate the final thickness distribution of the part, considering that the part is obtained by vacuum thermoforming with a male mold and a female mold.

Session 3.1: Circular Economy for Plastics and Recycling

Paper ID: S27-367

Progress in plastic mechanical recycling: Development of extrusion process for regeneration of mechanical properties and lamellar structures of recycled polyethylene

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Abstract

Recycling is an important approach which fulfil the circular economy for plastics. Plastic recycling consists of three main techniques: mechanical, chemical, and thermal process. Among them, mechanical recycling is the most effective method based on life cycle assessment because of less greenhouse gas emission, low consumption of energy, and low environmental impact. On the other hand, plastic mechanical recycling usage rate has been remained stable for many years. This is because the degradation of properties of mechanical-recycled products becomes the main obstruction which affects the narrower of their final applications. The development of mechanical recycling has been highly attractive to improve the properties of recycled products for prolonging their lifetime used, decreasing the amount of single-use plastic production, and reducing the amount of waste plastics in environment. Based on this motivation, our research group established a new unit which was connected between the end of screw and die of a twin-screw extruder namely as “Molten Resin Reservoir: MRR”. The addition of MRR unit affected the relaxation of polymer melts resulted in the increasing of entanglement and mechanical properties of recycled plastic products. Interestingly, the elongation at break of recycled plastics were highly improved not only than its original waste plastics but it was also increased than its virgin materials. In this study, various grades of virgin and recycled polyethylene are used as a targeted material for re-extrusion with a novel twin-screw extruder with MRR in various conditions. The relationship between extrusion conditions, mechanical properties, and lamellar structures are strongly focused. This study is expected to develop the plastic mechanical recycling techniques for our sustainable life.

Session 3.1: Functional Additives and Reactive Processing
Paper ID: S09-168

Mechanocatalysis-Driven In-Situ Synthesis of Two-dimensional Covalent Organic Frameworks within One-Dimensional Linear Polymer Chains of Nylon 12 and Utilizing Injection Molding to Achieve Polymer Chains Weaving

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Abstract

Polymers can be classified based on their geometric topological structures: one-dimensional linear materials (like general and engineering plastics), three-dimensional cross-linked networks (such as thermosetting resins and elastomers), and two-dimensional covalent organic frameworks (COFs). While each type excels in its field, there is limited research on the performance of combining polymers with different geometric structures. In this work, solid-state shear milling (S3M) and a twin-screw extruder were utilized for the first time to achieve the in-situ combination of one-dimensional linear polymer (Nylon 12 (PA12)) and two-dimensional COF, construct the COF-PA12 polymer chain junctions, and realize the weaving of two-dimensional COF on one-dimensional linear molecular chains through traditional polymer processing technology (injection molding). The chemical and physical confinement effect between COF and PA12 was the main influence mechanism of introducing two-dimensional COF on one-dimensional linear PA12 molecular chains. Furthermore, these non-uniform interactions induced multiple independent phase regions within the PA12 matrix. Each phase region consisted of freely flowing PA12 molecular chains, but varying degrees of confinement led to differences in fluidity. During micro injection molding, different shear flow fields resulted in distinct molecular chain responses, thus achieving weave and mechanical properties regulation.

Session 3.1: Functional Additives and Reactive Processing

Paper ID: S09-184

Natural Compounds as Additives in Active Food Packaging

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Abstract

The primary purpose of food packaging is to protect food during transportation and storage by slowing down its natural deterioration without affecting the food inside. Active food packaging is an innovative technology that aims to extend the shelf-life of food by enabling the exchange of compounds between the package and the food. This interaction involves the release of antioxidant or antimicrobial compounds, which, when in contact with the food's surface, can delay or even prevent natural deterioration and improve the sensory properties of the packaged food. Lipid oxidation remains a major cause of food loss and a significant challenge for the food industry. The solution may lie in the controlled release of active compounds with strong antioxidant capacity from the packaging material to the food's surface, inhibiting lipid oxidation in fatty foods. This presentation aims to provide an overview of natural extracts (such as, rosemary, green tea, garlic, curcumin, pomegranate, and proteins) that have been studied for their antioxidant and antimicrobial potential in various polymer matrices. The resulting films were characterized in terms of their chemical, mechanical, and barrier properties. Additionally, the effectiveness of the new active films was assessed by measuring the levels of lipid oxidation and microbial contamination in various model foods packaged with these films over different time periods. Active food packaging using natural compounds is a promising solution to meet the demand for effective and environmentally friendly food packaging. The use of natural compounds can help extend the shelf life of food products and improve their safety, while also addressing sustainability concerns.

Session 3.1: Functional Additives and Reactive Processing

Paper ID: S09-74

Photocatalytic Generation of Polar Polyolefin Surfaces with Long-term Stability

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Abstract

Incorporating polar functionality in polyolefins (POs) without reducing molecular weight has been a significant challenge in PO post-polymerization modification [1]. Here, we introduce a mild, photocatalytic method for the molecular functionalization of isotactic polypropylene (iPP) that prioritizes chain functionalization over degradation. Specifically, we developed an inexpensive, reusable α-Fe2O3 photocatalyst immobilized on glass beads, which, under blue 455 nm light, generates N-oxyl radicals. These long-lived radicals activate the PO of choice (iPP) via hydrogen atom transfer (HAT) in the gel state at 50 ºC, enabling functionalization with maleic anhydride. Precise control of the N-oxyl radical and radical scavenger stoichiometry creates an oxygen-scavenged medium that minimizes chain degradation, allowing high molecular weight iPP chains to be functionalized with polar groups. Building on this protocol for molecular functionalization of iPP, a surface functionalization technique for polyolefins in water was developed at room temperature, creating polar surfaces with exceptional stability with polarity lasting more than five months (tested on injection moulded PO tensile bars). The study is supported by a comprehensive set of synthetic, structural (GC-MS, HT SEC, NMR, IR...), rheological, surface (contact angle, XPS), and mechanical (bending, tensile) analyses as well as polymer processing of the made materials using compression-and injection moulding. Our methods provide a basis for a versatile and cost-effective approach for repurposing iPP into added-value materials.

[1] Franssen, N. M. G.; Reek, J. N. H.; Synthesis of functional polyolefins': state of the art and remaining challenges. Chem. Soc. Rev. 2013, 42, 5809-5832. https://doi.org/10.1039/C3CS60032G

Session 3.1: Industry 4.0 and AI
Paper ID: S10-235

Predicting Flow Channels in Water-Assisted Injection Molding with AI: A Step Toward Real-Time Feasibility Checks

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Abstract

Water-assisted injection molding (WAIM) is an essential technology for manufacturing hollow injection-molded parts where cores cannot be used. Accurate structural simulations require knowing the hollow channel dimensions. Predicting flow channels within complex parts, particularly in iterative design processes, can be tedious. By facilitating rapid predictions of water channel formations, this AI-driven approach reduces the need for simulations specifically at early design iterations, helping designers to quickly validate feasibility and address structural or process issues in (almost) real-time. This study aims to develop a predictive AI model that helps designers approximate water channel formations and identify potential process issues, such as water-fingering, early in design. This approach complements conventional finite volume/element simulations in later stages, with a primary focus on creating a data representation method that supports reliable predictions across varied geometries. Our approach involves extracting the flow path of arbitrary generated geometries provided as STL files and discretizing these paths by slicing the geometry at equal intervals along the flow path. These slices capture the input geometry's outline, serving as the model's feature set, while the outline of pre-simulated water channels serves as the target output. This water channel outline is then the output of the prediction of the network. The main findings of the study show that networks trained on arbitrary generated geometric data can effectively capture complex flow patterns and make accurate channel predictions within a few minutes compared to hours of simulations otherwise needed. This capability promises to improve design efficiency in WAIM by shortening design verification cycles. Future work will focus on optimizing network architecture and diversifying the variety of training geometries to cover a wider range of shapes and sizes to increase the accuracy of the predictions.

Session 3.1: Industry 4.0 and AI

Paper ID: S10-166

Digital transformation technologies of plastic compounds

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Abstract

Plastic compounds are very versatile materials that have been widely used in automobiles, home appliances, and so on. Plastic compounds are composed of neat resin, functional filler, elastomer, and additives to show performance such as high strength, stiffness, impact resistance, electrical and thermal conductivity, etc. To develop the compounds, researchers have tried many combinations of raw materials and processing conditions. This procedure, however, required a long period and considerable money and reduced competitiveness. To strengthen the competitiveness and effectiveness of R&D for the compounds, we have researched the digital transformation technologies of plastic compounds. First, we standardized vocabulary, unit, classification system, and database schema. Second, data generation infrastructures (so-called, miniature data factory, MDF) and a data collection system to get a large dataset were equipped. Finally, we gathered the dataset of plastic compounds which consisted of data related to raw materials, composition, processing conditions, and properties of compounds; and applied machine learning technology to build the property prediction models of plastic compounds. In this presentation, we will introduce our activities related to the digital transformation of plastic compounds R&D that we have carried out for the last several years.

Session 3.1: Industry 4.0 and AI

Paper ID: S10-41

Predicting and Optimizing Extrusion Dies – Bypassing CFD-Simulations by Using an Artificial Neural Network

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Abstract

The design of spiral mandrel dies requires considerable expertise and is generally a time-consuming process. As a complete analytical optimization is not possible due to the extended degrees of freedom, a simulation-based analysis is widely used to design and optimize spiral mandrel dies. Typically, the process of numerical die design is carried out iteratively: first an initial design proposal is created, and a CFD-simulation is performed. Based on the simulation-results, changes to the geometry parameters are then made to create an updated design proposal. After a number of iterations, an experienced engineer is able to approach the required target values. The quality of the solution depends significantly on the initial design proposal as well as on the changes derived from the previous iterations, and therefore on the experience of the engineer. This study deals with the optimization of spiral mandrel dies using artificial intelligence, in particular through an artificial neural network. The starting point is the simulation results of about 10,000 unique design proposals of an axial spiral mandrel die. Based on the results, an artificial neural network was trained that is capable of predicting the results of future simulations. This network was used to generate an extended database, consisting of simulated and predicted design proposals. Using this database, further simulations are only necessary to extend the database near edges and to validate final design proposals before manufacturing. Thus, the time-consuming iterative process that is highly dependent on the operating engineer can be evaded.

Session 3.1: Rubbers and elastomers
Paper ID: S38-357

Superior vibration-damping silicone elastomers via combining segment motion and chain reptation

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Abstract

Silicone elastomers, relying on their high and low-temperature resistance, are used in various fields. Yet, low-temperature crystallization and weak energy dissipation of commonly used PDMS limit their vibration-damping application. Here, we report a general strategy for constructing diethyl-modified PDMS (PEMS) polymer-fluid-gels (PFGs) that provide high energy dissipation over ultra-wide effective damping temperature and frequency ranges. Diethyl disrupts the regularity of PDMS and increases friction loss. The continuous, ultra-wide relaxation spectrum is realized via combining chain reptations from polymer fluids occurring at high temperatures or low frequencies and controllable segment motions from diethyl-modified chain segments occurring at designed, partially overlapping low temperatures or high frequencies. The PEMS PFGs exhibit excellent damping performance covering ultra-wide temperature ranges (-123 °C to 200 °C, with tanδ > 0.3) and frequency bands (10-2 Hz to 1010 Hz, with tanδ > 0.3), exceeding that of typical advanced damping materials. Furthermore, flexible piezoelectric sensors sandwiched around the PEMS PFGs maintain a high signal to noise ratio at external vibration and extend their practical applications in complex environments. This work will undoubtedly enhance the potential for high-sensitive devices and precision instruments to be applied in vibration environments covering low to high temperatures or frequencies.

Session 3.1: Rubbers and elastomers

Paper ID: S38-288

Stereochemistry-Tuned Hydrogen-Bonding Synergistic Covalent Adaptive Networks: Towards Recycled Elastomers with Recorded Creep-Resistant Performance

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Abstract

Chemical cross-linking is capable of improving the mechanical performance and creep-resistance of elastomers, but faces challenges in recycling and repair, leading to environmental concerns. Recent developments in covalent adaptive networks (CANs) have provided solutions for reprocessing and recycling. Although many different categories of CANs via various dynamic covalent bonds have been reported, developing strategies to overcome the dilemma between easy reprocessing and creep-resistance still deserves to be explored. This study focuses on the design and synthesis of polyurethane (PU) materials with targeted properties through the manipulation of stereochemistry in diamine chain extenders. By utilizing different cis- and trans-configurations of diamine extenders, we developed a range of PU materials with varying mechanical properties, thermal stability, and creep resistance. The trans-configured materials exhibited superior creep resistance and mechanical strength, attributed to dense hydrogen bonding arrays. Cis-configured materials displayed enhanced processability and elasticity. Both the trans- and cis-configured materials can be recycled through hot pressing or solvothermal approach via exchange reaction among urea bonds. This work demonstrates the critical role of stereochemistry in designing high-performance, recyclable elastomers with tailored properties for specific applications.

Session 3.1: Rubbers and elastomers

Paper ID: S20-193

Composites of 2D Materials and Rubber Blends

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Abstract

Elastomers are critical for applications as diverse as seals used in submarines and wind turbines to automotive products. Indeed, elastomer compounds through reinforcement with various fillers, like carbon black and silica, are essential for many industries requiring high-performance materials. The inclusion of these fillers contributes to improved properties as well as cost-effective production of rubber products in high volumes. However, the filler content required is typically very high, from 30 vol.% and higher. The isolation and discovery of 2-dimensional (2D) materials, such as graphene nanoplatelets (GNPs) and boron nitride nanosheets (BNNS) and their use as functional fillers for elastomers, at much lower filler loadings (<5 wt.%), provides a route to significantly improving the performance of rubbers. Such 2D materials can have extremely high aspect ratio, effective surface area and varied functionality, an ideal alternative to conventional fillers. Indeed, 2D materials may also contribute to the vulcanization of elastomers by promoting cross-linking and reducing cure time [1]. In this work, two different 2D material types, GNP (G1 and G2) and functionalized boron nitride nanosheets (f-BNNS) were added to two model rubber systems, a binary compound based on SBR and BR and, a ternary compound based on BR, IR and EPDM, and the change in mechanical properties (tensile, tear and abrasion) and rheological behavior studied. The inclusion of G1 and G2 in the binary elastomer compound resulted in exceptional curing behavior, while the inclusion of G2 in both the binary and ternary rubber compounds resulted in a stiffer compound due to strong filler-filler and filler-rubber interactions. The addition of the 2D materials into these elastomer blends resulted in improved tensile properties compared to that when filled with conventional micro-fillers.

[1] Habib, N.A., Jabbar, A.S., Hassan, F.L., and Intan, N.I. (2021). J. Phys.: Conf. Ser. 1795: 012072

Session 3.2: Biomedical applications

Paper ID: S02-429

EPL-g-O3HT Copolymers as Transient Polymer Electronics for Multifunctional Applications

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Abstract

As transient electronics advance, achieving a balance between conductivity and degradability is increasingly essential. Here, we present EPL-graft-oligo(3-hexylthiophene) (EPL-g-O3HT), an innovative material designed for transient electronic applications, uniquely integrating conductivity, controlled degradability and antimicrobial properties. By covalently grafting oligo(3-hexylthiophene) (O3HT) onto the biopolymer epsilon-polylysine (EPL) at various grafting densities, we developed a material suitable for biocompatible, degradable and antimicrobial electronic devices. Thin films of EPL-g-O3HT demonstrate substantial conductivity, while EPL-g-O3HT-1 exhibits degradation over 12 days due to amide linkages in the EPL backbone. Notably, EPL-g-O3HT-1 displays excellent broad-spectrum antibacterial activity against both gram-negative E. coli and gram-positive S. aureus. We validated EPL-g-O3HT's applications in electromyography (EMG) sensors and organic electrochemical transistors (OECTs), illustrating its potential in transient electronics with intrinsic antimicrobial functionality. Our findings open new avenues for O3HT-based graft copolymers in diverse transient applications, including skin-mounted devices, implantable sensors and eco-friendly electronics, especially where antimicrobial properties are crucial.

Session 3.2: Biomedical applications

Paper ID: S02-227

Development of a Multifunctional Calcium-Based Polymer Composite for Bioabsorbable Implants

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Abstract

Ligament disruptions, caused by overload between bone and ligament, are significant injuries that may take up to two years to heal. Orthopaedic clinical practice sometimes employs internal bone fixation devices to immobilize fractured bones and ligaments until the healing process is complete. This work describes the development of a polymer composite material that addresses the common limitations of biocompatible polymers (mechanical properties, inflammation due to degradation products and radiopacity) in the production of bioabsorbable implantable fixation devices. In order to achieve this, a calcium-based nanoparticle was produced which possessed both diagnostic and therapeutic capabilities, namely radiopacity and sustained drug release. The presence of calcium (Ca) has been demonstrated to support bone regeneration. The material can then be used to produce a device designed to serve three functions: fixation, bone healing, and ligament healing.

Session 3.2: Degradation, biodegradation and composting

Paper ID: S05-383

Marine-Biodegradability and Mechanical Properties of Polybutylene Succinate with Melt-Blended Enzymes

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Abstract

In recent years, marine pollution caused by plastic waste has become increasingly severe, emerging as a global issue. Polybutylene succinate (PBS) is expected to be used as a substitute for commodity plastics such as polyolefins due to its biodegradability and relatively well-balanced mechanical properties. However, the widespread use of PBS has been limited due to its low biodegradability in marine environments. On the other hand, it has been reported that adding the enzyme called lipase B, which has ester-cleaving capabilities, enables the degradation of PBS in a buffer solution.[1] However, it is well known that enzymes generally tend to become inactivated at high temperatures. In this study, we aimed to increase heat resistance by (1) using an enzyme with high heat resistance and (2) immobilization of it onto the cellulose particles. The immobilized enzyme was melt-blended in PBS, the mechanical properties and marine biodegradability were examined. The enzyme exhibited excellent heat resistance and retained its activity even after melt blending, imparting marine degradability to PBS. In contrast, a decrease in toughness was observed in terms of mechanical properties, presumably due to the large particle size of the cellulose. Thus, improving the toughness of marine-degradable PBS remains a challenge for its use as an alternative to existing products. Acknowledgement: This presentation is based on results obtained from a project, JPNP 18016, commissioned by the New Energy and Industrial Technology Development Organization (NEDO).

Reference

[1] Polym. Degrad. Stabil. 2021, 190, 109647

Session 3.2: Degradation, biodegradation and composting

Paper ID: S05-61

Analysis of hydrolysis reaction behavior of poly(lactic acid) (PLA) based on its solid-state structure

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Abstract

Poly(lactic acid) (PLA) is a biobased and biodegradable plastic derived from natural resources. The recycling of PLA is essential for reducing the use of raw renewable resources as much as possible. In this study, the degradation mechanism of PLA during hydrolysis was experimentally verified. The reaction rates and solid-state structure of PLA during hydrolysis were measured, and the hydrolysis behavior of the crystalline and amorphous phases was investigated. In the case of PLA with high D-lactic acid content, which did not undergo crystallization, the molecular weight distribution changed toward the lower molecular weight side with the same distribution. This indicated that the molecular chains were randomly cleaved in amorphous PLA. On the other hand, in the case of PLA with small D-lactic acid content, which underwent crystallization, the molecular weight distribution changed from monomodal to bimodal peaks in the middle stage of the reaction and then became monomodal peaks again in the later stage of the reaction, and its peak position did not change. This indicated that in the crystalline phase of semi-crystalline PLA, water cannot sorb into the crystalline structure, and chain scission occurs only at the folding surface of the lamellar crystal. Furthermore, the degradation behavior of amorphous and semicrystalline PLA during hydrolysis was modeled and simulated using the kinetic Monte Carlo method. The specific degradation behavior of the crystalline phase was described by considering the distribution of lamellar crystals and the dependence of the degradation rate on the molecular chain position. With this model, the molecular weight distribution and weight loss of PLA can be predicted. This study is the first to construct a degradation model based on a solid-state structure that can predict not only the average molecular weight but also the molecular weight distribution. The results obtained in this study are expected to contribute to the lifetime prediction of PLA for medical applications, chemical recycling, and industrial composting.

Session 3.2: Degradation, biodegradation and composting

Paper ID: S05-148

Enzymatic Degradation of Polybutylene Terephthalate (PBT): Influence of Material Properties on Degradability

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Abstract

The rise in plastic consumption, paired with inadequate end-of-life management, has led to severe environmental challenges [1]. Here, enzymatic hydrolysis presents a promising closed loop recycling strategy, potentially enabling selective recycling of mixed plastic waste under mild conditions without harsh chemicals [2]. Semiaromatic polyesters, especially polyethylene terephthalate (PET) and polybutylene terephthalate (PBT), are key targets for closed loop recycling due to their widespread use in packaging, automotive and electrical industries. Since the discovery of PET-degrading enzymes, while research for PET has advanced allowing for efficient hydrolysis, PBT remains largely unexplored, with no studies demonstrating even partial degradation [3,4]. Additionally, research on the influence of material properties on degradability of semiaromatic polyesters are limited [2]. Especially, studies on the influence of semicrystalline morphology are missing. However, understanding this influence is crucial to fully assess degradation pathways. This study shows that partial enzymatic hydrolysis of PBT is possible and examines how its material properties, namely degree of crystallinity, size of crystalline superstructures and lamellar thickness influence its degradability. Therefore, samples were characterized by Differential Scanning Calorimetry (DSC), Small Angle X-Ray Scattering (SAXS), and Scanning Electron Microscopy (SEM). Measurements of lamellar thickness distributions were supported by calculations from DSC data. Degradability was evaluated using Ultra High Performance Liquid Chromatography (UHPLC). After incubation, SEM and Fourier Transform Infrared (FTIR) spectroscopy were performed to interpret the results. This study provides a comprehensive understanding of how material properties influence the enzymatic hydrolysis of PBT. This paves the way for efficient enzymatic degradation and thus closed loop recycling of other semiaromatic polyesters beyond PET.

[1] www.openaccessgovernment.org/the-plastic-timeline-how-did-we-get-here/102481 (25.10.24). [2]10.1021/acs.chemrev.2c00644. [3]10.1016/j.bej.2023.109074. [4]10.3390/ijms222011257.

Session 3.2: Degradation, biodegradation and composting

Paper ID: S05-110

Preparation and Performance of PBAT-based Composites

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Abstract

Biodegradable plastic packaging instead of traditional disposable plastic packaging is an important way to solve "white pollution". The main commercialized biodegradable plastics are PBAT and PLA. PLA has good tensile strength, but brittle, the elongation at break is only 3~10%, resulting in difficulty preparation of blown-film. PBAT has excellent film-forming properties and ductility, while it has a low modulus and lower stiffness than the traditional non-biodegradable plastic PE. In general, blending is a key method for achieving the complementary advantages and prepare high-performance packaging materials. However, there are some problems such as poor compatibility between biodegradable plastic components, difficulty in dispersing inorganic micro and nano fillers, sensitivity to shear and easy degradation, high manufacturing costs, as well as poor mechanical properties. This paper addresses the challenge in preparing high-performance and low-cost biodegradable plastic films. By utilizing molecular structure design and free radical reactions, a novel high molecular weight comb-type compatibilizer was synthesized by co-polymerizing multiple active functional groups with monomers containing C=C bonds, which improves the compatibility between PBAT and PLA. PBAT/PLA/CaCO3 composites were prepared by solid state shear milling technology, and the effects of the ratio of PBAT/PLA, CaCO3 content and state shear milling process conditions on the structure and properties of the composites were investigated. High-performance PBAT-based films were prepared using biaxial stretching technology, which promoted the orientation and crystallization of polymer chains and improved the mechanical properties of the films. The tensile strength and elongation at break were 62.8 MPa and 699.3%, respectively.

The work was supported by National Key Research and Development Program of China (2022YFC3901800).

Session 3.2: Fibres and Films
Paper ID: S29-368

Fabrication of Bio-Based Poly(ethylene 2,5-furandicarboxylate) Nanofiber Webs via Laser-Heated Melt Electrospinning

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Abstract

In this study, poly(ethylene 2,5-furandicarboxylate) (PEF), which is a 100% bio-based polyester and considered an alternative material to poly(ethylene terephthalate), was used, and the Laser-heated melt electrospinning (LES) of PEF was conducted to examine the effects of spinning conditions on fiber formation behavior. LES is a solvent-free process in which the raw fiber is continuously fed, and a high voltage is applied between the nozzle and collector while irradiating a CO_2 laser to the raw fiber. This allows the raw fiber to be instantaneously and uniformly heated and melted, then stretched by the electrostatic field to create nano- and submicron fibers. The LES was performed at the applied voltage of 17 kV, and varying the laser power. At lower laser power, a single jet was formed, while multiple jets started to appear with increasing laser power. Under the conditions of multiple jet generation, a nanofiber web with an average fiber diameter of approximately 610 nm was successfully produced. The properties of the resultant webs were also investigated.

Session 3.2: Fibres and Films

Paper ID: S29-334

Assessing the impact of polyurethane adhesives on the recyclability of laminated polyethylene films

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Abstract

Laminated polyethylene (PE) films have attracted strong industrial interest over the past decade. In line with the circular economy and closed-loop concepts, discarded mono-material PE-based (MM-PE) laminates should be reused in a similar production process while preserving their performance. This study comprehensively assesses the recyclability of MM-PE laminates containing different polyurethane (PU) adhesives in the closed-loop, film-to-film mechanical recycling process. Three laminates containing different PU adhesives and a control film were mechanically recycled and converted to new films via the film-blowing process. The produced films were characterized by thermal, spectroscopic, rheological, mechanical, and morphological analysis. It is observed that a small amount of PU adhesives (< 3 m.%) may drastically reduce the stability of the film-blowing process, decreasing the zero-shear viscosity and changing the crossover frequency. PU adhesives also reduce the toughness and increase the haziness of the films. Thermal and spectroscopic analysis indicate that samples containing PU with a less interconnected network of hard and soft segments, leading to fewer hydrogen bonds, present higher stability during the film-blowing process and improved physical properties. The methodology adopted in this study can be used as a framework for assessing the effects of the composition of PE-based laminated films on their recyclability.

Session 3.2: Fibres and Films

Paper ID: S29-295

Manipulation of the Shape of Fibers through Melt-Spinning Process

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Abstract

Various technologies for the control of the shape of the fibers through the melt-spinning process will be introduced. Non-circular cross-section fibers can be prepared utilizing the non-circular nozzle, however, the cross-sectional shape of the prepared fibers becomes dull because of the effect of surface tension. Bicomponent spinning is widely utilized for the preparation of micro-fibers and fibers with distinct non-circular cross-sectional shapes. Production of ultrafine non-circular cross-section fibers utilizing sea-island fiber spinning through a non-circular nozzle was accomplished in this research. The surface of the melt-spun fibers tends to become smooth because of the effect of surface tension. A new technology for the production of fibers with surface roughness was developed utilizing the melt spinning of blend fibers with the enforced crystallization of one component. Fibers with varying thickness along the fiber axis can be prepared through the drawing process of the undrawn fibers with a draw ratio lower than the natural draw ratio of the fiber in the necking drawing. The fibers with varying thickness and molecular orientation were prepared through the melt-spinning process with a periodic change of take-up velocity. By combining the modulated take-up velocity and modulated heating near the spinning nozzle utilizing the irradiation of carbon dioxide laser enabled us to prepare the fibers with homogeneous thickness and varying molecular orientation along the fiber axis.

Session 3.2: Fibres and Films

Paper ID: S29-283

Impact of Low-Energy Electron Modification during Melt-Spinning of PLA/PCL Blends

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Abstract

The modification of semi-crystalline thermoplastic fibers through electron irradiation presents a significant challenge due to the inherent high degree of crystallinity in these polymer fiber structures. Primary electrons are captured by areas of crystalline structure within the fibers, resulting in the generation of radicals that can lead to chain scission. This effect is primarily due to the restricted chain mobility in these crystalline regions. This phenomenon substantially diminishes the mechanical properties of the fibers, including tensile strength and elastic modulus. To address this issue, we have developed a novel approach that involves coupling electrons into a crystallite-free polymer melt, thus circumventing the adverse effects associated with crystalline structures. Leveraging a Low-energy Emitter, our process enables electron irradiation in the melt during the fiber formation process, which opens up new avenues for creating high-performance polymeric fiber materials. The results indicate that an electron-induction during a fiber formation process not only mitigates the challenges posed by crystallinity but also enhances the mechanical properties of the resulting fibers. In particular, polymer chain orientation during the fiber drawing process has been shown to promote branching, which further contributes to improve material characteristics. Blends of polylactic acid (PLA) and polycaprolactone (PCL) will be serve as a compelling example to demonstrate the potential for enhanced thermomechanical properties as a result of electron modification during the melt-spinning process. Our findings underscore the promise of this innovative approach in the development of advanced polymer fibers, illustrating how specific blends can highlight the potential for performance improvements and broader applicability across various applications.

Session 3.2: Foams and Membranes

Paper ID: S08-442

Foaming behavior of polymer blends with oriented dispersed structures and their mechanical properties

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Abstract

Microcellular foams, with their unique properties, have spurred numerous innovative applications in fields such as packaging materials, insulation, sports equipment, and aircraft components. Among various foaming methods, those utilizing supercritical carbon dioxide (CO2) and advanced foaming technologies have garnered significant attention. This study focuses on the foaming behavior of a polystyrene (PS)/polyamide 6 (PA6) blends with various dispersed PA6 structure using CO2 as a blowing agent. The foaming temperature was carefully selected to be lower than the melting point of PA6 but higher than the glass transition temperature of PS. Under these conditions, the PA6 phase remains solid during the foaming process, effectively serving as a heterogeneous nucleation agent. After saturation under high pressure, followed by rapid depressurization to atmospheric pressure, a PS/PA6 foam was obtained. The resulting foam exhibited smaller cell sizes compared to pure PS foam due to the dual role of the PA6 dispersed phase: acting as heterogeneous nucleation sites and restricting cell growth. Interestingly, the cells were oriented perpendicular to the aligned PA6 dispersed phase, resulting in a highly ordered microstructure. The foam also displayed anisotropic mechanical properties. Specifically, the compressive strength was significantly higher when the cells were oriented perpendicular to the PA6 dispersed phase compared to the parallel orientation. This anisotropy highlights the potential for tailored mechanical performance in applications requiring directional strength and durability.

Session 3.2: Foams and Membranes

Paper ID: S08-278

Porous polymer nanocomposites for energy storage and environmental remediation

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Abstract

Porous polymeric materials find applications in energy storage and environmental remediation. Among these materials, polymeric foams and membranes are noteworthy. The present talk can be divided into two parts. The first part will focus on developing new nanofillers and subsequently the preparation of porous polymeric membranes using these nanofillers for water treatment and CO2 adsorption. Towards this, hybrids of (i) Laponite (L), a synthetic hectorite clay, and graphene oxide (GO) (LGO) and (ii) a plant-derived protein, viz., zein, and L (LZ) are used as fillers in thermoplastic polyurethane (TPU) to prepare membranes by phase-inversion method. The physicochemical, biocompatibility and mechanical properties of composite membranes have been systematically investigated. Subsequently, the composite membranes were used in organic dye and heavy metal ion adsorption. These fillers significantly improved the physico-chemical, mechanical, and adsorption properties of TPU membranes. Notably, LGO showed remarkable and synergistic improvements in pure water flux and mechanical properties of TPU membranes. Poly(caprolactone) (PCL)-based composite membranes were also prepared and their potential for fabricating biodegradable membranes was explored. The second part will focus on the preparation and modification of carbon foam (CF), prepared by carbonization of open-cell polyurethane (PU) foam. NiCo2O4 nanoneedles were grown on the porous CF and the resulting composite foams showed improved microwave absorption and excellent supercapacitor energy storage properties. In another attempt, CF was coated with poly(dimethyl siloxane) (PDMS) oil using vapor deposition. The resulting foam showed superhydrophobic and efficiently separated oil from the oil-water emulsion. Nanocomposite foams also showed biocompatibility and osteogenic differentiation of gingival-mesenchymal stem cells.

Session 3.2: Foams and Membranes

Paper ID: S21-317

Nucleating Foams with Waste Mussel Shell

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Abstract

New Zealand has a growing aquaculture sector whose value is expected to increase from $600 million in 2018 to $3 billion by 2035 according to the government strategy. Currently, frozen half shell mussels equate to approximately 50% of this value. While scaling up this industry may result in the diversification of species being cultivated it is likely to also scale mussel production with new areas gazetted for mussel farms. Mussel processing removes either all or half of the mussel shell generating thousands of tonnes of waste shell each year which is landfilled which consists primarily of calcium carbonate. This work investigates the ability of mussel shell to nucleate foams, specifically Low-Density Polyethylene (LDPE) and Poly-lactic acid (PLA) during extrusion without intensive processing for use in short term applications such as packaging. Mussel shells were collected, cleaned, and milled to produce a fine powder and then used to nucleate LDPE and PLA foams during extrusion with sodium bicarbonate as a chemical blowing agent. The addition of up to 2 wt.% of mussel shell did not significantly change the expansion ratio of LDPE foams (ER=1.5). However, it decreased the expansion of PLA foams from 3 to 2.4 by producing larger bubbles and thicker wall structures. The compressive strength of LDPE foams (10-15 MPa) was lower than some of the PLA foams (22 MPa). These results correlated well with respective expansion ratios, with the LDPE results showing less variability compared to the PLA foams. This work also presents the effect of using mussel shell as a nucleating agent on other properties including foam morphology, Young's modulus and recovery. The results indicate that mussel shell can be utilised with minimal processing to nucleate LDPE and PLA foams. Overall, this work suggests that waste mussel shell can be an effective nucleating agent, providing a potential application for a growing local waste stream.

Session 3.2: Foams and Membranes

Paper ID: S08-241

Advancing Cryogenic Insulation: The Integration of Rigid Polyurethane Foams and Phase Change Materials

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Abstract

Cryogenic insulation is crucial for preventing heat gain, conserving energy, and maintaining the integrity of gases at extremely low temperatures. Its applications range from cold storage units to LNG carriers and cryogenic propellant tanks for space launchers. Selecting the right insulation material can be complex, as materials effective at room temperature may not perform well under cryogenic conditions. Ideal cryogenic insulation should have low thermal conductivity, high mechanical strength, good adhesion, and durability under mechanical stress. In aerospace, for instance, the successful launch of the Ariane-6 on July 9, 2024, highlighted the importance of high-quality insulation. This vehicle relies on liquefied hydrogen (LH2) and oxygen (LOX), with its fuel tanks insulated using rigid polyurethane foam (PUR) developed in collaboration with the European Space Agency (ESA). Meanwhile, LH2 is emerging as a promising alternative fuel for future aircraft, necessitating the development of lightweight, refillable LH2 storage tanks. The effectiveness of cryogenic insulation is critical, particularly for safety, requiring no cryo-pumping effects, resilience to cryo-shock, and minimal risk of cracking or peeling. Recent research introduced a novel approach using phase change materials (PCM) to enhance insulation efficiency. CrodaTherm ME29P, an acrylic core-shell particle powder, was explored as a potential PCM for PUR-PCM composites. Lab and pilot-scale tests showed that increasing PCM content in PUR-PCM composites maintains or even improves adhesion to aluminum surfaces after cryo-shock, with optimal PCM concentrations between 5% and 7.5%. These composites met aerospace industry standards: density under 40 kg/m^3, thermal conductivity below 20 W/m·K, and compression strengths of over 0.2 MPa at room temperature and 0.4 MPa at 77 K. This advancement is pivotal for developing efficient insulation solutions for next-generation cryogenic applications.

Session 3.2: Injection moulding
Paper ID: S31-282

Metal-polymer direct joining on cylindrical surfaces using injection molding

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Abstract

Metal-polymer direct joining research has recently been promoted. The injection molding direct joining (IMDJ) technique is one of the direct joining methods, in which molten polymer infiltrates into small textures on metal surface mainly via injection molding, leading to strong metal-polymer joints. Most previous studies have been performed with lap-joining shapes with two flat plates. We here need to note that metal polymer direct joining is practically performed with not only lap-joining shapes but also other shapes. One example is a polymer ring joined to the surface on a metal rod, where possible applications include substituting insert molding. Our objective is to establish an injection molding direct joining (IMDJ) technique on cylindrical surfaces, which has a wide range of possible applications such as insert molding. In this study, we designed a specimen shape and a mold for a cylindrical shape which shows maximum joining strength due to shrinkage as well as mechanical interlocking, and evaluated the joining strength of the test specimens. Specifically, a shrinkage analysis was conducted using polymer fluid analysis software to design test specimens showing maxim shrinkage in the compression direction. Then an injection mold was developed based on the design, and finally the joining strength of specimens manufactured using this mold was evaluated.

Session 3.2: Injection moulding

Paper ID: S31-231

Advancing Projectile-Assisted Injection Molding for Non-Circular Cross-Sections

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Abstract

Creating complex hollow structures with uniform wall thickness in a conventional injection molding process is challenging. Traditional methods, such as core pullers, do not lead to the desired results. Fluid-assisted injection molding (FAIM) enables the creation of curved hollow channels. However, a significant challenge with FAIM is achieving uniform wall thicknesses, especially for non-circular cross-sections. An alternative approach is to use projectiles in the process, enabling the creation of uniform, close to outer contour walls. However, projectiles are primarily used for circular cross-sections, limiting the versatility of this method to create varying shapes. This study explores the use of non-circular projectiles in a projectile-assisted injection molding (PAIM) process. A specially designed injection molding tool was developed to investigate the PAIM process. With this tool, plates with different channel geometries can be manufactured. Depending on the cross-section of the channels the cross-sections of the projectiles were adapted (i.e., trapezoidal projectiles for trapezoidal channel cross-sections). Thus, ensuring that the channels are hollowed out close to outer contour. To closely investigate the process the plates with different channel geometries were manufactured in a conventional injection molding process, a FAIM-process and a PAIM-process. This study evaluates the effect of critical process parameters, such as material viscosity, packing time and gas pressure on the quality and uniformity of the residual wall thickness in complex, hollow structures. Findings of this study underscore the potential of PAIM in improving the manufacturing process of non-circular hollow structures for bicycle, automotive, and aerospace components, among others.

Session 3.2: Injection moulding

Paper ID: S11-161

Innovative Air Trap Mitigation in Injection Moulding: Efficiency and Effectiveness Assessment

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Abstract

Air traps in injection moulding cause various quality issues, such as increased residual stresses and surface defects like sink marks and surface irregularities. Traditional passive venting methods often fall short due to mould design limitations. While active vacuum venting systems (AVVSs) offer a more efficient solution, they are typically bulky and costly, requiring significant mould modifications. A key drawback of conventional AVVSs is the need for a fully sealed mould to establish a complete vacuum before injection, which lengthens cycle times, adds complexity and labour and hence reduces overall manufacturing efficiency. This study introduces a novel, compact AVVS that integrates seamlessly with the mould, minimises space requirements and reduces the need for extensive machining. Initial tests have shown an increase in moulding process efficiency since a 17% reduction in cycle time and a 12% decrease in energy consumption were achieved. Moreover, the effectiveness of this AVVS was verified by assessing the quality of the moulded parts. This was carried out by measuring sink marks, voids, weld line strength, and residual stress in the moulded parts, among other factors. This study includes a comparison between an amorphous thermoplastic (ABS) and a semi-crystalline thermoplastic (PP) in terms of our quality comparison criteria. This research provides valuable insights into how advanced venting solutions can significantly improve the efficiency and effectiveness of current injection moulding processes.

Session 3.2: Injection moulding

Paper ID: S11-149

Investigation of surface-textured area affecting polymer-metal joining manufactured by injection molding

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Abstract

An injection molded polymer part can be joined with a metal plate the surface of which is micro/nano-textured during the injection molding process. Laser processing is often used as one of the surface-texturing methods because it has high controllability of shape of textures. The present study focuses on the effect of the textured area produced by laser processing. We prepared joining samples that had a single lap joint geometry. The overlapped area between polymer and metal parts was 10 mm x 5 mm. By using laser processing, we fabricated micro dimple arrays in the overlapped area. Each dimple had a diameter of 50 um and a depth of 100 um. To investigate the area dependency, two types of laser processed areas were prepared; the full area processed type and the partial area processed type. For the partial area processed type, only the peripheral part of the overlapped area was laser-processed, but the central part, which is the overlapped area except for the peripheral part, was not processed. Using the two types of metal plates, the direct joining samples were produced via injection molding. In this study, we used two types of polymer, PP and PBT, and carried out the injection molding under different mold temperature conditions. Then, the joining samples were evaluated by a tensile shear test. The result of the test showed that the ultimate load of the full area processed type was higher than that of the partial area processed type with any polymers and any conditions. However, in terms of the load per unit processed area (the load divided by the processed area), the partial area processed type had much higher values than the full area processed type. This means that the peripheral area contributes to the joining strength. To achieve high efficiency joining, the surface texturing on the peripheral area is much more important.

Session 3.2: Polymer Composites

Paper ID: S36-387

The Effect of Solvent Ratio on Conductivity, EMI Shielding, and Crystallinity of PVDF/CNT/Graphene Oxide Films

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Abstract

With the rapid advancement and widespread use of electronic devices, electromagnetic (EM) wave pollution has emerged as a significant concern, affecting both the functionality of electronic instruments and human health. In this study, we fabricated PVDF/CNT/Graphene oxide (GO) films through a solution-casting technique using a mixed solvent system of acetone and dimethylformamide (DMF). We investigated the influence of solvent ratio on the films' crystallinity, electrical conductivity, and particularly electromagnetic interference (EMI) shielding properties. The results revealed that the solvent ratio significantly influences the crystallization behavior of the polymer matrix in the presence of the fillers, which in turn affects both the conductivity and EMI shielding effectiveness (EMI SE) of the films. Notably, for samples containing a hybrid filler of GO/CNT (20/10 wt.%), a 50:50 acetone-to-DMF ratio yielded a higher conductivity of about 10.1 S/cm, which has a lower crystallinity compared to the samples containing same filler loading with other solvent ratio. In contrast, PVDF samples filled with only GO (20 wt.%) showed a higher conductivity of about 0.75 S/cm at 3:7 acetone-to-DMF ratio, with improved crystallinity compared to other ratios. These results demonstrate the influence of crystallinity on the dispersion of conductive fillers within the PVDF matrix. Additionally, EMI SE varied with different solvent ratios; for example, the hybrid filler system peaked at around 25.6 dB with a 7:3 acetone-to-DMF ratio. Furthermore, we developed a flexible, durable, and lightweight multi-layer film structure, optimed for absorption-dominant EMI shielding. The PVDF-based composite film demonstrates desirable mechanical properties, flexibility, and EMI shielding, showcasing their potential use for wearable electronics and other advanced applications requiring effective electromagnetic protection.

Session 3.2: Polymer Composites

Paper ID: S35-326

Modelling The Mechanical Properties of Microfibrillar Composites (MFCs)

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Abstract

Researchers are exploring new materials to address waste problems, leading to the development of polymer-polymer composites known as Microfibrillar Composites (MFCs) [1]. The MFC concept involves the melt-blending of two non-miscible polymers, stretching (fibrillation) and moulding to create these composites. A key advantage of MFCs is their ability to develop in situ microfibrils, which achieve a highly uniform distribution of reinforcement within the matrix [2]. Microfibrillar composites exhibit excellent mechanical properties, and the aspect ratio of the fibrils produced during the drawing process plays a significant role in determining these mechanical characteristics [2,3]. The research aims to develop Microfibrillar composites using a combination of polyethylene as the matrix and polyamide-6 as the fibre reinforcement, with a composition of 70% polyethylene and 30% polyamide-6 by weight. The study focuses on examining the mechanical properties at various stages of the production process, as well as identifying the factors that influence these properties. Additionally, mechanical characterization techniques will be employed to model and simulate the materials, allowing for the calculation of their effective properties. Tensile testing was conducted on the extruded filament, drawn blend filament, and MFC thin sheet to analyse the elastic modulus. SEM was utilized for an in-depth examination of the blend's morphology. Lastly, DSC was employed to calculate and study the degree of crystallinity. The study of the mechanical properties from the tensile testing revealed that the drawn blend filament exhibits superior mechanical properties due to increased crystallinity. The morphology showed highly oriented fibrils that significantly influenced the mechanical properties of microfibrillar composites. Additionally, micromechanical modelling and simulations were conducted to calculate the effective properties of the material. The results from the tensile tests aligned closely with the numerical modelling results, with some minor errors noted.

Session 3.2: Polymer Composites

Paper ID: S35-318

Improved toughness-stiffness balance of glass fibers reinforced Polypropylene composites through hybridization with polyolefin elastomers and polymeric fibers for automotive applications

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Abstract

Polypropylene-reinforced composites mostly exhibit a trade-off between stiffness and toughness. In this study, the impact of incorporating Polyolefin Elastomer (POE) and Polyvinyl Alcohol (PVA) fibers as individual and hybrid reinforcement to Glass fiber-reinforced polypropylene composite in the presence of a compatibilizer was explored. The main focus of this study was on achieving an optimal stiffness/toughness balance. Several ternary and quaternary hybrid composite systems were developed and analyzed. All components were melt-blended using a twin-screw extruder and then injection molded for subsequent mechanical and morphological analysis. Tensile, flexural, and izod impact tests were utilized to assess the mechanical properties of the developed composites. A scanning electron microscope was employed to explore the micromechanical deformation processes that contribute to the impact toughening mechanism of these composites. Different micromechanical deformation processes were identified in the deformed samples. The predominant energy-absorbing mechanism for glass fibers was found to be fiber fracture due to the strong adhesion achieved through the adoption of Silane sizing treatment and the addition of a coupling agent. For PVA fibers, the dominating micromechanical deformation process was fiber pull-out. A significant stiffness of approximately 2.4 GPa Young's modulus, and notched izod impact strength ranges between 250 and 400 J/m can be attained with the quaternary hybrid system, PP/GF/POE/PVA fibers. Its performance can be controlled by altering the POE/PVA fibers ratio to achieve the targeted stiffness/toughness balance. These values represent a remarkable increase, with Young's modulus being 120% higher and the izod impact strength surpassing that of the control sample by over 800%. The low density of PVA fibers reduces the overall hybrid composite density, making it more suitable for automotive applications.

Session 3.2: Polymer Composites

Paper ID: S35-307

Preparation and Promising Use of Bacterial Cellulose

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Abstract

Bacterial cellulose (BC), also known as microbial cellulose, is a natural cellulose synthesized by microbes (bacteria). BC is considered a renewable biopolymer consisting of nanofibers produced from various microbial sources, which results in the formation of hydrogel with higher surface area and porosity, containing around 99% water. It maintains a unique structure of cellulose nanofiber-weaved three-dimensional reticulated network providing excellent mechanical properties, high water holding capability and outstanding suspension stability. Prepared BC has high purity, a high degree of crystallinity, significant biocompatibility and biodegradability. BC is generally produced from Komagataeibacter xylinus, a Gram-negative aerobic bacterium, that can absorb various types of sugars, leading to higher yields of cellulose under acidic conditions (pH 3-6) and at mesophilic temperatures of 25-30 ℃ in liquid media. In our research, we use Hestrin- Schramm medium, in the presence of carbohydrate substrates derived from bio-waste sources, including sour whey, apple juice, fruit stillages and extracts from brewer's spent grains. Promising results were achieved with non-woven structures prepared by biosynthesis from Kombucha. Although BC possesses several unique properties, it also has some limitations, including a lack of antibacterial activity and optical transparency. To address these limitations while utilizing its distinctive features, BC biopolymer has been modified for various applications. These include wound healing/wound dressing biomaterials, scaffolds for bone tissue engineering, injectable hydrogels from a healthcare perspective, green adsorbents for dye removal, leather substitute biomaterials for the footwear and fashion industries as well as flexible electrolytes for supercapacitors or green batteries. These applications will be introduced during the presentation.

Session 3.3: Biopolymers
Paper ID: S03-453

Engineered Polysaccharides and the Modification of Polysaccharides and Poly(lactic acid) for Sustainable Multiphase Polymer Development

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Abstract

Polymers and plastics have revolutionized nearly every aspect of modern materials—from the clothes we wear to the cars we drive to the adhesives in our Band-Aids. However, their reliance on fossil fuels, long environmental persistence, and ecological impact present significant challenges. The indiscriminate disposal of petrochemical-derived, non-degradable plastics is causing lasting environmental damage and worsening over time. To address this, we must accelerate the development of inherently sustainable materials that can be produced through environmentally benign processes without compromising product performance. There is a growing emphasis on product and process innovations that enable greenhouse gas and carbon footprint reduction, driving the need for plastics aligned with circular economy principles to prevent undesirable end-of-life outcomes. Ideally, new plastics should integrate seamlessly into existing conversion processes and utilize fungible feedstocks to ensure industrial feasibility. This presentation focuses on: (i) enzymatic polymerization approaches for engineered polysaccharide development and applications, (ii) carbohydrate modifications for multiphase polymers, and iii) rheology modification of PLA for advanced material applications, including biodegradable air filters, foams, and high-performance 3D printing filaments.

Session 3.3: Biopolymers

Paper ID: S03-449

Biopolymers and their composites for packaging applications: Scientific challenges and prospects

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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.

Session 3.3: Biopolymers

Paper ID: S25-416

Elucidating the Pyrolysis Behaviour of Extracellular Polymeric Substances-based Biomaterials from Wastewater Sludge for Flame-Retardant Applications: Effects of Component Interactions

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Abstract

Recovery of extracellular polymeric substances (EPS)-based biomaterials from wastewater sludge has attracted significant interest in developing sustainable wastewater treatment plants. Flame retardancy is one of the outstanding characteristics of EPS-based biomaterials. However, understanding the flame-retardant mechanism of the biomaterials is challenging due to the complexity and interactions among their components, creating a barrier to flame-retardant applications. In this study, the flame-retardant mechanism of EPS-based biomaterials are investigated through the single pyrolysis and co-pyrolysis of their components, including proteins (PN), polysaccharides (PS), lipids (LP), and humic-like substances (HS), using thermogravimetric analysis. Since pyrolysis is a key pathway in the combustion process, it directly affects the flame-retardant properties of EPS-based biomaterials. PN and HS have higher decomposition temperatures than other compounds, which contribute to increasing the thermal stability of EPS-based biomaterials. PS produce the highest char residues of 48.7% at 900 oC and can promote the formation of char layers, acting as a protective barrier against fire and heat. The gas analysis of pyrolysis products shows that PN and HS are the main sources of N-compounds, which are beneficial for reducing fire propagation. In contrast, the presence of LP tends to promote the formation of combustible gases. Potential interactions of these components suggest the significant role of PN, PS, and HS on flame-retardant properties of EPS-based biomaterials. The findings provide critical information for understanding the flame-retardant mechanism of EPS-based biomaterials, which are vital for optimising their production from wastewater sludge.

Session 3.3: Biopolymers

Paper ID: S03-261

Investigation of novel polymer nanocomposites based on PLA/lignin-MWCNTs for printed electronics (PE)

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Abstract

Printed electronics (PE) can find numerous applications in the field of sensors and storage. The substrates that are currently used for PE were derived from fossil-based raw materials and poly(ethylene terephthalate) (PET) is one of the typical substrate for PE. PLA is an eco-friendly polymer and is used in the electronic industry due to its unique properties such as high tensile strength and Young's modulus, it is non-toxic, recyclable and compostable. The main goal of the present project is to produce PLA-based materials as alternatives substrates to substitute PET in the field of printed electronics. However, PLA presents some drawbacks such as inherent brittleness, low crystallization rate, and slow biodegradation in the soil. To overcome these limitations PLA copolymers with azelaic acid have been synthesized. Also, to enhance mechanical and physicochemical properties, PLA-nanocomposites were prepared with nanolignin hybrid materials, containing 10% of MWCNTs. Herein, PLA nanocomposites with different content of lignin_10%MWCNTs were prepared by a combination of solvent casting technique, followed by melt mixing in a Brabender plasticorder. The presence of the filler did not affect the melting and the glass transition temperature of the PLA, however the crystallization temperature from the melt was significantly enhanced. The tensile strength and Young's modulus were improved by the addition of hybrid lignin materials. The well-defined thermal transitions and tensile properties of the PLA-nanocomposites indicated the fine dispersion of the lignin hybrid materials into the PLA matrix. Acknowledgements Funded by the European Union under the GA no 101070556. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or RIA. Neither the European Union nor the granting authority can be held responsible for them.

Session 3.3: Circular Economy for Plastics and Recycling
Paper ID: S04-439

Hybrid Chemical-Mechanical In-Melt Separation and Upcycling of PE/PET Blends: A First Step Towards Recycling at Scale of Mixed Plastic Waste

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Abstract

Multilayer, multicomponent packages, e.g., films and bottles, are widely used for their excellent barrier properties, which makes them the construction of choice in flexible packaging applications, with more than 40 million tons of the approximately 400 million tons of plastic being produced annually. This creates an enormous challenge as recycling of these multicomponent systems is not technically feasible currently. This presentation focuses on a novel hybrid chemical-mechanical approach based on reactive extrusion that aims to establish the pathway to future recycling at scale of mixed plastic waste. Herein, we will present two approaches to achieving this goal for mixed polyolefin/polyester melt streams. In the first route, the polyester phase is chain-extended in order to increase the viscosity ratio between polar phase (PET) and non-polar matrix (PE) and induce coalescence, followed by mechanical extraction of the coalesced PET. In the second route, PET is subject to glycolysis, followed by solubilization in Sc CO2 and removal via degasification. Our initial scale-up results in an industrial pilot plant show that approximately 90% separation can be achieved between the two streams. The two separated melt streams can then be individually upcycled, the PET stream by glycolysis and the PE stream by continuous catalytic cracking in twin-screw extrusion, resorting to solid-state zeolite catalysts. The latter allows low hydrocarbons (8<n<="" td=""></n

Session 3.3: Circular Economy for Plastics and Recycling

Paper ID: S04-438

Envisioning circular futures: Enabling conditions for industry-level transitions in New Zealand's plastics sector

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Abstract

This study addresses the limited understanding of how circular transitioning processes can be enabled at an industry level, focusing on the New Zealand plastics sector. As industries worldwide face the imperative to move from linear to circular systems, significant knowledge gaps persist regarding the structural, economic, and technological capabilities required for large-scale transformation. New Zealand's plastics industry, in particular, encounters significant challenges, including reliance on imported virgin plastics, inadequate recycling infrastructure, fragmented collaboration, and limited regulatory support, all of which hinder circularity. Economic constraints due to the country's geographical isolation and small market size make importing virgin materials cheaper than recycling, further disincentivizing circular business models. Additionally, New Zealand's "clean, green" image restricts the acceptance of certain recycling processes, such as chemical recycling, that could otherwise support circular goals. To foster industry-wide circular transformation, this project leverages scenario thinking and backcasting methods in a co-creative process with diverse stakeholders from New Zealand's plastics sector, including industry representatives, the plastics association, and regional government bodies. Through this process, stakeholders collaboratively envision possible futures for a circular plastics market, navigating uncertainties, anticipating structural shifts, and co-designing adaptive pathways tailored to New Zealand's unique market conditions. By mapping a range of future scenarios at both individual stakeholder and broader industry levels, this study identifies key enabling conditions—such as advanced plastics manufacturing technologies, regulatory interventions, cooperative business models, and enhanced digital and physical infrastructure—essential for supporting circularity at an industry level.

Session 3.3: Circular Economy for Plastics and Recycling

Paper ID: S04-436

Modelling the New Zealand Plastics Ecosystem to Test the Efficacy of Circular Economy Strategies. A Game Design Approach.

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Abstract

This paper presents the design and development of robust, data-driven simulation models to assist in a cooperative reshaping of the NZ plastics market towards sustainable circularity. Incorporating all relevant factors and impacts of a complex market system is a significant challenge due to the dynamic, non-linear, multi-sectorial, multi-scale nature of the network. Similar to world building and logic design processes in game development, the team started with 'Market Mapping' followed by 'Scenario Modelling'. Mapping both the stakeholder network (collectors, recyclers, processors, manufacturers, etc) and the pathway dependencies that constitute the plastics ecosystem was necessary to understand the underlying structure of the market and the ways in which sector players cooperate and compete. The second stage, 'Scenario Modelling', uncovers the detailed mechanics and system rules by focusing on a more discreet slice of the map. In one such scenario, we follow a single plastic product from production through disposal, reuse, recycling, and reintegration into the economy with an interactive interface to explore persistent waste flows, import dependencies, product contamination, investment gaps, and regulatory opportunities. The final stage is to translate these functional models into applications that forecast the impact of various circular economy strategies to support more informed decision making. This project is a collaboration between University of Auckland and RMIT Melbourne. This paper will outline the value of diverse perspectives and collaboration.

Keynote

Session 3.3: Circular Economy for Plastics and Recycling

Paper ID: S28-426

Circularity micro-indicators: a way to assess the circularity in plastic products

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Abstract

Plastics applications brought tremendous social progress, through the increase of safety and quality of life. How-ever, its future demands to look closely to its sustainability and circularity, either by changing the origin of materials or by rethinking on how to manage its end-of-life. Also, early stages decisions on the product development process may help on reducing the environmental impact and to promote the circularity of plastic products. The scientific community has proposed the use of circularity microindicators to assess the circularity of products. They can range widely in complexity, philosophy, calculation method, required information, and focus regarding the product life cycle. This presentation provides an overview on circularity micro-indicators and their applicability to different industrial sectors. Different case studies are presented, focusing in the automotive and building & construction. The use of micro indicators helps reflecting holistically the entire life cycle of the product to make better decisions on materials, part design and assembly to promote the full recovery of the product components through currently existing waste management routes. It is concluded that inherent complexity and diversity of goods made with plastics benefits from the inclusion of circularity indicators in early stages of decision making and product development processes for a better transition of plastics to a circular economy. Players must come together to address the sustainable use of plastics and its circularity.

Session 3.3: Degradation, biodegradation and composting
Paper ID: S05-448

Environmentally friendly matrices for Enhanced Efficiency Fertilizers: design, release, and degradation

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Abstract

The encapsulation of nutrients to create Enhanced Efficiency Fertilizers (EEFs) is a vital strategy for promoting sustainable agriculture by enhancing nutrient use efficiency and reducing environmental impact. This study investigates the development of eco-sustainable matrices composed of natural and biodegradable polymers for EEF applications. Cellulose nanofibrillated (CNFs) were employed as nutrient carriers and chemically modified to enhance interactions with both the nutrients and the polymeric matrix. Nutrients, specifically KNO_3, were encapsulated within CNFs using a spray-drying process to form nutrient-loaded microparticles (CNF/Nutrients). These microparticles were subsequently incorporated into a polymeric matrix based on thermoplastic starch (TPS), starch (St), and poly(3-hydroxybutyrate) (PHB) through melt-compounding. The materials underwent comprehensive physicochemical, structural, and thermal characterization. Nutrient release assays revealed that pure CNF.KNO_3 mixtures ceased releasing nutrients after 1 h, while composites containing CNFs within the PHB/TPS matrix exhibited controlled release for up to 8 h in water and over 80 days in soil. Additionally, the charged sites on CNFs influenced nutrient release behavior, with CNF^- facilitating faster NO_3^- release and CNF^+ favoring K^+ release. Biodegradation studies demonstrated that the matrices degraded up to 75% within 120 days, confirming their environmental compatibility. In conclusion, this research highlights the potential of using PHB, starch, and CNF-based matrices as sustainable solutions for EEFs, offering prolonged nutrient release, superior biodegradability, and minimal ecological footprint, aligning with the principles of sustainable agriculture.

Keynote

Session 3.3: Degradation, biodegradation and composting

Paper ID: S05-415

Processing of Biodegradable Plastics and their Biodegradability for Single-use Plastic Alternatives: Challenges and New Opportunities

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Abstract

This presentation will discuss few critical points from polymer processing prospective of bioplastics, their bio-blends and the biodegradable composites. The plastic wastes and the related pollution continue to affect communities and ecosystems globally. The plastic pollution leads to “micro-plastics” (less than 5 mm in size) that is quite alarming – found in human blood and in human breast milk. There are ongoing efforts to reach 100% reusable, recyclable or compostable plastic packaging by 2025. We invented (US 11,279,823 B2) nanostructured bioplastic composite from polybutylene succinate (PBS) and polybutylene adipate-co-terephthalate (PBAT) using a small amount of organic peroxide. Such nano-structure bioplastic exhibited super toughness and modulus exceeding 1 GPa with heat deflection temperature (HDT) around 100 degree C. We could further engineer ternary and quaternary blend of this binary nanostructure by adding either polylactic acid (PLA) or polyhydroxybutyrarate-co-valerate (PHBV) alone or both. 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 environmental pollution. Reference: A. K. Mohanty, M. Misra and Feng Wu, “Biodegradable Nanostructured Composites”, US 11,279,823 B2 Acknowledgement: (i) The Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), Canada – University of Guelph, Bioeconomy Industrial Uses Research Program Theme; (ii) the Ontario Research Fund, Research Excellence Program; Round-11 (ORF-RE 11) from the Ontario Ministry of Colleges and Universities, Canada and (iii) the Natural Sciences and Engineering Research Council of Canada (NSERC), Canada.

Session 3.3: Degradation, biodegradation and composting

Paper ID: S05-224

Organic vs. enzymatic polymerization in circular polyester design

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Abstract

In the quest to reduce the environmental impact of plastics, the development of circular materials through scalable methods is gaining significant attention. Ethylene brassylate (EB), a macrolactone derived from castor oil, can undergo ring-opening polymerization (ROP) to produce poly(ethylene brassylate) (PEB), a fully bio-based polyester. Previous studies have demonstrated the polymerization of EB on a laboratory scale, in solution or bulk, using enzymatic, organometallic, or organic catalysts. This study explores the synthesis of PEB through reactive extrusion (REx) in conventional melt processing equipment, without the need for organic solvents. This single-step and scalable process was tested with various catalytic systems, with two proving successful: the organic base 1,5,7-triazabicyclo[4.4.0]dec-5-ene (TBD) and immobilized enzymes, Lipase B from Candida antarctica and Lipase from Pseudomonas cepacia. Tensile testing revealed that PEB (molar mass of 8000 g/mol) exhibited brittle behaviour, with a Young's modulus of 290 MPa and 4% elongation at break. Given the novelty of this polyester, three potential end-of-life pathways for PEB were evaluated in this study: mechanical recycling, enzymatic depolymerization, and disintegration in compost. PEB was mechanically recycled showing limited loss in thermal and mechanical properties after four recycles. Additionally, Candida antarctica Lipase B was proven effective for enzymatic depolymerization. In industrial compost, PEB degraded via surface erosion losing 93% of its initial weight after 90 days. Moreover, the already embedded enzymes for the polymerization may offer further end-of-life solutions.

Session 3.3: Degradation, biodegradation and composting

Paper ID: S05-228

PLA-LDH nanocomposites for Implants and its degradation

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Abstract

Adding fillers to biopolymers for osteosynthesis applications can significantly improve the material's mechanical, biological, and degradation properties, aligning it more closely with the requirements for bone repair. Two PLA/CaAl stearate LDH nanocomposites, with 1 wt% and 5 wt% LDH respectively, were prepared and characterised. It is crucial that the support and degradation timeline of resorbable osteosynthesis matches the healing of tissue. Therefore, in this work the degradation of PLA and PLA nano-composites in SBF was studied with the aim of understanding the mechanism of degradation as well as the influence of the nanoparticle on the degradation behaviour. GPC showed a decrease in molecular weight and an increase in dispersity of LDH containing composites after submersion in SBF for 28 days. This, together with mass loss data suggest that inter chain scission to be dominant – which is very important for the mechanical performance of the implant over time. Composite morphology and mechanical properties were also examined.

Session 3.3: Injection moulding
Paper ID: S31-340

Transfer of powder-based direct coating in the injection molding process from two-dimensional components to three-dimensional components

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Abstract

A range of painting and coating processes are available in production for painting or finishing plastic components. However, in most cases these require additional handling and external coating steps, which lead to additional costs and time losses. Conventional powder coating of plastic components is also not possible without the prior application of an adhesion promoter due to the poor electrical conductivity of common plastics. Previous studies have shown that in-situ coating of plastic components is possible without pre-treatment, without separate coating of the cavity and within an injection mold during the injection molding cycle for two-dimensional components. The powder is sprayed into a temperature-controlled cavity (coating cavity) using a corona powder gun. During a handling time, the part produced from the previous cycle in the second cavity (component cavity) and cooled to mold temperature is transported via a rotary table to the level of the pre-painted cavity. After rotation, the mold is closed and the prefabricated part is pressed into the pre-painted cavity. In this work, these results are transferred to three-dimensional component geometries and a modified process sequence is investigated. In order to be able to use existing injection molds for in-situ painting, the rotary plate is omitted from the mold of the three-dimensional component and a component is first produced in one cavity, but not ejected. The powder gun is then moved into the cavity by a robot and powder is applied to it. The mold then closes, pressing the coating layer onto the component. It was shown that the results of the two-dimensional investigations can be transferred to a three-dimensional geometry. In particular, the temperature control of the cavity, the handling times and the surface roughness have an influence on the coating quality. It was found that coating with existing injection molds is possible, but that this leads to restrictions in the coating thickness.

Session 3.3: Injection moulding

Paper ID: S31-306

Influence of the processing parameters on the mechanical strength of injection moulded BMC components for direct screwing

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Abstract

As temperature requirements increase, thermoset molding compounds are becoming an attractive alternative to expensive high-temperature thermoplastics and light metals. Due to their significantly lower density compared to metals, thermosets also offer significant weight savings. For example, weight savings of up to 25% can be achieved by using thermoset compounds instead of aluminum. Thermosets also have excellent dimensional stability and low handling and post-shrinkage. This can be very well controlled by the material manufacturer, especially in the case of non-shrinkable thermosets such as Sheet Molding Compounds (SMC) and Bulk Molding Compounds (BMC). In order for SMC/BMC parts to be used as lightweight replacements for metal parts, suitable joining processes are required. As the most widely used mechanical joining process for plastics, direct screw fastening offers decisive advantages. It allows dissimilar materials to be joined without thermal effects. It also offers a high strength to cost ratio. While the “Deutscher Verein für Schweißen und verwandte Verfahren” (German Welding Society) already has recommendations (DVS-2241) for the direct screw fastening of injection-molded thermoplastics, these cannot be applied to thermosets due to their brittle material behavior. The aim of the research project "Material-specific design of direct screw joints in SMC/BMC components" (IGF 01lF22904N) is to provide manufacturing and design recommendations for direct screw joints in SMC/BMC components. This publication examines the influence of processing parameters such as processing temperature, mold temperature, injection pressure and holding pressure on the mechanical strength of direct screw fastened SMC/BMC components.

Session 3.3: Injection moulding

Paper ID: S31-287

Challenges and opportunities in processing recycled materials by injection molding

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Abstract

The reduction of defective products in injection molding is still one of the greatest challenges. In times of increasing recycling rates and challenges in separation preciseness new strategies are needed to achieve or overfulfill the actual targets. Precisely because these targets and limitations exists, there is the need to understand the molding process and the behavior of plastic materials during the transfer from the antechamber to the mold to process perfect parts. The aim of the contribution is to investigate the behavior of the melt during the injection phase by interpreting the results of pressure and temperature sensors in the melt channel. Therefore, six thermoplastic materials were chosen and injection molded at their specific melt temperatures and identical volume flow rates while the process was stopped at the same mold fill status. Consequently, due to their specific volume compression rate, the time during the injection phase varied for each material. The recorded data from the sensors was used to correlate the time during the injection phase to the material behavior. The contribution gives opportunities how to deal with changing materials and mixtures and addresses remaining challenges in process design.

Keynote

Session 3.3: Injection moulding

Paper ID: S31-252

Ensembled Explainable Artificial Intelligence (XAI) for Quality Prediction of Injection Molded Parts

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Abstract

Machine learning-based applications have been widely utilized for predicting injection molding part qualities in the last decade. In addition, Explainable AI (XAI) has recently been employed to enhance model transparency. However, most of the prior studies rarely extended to factors other than the post-hoc feature importance analysis. This research aims to extend the application scope and increase trust in the use of polymer processing expertise. Simulation data for injection-molded optical products are first analyzed. Then, two XAI-infused methods are derived for evaluating model training while incorporating ensembled neural networks (ENN) predictions. The explainable stability value (ESV) provides a means to evaluate model robustness with domain specificity considered. Polymer specialists can monitor their training progress based on their domain expertise and knowledge in the field. Moreover, the explainable entropy weight method (EWM) is applied to facilitate ensemble learning. The predictions unequivocally enhance the overall accuracy across various levels of data utilization and multiple optical quality parameters. Without needing to consider the randomness of the training process, the outcome renders a coefficient of determination value (R2) of 0.98. The ensembling rationale proposed in this study incorporates different perspectives with field-specific explanations in polymer processing, ultimately striving to boost the confidence in the application of ensembled XAI.

Session 3.3: Modelling and Simulation
Paper ID: S33-393

Development and Assessment of an Integrated Modelling Approach for the Extrusion Blow Modelling Process

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Abstract

In the packaging industry, extrusion blow molding (EBM) is a pivotal manufacturing process. The ongoing drive to optimize product development has motivated the integration of computational tools. However, compared to more established plastic processing methods like injection molding, existing modeling tools for EBM face significant limitations. Foremost is the inability to seamlessly simulate all process stages in an integrated manner, which hampers the potential impact of modeling tools on optimizing this complex process. The EBM Simulator project is a collaborative effort between the Logoplaste Innovation Lab and the University of Minho, combining expertise to develop computational tools that emulate every aspect of the extrusion blow molding process. This initiative focuses on creating codes to simulate all stages of the EBM process while using tailored models to accurately reflect the behavior of plastic materials. Importantly, the project aims to bridge the gap that has historically hindered the comprehensive simulation of interconnected process stages. This presentation outlines the development and assessment of the simulation tools currently in progress as part of the EBM Simulator project. It also examines the extensive experimental work conducted to rigorously evaluate and refine these tools, highlighting the synergy between theoretical modeling and practical validation within this innovative initiative.

Acknowledgements

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Session 3.3: Modelling and Simulation

Paper ID: S33-269

Improved Accuracy of Process and Shrinkage Predictions for Talc-Filled Injection Molding Compounds

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Abstract

The morphology of talc fillers used in injection molding compounds is often not well understood. While it is commonly assumed that the talc has a spherical shape, this study presents Scanning Electron Microscopy (SEM) images which demonstrate otherwise. Further, in this study, we look in detail at the properties, morphology and molded shrinkage behavior of two talc-filled compounds and investigate methods to improve the prediction of anisotropic conductivity and solidification in order to achieve more accurate modelling of the packing performance and final part shrinkage. Also considered is the effect of the talc particle orientation on the realized mechanical properties and their role in achieving more accurate predictions of part shrinkage and warpage.

Session 3.3: Modelling and Simulation

Paper ID: S33-262

Robomould Product Quality Prediction and Parameter Optimization using a Bayesian Network

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Abstract

This study presents the implementation of a Bayesian Network model to predict product quality in a Robomould process, an advanced, patented version of conventional rotational moulding. Robomould employs a robotic arm for mould movement and electrical heating elements for direct and more efficient mould heating. These advancements introduce additional process parameters, creating a complex parameter space that makes finding optimal settings, such as those ensuring minimum shell thickness, both challenging and time-consuming. Identifying the optimal process parameters in minimal time is essential to reduce material waste and decrease reliance on the traditional trial-and-error method. The challenge in this process lies in the lack of clear relationships between process parameters and product quality, making it difficult to determine optimal values. To address this, a Bayesian Network model is developed to estimate optimal process settings and predict product quality. A high-fidelity simulation from prior research complements experimental data, enabling a hybrid model. Key features are extracted from raw process data to reduce the abstract nature of this data and improve the settings-quality relation. The low initial correlations between process parameters and quality metrics require a careful selection of relevant parameters to construct the Bayesian Network model. This study highlights the added value of Bayesian Networks in setting up difficult-to-model polymer processes and emphasizes the importance of selecting meaningful parameters to enhance model performance.

Keynote

Session 3.3: Modelling and Simulation

Paper ID: S33-229

Multimodal Shear Molecular Dynamics Analysis of Semicrystalline Polymers

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Abstract

Plastic accumulation in the environment is the biggest challenge to evolving into a sustainable polymer society. New strategies have been directed at recycling used plastics. However, most have not yet attained the level required to minimize plastic accumulation effectively. Twin-screw extruders equipped with molten resin reservoir experiments in the mechanical recycling process restored the intrinsic mechanical properties of physically degraded plastics under optimal processing conditions. Combined equilibrium molecular dynamics (EMD) and non-equilibrium MD (NEMD) simulations have been performed to understand the relationship between the melt microstructure and its mechanical properties by mimicking the restoration process through mechanical recycling. This study examined the structure-property relationship in the crystalline models of static and dynamic shear deformation in high-density polyethylene (HDPE). Simulated results indicate that the static shear deformation (SSD) lowers the topological average entanglements per chain (< Z >), whereas the < Z > is marginally higher when the dynamic shear deformation (DSD) is performed for the isotropic melt structure at 450 K. These results corroborated with the improved ductility of recycled plastics in experiments. The lamellar orientation in SSD is aligned along the shear deformation direction, leading to a brittle stress-strain (S-S) curve, and lamellar orientation is perpendicular to the deformation direction in DSD, giving ductile stress-strain curves. Moreover, when mixing the static shear deformation with dynamic shear deformation, a significant enhancement in the < Z > is observed, supporting the crucial role of the DSD method in optimizing the processing condition for polymer processing.

Session 3.3: Polymer Composites
Paper ID: S36-406

Controlled filler exfoliation and thermal conductivity of polymer composites with hybrid fillers

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Abstract

A 3D interconnected filler network is crucial for achieving efficient thermal conductivity in polymer composites. Utilizing fillers of varying sizes and shapes can create a synergistic effect on thermal conductivity enhancement through a ‘bridging’ mechanism between fillers. In this study, we combined spherical and flaky fillers to investigate filler interactions in ultrahigh-filled polymer composites. The close-packing structure of the hybrid fillers induces in-situ exfoliation of the flaky fillers under shear forces during melt compounding. An increase in the size-to-diameter ratio of the flaky and spherical fillers does not alter the degree of exfoliation but reduces the lateral size of the flaky fillers. Additionally, extending the compounding time further reduces the lateral size of the flaky fillers once exfoliation approaches saturation. Consequently, the thermal conductivity of the polymer composites initially increases to a maximum, as exfoliation of the flaky fillers raises the ‘effective’ filler concentration at a critical point, but subsequently decreases due to increased interfacial thermal resistance arising from the reduced lateral sizes of the exfoliated fillers. This work provides new insights into the in-situ exfoliation of flaky fillers facilitated by hybridization with spherical fillers under close-packing conditions and reveals the correlation between filler exfoliation and the thermal conductivity of polymer composites.

Session 3.3: Polymer Composites

Paper ID: S36-404

High viscosity, lignocellulose reinforced UV curing bio-resins for 3D printing

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Abstract

High-viscosity, lignocellulose-reinforced bio-resins for UV-assisted 3D printing hold significant potential for sustainable material applications. In this study, hybrid lignocellulosic fillers—including lignin (LN), cellulose nanocrystals (CNC), nanofibrils (CNF), and hemicellulose (HC)—were integrated into UV-curable vegetable oil acrylate resins optimized for extrusion-based 3D printing. Bio-resins were successfully printed using an extrusion-based 3D printer with UV LEDs, enabling precise, low-waste application with high-viscosity materials. Effects of HC/CNC/CNF ratio variations on resin surface morphology, macromolecular chain network, thermomechanical properties, and thermostability were systematically investigated. Results indicate that CNC enhances surface smoothness, HC improves particle dispersion and contributes to porosity, and CNF reinforces structural integrity, yielding wood-like texture and performance. DMA testing revealed that hybrid fillers enhance thermomechanical properties over single-filler systems, demonstrating the feasibility of wood-mimicking, customizable 3D-printed objects with bio-based resin systems.

Session 3.3: Polymer Composites

Paper ID: S36-391

Enhanced Actuation of Liquid Crystal Elastomer Composites

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Abstract

Liquid crystal elastomers (LCEs) have large T-responsive actuation strain but low strength and power. We explored several approaches to impower this flexible actuator for promising wider applications. For example, an LCE network was modified with polyethylene glycol soft segments to lower its phase change temperature (Ti), which was adjusted close to body temperature. Additionally, a mesh-structure fabric was introduced into the LCE matrix to reinforce the soft actuators. The obtained LCE composites exhibited higher Young's modulus (13.3 MPa, over 3 times of that of LCE) and retained an actuation strain of 15 %. During a single actuation cycle, it experienced a retractive stress of 1.21 MPa, accompanied by a maximum work density of 121 kJ/m^3. Both the strength and actuation ability of LCE have been improved. This new strategy made the LCE actuators closer to practical applications.

Keynote

Session 3.3: Polymer Composites

Paper ID: S35-302

Harnessing Synergy-Induced Multifunctionality in Bio-inspired Hybrid Composites via Physio-Geometric Architecture Optimization

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Abstract

Considering 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 lightweighting in emerging electric vehicles. Our laboratory focuses on advancing the field of lightweight multifunctional structural materials, through the development of synergy-induced hybrid composites, consisting of self-assembled nano-sized graphene nanoplatelets (GnPs) covalently bonded onto micro-sized glass fibers (GFs), within a common semi-crystalline material, emulating the hierarchical architecture of biological systems. Optimizing the density of covalently bonded GnPs at the fiber/matrix interface creates a gradient interphase that enhances load transfer, resulting in exceptional multifunctional performance driven by synergistic effects. This is attributed to the local nanoscale stiffness variations, due to the increased degree of trans-crystallization encapsulating hierarchical fibrous assembly, producing a gradient interphase. Specifically, this work showcases the effect of GF geometry (classical round cross-section versus flat cross-section) on the GnPs preferential self-assembly arising from physio-geometric compatibility leading to greater covalent bonding. Additionally, mean-field core-shell homogenization theory was applied to predict the effective modulus of the fabricated hybrid composites with both round and flat fibers, elucidating the impact of physio-geometric compatibility through observing synergistic effects. Overall, our hybrid composites surpass the industrial polymer substitute for metallic structural components mechanical properties, exhibiting improvements up to 35% in tensile strength, 84% in impact strength, and 38% in flexural strength compared to the industrial standard, while providing a 20% weight reduction.

Session 3.4: Biomedical applications
Paper ID: S02-432

Biodegradable tissue scaffolds and coronary stents using nano-/micro-fibrillar polymer composites approach

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Abstract

In several branches of the medical field, from cardiology to orthopaedics to tissue engineering, there has been an increasing trend to use biodegradable materials in place of traditional, biostable materials, such as metals, ceramics and synthetic polymers. This paper focuses on the applications of nano-/micro-fibrillar polymer composites in tissue scaffolds and bioabsorbable stents. Poly(L-lactic acid) (PLLA) is a common material under investigation for tissue scaffolds. A large proportion of work in this area focuses on electrospinning to create scaffolding material but this process requires the use of organic solvents, which leave undesirable traces even after washing. This research finds a novel way of manufacturing scaffolds without the use of organic solvents. The process involves drawing of an extruded polymer composite filament to fibrillate the dispersed phase. After producing a network of nano-/micro-fibrils through a common manufacturing technique, the matrix is removed via dissolution in water, leaving a 3-D fibrillar, nanoporous network, which can be used as a tissue scaffold with the advantage of having no residual organic solvent content. The in-vitro cell culture results using bone and tendon cells show some excellent prospects for these solvent-free novel scaffolds. PLLA is also prominent in the field of bioabsorbable stents but it suffers from brittleness, which must be mitigated. Polybutylene adipate co-terephthalate (PBAT) blended with PLA improves its ductility but lowers the mechanical strength. Addition of Polyglycolic Acid (PGA) increases the mechanical strength of the blend. A fourth polymer, Joncryl® ADR is a chain extender able to modify and control the intrinsic viscosity of polyester plastics. Finally, drawing (stretching) this four-polymer blend fibrillates the PGA. The microfibrils of PGA further improve the mechanical properties of the blend. Coronary stents were successfully 3D printed using drawn filament of this composite blend.

Session 3.4: Biomedical applications

Paper ID: S21-372

A 4D-printed biopolymer triboelectric nanogenerator (TENG) device for mechanical energy harvesting

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Abstract

This presentation covers the design and development of biodegradable triboelectric nanogenerator (TENG) devices with a functional 4D structure. These devices are engineered to achieve maximum contact area, optimized triboelectric charge generation, large separation gaps, and rapid disengagement, enhancing their effectiveness in mechanical energy harvesting. The 4D TENG devices are intended for applications in pressure and tactile sensing, as well as in wearable devices for energy harvesting. Our goal is to create a TENG device that naturally degrades at the end of its lifecycle, minimizing any long-term environmental impact. Expected advantages include lower production costs through the use of polymer materials, expanded applicability of biodegradable biopolymers (e.g., as electrodes), improved operational safety with greater accuracy and stability, and increased automation potential due to enhanced sensor sensitivity and TENG power output.

Session 3.4: Circular Economy for Plastics and Recycling
Paper ID: S04-451

Recycling of Rigid Polyolefins: how Polymer Matrices can Mitigate the Impact of Contaminants

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Abstract

Mechanical recycling of post-consumer plastic packaging, particularly post-household waste, remains an important lever for plastics circularity. Polyolefins (PO) represent a significant share, consisting of around 15-20% polypropylene (PP) and 30-40% polyethylene (PE). While technically it is possible to sort these waste streams back to high purity (e.g. 98% main polymer type), this also results in low yields and high costs, while it may not always be required from a technical quality perspective. This research investigates the value of high-purity sorting in the mechanical recycling of rigid post-household PO, with a specific focus on various grades of PP and high-density polyethylene (HDPE) used in packaging. The study focused on evaluating the impact of polymer cross-contamination on and the technical quality of different PP and HDPE grades. Two specific scenarios were considered: (1) injection moulded PP grades, contaminated with various representative HDPE grades, commonly sourced from bottles, caps, and containers within the sorted PP bales; and (2) extrusion blow moulded HDPE grades, contaminated with various representative PP materials, primarily derived from caps within the sorted HDPE bales. For these scenarios cross-contamination levels of 2.5 wt.% and 10wt.% were examined, which represent realistic PO cross-contamination scenarios in recycled streams. The findings indicate that the effect of cross-contamination on mechanical properties is an interplay between the types and amount of PP and HDPE, both as the primary material and as the cross-contaminant. A quality assessment focusing on substitutability indicates that with or without cross-contamination recycled PP and HDPE can meet the requirements for applications like closures, containers, bottles etc, with quality scores up to 1.00 for certain applications. The results highlight the importance of balancing purity levels with application-specific requirements to optimize recycling processes and enhance the sustainability of packaging solutions.

Session 3.4: Circular Economy for Plastics and Recycling

Paper ID: S04-123

Breakthrough strategies for recyclable cross-linked polyolefins

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Abstract

Cross-linked polyethylene (PEX) is a type of polyethylene with improved properties, notably thermal stability and mechanical performance. This enhanced behavior is due to the formation of intra-chain bonds, linking the PE chains together in a network. PEX cannot be recycled and is generally downcycled as a filler in other composite materials, posing sustainability challenges in the present context of intense reflection on more environmentally friendly practices. The Horizon Europe-funded REDONDO project is tackling this issue by developing a fully reversible cross-linking process, allowing the synthesis of recyclable and sustainable-by-design polyethylene (rPEX). The project also explores the use of innovative biobased additives, such as nanolignin and nanocellulose, to enhance rPEX's properties. The feasibility of REDONDO's rPEX will be demonstrated in the fields of piping and cables. This presentation will outline the REDONDO concept and strategies, along with the latest results on HDPE-based composite materials with nanolignin and tannic acid. These two biobased additives, especially lignin, have a great potential and indeed their incorporation to HDPE contributed to preparation of composites with interesting properties. The composites were characterised by standard techniques such as infrared spectroscopy, differential scanning calorimetry and thermogravimetric analysis, and additionally mechanical properties and antioxidant properties were evaluated. Acknowledgements 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.

Session 3.4: Industry 4.0 and AI
Paper ID: S10-274

Multi-Quality Prediction in Injection Molding Using CPS and Ensemble Learning

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Abstract

In smart manufacturing, integrating physical and virtual data is essential, yet challenging due to the complexities of real-world environments. Simulation analysis effectively bridges this data gap. This study combines virtual sensor data from simulation software with in-mold pressure data from injection molding, utilizing machine learning and deep learning models to predict product qualities. A design of experiments (DOE) approach enables the systematic collection of multidimensional sensor data, building a comprehensive database. Using unsupervised learning, key pressure features are extracted, with product dimensions and weight as outputs, enabling precise multi-quality predictions. This approach, integrating pressure features with simulation data, achieves an R^2 of 0.93 in weight prediction, significantly enhancing accuracy while reducing data collection costs and time. This efficient, data-driven solution strengthens the competitiveness of smart manufacturing and opens new opportunities for injection molding applications.

Session 3.4: Industry 4.0 and AI

Paper ID: S10-247

Decoupling data acquisition, data analysis and decision making in an injection molding workflow, by use of Dataspaces and Asset Administration Shells

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Abstract

The advent of Industry 4.0 has enabled advanced interoperability and connectivity between systems, leading to transformative shifts in manufacturing and polymer processing. Some of the most promising areas of Industry 4.0 are the concepts of industrial dataspaces, and asset administration shells, which represent a framework for standardized, secure, and sovereign data sharing among organizations, and allow for a standardized structure of the shared data, respectively. This research explores one of the core benefits of decoupling data acquisition from analysis using dataspaces and AAS. The data sovereignty and granular access control provided by the dataspace architecture allows that each data source remains under the control of its original owner. This access control is especially important in the context of injection molding where multiple material suppliers might have an interest in the performance of each other's plastics grades. Using standardized data formats enables the easy insertion of a middleman, between data providers and users. Potential customers can thus be provided with ideal machine settings, or adjustments in mold design to achieve desired product characteristics, or reduce production costs, without knowing specifics about their material or machine. Customized solutions tailored to the unique requirements of each customer can be provided. This capability is invaluable in the injection molding sector where end users seek guidance on configuring machines and materials for specific applications. Instead of relying on trial and error or generic recommendations, potential customers can receive recommendations that enhance productivity and product quality. Since the format of that data is already predefined, seamless incorporation of new data providers and consumers is possible.

Session 3.4: Morphology and Structural Development
Paper ID: S14-239

Construction of entwined TiN-CNT hybrid network via electrostatic self-assembly: Achieving a durable and photothermal superhydrophobic surface for anti-icing/de-icing application

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Abstract

Photothermal superhydrophobic surfaces are potentially ideal for anti-icing/deicing, due to the fast water removal, delayed icing and photothermal deicing properties. However, the tedious fabrication procedures and inadequate durability limit their practical applications. Here, entwined TiN-CNT hybrid network is successfully constructed via electrostatic self-assembly, and further modified with SiO2 and HDTMS to achieve a durable and photothermal superhydrophobic surface for anti-icing/de-icing application. By tuning the nanoparticle ratio, the hybrid network not only realizes full-spectrum high absorption, but also achieves the high surface non-radiative relaxation and thermal vibration. Besides incorporating PDMS with the hybrid network as the photothermal superhydrophobic surface, the adhesion of the surface to the substrate is further enhanced by fabricating PDMS with epoxide silicone resin (ESR) as a bonding layer. After various robustness tests, the surface maintained excellent consistency. As a result, the surface exhibits excellent anti-icing/de-icing performance with stable icing delay time (1140 s) and rapidly photothermal deicing capabilities (198 s) under low temperature and high humidity conditions. This studying offers an insight into design of novel materials with stable anti-/deicing surfaces, which would be extended into some applied realms, e.g., wind turbine blades or power systems in cold or low-temperature climate.

Session 3.4: Morphology and Structural Development

Paper ID: S14-211

Toward high performance by stress-induced hierarchical structure during polymer processing

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Abstract

Applying an external force field during processing is an effective way to prepare high performance and functional polymer materials. External force affects hierarchical structure evolution such as orientation and relaxation of the molecular chains, the stress-induced crystallization, deformation of crystal structure, cavitation, as well as deformation of phase structure. The tunable hierarchical structures can impart the products with promising properties like mechanical properties of high strength and ductility, high barrier performance for oxygen and water-vapor, transparency, and other functional properties. However, the evolution of microstructure induced by external force is not deeply understood due to the complex transformation of hierarchical structure in processing conditions. Moreover, the relationship between performance and hierarchical structure needs to be revealed further, which is expected to provide novel method for advanced polymer materials with high mechanical properties and new functionality. Therefore, we will give some recent work which use the controllable processing fields to obtain micro-nano structure and to pursue performance improvement for commodity polymer and biodegradable polymer. These include structure and properties of films using melt stretching technique [1], the semi-solid stretching technique [2-4] and the functionalization of oriented technique [5].

Acknowledgements: Thanks to the Grants 52173040 and 52033005 from National Nature Science Foundation of China.

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Session 3.4: Polymerisation and synthesis
Paper ID: S18-358

Polyethyleneimine and molecularly imprinted polymers in designed magnetic nanocomposites for extraction and determination of gallic acid in green tea

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Abstract

Phenolic acids derived from plants possess specific physiological activities such as antibacterial, anti-inflammatory, anti-tumor, anti-mutagenic and other biological effects that have made them valuable in pharmaceuticals, dyes, food, light industry, and organic synthesis. The leaves of some plants are rich in gallic acid (GA) (phenolic acid). GA has higher content in green tea, so it is an important physiological active component. However, the composition of tea is complex, which is not conducive to the direct determination of GA. Several nanocomposites or polymerization on composites using multiple of reagents have been reported for their purification, however the use of polyethyleneimine (PEI) in composites or in molecularly imprinted nanocomposites is not well established. Herein, two sets of study have been developed. In one side, an innovative and simple nanocomposite denoted as MHNTs@PEI was synthesized for GA analytical sample pretreatment. PEI was bound onto magnetic halloysite nanotubes (MHNTs) to enhance adsorption capacity (158 mg·g-1). MHNTs@PEI was obtained only through two steps modification (amination and PEI modification). Characterizations showed that there are layers of synthetic PEI on the tubular structure of the material and magnetic spheres on its surface, both indicating successful synthesis of the nanocomposite. Furthermore, the adsorption isotherms and kinetic modeling showed that the Langmuir model and pseudo-first-order model fit the adsorption data, respectively. Overall, the abundant adsorption sites significantly improved its adsorption performance with the recovery of 95.67–99.43%. In the other side, on the surface of MHNTs@PEI, polymerizations to generate molecularly imprinted nanocomposites are performed to visualize full synergistic effect of each contributing elements on the effectiveness improving features toward GA in its purification and quantitation with promising results in the field to be shared in the events.

Session 3.4: Polymerisation and synthesis

Paper ID: S18-286

Optimisation of the process of obtaining furan-based polyesters employing the design of experiment method (DoE)

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Abstract

Diminishing fossil fuel resources, fluctuating oil prices, high greenhouse gas emissions, and the limited biodegradability of polyesters derived from petrochemical feedstocks result in the need to search for renewable raw materials for their production. Plant biomass such as lignocellulose, starch, vegetable oils, plant proteins, and aliphatic hydrocarbons holds a key position among renewable raw materials. Starch in its natural form and after chemical modification, is a biopolymer that can be used in the synthesis of different types of polymers. Compounds derived from starch through biochemical and/or chemical methods can serve as replacements for existing petrochemical-based components. One example is 2,5-furan dicarboxylic acid (FDCA), whose chemical structure closely resembles that of terephthalic acid (TPA), a compound derived from non-renewable sources. FDCA has been recognized as one of the "Top Value-Added Chemicals from Biomass" with the potential to replace TPA in many industrial applications, including the synthesis of semi-crystalline aromatic polyesters. The purpose of this work was to carry out an experimental study involving the determination of the effect of manufacturing parameters on the key properties of thermoplastic polyesters based on raw materials of plant origin. Furan-based polyesters were synthesized by two-step polycondensation in the molten state and processed using conventional thermoplastic processing techniques (i.e. injection molding). The effect of experimental settings on polymerization efficiency and injection molding accuracy was investigated and optimised with the Taguchi approach of design-of-experiments (DoE).

This study was financed by the National Science Centre within project OPUS (no. 2023/51/B/ST8/00775).

Session 3.4: Rheology and characterisation
Paper ID: S19-364

Influence of degree of fusion on Rigid PVC rheology for industrial processing

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Abstract

Rigid PVC is a common used material within a lot of structural applications all over the world. In the field of window profiles, the cross section geometry consists of several sections with varying thicknesses. To distribute the material flow in an appropriate way throughout the cross section, a good understanding of the rheological behaviour is necessary. For rigid PVC, there is the combination of shear viscosity behaviour, slip at wall and the degree of fusion. Within this research, an industrial extrusion line equipped with different dies is used to end up with relevant data. Measurements are performed using different screw speeds with different temperature settings combined with different slit die heights. Each slit die is equipped with three pressure sensors to be able to cope with changes within pressure drops along the slit die length. As the rheological behaviour of rigid PVC is also strongly temperature dependent, accurate measurements of the die temperature are also performed. Within this research, the degree of fusion is defined using DSC technique. The degree of fusion was measured at different locations along the extrusion line. This allows to define the thermo-mechanical influence on the degree of fusion. Starccm software from Siemens has been applied to perform data fitting using optimisation routines. Using this software strategy allowed to cope with different process parameters which can not be covered by manual calculations due to the highly coupled behaviour between the process parameters. This research resulted in a good strategy to come up with industrial applicable rheological data. For the different conditions and dies (ranging from 1 to 3mm die height), the maximum errors for the pressure values registered at the different locations along the die, are below 5% which is challenging for this type of material.

Session 3.4: Rheology and characterisation

Paper ID: S19-271

Deformation and Fracture Analysis of Glassy Polymers under Uniaxial Tension by Acoustic Emission Method

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Abstract

Although there have been many studies on the deformation and fracture behavior of polymers, it is still not fully understood because the behavior is very complex. In this study, we focused on the acoustic emission (AE) as a method to measure microscopic fracture phenomena inside materials in real time. This method detects elastic waves (ultrasonic waves) generated when materials are deformed or fractured, and has been used for fiber fracture and interface fracture in composite materials, but has not been widely used for pure polymers. Here, the AE method was used to analyze the uniaxial tensile behavior of amorphous glassy polymers such as polycarbonate (PC) and polystyrene. Even in the elastic deformation region of every polymer measured, many counts were generated and small cracks were formed. In the necking region of ductile polymer such as PC, few AE waves were observed, but then crack formation and growth occurred again as the fracture approached. When the preceding load was removed and the load was applied again, the "Kaiser effect" was observed, in which AE waves were hardly generated up to the preceding load, and the stress at which this effect was no longer observed indicated the boundary between elastic and plastic deformation.

Keynote

Session 4.1: Fibres and Films
Paper ID: S29-377

Flow-Assisted Gel Spinning Technique for Fabricating Stretchable and Thermally Insulating TPU-Silica Aerogel Fibers

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Abstract

Aerogel fibers hold great promise for diverse applications, especially in textiles like firefighter clothing and personal thermal management. However, the inherently porous structure of aerogels often compromises their mechanical strength. This study introduces a novel approach to fabricate continuous thermoplastic polyurethane-silica aerogel (TPU-SA) hybrid fibers using a flow-assisted gel spinning method. This technique allows for in-situ nanofibrillation of modified TPU (mTPU), resulting in a fiber-in-fiber structure with mTPU nanofibers embedded within a silica aerogel matrix. Rheological analysis revealed that the hybrid pastes exhibit shear-thinning behavior, with the silica aerogel content significantly influencing the viscosity and yield stress. The chemical crosslinking reactions were confirmed via FTIR. SEM imaging revealed a fiber-in-fiber morphology with mTPU nanofibers predominantly aligned in the tensile direction and encapsulated by a mesoporous SA matrix. The fiber structure is further characterized by N2 absorption-desorption isotherms, revealing a mesoporous nature with two predominant pore sizes around 6 and 30 nm, similar to the original SA. The mesoporous structure of the silica aerogel reduced thermal conductivity to 0.024 W·m−1·k−1. The incorporation of SA particles also enhances the thermal stability of the hybrid fibers, extending their performance range up to 150 °C. This unique structure significantly enhanced mechanical properties of the aerogel fibers, achieving a tensile strength and elongation at break of 10.26 MPa and 100.94%, respectively. All in all, the versatile gel spinning technique offered a promising approach to produce high-performance aerogel fibers with tunable properties. These fibers hold significant potential for various applications, including protective clothing, stretchable apparel, and thermal insulation, particularly in harsh environments.

Session 4.1: Fibres and Films

Paper ID: S29-376

Effect of High-Temperature Local Heating in the Vicinity of Spinning Nozzle on the Structure and Properties of Poly(Ethylene Terephthalate) Fibers

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Abstract

This study investigated the effect of melt structure control on the structural and physical properties of PET fibers in detail, employing a high-temperature local heating (HTLH) technique in the vicinity of the spinning nozzle. The heating apparatus for HTLH consists of a specialized spinning nozzle integrated with a conventional heating element, featuring a streamlined design. The application of HTLH in the vicinity of the nozzle during the melt-spinning process of PET (I.V. 1.05) was shown to significantly decrease both the melt viscosity (Poise) of PET in the nozzle's capillary and the spinning stress of fibers in the spin line. Notably, the coefficient of variation (CV) in fiber diameter and the intrinsic viscosity (I.V.) of the as-spun fibers produced with HTLH treatment were comparable to those of untreated fibers, indicating minimal difference between the two. The as-spun fibers treated with HTLH exhibited an increased Natural Draw Ratio (NDR) on the stress-strain (S-S) curve compared to untreated fibers, with an elongation at break point exceeding a 10% increase. During the drawing process, the HTLH-treated as-spun fibers demonstrated a higher maximum draw ratio and an improvement of over 15% in tensile strength compared to untreated fibers. These findings indicate that controlling the melt structure through HTLH can enhance both the mechanical properties and processability of PET fibers. Furthermore, HTLH method developed in this research shows considerable potential for seamless integration into various commercial melt spinning processes, due to its simple, compact, and energy-efficient apparatus design.

Session 4.1: Fibres and Films

Paper ID: S16-173

Scalable In-Situ Micro/Nanofibrillar All-Organic Polymer Dielectric Films for Electric Energy Storage

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Abstract

Polymer film capacitors have the advantages of fast charging and discharging rate, good reliability, light weight and low cost, playing an important role in advanced electronic devices and power systems. The state-of-the-art linear dielectric of biaxially oriented polypropylene has high breakdown and low loss, but suffer from low energy density. The nonlinear dielectrics such as polyvinylidene fluoride (PVDF) and its copolymer have high dielectric constant and energy storage density. However, their pretty high ferroelectric domain relaxation loss and ionic loss can hardly meet the requirements of film capacitors. Thus, it is a formidable challenge to combine the performance advantages of linear and nonlinear polymer dielectrics for developing all-organic film capacitors with high energy density and low loss. In our current work, the strong intermolecular hydrogen bonding between poly(methyl methacrylate) (PMMA) and PVDF was utilized to totally degrade the crystallization ability of PVDF, thus suppressing its ferroelectric loss. Furthermore, an innovative technology of “melting extrusion-hot stretching-quenching” was put forward for the large-scale preparation of all-polymer dielectric films containing micro/nanofibrils of poly(ethylene terephthalate), PVDF, and PMMA/PVDF. The solid-state stretching processing was also performed to further structure the fibrillar morphology, molecular chain orientation, and crystalline structure. As a result, the as-prepared in-situ microfibrillar all-organic polymer dielectric films exhibited a discharged energy density of 9.4 J/cm3 and a discharged energy efficiency of 90.9%, which is significantly superior to most of the current all-organic polymer dielectric films. The new insight into the relationship between the microscopic structure of the polymer dielectrics and their macroscopic dielectric properties effectively promotes the development of next-generation high-energy density and low-loss dielectrics.

Session 4.1: Functional Additives and Reactive Processing
Paper ID: S09-369

Novel epoxy vitrimer chemistry with improved melt processability

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Abstract

The viscosity of epoxy-based polyester vitrimers can be controlled by the stoichiometry and the choice of catalyst, aside the temperature and shear rate for melt processable materials. Previous work showed that poly(ethylene-co-glycidyl methacrylate) and an anhydride react in the molten state resulting in a polyolefin/polyester vitrimer with relatively low Tg ad Tv values, allowing their incorporation into thermoplastic blends for various applications. Currently, epoxy vitrimers are primarily based on transesterification reactions, resulting in relatively high viscosities. Lower viscosities should enable wider application of vitrimers in melt processable systems. This study investigates transetherification through catalyzed ring opening homo-polymerization of epoxy. Characterization includes FTIR, swelling tests, DMA, TGA, rheology and stress relaxation. The viscosities of the transetherified epoxies are indeed lower compared to classic transesterified-based epoxy vitrimers, at similar cross-link densities. Transetherification is achieved within typical polyolefin processing conditions (up to 230oC). These results may offer an alternative route to epoxy vitrimers, eliminating the need for cross-linkers.

Session 4.1: Functional Additives and Reactive Processing

Paper ID: S09-277

Laser holographic processing of plastics for augmented reality

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Abstract

Laser holographic processing of plastics is renowned for its capacity of manufacturing intricate optical elements, which have demonstrated promising potential for augmented reality (AR). Reflection-type holographic optical elements (rHOEs) based on holographic plastics have recently garnered substantial interest from both industry and academia due to their advantages such as low cost, light weight and ease of processing. However, simultaneously enhancing the diffraction efficiency and thermal reliability of full-color rHOEs remains challenging, presenting a major barrier to their broader applications. Herein, we report an innovative method to fabricate thermally reliable full-color rHOEs with high diffraction efficiency. Initially, blue, green, and red color rHOEs were separately fabricated to evaluate the potential of holographic plastics in producing monochromatic rHOEs. The results show that these monochromatic rHOEs exhibit a diffraction efficiency exceeding 85%, haze below 2%, and robust long-term reliability at 85 °C. Furthermore, utilizing the principle of wavelength multiplexing, full-color rHOEs with an average diffraction efficiency of 60% and haze below 2% are produced, exhibiting stable performance at elevated temperatures, and enabling reliable full-color AR displays.

Keynote

Session 4.1: Functional Additives and Reactive Processing

Paper ID: S09-185

Reactive extrusion of poly(lactic acid): a model-based design study for viscosity control

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Abstract

Poly(lactic acid) (PLA) is a biopolymer with significant potential in the circular economy, due to its similarities to polystyrene (PS) and polyethylene terephthalate (PET), and its good barrier properties [1]. However, the direct use of (unmodified) PLA is complicated due to unfavorable material properties, e.g. high brittleness, less defined crystallization speed and low melt strength [1]. PLA's properties can be improved by chemical modification via reactive extrusion (REX), e.g. (natural) crosslinking by free radical-induced grafting (FRIG). In this process, a peroxide is added during extrusion. Consequently, mid-chain radicals are formed which will recombine and form a crosslink [2]. It has been demonstrated that chemical modifications occur for the polymer chains from lower to higher chain length regions [3]. Understanding the influence of the chain length distribution on modification purely experimental is tedious and even impossible for complex structures. Experimental results together with model development tracking molecular details lead to a synergy in which a much better understanding of the molecular scale is possible and an efficient process optimization is obtained. In the present work, varying quantities of dicumyl peroxide (DCP) initiator were used to naturally crosslink PLA via a FRIG-REX process. Different process parameters were altered, i.e. temperature, residence time distribution and DCP load. The characterization of the modified PLA included the quantification of the molecular structure of the soluble and insoluble molecules based on size exclusion chromatography, Soxhlet extraction and rheology. Thanks to the synergy with the model predictions, a link to the molecular structure could be drawn.

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Session 4.1: Functional Additives and Reactive Processing

Paper ID: S09-204

Application of Cold Atmospheric Pressure Plasma Jet Treatment for Producing Functional Polymers by Melt Grafting Processes

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Abstract

Functional polymers are widely used in several industries, from biomedical to food packaging and electronics. In engineering, they are applied for the compatibilization of polymer blends, improving interfacial strength in fiber composites, ionomer production, and more. Distinct routes for producing functional polymers exist, such as copolymerizing olefins with functional monomers using appropriate catalysts or post-polymerization grafting in solution or melt. From an economical and environmental perspective, melt grafting by reactive extrusion is the preferred method for large-scale post-polymerization functionalization. Reactive extrusion relies on free radical reactions and is traditionally accomplished by adding the selected functional monomer with an initiator, typically an organic peroxide, which decomposes at high temperatures into alkoxy radicals that abstract hydrogens from the polymer chain, creating free sites where the monomer is grafted. While a relatively straightforward process, its main disadvantages are the low grafting efficiency and undesired side reactions. This work reports a novel process using plasma treatment in the melt state as the free radical generator. While extensively applied in surface modification, the focus here is on developing a process to modify the bulk properties of polymers by plasma treating the melt polymer. Initial results show that plasma is effective in generating radicals, evidenced by the formation of a cross-liked network and increased melt viscosity. Currently, optimizations are being explored to improve the degree of grafting and reduce side reactions.

Session 4.1: Modelling and Simulation
Paper ID: S13-433

Modelling of Robotic Rotational Moulding Using the Discrete Element Method

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Abstract

One of the latest and most advanced forms of rotational moulding employs the movement of a robotic arm to distribute a polymer powder onto the internal surface of an electrically heated mould. This is truly transformative as it provides a step change in the levels of measurement and control that are possible in a polymer processing technique that has lagged well behind other processes in its technological development. With a robotic arm now controlling movement it is theoretically possible to employ complex combinations of multi-axial rotations and velocities to control the wall thickness distribution in a part. However, as the effects of such movements have not been studied before and they would require huge resources to investigate experimentally, the solution is to employ simulation. In this work the effects of robotic movement on the process have been investigated using the discrete element method (DEM). The aim is to determine the links between different forms of robotically controlled movement in the mould and the paths taken by the polymer powder that ultimately lead to its final distribution across the part. In this study the commercial DEM software Ansys Rocky has provided the platform for simulation development and corresponding particle models have been developed to represent the polymer powder. With these the trajectories of particles have been traced and mapped across the internal surfaces of the mould. The types and numbers of particles have been optimised to provide a balance between accuracy of representation and simulation time. Model validation has been carried out through comparison with part wall thickness distributions obtained experimentally and good correlation has been observed. The DEM method is therefore showing considerable promise as a tool in simulating the robotic rotational moulding process.

Session 4.1: Modelling and Simulation

Paper ID: S33-403

Influence of mold-sheet interaction in thermoforming processes

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Abstract

Around 400 million tons of plastic are produced every year. Over 40 % of this is used for packaging alone. Within packaging, a large proportion is accounted for by the production of thin-walled plastic parts, which are manufactured using industrial thermoforming processes. In thermoforming, a thermoplastic sheet is softened by heating and then forced into a mold by applying a pressure difference. Sometimes additional forces are applied by a plug or by blowing air. Compared to other plastics processing methods, the thermoforming process has been investigated relatively little. When the hot sheet comes into contact with the cooler mold, the temperature of the sheet drops with simultaneous friction. The sheet tends to deform less as the temperature decreases. On the other hand, the coefficient of friction decreases with increasing temperature. This study presents a measurement method for determining the temperature-dependent friction at elevated temperatures. For this purpose, a standard friction tester according to ISO 8295 / ASTM D1894 is modified by a heated plate and a heated sled. The coefficient of friction between high-impact modified polystyrene and various mold materials is evaluated. In addition, the heat transfer between sheet and mold is determined based on in-situ measurements of temperature and thickness for an existing thermoforming process. The necessary thermal material properties of the high-impact modified polystyrene are determined from DSC measurements and manufacturer specifications. The results are verified using a forming simulation. The dependence of the material on temperature and forming speed is taken into account using a viscoelastic-viscoplastic material model. It is shown that the measured friction and heat transfer properties together are in high agreement with the experimental data.

Keynote

Session 4.1: Modelling and Simulation

Paper ID: S33-320

Advanced Simulation of Morphology and Property Distributions in Polymer Injection Molding

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Abstract

During polymer processing operations, molten polymers are deformed to fit shape and dimensions of the part. For the injection molding process, the final shape of the part is determined by the geometry of the mold cavity. The part final morphology distribution (and thus the properties distributions) is determined by the evolutions of temperature and flow fields within the polymer during both mold filling and subsequent cooling up to polymer solidification. Obviously, during mold filling, the shear will be intense at the mold wall and will decrease toward the mold mid-plane, being essentially symmetric with respect to the thickness mid-plane. Once the mold has been filled, the orientation distribution, determined in the polymer by mold filling, will start relaxing; however, close to the mold wall, where the temperature is smaller, the relaxation phenomena will be very slow. In other words, a relevant molecular orientation (giving rise to the fiber formation) can remain frozen at the mold surface; viceversa, close to the thickness mid-plane, a wide area is expected to solidify essentially unoriented: spherulites are, there usually found. A software for the simulation of the whole injection molding process (filling, packing and cooling) has been developed at the University of Salerno within the framework depicted above. The software is based on an advanced characterization that describes the main phenomena taking place in the polymeric material during the process. In particular, the formation of fibers and spherulites, the role of flow intensity on alpha phase morphologies and crystallization kinetics, the interplay between crystallinity and rheology, and the effect of pressure on rheology and crystallization are accounted for. In this work, in order to continue along this direction, characterization of the material has been further enhanced by refining material thermal and volumetric description and assessing their influence on the simulation predictions.

Session 4.1: Morphology and Structural Development

Paper ID: S14-325

Bulk Acoustic Wave resonators fabricated from modified piezoelectric polymers

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Abstract

Polymers that can convert motion to electricity are critical technologies for future electronic devices. Inducing phenomena that enable electricity generation in polymers is primarily focussed on designing piezoelectric (deformation to electricity) and triboelectric (friction to electricity) polymers and devices. Recently, it has been demonstrated that bombardment of ions into polymers can lead to a dramatic enhancement in triboelectrification across arbitrary polymers.[1,2] In this study, we examine the effects of ion beam modification on fluorinated polymers, comparing them to their unmodified counterparts. Both triboelectric and piezoelectric measurement techniques are used to investigate the observed changes. Additionally, we assess the piezoelectric performance of Bulk Acoustic Wave (BAW) resonators fabricated from the modified piezoelectric polymers, with varying thicknesses, and compare them to unmodified versions featuring different metallic electrode configurations. We highlight the potential of this approach as a temperature sensor. When integrated with existing laminate technology, our method could lead to the development of future sustainable vibration-based sensors.

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Session 4.1: Morphology and Structural Development

Paper ID: S14-329

Effects of Plasma Treatment on Morphology, Rheology and Mechanical Properties of Microfibrillar Composites

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Abstract

The demand for high-quality polymers, particularly in the packaging sector, is steadily rising to meet stringent requirements for mechanical strength and barrier properties. However, multilayer or blended plastics used in packaging pose significant recycling challenges due to their low recyclability and limited mechanical integrity. Consequently, a substantial portion of these plastics ends up in landfills. Low-density polyethylene (LDPE) and polyamide 6 (PA6) multilayer films are commonly used in packaging and are a typical example of this recycling challenge. Recently, researchers have explored a novel approach to craft polymer-polymer composites by developing in situ microfibrils, introducing a new class of materials known as microfibrillar composites (MFCs). These composites offer advantages through the utilization of thermoplastic fibres, enhancing mechanical properties and compatibility without requiring mineral additives. Manufacturing the MFCs consisted of three steps: melt blending, fibrilization, and thermal treatment. Plasma treatment, specifically, offers a unique method for modifying surface morphology and rheology, potentially optimizing the performance characteristics of these composites. In this study, virgin 70% LDPE and 30% PA6 are used as the matrix and reinforcement polymers, respectively, to systematically investigate the impact of plasma treatment during melt blending on the morphology and rheology of the extrudate. Moreover, correlations between the morphology and mechanical properties of drawn filaments and composites are examined following the plasma treatment on the LDPE and PA6 blends. Preliminary results indicate that plasma treatment enhances dispersion of PA6 droplets compared to the untreated polymers, and the complex viscosity of plasma-treated polymers increases. Future work will involve applying these techniques to waste materials to evaluate their effectiveness in real-world recycling scenarios.

Session 4.1: Morphology and Structural Development

Paper ID: S14-301

In-situ studies on the crystallization of stereo complex polylactic acid

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Abstract

Polylactic acid (PLA) is a bio-based and biodegradable polyester used in common consumer products and medical applications. Depending on the position of the OH group, PLA exists in two enantiomers: poly(L-lactide) (PLLA) and poly(D-lactide) (PDLA). By mixing the two, a stereo complex (sc) of PLA is formed. Compared to the homogeneous crystal (hc) of PLLA and PDLA, sc-PLA exhibits outstanding thermal and mechanical properties due to the strong intermolecular hydrogen bonding between the unit sequences of PLLA and PDLA. In order to utilize these properties, it is necessary to understand how they are influenced by the processed-induced structures and morphologies. In this study, we investigated the formation of crystalline structures and morphologies of sc-PLA with different PLLA/PDLA ratios using in-situ X-ray measurements and hot-stage experiments. For the X-ray studies, we used a newly developed experimental set-up to record the formation of the crystalline phase. In the so-called FlowCell, PLA was heated above its melting point and then cooled to various temperatures. During cooling, the formation of crystalline structures was monitored using synchrotron scattering experiments. In parallel to the X-ray studies, the formation of crystalline structures was investigated using hot-stage experiments with the same temperature profiles that were used for the X-ray scattering experiments. Based on the time- and temperature-controlled microscopic images of the crystallization, we were able to follow the crystallization kinetics of sc-PLA more closely. It was found that depending on the PLLA/PDLA ratio and crystallization conditions, PLA crystallizes into different crystalline structures (hc-PLA and/or sc-PLA). It was also found that, in contrast to hc-PLA, where the onset of crystallization shifts to lower temperatures with increasing cooling rate, the onset of crystallization of sc-PLA shifts to higher temperatures with increasing cooling rate.

Keynote

Session 4.1: Morphology and Structural Development

Paper ID: S14-202

Synergistic Effects of Graphite Particle Size, Hybrid Graphite, and Reduced Graphene Oxide on the Properties of Co-Continuous PET/PVDF Composites

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Abstract

In this study, electrically conductive polyvinylidene fluoride/polyethylene terephthalate (PVDF/PET) (50:50) composites filled with 60 wt.% of various graphite (GR) types were developed to investigate the effects of GR particle size (G1: 5.9 μm, G2: 17.8 μm, and G3: 561 μm), GR concentration (20-60 wt.%), and hybrid combinations of GR/GR and GR/GR/reduced graphene oxide (rGO) on electrical conductivity, morphology, thermal, and mechanical properties. SEM analysis showed a co-continuous morphology across all composites, with GR preferentially located in the PET phase. For single GR fillers, medium-sized G2 particles formed the most efficient conductive network, achieving a resistivity of 1.5 Ω·cm (at 60 wt.% G2) due to optimal particle packing and conductive pathway development. Hybrid GR types further reduced resistivity to 0.93 Ω·cm in the 60 wt.% G2/G3 (45:15) composite, indicating filler synergy. The large size difference between G2 and G3 allows G2 to form a connected network, while G3 improves packing and electron transport by bridging gaps. Replacing 2 wt.% G3 with rGO lowered resistivity to 0.89 Ω·cm, as rGO's 2D structure enhances contact, creating efficient conductive pathways. Thermal stability in the (PVDF/PET) composite with 60 wt.% G2/G3 (45:15 wt.%) was improved, with an onset temperature around 490°C compared to 420°C for the neat PVDF/PET, attributed to an effective thermal network from different-sized GR particles. Mechanical testing showed that composites with 60 wt.% G1 (smallest size) had the highest flexural strength and modulus among single GR composites, highlighting the reinforcing effect of smaller particles. This study underscores the importance of optimizing GR particle size and hybrid combinations of GR/GR and GR/GR/rGO in PVDF/PET composites to balance electrical, thermal, and mechanical properties, making them promising for high-performance proton exchange membrane fuel cell (PEMFC) bipolar plates.

Keynote

Session 4.1: Polymer Blends and Alloys
Paper ID: S16-259

Toward Processable Upcycled Blends with Enhanced Mechanical Properties Using Electron Beam Irradiation

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Abstract

Electron Beam Irradiation (EBI) of up to 50 kGy has been used to partially crosslink Low-Density Polyethylene (LDPE), Polypropylene (PP), and recycled Polyethylene Terephthalate (rPET) blends at different compositions. Their mechanical and rheological properties were investigated with the aim of developing an innovative method to upcycle post-consumer resins (PCRs) while maintaining their processability. To obtain processable PCRs, a degradable polymer, by the effect of EBI, should be included, while the other should be cross-linkable by the EBI. Thus, the addition of LDPE to PP (degraded by EBI) and irradiation to 25 kGy decreased the complex viscosity (CV) by almost ten-fold (measured at 1Hz at 230oC), and the addition of rPET to PP and irradiation to 25 and 50 kGy decreased the CV by a factor of 4 to 5 respectively (measured at 1 Hz at 290oC). The addition of PP, when blended with LDPE or rPET, should be limited in composition and irradiation dose for optimal mechanical properties. Hence, PP/rPET blends of more than 50% PP and EBI at 50kGy were too brittle to process. However, blends of PP/LDPE of more than 50% PP were not. By comparison, neat PP irradiated to 50 kGy was too brittle to form into 0.5 mm sheets. Scanning electron and optical microscopies showed that phase separation of the incompatible PE, PP, and rPET decreased after EBI and subsequent processing. In conclusion, irradiation dose is decisive in controlling the mechanical and rheological properties of PCR blends composed of balanced cross-linkable and degradable constituents. Furthermore, compounding incompatible PCR blends followed by pelletizing and controlled EBI could lead to the production of upcycled processable PCR pellets in an economical and facile route for the circular economy of commodity PCRs.

Session 4.1: Polymer Blends and Alloys

Paper ID: S16-280

Influence of blasted metal surface textures on joining strength via injection molded direct joining

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Abstract

Joining light metals and polymers is a tendency in the transport industry to reduce CO2 emissions and costs. We focus on one of the speedy low-cost direct metal-polymer joining techniques, blast-assisted injection molded direct joining (IMDJ). In the blast-assisted IMDJ process, micro-sized textures are manufactured on the metal surface by abrasive blasting at first, then molten polymer flowing over the roughened metal surface infiltrates surface structures by the injection molding process. This direct joining technique can effectively reduce the cost and number of processes. Successful joining is achieved through the infiltration of melted polymer into blasted surface structures. However, the relationship between these surface structures, determined by blasting conditions, and the resulting joining strength remains unclear. This study aims to clarify the effect of surface texture on joining strength. Additionally, we aim to extract specific surface profile features that represent joining effectiveness. We measured and analyzed the surface profiles of samples blasted with conditions. Single lap joints were manufactured by IMDJ under constant molding conditions and then subjected to tensile shear testing. In this study, hybrid joints of a 30% glass fiber-reinforced polybutylene terephthalate (PBT) and aluminum alloy A5052 plates were produced. We subsequently investigated how different blasted metal surface textures affect joining strength. The results show that standard roughness parameters do not accurately reflect joining effectiveness. We introduced two new parameters, Effective Slope Ratio (ESR), which illustrates the sample joint surface's capability to withstand shear stress; And Effective Structure Number (ESN), which indicative of the stress dispersion ability of the effective joining structures. The result of multivariate linear correlation coefficient R was 0.75. The high correlation coefficient has been got.

Session 4.1: Polymer Blends and Alloys

Paper ID: S16-255

Appealing Through Annealing: Exploiting Filler-Enhanced PEEK/PEI Blend Behavior for High-Frequency PCB Applications

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Abstract

Electronic components have to deal with ever increasing radio frequencies, driven by the development of short-range, low-latency and high-capacity wireless communication (5G/6G broadcast standard, mmWave, etc.). This, in turn, raises the demand for certain properties of materials in use as substrate material for printed circuit boards (PCB). In particular, dielectric properties, i.e. relative permittivity and dielectric losses, must meet certain thresholds to allow for circuit board layout and antenna designs suitable for high-frequency (HF) applications. In the HF spectrum, some engineering thermoplastics render a viable alternative to conventional thermoset-based PCB substrate materials due to their intrinsically lower dielectric properties. In recent research, we discovered that a phase segregation effect, triggered by controlled annealing of the initially miscible blend of PEEK and PEI, can be exploited to create a desirable minimum in both the material's permittivity and dielectric loss factor. However, to employ this blend successfully as HF-PCB substrate material, its thermal expansion has to be reduced to fit to that of the copper layer forming the PCB conductive tracks and avoid delamination under thermal loads. In our investigations, various inorganic particle fillers were compounded in the PEEK/PEI melt matrix to assess their influence on relative permittivity and loss factor, measured at 10 GHz utilizing split post dielectric resonators. As filler presence affects the crystallization and annealing kinetics of the matrix blend system, PEEK/PEI blend ratio was adjusted to individual filler materials. In the oral presentation, we will present a promising compound of PEEK/PEI matrix blend with CTE-reducing fillers, successfully combining both the beneficial annealing effect on dielectric properties and a reduced substrate material CTE. This allows for the manufacturing of a demonstrator PCB, showcasing the capabilities of PEEK/PEI blends for HF applications.

Session 4.1: Polymer Blends and Alloys

Paper ID: S16-246

Correlation of Processing and Aging in Styrene-butadiene-styrene (SBS) Modified Bitumen

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Abstract

SBS is used to modify bitumen due to its excellent durability, resistance to permanent deformation, and enhanced flexibility. The conditions used to blend SBS with bitumen are critical in determining the morphology, thermal and rheological properties of these blends, particularly concerning ageing. The effects of varying shear rate and mixing time on SBS-modified bitumen were examined to assess their impact on ageing and material performance. Higher shear rates and prolonged mixing significantly increase bitumen oxidation, changing functional groups, signalling oxidative ageing. SBS modification enhanced thermal stability by altering the degradation mechanism increasing the onset temperature of thermal degradation. The specific heat capacity (Cp) and glass transition temperature (Tg) of the blends also increased with longer mixing times and higher shear rates, largely due to ageing [1]. Rheological analysis showed increased shear rates and extended mixing times resulted in higher complex shear modulus (G*) and phase angle (δ) values, correlating with improved rutting resistance and higher Performance Grade (PG) temperatures. This suggests greater resistance to deformation at elevated temperatures, improving long-term durability [2]. Examination of blend morphology revealed mixing significantly influenced SBS dispersion. Prolonged mixing and higher shear rates promoted blend homogeneity, although ageing led to phase separation, particularly the asphaltene component. The swelling behaviour of the SBS phase contributed to its stable dispersion within the bitumen, confirmed from optical, confocal laser scanning (CLSM) and atomic force (AFM) microscopy [3,4].

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Session 4.1: Polymer Composites
Paper ID: S17-434

Graphene and its derivatives as fillers for biodegradable polymer matrices: Ecofriendly and performance improvements

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Abstract

With its exceptional mechanical, thermal, and electrical properties, graphene has garnered considerable attention as a nanofiller in biodegradable polymer matrices, significantly enhancing their overall performance. Incorporating graphene into biodegradable polymers has shown remarkable improvements in mechanical strength, toughness, and thermal stability [1]. Graphene's high surface area and intrinsic strength contribute to superior stress transfer, while its thermal conductivity aids in stabilizing the material at elevated temperatures [2,3]. Research has demonstrated that graphene-reinforced biodegradable composites can offer performance comparable to conventional plastics, bridging the gap between sustainability and functionality. Here, graphene and its derivatives were used as fillers, and nanocellulose and natural fibers were added to biodegradable polymers such as PHBV, PBAT, and PLA. The main idea is to obtain materials with high mechanical and thermal performance without compromising biodegradability and toxicity. The formulations were prepared using a melt mixing strategy in a twin-screw extruder. The materials were characterized through Scanning Electron Microscopy (SEM), molecular weight, rheological analysis, differential scanning calorimetry (DSC), thermogravimetric analysis (TGA), mechanical properties, biodegradability, and toxicity. The results demonstrated increased thermal stability and enhancements in mechanical performance by incorporating minimal filler content, specifically less than 0.1% in the case of graphene. The nanocomposites containing graphene, nanocellulose, natural fibers, or even hybrid fillers did not exhibit any significant adverse effects on the biodegradability or toxicity of the PB matrices utilized in this study.

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Session 4.1: Polymer Composites

Paper ID: S37-423

Counterintuitive effect of the degree of cure of some epoxy resins on the compressive strength of continuous fibre composites

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Abstract

In most composite engineering circles, it is widely accepted that the full curing of epoxy resins is essential to achieve the highest mechanical properties. Yet, it has been documented that, in the case of certain epoxy resins, the full curing process does not necessarily result in the highest tensile stiffness values. This study seeks to determine whether this phenomenon can be extended to certain properties of some epoxy fibre composites. Among the mechanical properties of composites that are closely related to those of the matrix, axial compressive strength is selected for investigation. In accordance with the prevailing hypothesis regarding fibre micro-buckling constrained by the shear stiffness of the composite ply, a reduction in elastic stiffness should result in a corresponding decline in the non-linear shear behaviour of the composite ply, ultimately leading to a decrease in the axial compressive strength of a composite structure. Accordingly, an epoxy resin, renowned for these specific characteristics, is selected and subjected to mechanical testing at different scales: the resin itself, a composite ply, and a composite part. Three polymerisation cycles, recommended by the epoxy resin manufacturer, are selected to obtain markedly disparate elastic tensile moduli. The use of the same type of polymerisation cycle for the three types of material enables the degree of conversion of the epoxy resin to be measured. By verifying that other variables remain constant (fibre volume fraction or level of initial fibre misalignment) for each type of cure, we demonstrate at all three scales that specific mechanical properties (tensile stiffness for the pure resin, shear stiffness for the composite ply and compression fracture strain for the composite part) exhibit a consistent decline, following the same pattern, from the lowest degree of conversion studied up to complete polymerisation of 30%. The results of these studies will be presented during the conference.

Keynote

Session 4.1: Polymer Composites

Paper ID: S36-412

Innovations on Advanced Biocarbons and their Sustainable Composites: Materials to Real-World Applications

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Abstract

Lightweight green composites from renewable resources are attracting increased attention from advanced manufacturing sectors. A strong momentum for weight reduction in auto parts without compromising strength and durability is motivated by a need for a better fuel economy, particularly in electric vehicles. To increase renewable content in materials, we have used thermo-chemical conversion (pyrolysis) of biomass/agri-food/forestry resources and waste feedstock to overcome the key challenges associated with the use of traditional natural fibres in melt processed biocomposites. Biocarbons have high thermal stability, which broadens their use as a reinforcing filler in a range of plastics - from traditional thermoplastics like polypropylene, polylactic acid (PLA), to engineering thermoplastics such as polyamide and polyphthalamide (PPA). In addition, biocarbons have been also used effectively in composites with waste plastics. Overall, biocarbon composites can be very effective as one of the enabling strategies towards sustainable materials in advance manufacturing and a circular bioeconomy. Acknowledgement: (i) The Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), Canada – University of Guelph, the Bioeconomy Industrial Uses Research Program Theme; (ii) the Ontario Research Fund, Research Excellence Program; Round-11 (ORF-RE 11) from the Ontario Ministry of Colleges and Universities, Canada and (iii) the Natural Sciences and Engineering Research Council of Canada (NSERC), Canada.

Session 4.1: Polymer Composites

Paper ID: S17-410

Role of biological routes in surface modification of natural fiber and biopolymer extraction

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Abstract

Sustainable and environmental friendly approach in the polymer field is of growing interest. Enzymes and fungal routes are used in surface treatment of fibres and in extraction of value added products from biomass. This work discusses the enzymatic treatment of fibres such as coir and jute and their effect on surface morphology and interfacial adhesion modification in polymer composites. The biological route of enzymes and fungus is also used in extraction of nanomaterials from biomass. This mehtod is also explored and it has been found that enzymes are more economical in the extraction of nanomaterials from biomass.

Abstracts – Posters

Poster: Additive manufacturing

Paper ID: S01-452

Nanocomposite Additive Manufacturing using Fused Deposition Modelling

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Abstract

Fused deposition modeling (FDM) is an increasingly common form of additive manufacturing technique that allows for the production of thermoplastic parts. As a result of its adaptability as well as simplicity of use, it has gained considerable traction in the industrial sector. Nanoparticles, short fibers, and continuous fibers are just some of the additives that are impregnated into the commonly used thermoplastics (like PLA and ABS). Nanofillers can be added to a variety of polymeric matrices to create a superior filament with enhanced mechanical and electrical characteristics. In this work, we'll compare and contrast the various approaches employed for the fabrication of FDM nanocomposite filament. Additionally, electrical properties, microstructural defects, and failure modes displayed by the nanocomposite FDM components will be examined, as will the mechanical properties such as tensile, compression, flexural, and impact properties.

Poster: Additive manufacturing

Paper ID: S22-421

Advancements of 3D Printing by Utilizing Machine Learning and Bayesian Optimization for Ocean-Recycled Polymer Composites

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Abstract

As the demand for sustainable materials grows in the automotive industry, this study explores the mechanical performance of a sustainable composite made from ocean-recycled high-density polyethylene (rHDPE) and polypropylene (rPP), reinforced with burlap biocarbon from post-industrial waste. The aim was to upcycle ocean-recycled plastic and post-industrial waste while comparing conventional injection molding with 3D printing techniques. Printing parameters, including printing speed, nozzle temperature, and raster angle, were optimized to achieve superior mechanical properties. Bayesian optimization (BO) techniques were proposed to enhance the 3D printing process of sustainable composites for automotive applications.

Poster: Additive manufacturing

Paper ID: S21-392

Influence of remote plasma jet treatment during 3D printing on the properties of PLA

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Abstract

Additive Manufacturing (AM) is increasingly recognized for its ability to produce customized materials with optimized properties for biomedical applications. Atmospheric plasma treatment is known to alter surface properties such as wettability and cell adhesion. In this study, we aim to evaluate how varying the excitation frequency of a remote plasma jet affects the in situ surface modification of PLA parts obtained by additive manufacturing. For the experiments, test specimens (TS) measuring 60 x 10 mm with a thickness of 1.5 mm were obtained using PLA filament and a hybrid 3D printing system equipped with a remote plasma jet. The plasma was generated through a high-voltage Inergiae Alternis power supply. The TS were exposed to an argon plasma generated at a nominal peak voltage of 18 kV, with the frequency varying every 2 kHz, between 8 kHz and 20 kHz. The surface wettability was evaluated by measuring the contact angle with water; the PLA degradation was analyzed by FTIR and thermogravimetric analysis, and mechanical properties were also evaluated. The analysis of the contact angles of the TS showed that the variation of the excitation frequency directly impacts the PLA surface. Without treatment, it presented the highest contact angle (78.1°), indicating the lowest hydrophilicity. The contact angle was significantly reduced with the treatment, especially between 10 kHz and 16 kHz, with 12 kHz presenting the lowest value (53.2°). From 16 kHz onwards, the contact angle increases, suggesting that higher frequencies may decrease plasma efficiency. The analysis revealed no notable differences in the material's mechanical properties, and no evidence of thermal degradation was observed under the conditions examined.

Poster: Additive manufacturing

Paper ID: S21-300

Enhancing Electrical Conductivity in 3D Printing: Effects of Design and Measurement Methods in New Recycled Polymeric Composites

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Abstract

This study investigates the influence of design parameters in 3D printed pieces—specifically shape, infill density, and printing orientation—on the electrical conductivity of components fabricated from recycled polymeric materials derived from electronic waste and enhanced with carbon nanotubes. The primary objective is to establish a correlation between these design variables and the conductive properties of the resulting printed objects. The research utilizes a systematic approach to create various geometrical configurations and infill patterns, allowing for a comprehensive analysis of how these factors affect conductivity. The materials used in the 3D printing process are a blend of recycled polymers, which present an eco-friendly alternative to traditional materials, and carbon nanotubes, known for their exceptional electrical properties. Conductivity measurements are performed using different methods to ensure accuracy and reliability in data collection. The results are compared across varying designs to assess the consistency and reproducibility of conductive properties. Preliminary findings indicate that specific design choices significantly impact conductivity. For instance, higher infill densities tend to enhance conductivity, while certain geometrical shapes exhibit superior performance due to more efficient carbon nanotube distribution. This research highlights the potential of tailored 3D printed components in various applications, including electronics and sensors, demonstrating that the design of the printed piece plays a crucial role in maximizing functional properties. Ultimately, this study not only contributes to the understanding of the interplay between design, material composition, and measurement techniques but also promotes the sustainable use of recycled materials in advanced manufacturing processes, paving the way for innovative applications in the field of conductive materials.

Poster: Additive manufacturing

Paper ID: S21-251

Analysis of thermal distribution in a FFF hotend using passive thermography

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Abstract

This study investigates the thermal behavior of a Fused Filament Fabrication (FFF) hotend using passive thermography, aiming to analyze the temperature profile within the extruder unit to improve part quality and process efficiency. The experimental setup utilized an Optris PI 450i infrared camera, capable of detecting temperatures in the range of -20 °C to 900 °C with a thermal sensitivity of 40 mK. The camera operated at 27 Hz with a resolution of 382 x 288 pixels and a spectral range of 8 to 14 µm. The hotend provided by NEVO3D GmbH featured a hybrid heatbreak system, combining a brass-threaded component with a stainless-steel tube, and was equipped with a fan for enhanced cooling. A custom test rig was designed to monitor both stationary and dynamic in-process temperature profiles under varying extruder settings. Key experiments included varying the extrusion speed and analyzing different nozzle materials (stainless steel vs. brass). Thermographic measurements were synchronized with thermocouple data from the extruder block and environmental sensors. Reproducibility was assessed by conducting three identical trials with elevated temperature settings, initially set to 285 °C and maintained for 12 minutes in a stationary phase. The use of heatbreak cooling demonstrated a reduction in temperature levels in the relevant zones by approximately 23 °C, preventing premature plasticization and ensuring a controlled transition through the glass transition region of the polymer. The findings indicate that adjustments in the extruder's design, such as the position of the heating element, can enhance thermal management. These modifications may yield a more stable extrusion process, improving both the mechanical properties and consistency of the printed parts. The results offer insights into thermal optimization for industrial FFF applications, with potential for further process control advancements using infrared-based monitoring technologies.

Poster: Additive manufacturing

Paper ID: S01-164

FDM of Isotactic Polypropylene/Graphene Nanoplateles Composites:Achieving Enhanced Thermal Conductivity through Filler Orientation

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Abstract

High-performance thermally conductive composites are increasingly vital due to the accelerated advancements in communication and electronics, driving the demand for efficient thermal management in electronic packaging, light-emitting diodes and energy storage applications. Controlling the orderly arrangement of fillers within a polymer matrix is acknowledged as an essential strategy for developing thermal conductive composites. In this study, isotactic polypropylene/GNP(iPP/GNP) composite filament tailored for fused deposition modeling (FDM) was achieved by combining ball milling with melt extrusion processing. The rheological properties of the composites were thoroughly studied. The shear field and pressure field distributions during the FDM extrusion process were simulated and examined using Polyflow, focusing on the influence of the 3D printing processing flow field on the orientation of GNP within the iPP matrix. Exploiting the unique capabilities of FDM and through strategic printing path design, thermally conductive composites with GNPs oriented in the through-plane direction were 3D printed. At a GNP content of 5 wt%, the as-printed sample demonstrated a thermal conductivity of 0.64 W/mK, which was 1.5 times the in.plane thermal conductivity for 0.42 W/mK and triple pure iPP for 0.22 W/mK. Effective medium theory (EMT) model fitting results indicated a significantly reduced interface thermal resistance in the through-plane direction compared to the in-plane direction. This work shed brilliant light on developing PP-based thermal conductive composites with arbitrarily-customized structures.

Poster: Additive manufacturing

Paper ID: S01-160

Shape recovery characteristics of additive manufactured specimens according to tool path in ME-type 3D printing

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Abstract

A shape memory polymer (SMP) specimen returns to its original shape when an external stimulus is applied after its shape is deformed. The shape recovery characteristics of SMP specimens manufactured by 3D printing were analyzed. ME-type 3D printing specimens have different physical properties depending on the tool path. Therefore, 3D-printed specimens using SMP also have different recovery abilities depending on the printing method. In this study, specimens were manufactured with ME-type 3D printing using SMP to examine shape recovery characteristics. The specimen is rectangular (25mm□80mm) and has a thickness of 1.5mm. The specimen was manufactured with six different tool paths (concentric, +45o/-45o, 90o/90o, 45o/45o, 0o/90o). The manufactured specimen was heated above Tg, bent at a right angle, and cooled to room temperature. Then, the specimen was heated again above the Tg of the material and the phenomenon of the specimen returning to its original shape, a flat plate, was analyzed. Bending and recovery were repeated five times to measure the recovery ability, which varies as the cycle is repeated. Recovery ability was evaluated by recovery time and recovery speed. Recovery ability varied depending on the tool path, and recovery speed was fastest in the concentric tool path. For all tool paths, recovery ability decreased linearly as the number of repetition cycles increased.

Poster: Additive manufacturing

Paper ID: S22-67

Direct-ink-write 3D printing of “living” polymer hydrogels via type I photoinitiated RAFT polymerisation

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Abstract

Light-responsive 3D printing is a popular method of additive manufacturing. In this technique, light is used to cure liquid precursor resins in a layer-by-layer fashion via radical photopolymerisation. Recently, type I photoinitiated reversible addition-fragmentation chain transfer (RAFT) polymerisation has been used in light-responsive 3D printing. Objects prepared via this mechanism demonstrate a “living” character, whereby the RAFT polymerisation process can be restarted in the post-printing stage to insert new monomers into the polymer chains, allowing the physical properties of the object to be modified. So far, “living” 3D printing has been demonstrated with vat-based 3D printers. While these printers offer good resolution, they are generally unable to perform multimaterial printing operations, which is crucial for creating more intricate and useful objects. On the other hand, direct-ink-write (DIW) 3D printers are specifically designed for multimaterial printing. In this work, “living” hydrogel photoinks based on the type I photoinitiated RAFT polymerisation mechanism were formulated for use in a DIW 3D printer. “Living” hydrogel cubes were 3D printed from these photoinks which could undergo post-production network modification through the insertion of new monomers into the polymer matrix. The multiple extruders of the DIW 3D printer were also exploited to 3D print multimaterial hydrogel objects. The “living” material sections swelled more extensively, leading to a swell-induced bending effect in the macroscopic multimaterial object.

Poster: Biomedical applications

Paper ID: S02-285

Enhanced Chitosan-Based Hemostatic Agents with Antimicrobial and Controlled Anticoagulant Properties for Trauma Care Applications

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Abstract

Despite significant advances in medicine and the technological development of protective equipment, lethal hemorrhage caused by trauma remains a critical challenge in both general and military medicine. Natural polymeric materials, particularly chitosan (CS), have become a focal point in developing hemostatic products due to their affordability and versatile properties. Chitosan-based products, such as HemCon, Chitoflex, Chitosea, and Hemostatic Granules, are commercially available hemostatic agents offering rapid hemostasis. However, these products are limited by the large amounts needed for effectiveness, high costs, and insufficient hemostatic action, sometimes leading to fatal outcomes. Furthermore, their lack of antimicrobial properties can increase the risk of wound infections. To address these limitations, chitosan was chemically modified with 2-Acrylamido-2-Methylpropane Sulfonic Acid (AMPS) to enhance its hydrophilicity, swelling capacity, and antibacterial properties, expanding its potential for use in drug delivery applications. Additionally, heparin, a well-known anticoagulant, was encapsulated in poly(butylene succinate) (PBSu) nanoparticles to prevent excessive clotting in unintended areas after application. Enhanced efficacy in hemostasis was also achieved with additives such as vitamin K, protamine sulfate, and iron sulfate to accelerate thrombosis. The resultant hemostatic product was characterized using FT-IR and XRD, confirming successful synthesis and reduced crystallinity compared to CS alone. Swelling studies demonstrated a high swelling capacity, up to 4000%, supporting the product's suitability for trauma care by providing rapid and effective hemostasis with integrated antimicrobial activity.

Poster: Biomedical applications

Paper ID: S02-232

BioIMplant: Enhancing Biopolymer/Bioglass Composite Performance through Surface Modification for Bioabsorbable Implants

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Abstract

Bioactive glasses are commonly incorporated into biopolymers to enhance the performance of bioabsorbable implantable fixation devices by improving bioactivity, osteoconductivity, cellular responses, and mechanical properties. However, achieving uniform dispersion of bioglass particles within biopolymers presents significant challenges, often resulting in inhomogeneities that can negatively impact mechanical strength and degradation behaviour. These dispersion challenges also increase manufacturing complexity and costs due to the need for specialized techniques to ensure consistent material properties. To address these issues, surface modification of bioglass with silane coupling agents is typically employed to improve the interaction between bioglass and the polymer matrix, leading to better dispersion and reduced agglomeration. As part of the M-ERA.NET project BioIMplant, this work further explores surface modification of bioglass by introducing bifunctional compatibilisers and healing aid to develop process-specific biopolymer/bioglass composites. This work is co-financed with tax revenue on the basis of the budget adopted by the Saxon State Parliament and M-ERA.NET.

Poster: Biomedical applications

Paper ID: S23-97

Improving Injection Moldability of medical grade UHMWPE by Blending with Short-Chain Maleated Polyethylene via Melt Compounding While Preserving Clinical Mechanical Properties for orthopaedic application

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Abstract

The global orthopedic implant market is projected to reach USD 68.51 billion by 2027, driven by an aging demographic and increasing trauma cases. A critical challenge in this sector is that approximately 80% of these implants are imported and tailored for Western anatomies, complicating accessibility for economically disadvantaged patients in India. This research focuses on developing indigenous, cost-effective orthopedic implants, utilizing injection-molded medical-grade ultra-high molecular weight polyethylene (UHMWPE) to enhance moldability and performance. The selection of injection molding as a processing technique is motivated by its capacity to fabricate complex geometries with high dimensional accuracy while minimizing material waste, representing a novel application of this method for acetabular liners in the orthopedic domain. Traditional fabrication methods such as extrusion and machining are associated with elevated costs, significant material loss and time consuming. To augment the viscoelastic properties and flow characteristics of UHMWPE, we introduce an innovative polymer blend formulated with short-chain maleated polyethylene via melt compounding. Comprehensive characterization techniques, including FTIR, XRD, SEM, DSC, TGA, and mechanical testing of injection molded samples, demonstrated substantial enhancements in melt viscosity, with optimized injection molding parameters yielding tensile strengths exceeding 35 MPa. Overall, this research demonstrates improved injection moldability of UHMWPE by blending with maleated polyethylene via melt compounding while preserving clinical mechanical properties and successfully produced an injection molded acetabular liner components with no internal defect (3D micro CT) and dimensional accuracy for total hip arthroplasty applications that help to minimizing production waste.

Poster: Biopolymers

Paper ID: S25-414

Biodegradable Composites from Poly(Hydroxybutyrate-Co-3-Hydroxyvalerate) and Cellulosic Fiber: Effect of Compatibilizer on Material Performance

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Abstract

Biocomposites for rigid packaging application was developed using poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV) and cellulose fiber at high filler content up to 25wt.%. Tributyl citrate, a plasticizer, was used to help in processing of such highly filled systems. Biocomposites were compatibilized with maleic anhydride-grafted-PHBV (MA-g-PHBV) to enhance fiber-matrix interaction, and the effect of varying grafting-percentages on biocomposite performance was analysed. With 25 wt.% filler, the tensile strength, modulus, and elongation-at-break were higher by a maximum of 44%, 23%, and 18% after the addition of compatibilizer, compared to the un-compatibilized counterpart. MA-g-PHBV with the highest grafting percentage was found to be the most effective.

Poster: Biopolymers

Paper ID: S24-314

Finding the processing window for additive-free irradiation crosslinking of stereo complex Poly-(Lactide Acid)

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Abstract

Recent studies show that irradiation crosslinking of various biopolyesters, such as PLA and P3HB, can be achieved without the utilization of crosslink promoters via electron beam irradiation high temperatures. E.g. for PLA, two distinct irradiation windows allow crosslink formation: one between the glass transition and cold crystallization temperature in amorphous homo PLA, and another above the melting temeprature. Both irradiation windows share the absence of a crystalline phase, which reduces chain and radical mobility. However, additive-free irradiation crosslinking of stereocomplex PLA (scPLA) has not yet been achieved the authors knowledge. This is attributed to the unique properties of scPLA: The existence of physical crosslinks with stereocomplex crystals as network points and the high melting point of the stereocomplex phase. The physical network restricts chain and radical mobility above glass transition and the early onset of the cold crystallization after the glass transition up to the melting point of the stereocompley phase chain and radical mobility decrease even further. Additionally, the enantiomerism of PLLA and PDLA in the melt increased interaction forces between polymer chains and the early onset of thermal degradation when increasing the melt temperature contribute to this challenge. By systematically adjusting the irradiation parameters and optimizing sample handling, we can now report on the successful irradiation crosslinking of scPLA without the use of crosslink promoters. As with other biopolyesters, we are now able to balance thermal and thermo-oxidative degradation with radical and chain mobility. We demonstrate sample and process handling techniques used and show how irradiation crosslinking affects the molecular properties of scPLA, as analyzed by GPC and rheology, as well as its thermal properties, assessed by DSC and TGA. These findings are then correlated with the crystallization characteristics observed in hot-stage experiments.

Poster: Biopolymers

Paper ID: S03-104

Influence of fibre characteristics on PHA-based biocomposites properties

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Abstract

The addition of fibres from biomass in PHA-based biocomposites offers several advantages, including reducing raw material cost and environmental impact, enhancing biodegradation, and providing a natural appeal to the final products, which all contribute to a circular economy. However, incorporating fibres increase brittleness of the biocomposite, diminishing its market uptake. To address this challenge and improve our biocomposites properties, we focused on identifying key fibre characteristics, such as shape, dimension, and composition, which influence overall properties. Queensland fibres derived from over ten different organic waste agricultural sources were investigated. In addition to mechanical properties, the evolution of thermal and rheological properties was also examined. This study was conducted collaboratively with the Materials & Energy Research and Innovation Centre of Southern Brittany University (UBS) and the National Research Institute for Agriculture, Food and the Environment (INRAe) in France. They conducted accurate fibre biochemical composition and shape analyses which were essential to understanding their impact. Through this data, we developed a reproducible methodology to assess fibre composition (extractives, hemicellulose, cellulose, lignin ratios) using common laboratory tools as TGA, NMR, and FTIR. The results from this study can be used to predict and effectively select the most suitable fibres for developing PHA-based biocomposites, which is crucial given the diversity of available biomass. This research is part of a broader holistic approach to enhance the toughness of PHA-based biocomposites, including investigating PHA chemical structure, thermal degradation, fibre dispersion and distribution and crystalline microstructure. The aim is to establish a comprehensive platform to support long term development of advanced biocomposites.

Poster: Circular Economy for Plastics and Recycling

Paper ID: S28-425

Rotational molding of recycled HDPE with organoleptic and insect repellency agents

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Abstract

In this research the properties of post-consumer recycled (PCR) materials with aromatic additives are evaluated to deliver active insect repellency and fragrance in products made by rotomolding. This technique is known for manufacturing hollow parts through a slow process at high temperatures. Therefore, it is important to evaluate the properties of both the polymeric matrix and additives, as they must remain stable under such conditions. PCR-HDPE was supplied by SIRPLASTE company (Portugal) in powder form. The additives were different aromatic oils and powders. The study focused on the effect of the additives on PCR-HDPE, on its processing characteristics and also on the morphological and mechanical properties of the parts. A mixture of 3wt% of additive was used. Pristine and compounded materials were characterized by granulometry, dry flow, apparent density, MFI, DSC, TGA, and FTIR. The MFI results indicated a plasticizing effect of the oil. Furthermore, its addition reduced the apparent density and hindered the dry flow; that was attributed to the polymer's humidification. Despite of that the direct introduction of oil improved the surface finish of the part, reducing the occurrence of surface pinholes. The additives in powder, such as cinnamon, caused the appearance of pinholes and voids on the part. The citronella and cinnamon fragrances are well present on the parts after processing. Field studies using rotational molded small containers filled with organic products demonstrated insect's repellency for couple of days, using PCR HDPE and citronella. After that boxes should be cleaned and washed to recover its functionality. Other properties, such as mechanical and morphological, are still under study.

Poster: Circular Economy for Plastics and Recycling

Paper ID: S27-417

Technoeconomic Evaluation of Integrated Systems for Ammonia Synthesis via Plastic Gasification and Partial Oxidation

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Abstract

Plastic waste has emerged as a critical environmental challenge, with increasing production and disposal rates leading to significant accumulation in landfills and natural ecosystems. Since most plastics are non-biodegradable, their environmental impact is substantial, posing serious ecological risks. Simultaneously, the demand for energy continues to rise, driven by population growth and economic development, with annual increases surpassing 2%. This growing energy need contributes to the acceleration of climate change due to rising greenhouse gas emissions. Therefore, there is an urgent need to address both the plastic waste dilemma and the demand for clean energy. Ammonia presents a promising solution as a carbon-free fuel and hydrogen carrier, playing a vital role in renewable energy storage and distribution within a low-carbon economy. However, traditional ammonia production methods, primarily based on natural gas reforming, are carbon-intensive. This study introduces an innovative integrated process that uses plastic waste gasification, combined with partial oxidation, to generate clean hydrogen and produce ammonia. This approach offers a circular economy solution by converting plastic waste into valuable chemical products while ensuring carbon neutrality.Using Aspen Plus process simulation software, three integrated plastic gasification and hydrogen production systems were modeled. The results revealed that the configuration combining plastic waste gasification with natural gas partial oxidation achieves the highest cold gas efficiency (49%) and an overall process efficiency of 45.5%, outperforming the other designs. The updated design also demonstrates the lowest levelized ammonia production cost at $0.310 per kilogram and is the only configuration deemed economically viable through cash flow analysis. The proposed integrated plastic-to-ammonia process presents a compelling strategy for tackling the escalating issues of plastic pollution. By enabling chemical upcycling, this approach offers a sustainable pathway for managing waste while supporting the shift toward carbon circular economy.

Poster: Circular Economy for Plastics and Recycling

Paper ID: S04-401

Design and simulation of plastic waste conversion to light olefins

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Abstract

The increasing accumulation of plastic waste presents a critical environmental challenge, necessitating the development of efficient recycling technologies to mitigate both economic and ecological impacts. One promising approach is the chemical recycling of plastic waste into valuable light olefins, such as ethylene and propylene. This study evaluates two thermal recycling pathways: (1) pyrolysis followed by steam cracking and (2) gasification followed by the methanol-to-olefin (MTO) process. In the first pathway, mixed plastic waste undergoes pyrolysis, yielding pyrolysis oil and gas. These products are subsequently processed through steam cracking, a high-temperature decomposition method that generates light olefins alongside byproducts such as methane, hydrogen, and aromatics. The second pathway involves gasifying plastic waste to produce synthesis gas (syngas), primarily composed of hydrogen and carbon monoxide. The syngas is then converted into methanol, which serves as a feedstock for the MTO process to produce light olefins. Both pathways offer distinct advantages. The pyrolysis-steam cracking route leverages existing steam cracking infrastructure, while the gasification-MTO route provides greater flexibility by producing intermediate products, such as methanol, which can be used in various chemical processes. This study uses Aspen Plus software to simulate both conversion processes, optimizing key parameters such as temperature, pressure, and feedstock composition to maximize olefin yields. A comprehensive techno-economic and environmental assessment is conducted, evaluating energy efficiency, CO_2 emissions, and operational costs. Preliminary findings indicate that the gasification-MTO pathway offers lower production costs due to higher carbon efficiency and more favorable operational economics. This work contributes to advancing circular economy strategies by proposing scalable and sustainable solutions for plastic waste recycling.

Poster: Circular Economy for Plastics and Recycling

Paper ID: S27-323

Using Plasma to Enhance the Recyclability of Polyethylene/Polypropylene Blends

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Abstract

Recycling polymer blends containing polyethylene (PE) and polypropylene (PP) presents significant challenges due to the inherent immiscibility of these polymers, which often results in poor mechanical properties[1, 2]. Therefore, controlling the structural morphology to enhance the properties of the blends is critical in recycling[3]. This study investigates the efficacy of plasma-treated polypropylene (PT-PP) as a compatibilizer to enhance the miscibility and performance of PE/PP blends. We systematically examine the effects of plasma compatibilization, using both directly plasma-treated blends (PTB) and PT-PP as a compatibilizer, across varying blend ratios. Mechanical and rheological properties of PE/PP blends containing PTB and PT-PP were evaluated and compared to those of untreated blends (control - NT). Results show that PT-PP significantly improves tensile strength and modulus of elasticity, demonstrating plasma treatment's efficacy in modifying interfacial properties. Scanning electron microscopy (SEM) images further confirm improved dispersion and minimal phase separation, indicating enhanced morphological stability. This study provides a cost-effective, sustainable pathway for upgrading recycled polyolefin blends by addressing immiscibility, ultimately transforming complex thermoplastic waste into high-performance recycled materials with superior mechanical properties and processability.

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Poster: Circular Economy for Plastics and Recycling

Paper ID: S26-156

Revisiting the state-of-the-art of PET mechanical recycling: from ideal to contaminated waste streams

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Abstract

Polyesters are widely used in bottles, fibers, and engineering materials, and they are recyclable. Polyethylene terephthalate (PET) waste streams, in particular, hold significant societal and economic value with key end-markets in rPET trays and food-contact bottles [1], [2]. However, PET recyclability is strongly influenced by its chemical composition, including specific (co)monomers and Non-Intentionally Added Substances (NIAS) like water, acids, and foreign polymers. Mechanical recycling may lead to various and complex degradation reactions, influenced by not only the type of contaminant, but also by specific processing conditions such as temperature, shear, residence time and oxygen concentrations . This study therefore provides in a first apart [1] a comprehensive analysis of these degradation reactions mechanisms, including thermal, thermo-mechanical, thermo-oxidative, photo-oxidative, hydrolytic, and enzymatic reactions. It emphasizes how molecular changes, observed even under (low TRL) ideal recycling conditions, influence the rheological, thermal, and mechanical properties of PET, which are key to optimizing (high TRL) industrial recycling processes for polyesters in second part [2]. This second part highlights how insights from both polymer reaction engineering (PRE) for critical processing units (e.g. extrusion and solid-state modification) and life cycle analysis (LCA) at the process level (e.g. energy calculations) can be utilized to deliver science driven guidelines and boundaries for the selection of a certain mechanical recycling technology, acknowledging low and high TRL influencing factors [2]. This integrated framework therefore acknowledges the most essential reactions at the molecular scale as well as the most important units at the process scale to bridge the gap between those lower and higher TRL tasks, taking into account the current standards and regulations to introduce a long-term circularity for PET [1], [2].

[1] Fiorillo et al. RSC Sustain. 2024, Advance Article doi.org/10.1039/D4SU00485J

[2] Bezeraj et al., RSC Sustain. 2024 provisionally accepted

Poster: Circular Economy for Plastics and Recycling

Paper ID: S26-189

Towards Sustainability in the Cosmetic Packaging Industry

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Abstract

Sustainability has proven to be challenging in the cosmetic packaging sector. Several solutions, such as using renewable resources like bio-PE and bio-PP, as well as recycled or reusable packaging, have been tested. Biopolymers from sustainable sources, like PLA and TPS, have been identified as good alternatives to conventional plastics, but they still face challenges in the cosmetic industry. The effects of prolonged exposure between biopolymers and cosmetic creams are not yet well understood. Due to the high water content of cosmetic creams, this exposure could accelerate the degradation (hydrolysis) of the matrix and cause the migration of potentially hazardous components into the product. These factors could affect the shelf life, original characteristics, and safety of the product. Additionally, enhancing the interaction between the product and the customer is important for promoting a more engaging user experience. Therefore, this project aims to develop a fully functional biodegradable cosmetic package that can communicate with customers by releasing fragrance and incorporating sensorial elements such as texture and color. This will enable the transmission of sensations and messages. To achieve these objectives, various bio-compositions were developed using local natural waste and fragrances, employing encapsulation methods. These compositions were tested and validated to ensure they meet the quality and safety standards of the cosmetic industry.

Poster: Circular Economy for Plastics and Recycling

Paper ID: S04-101

Temperature controllable wood-plastic composite plate with excellent comprehensive properties

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Abstract

Wood-plastic composite (WPC) is generally fabricated by recycled plastics and waste/leftover wood materials, which possesses the advantages of both plastic and wood materials and has been widely used to replace solid wood both outdoors (floor and railing of park and garden) and indoors (floor, wallboard, furniture, etc) . However, there will be high surface temperature (more than 55°C) in summer for outdoor applied WPC plates, which seriously affects the thermal comfort when the human body keeps in touch with it. Herein, we propose a triple thermal management strategy to solve the above problem of WPC plates by combining heat conduction, high solar reflection and radiation cooling to quickly dissipate heat while blocking solar absorption, and fabricate a tri-layer WPC plate with excellent comprehensive properties. The embedded titanium dioxide (TiO2) nanoparticles not only significantly improve the solar reflectance (53.8 %) and mid-infrared emissivity (89.2 %) of the coloured top layer, but also endow the surface with good hydrophobicity and abrasion resistance. By incorporating hexagonal boron nitride (h-BN) and short-cut glass fibres (GF) into the core layer of the WPC to enhance the thermal conductivity (0.9~1W/(m·K)) and impact strength (8.7KJ/m2), the heat accumulation of the surface and the overall mechanical strength are improved. For the bottom layer, addition of h-BN increases its thermal conduction and improves downward thermal transfer from the surface besides the water-proof function. Notably, the outdoor tests show that the tri-layer WPC plate can keep around 45°C, about 10 °C lower than the ordinary WPC plate under direct sunlight. This strategy of combining PDRC and enhanced thermal conduction offers promising avenues for developing advanced thermal management WPC plates and widening WPC's application fields.

Poster: Circular Economy for Plastics and Recycling

Paper ID: S28-62

Transforming Waste into Resources: Recycling Polypropylene Using Depolymerized PET

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Abstract

Global plastics pollution has a triad impact on the environment, energy, and climate. Numerous innovative closed- and open-loop plastics recycling or upcycling methods have been created or suggested, addressing a range of concerns related to the realization of a circular economy. In the pursuit of sustainable polymeric materials, this study explores the use of depolymerized polyethylene terephthalate (PET) waste as a dynamic crosslinker to enhance the properties of functionalized post-consumer recycled polypropylene (PCR PP). Using glycolysis process, waste PET was utilized to produce BHET (bis(2-hydroxyethyl) terephthalate), which was subsequently employed to introduce dynamic covalent bonding in maleated PCR PP through transesterification reactions with the maleic anhydride groups following industrially viable melt extrusion approach. The resulting crosslinked PCR PP, exhibits vitrimer-like properties, allowing for reprocess ability, high dimensional stability and enhanced mechanical and rheological performance. Characterization of the crosslinked polymer network confirmed the formation of reversible ester linkages, contributing to improved material durability and recyclability without any significant phase separation. This approach not only adds value to PET waste by converting it into a functional additive but also enhances the properties of polyolefins, offering a sustainable and circular solution for advanced polymer applications. This study demonstrates the potential of using depolymerized polymers as dynamic crosslinkers to create high-performance, reprocessable materials, promoting both environmental and economic benefits. Keywords: Upcycling, Depolymerized PET, Dynamic crosslinking, Vitrimer, Circular economy.

Poster: Circular Economy for Plastics and Recycling

Paper ID: S28-44

WPC from Uruguayan industrial waste – New Advances in the project

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Abstract

Since the publication of the forestry law in Uruguay in 1988, the wood industry has been advancing and therefore the waste it generates. Last year, at the International Conference of the Polymer Processing Society, PPS 39, we presented the start of a project to mix sawmill waste and plastic in what we technically call WPC, (Wood plastic compound). In this work, we intend to show the progress of the project, comparing the results of the mixtures of pine and eucalyptus wood flours with two polyolefins (polyethylene and polypropylene), starting from a 2 to 4 factorial experimental model, handling as variables, particle size, polymer-wood ratio, percentage of processing aids and the rpm of the twin-screw extruder used to obtain the pellets, at two levels (high and low). To improve the mixing conditions, propylene glycol or polyethylene glycol was used, depending on the case. As a response variable, the mechanical properties, resistance to breakage, hardness, and water absorption were used, all measured under ASTM standards. For the characterization of the materials, the FTIR technique was used, and their dispersion in the mixtures was verified through microscope. From the results obtained, it is concluded that the mechanical properties of the samples containing eucalyptus were superior to those made from pine. On the other hand, for both cases, after performing the ANOVA analysis, it is shown that the only significant variable is the percentage of wood, under test conditions. At this moment, we are analyzing the influence of the coupling agents on both woods, with the aim of improving the mechanical properties of the product obtained.

Poster: Degradation, biodegradation and composting

Paper ID: S05-370

Unraveling the UV-Responsive Leaching Profiles of Polyolefin Microplastics in Aquatic Environments

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Abstract

To grasp the complexity of microplastics (MPs), which are pervasive environmental contaminants, it is important to consider that over 13,000 chemicals are associated with plastics, including more than 3,200 classified as hazardous. Alongside intentionally added substances, numerous non-intentionally added substances (NIAS)—such as degradation products, processing aids, residual monomers, impurities in plastic additives, and transformation products—are present in varying amounts and often evade detection through standard instrumental analysis. Despite the environmental risks posed by these compounds, the behavior of plastic additives and oligomers in MPs is mostly unregulated and understudied, with only a few studies addressing degradation pathways in detail. The photoaging behavior of polyolefin MPs in aquatic environments is thoroughly examined utilizing liquid chromatography-high-resolution mass spectrometry (LC-HRMS). UV aging was simulated with a Suntest solar simulator to examine environmental degradation behavior. Data analysis involved both suspect screening using an in-house database and non-target analysis through a customized workflow. The data were processed for peak picking, retention time alignment, compound grouping, and filtering. Compound identification was facilitated by in-house and online spectral databases (mzCloud), which allowed for the provisional identification of numerous potential migrants, some of which were detected as NIAS. The results showed that variations in the release profiles of additives and leachates correlated with aging time. These findings offer new analytical approaches for investigating plastic leachates, thereby aiding environmental monitoring and future regulatory initiatives.

Acknowledgement The research work was supported by the Hellenic Foundation for Research and Innovation (HFRI) under the 3rd Call for HFRI PhD Fellowships (Fellowship Number: 6567).

Poster: Degradation, biodegradation and composting

Paper ID: S05-183

Preparing hydrogel/ZIF-8 composite materials and applying Fenton-like reactions for the degradation of Acid Orange 7(AO7)

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Abstract

The polyelectrolyte network, due to its capacity to dissociate in water, demonstrates high water absorption and functional groups that can carry either positive or negative charges. This distinctive property renders it widely applicable in both single-network and double-network hydrogel systems. Recently, various innovative mechanisms have been developed by harnessing the characteristics of polyelectrolyte networks, including double-network hydrogels, electrostatic interactions, chelation of metal ions with negatively charged functional groups, and nanocomposites. In this study, we synthesized a hydrogel composed of poly(acrylamide-co-[2-(acryloyloxy)ethyl]trimethylammonium chloride) (P(AAm-co-DAC)), which contains positively charged functional groups, aimed at the removal of anionic dye pollutants. Acid Orange 7 (AO7) was selected as the target dye. The metal-organic frameworks (MOFs) ZIF-8 was in situ grown within the P(AAm-co-DAC) hydrogel. This integration exploits the hydrogel's affinity for anionic groups and utilizes ZIF-8 as a photocatalyst to facilitate the degradation of the dye under various environmental conditions through a Fenton-like reaction. Comprehensive analyses were conducted to assess the dye removal efficiency and the hydrogel's removal capacity. Keywords : Double-network hydrogel, metal-organic frameworks, porous materials.

Poster: Extrusion

Paper ID: S06-450

Extruder design to improve bulk functionalization of polymer blends in an in-line plasma treatment process

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Abstract

For, recycling the compatibilization of polymer blends plays an important role. Amongst a variety of approaches, bulk functionalization utilizing an atmospheric pressure plasma treatment during extrusion seems promising due to low investment costs and no need for chemicals. Experiments have proved the capabilities of bulk functionalization using plasma but attempts to implement this approach into a continuous process have been challenging. Reported issues are the low efficiency of the plasma treatment as well as the short treatment time due to the integration into the extrusion process. To overcome these issues, some modifications to the extruder design are considered. Firstly, the screw design has been modified to maximize the residence time of the polymer melt in the plasma treatment zone. Secondly, modifications to improve entrapment of plasma from the atmospheric pressure plasma jet in the treatment zone have been investigated to increase the reaction capabilities of the active species. Experiments were conducted using a PE/PP blend. The samples were measured in regards of functional groups and mechanical properties.

Poster: Fibres and Films

Paper ID: S29-400

Study on Eco-friendly Poly(ethylene terephthalate) Security Fiber Utilizing Near-Infrared (NIR) Fluorescent Ceramic Particles in the Melt Spinning Process

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Abstract

Reducing global greenhouse gas (GHG) emission is recently becoming important by utilizing recycled materials in various industries. With the escalating demand for recycled materials, ensuring their traceability has become paramount. This study investigates the fabrication of recycled PET fiber infused with near-infrared (NIR) fluorescent particles to enhance its security features. The security fiber was crafted with varying concentrations of NIR particles (0, 0.5, 1.0, 1.5, and 2.0 wt%) and take-up speeds (1, 2, 3, and 4 km/min) via melt-spinning. Thermal and mechanical properties of the NIR/PET fiber were assessed using techniques like differential scanning calorimetry (DSC) and single fiber testing. The uniformity of the NIR/PET fiber was evaluated through FE-SEM cross-sectional diameter analysis. The obtained fibers were used to make two-ply and three-ply embroidery threads, and the sample embroidery was performed using each thread. Security features were characterized using photoluminescence (PL). Analyzed results confirm that the NIR/PET fiber demonstrates favorable spinnability, mechanical resilience, and security features, making it an effective medium for recycled PET identification.

Poster: Fibres and Films

Paper ID: S29-379

Superior Oxygen Barrier Properties and Stiffness in High-Density Polyethylene: Unveiling Novel In-situ Nanofibrillation Technique with Ethylene-Vinyl Alcohol Copolymer

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Abstract

This study introduces an innovative method to simultaneously improve the oxygen barrier performance and stiffness of High-Density Polyethylene (HDPE), while retaining its ductility. We achieved this by fabricating fiber-in-fiber composites through in-situ nanofibrillation, which incorporated ethylene-vinyl alcohol (EVOH) nanofibers into an HDPE matrix. Given the considerable interfacial tension between HDPE and EVOH, arising from their distinct chemical structures and polarities, styrene/ethylene-butylene/styrene copolymer grafted with maleic anhydride (SEBS-g-MA) was employed as a compatibilizer to enhance the compatibility between the two polymers. Scanning electron microscopy (SEM) images showed that the compatibilizer reduced the fiber size (from 147 ± 54 nm to 65 ± 27 nm for 6 wt.% compatibilized EVOH), which in turn improved the fiber aspect ratios. Furthermore, the presence of the compatibilizer resulted in better nanofiber dispersion throughout the HDPE matrix. By increasing the aspect ratio and optimizing the distribution of EVOH nanofibers, HDPE's oxygen permeability decreased by 61% after incorporating 10 wt.% compatibilized EVOH. Additionally, non-isothermal and isothermal crystallization analyses revealed that the EVOH nanofibers had a significant effect on HDPE crystallization, reducing both crystallinity and crystallization rate. This change in the crystalline structure was found to contribute to the improved oxygen barrier properties. The presence of EVOH nanofibers led to the formation of smaller, more uniformly distributed HDPE crystals, which proved beneficial for lowering oxygen permeability. Finally, mechanical testing indicated that the incorporation of EVOH nanofibers, regardless of the presence of a compatibilizer, enhanced the stiffness of HDPE. However, in the absence of a compatibilizer, a significant loss in elongation at break was observed. In contrast, using a compatibilizer improved stiffness while maintaining the ductility of HDPE.

Poster: Fibres and Films

Paper ID: S29-316

On-line Diameter Measuremet of PET Fibers Containing TiO2 Additives with in High-speed Melt Spining

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Abstract

Generally, PET resin is classified into Super Bright (SBr) and Semi Dull (SD) grades, each used according to its specific applications due to their distinct characteristics. The two grades have nearly the same intrinsic viscosity (IV) values and other properties, except for the slight difference in TiO2 content in SD (approximately within 0.3%). The addition of TiO2 does not significantly affect the final fiber properties, but it can cause variations in the spinning process. However, there is no research specifically addressing these differences. In this study, the effect of TiO2 on fiber formation behavior during high-speed melt spinning of PET fibers was investigated using a high-precision on-line diameter measurement device. Spinning was conducted using SBR and SD grade PET resins with the same IV values, and the diameter changes were monitored at 5 cm intervals between the nozzle and the take-up roller during the spinning process. Diameter monitoring revealed that while the final solidified diameters of the two fibers were identical, the onset point of rapid solidification (neck-like deformation) from the nozzle differed. Significant fluctuations in diameter were observed at the neck-like deformation region, as measured by the upper and bottom cameras. sing the time data from these specific deformation points, the neck-moving velocity and strain rate were calculated, enabling a detailed analysis of the characteristic changes in the fibers.

Poster: Fibres and Films

Paper ID: S07-275

Electromagnetic Shielding Efficiency in Carbon Nanotube Sheets: Distinct Role of Structural and Electrical Properties

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Abstract

This study shows that solvent densification enhances the bundling behavior and thickness densification of carbon nanotube sheets (CNTSs), leading to improved electrical properties and better electromagnetic interference shielding efficiency (EMI SE). Unlike traditional shielding materials, where electrical conductivity is typically the key factor, in CNTSs, it is actually the sheet resistance—reflecting bundling and microstructural characteristics—that plays a more crucial role in determining EMI SE. These insights highlight the importance of controlling microstructure and bundling to achieve optimal EMI performance in CNT-based materials, providing valuable guidance for designing high-performance, lightweight EMI shielding films.

Poster: Fibres and Films

Paper ID: S07-215

Stretchable and Leakage-Free Liquid Metal Networks for Thermal Management

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Abstract

Stretchable thermally conductive materials (TCMs) are highly desirable for efficient thermal management in the emerging of wearable electronics. However, it is a great challenge to synthesize stretchable TCMs that can simultaneously achieve superior thermal conductivity (TC) and high stretchability due to the contradiction between thermal and mechanical behaviors. Here, we report the design of a bi-continuous structure to yield highly stretchable composites by incorporating liquid metal (LM) within the thermoplastic urethane (TPU) frameworks. In such structure, the continuous TPU frameworks act as the load skeleton to ensure stretchability, and LM forms 3D continuous thermal networks as high-speed channels for heat conduction. The ingenious bi-continuous structure endows the resultant composite with high out-plane TC ($\kappa\perp$, 4.16 W/ (m K)) and outstanding stretchability (606%), and extremely stable TC, with high retentions of 92% at strain of 100% and after stretching-releasing 10,000 cycles, respectively. The stretchable composite also shows excellent leakage-free behaviors, without any LM leakage at large strain of 400% and under pressure of 500 kPa. These remarkable comprehensive performance makes it hold great promise as stretchable TCMs for thermal management in the wearable electronics.

Poster: Foams and Membranes

Paper ID: S08-394

Modification of polyurethane foam-derived reticulated vitreous carbon foam for oil-water separation, microwave absorption and energy storage supercapacitor

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Abstract

Reticulated vitreous carbon (RVC) foam is a glassy electrically conducting open cell carbonaceous foam with three-dimensional network-like structure. RVC is generally prepared by carbonization of various polymeric precursors, such as polyurethane foam, pitch, melamine foam etc. RVC foam finds uses in wide applications, such as electrode materials in energy storage devices, field emission, metal slag filters etc. However, in the pristine state, its properties are not up to the expectation. Therefore, the foam is suitably modified with various nanofillers or coated with different materials to impart and improve various properties such as hydrophobicity, microwave absorption and electrochemical energy storage. In this context, the present talk will focus on our recent efforts in modifying RVC foam for making it superhydrophobic for efficient oil-water separation, improving microwave absorption and electrochemical charge storage. RVC foam was prepared by carbonization of flexible polyurethane (PU) foam, subsequently coated with poly(dimethyl siloxane) oil by vapor deposition. The coating was performed at different temperatures and times. The coating at 320°C for 14 h produced a superhydrophobic foam with water contact angle of 170°. In another study, fumed silica was incorporated into RVC foam through PU foam. The resulting foam exhibited significant improvement in electromagnetic interference (EMI) and microwave absorption properties. In a further study, nickel cobalt oxide (NiCo2O4) nanoneedle-like structures were hydrothermally grown on RVC foam surface for various time periods. The resulting NiCo2O4-coated RVC foam exhibited improved microwave absorption and excellent electrochemical energy storage supercapacitive properties. Subsequently, symmetric supercapacitor device was fabricated to demonstrate the real-life energy storage application. These results will be presented in detail.

Poster: Injection moulding

Paper ID: S31-338

Graph Attention Network-Based Surrogate Model for Accelerating Injection Molding Numerical Simulations

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Abstract

Currently, the application of Digital Twins (DT) for injection molding processes is mainly focused on real-time process equipment monitoring and data collection for system control. Further advancement of DT for injection molding requires real-time molding prediction technology based on process conditions through real-time injection molding numerical simulations. In this study, a surrogate model based on the Graph Attention Network (GAT), an extension of Graph Neural Networks (GNNs), was used to accelerate finite element method (FEM)-based injection molding numerical simulations. GAT utilizes an attention mechanism to learn the complex relationships and characteristics between nodes to determine the relevance of each node to its neighbors and weight them accordingly. This attention-based learning approach offers advantages in flexibility and applicability and can better aggregate neighboring node information. In this study, a finite element-based injection molding simulation model of an automotive airbag cover composed of 46,902 nodes was used, and to enhance prediction accuracy, two attributes containing geometric information were assigned to all nodes in the mesh. The results of simulation prediction using the proposed GAT-based surrogate model showed that the fill time, pressure, and temperature for the new process conditions were predicted within an average of 8 seconds, approximately 196 times faster than injection molding simulations. The prediction accuracy was validated with a Mean Absolute Percentage Error (MAPE) of 3.61%, 7.38%, and 4.59% between prediction and ground truth across all nodes for fill time, pressure, and temperature, respectively.

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Poster: Injection moulding

Paper ID: S32-373

A study on the effects of gate and gusset stiffener on the bending strength of fiber-reinforced injection-molded parts

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Abstract

In this study, the effects of gate structure and gusset stiffener on the bending strength of injection molded specimens of PA66 reinforced with 33% of glass fiber were investigated. An injection mold of standard specimen(ISO 295-5) was designed and manufactured to evaluate the stiffness and strength of the resin. Molded specimens at various resin temperatures and injection speeds were machined at the angles of 0, 45, and 90 degrees to the gate direction and tensile tests were performed. L-shaped bending specimens with equal volume of gusset stiffener were designed to analyze the effect of fiber orientation and shape changes of the gusset stiffener on the bending strength. The angles of the gusset stiffener were designed at 15, 30, 45, 60, and 70 degrees. For the molding of bending specimens, four types of gates were considered, with two types each based on direction and shape. Tensile test results showed that changes in specimen cutting angle had a greater impact on mechanical properties than molding process conditions. For elastic modulus and yield strength, the mean deviation between 0° and 45° was 5.7 times and 18.1 times higher, respectively, than the mean deviation between 45° and 90°. In the injection molding analysis of the L-shaped bending specimen, the side gate along the side wall showed the lowest injection pressure, while the minimum warpage occurred with the pin-point gate in the longitudinal direction of the specimen. As a result of the bending test, the longitudinal direction gate showed a higher bending strength than those with side wall gate. In the longitudinal gate, the gusset stiffener with a 30° angle showed relatively higher bending strength. In the design of gusset stiffeners for structural reinforcement, it was confirmed that the orientation of the gate and the angle of the gusset stiffener are far more critical factors than variations in injection molding process conditions.

Poster: Injection moulding

Paper ID: S31-337

AI-Based Prediction of Surface Roughness and Tool Wear Using Cutting Force and Machining Conditions in Precision Injection Mold Machining

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Abstract

Injection molding, one of the primary processes in polymer production, is a highly efficient process of producing a large number of products using a single mold. As molds, once made, are used for mass production for a long time, the completeness of the mold should be close to perfection, which leads to increased mold manufacturing costs. Furthermore, about two-thirds of the total manufacturing cost of the mold cavity is used for processing and polishing to optimize the surface roughness of the mold that directly affects the surface shape and properties of the final plastic product. In order to lower the production cost, it is essential to reduce the manufacturing cost of the mold, and to this end, research has been conducted to obtain improved surface roughness in the cutting stage. However, in ultra-precise machining, it is difficult to intuitively infer the correlation between cutting force, machining conditions, surface roughness, and tool wear, so it relies on optimizing machining conditions through experiments. In this study, the cutting force experimental data obtained using a multi-component dynamometer were analyzed by FFT and input into the artificial neural network(ANN) model along with the machining condition data to establish the correlation with output factors such as surface roughness and tool wear. Using the trained model, the optimal machining conditions and tool replacement timing to achieve the surface roughness targeted for mold manufacturing were predicted with over 98% accuracy. This study will help simplify the mold machining process and contribute to reducing mold costs.

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Poster: Injection moulding

Paper ID: S11-128

Study on the Influence of Gas Pressure and Temperature Changes on the Process Characteristics of Gas-Assisted Injection Hollow Parts

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Abstract

The aim of this study is to create a net zero industry and provide a green and low-carbon technology. This study improves the level of smart manufacturing and applies it to the plastic injection molding. We will build a heating gas-assisted device for molding the hollow lightweight product. Gas-assisted injection molding (GAIM) uses a gas supply device to inject a certain amount of molten plastic into the product mold cavity. After a period of delay, before the molten plastic has cooled and solidified, the gas is injected into the molten plastic of product cavity to make it push the melt to fill the mold cavity to create a hollow structure; the benefits of this process are (1) reducing the amount of plastic raw materials, reducing product weight, and reducing production costs; (2) gas filling inside the product assists product molding and improves packing effect, (3) improve product quality and production yield (improve shrinkage, sink mark and other defects). From the research results, a gas-assisted heat source system, a real-time sensing system, and a gas-assisted heat source predictive CAE analysis technology were successfully built to grasp the temperature and pressure change trends during gas heating and output. On the other hand, research results show that GAIM uses heated gas to increase the kinetic energy of gas molecules. At the same time, increasing the gas temperature can not only increase the penetration effect of the gas, but also achieve the effect of plastic reduction.

Poster: Injection moulding

Paper ID: S32-35

Investigation on the molding efficiency of the cooling channel layout and its effect on the dimensional accuracy of injected parts through the differences of the conformal cooling size design

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Abstract

In terms of traditional cooling channels, they are limited by subtractive processing, which makes the channel far away from the finished product, and flow dead areas are prone to appear at corners, resulting in a decrease in cooling efficiency. In order to manage and control the mold cooling mechanism, special shaped coolant channel produced by 3D metal printing have been developed. It is recognized by the industry that it can effectively solve this need. Although the design flexibility of special-shaped coolant channels is an important key factor, people usually increase the channel diameter and increase the coolant flow rate, or increase the channel density. However, the former reduces the flexibility of the channel layout, the latter must consider the cooling design criteria to ensure the mechanical strength of the mold. In this paper, both numerical simulation and experimental studies have been adopted to design and develop three sets of molds with different coolant channel layouts. It follows the concept of reducing channel diameter design while meeting the needs of design flexibility and increasing coolant channel density. Specifically, it is further explored the benefits of the diameter differences on those channel layouts. The simulation results show that those special-shaped channel design molds that apply small diameter structure can effectively improve the mold temperature uniformity by more than 6%, the mold temperature cooling efficiency by more than 20%. They also reduce the warpage deformation of injected parts by 30%. Furthermore, the real molds utilized 3D metal printing technique have been created and real molding validation were performed. The experimental results, including improvement in mold temperature uniformity, improvement in mold temperature cooling efficiency, and improvement in product warpage deformation, are quite consistent with the simulation analysis results.

Poster: Injection moulding

Paper ID: S32-60

Hollow Product Fabrication Using Salt Core and Injection Molding Method

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Abstract

The concept of an enveloped salt core offers both rigidity and toughness to withstand the pressure during the injection molding process. It makes a complicated hollow product can be molded in one piece and without assembly assistance. However, the efficiency of preparing the salt core is low due to the slow melting process of salt and sugar mixture. In this work, an improved method is developed, enabling the production of similar products with a significantly reduced preparation time for the salt core. A syrup primarily made of sugar is prepared in advance, and then a mixture of coarse and fine salt is added to the syrup to form the salt core. The effects of both the sugar content and the salt particle size on the compressive strength of the salt core were investigated. A Tri-ring connector, which is challenging to produce using conventional injection molding methods, has been presented to demonstrate the effectiveness of the proposed approach. The optimal molding parameters for the salt core used in the injection molding process were determined using the Design of Experiments (DOE) methodology. The results show that the compressive strength of the salt core increased to over 22 MPa, while the total preparation time was reduced by 55%. Additionally, dimensional measurements of the product produced by these optimal parameters demonstrated a notable improvement, achieving over 90.3% accuracy.

Poster: Modelling and Simulation

Paper ID: S33-395

Modeling Polymer Extrusion with Moving Meshes

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Abstract

This work is integrated into the PrecisionPlastics project, specifically within the task of developing advanced computational modeling tools to address the challenges of plastic recycling and optimize the extrusion process. A central aspect of this effort is the use of OpenFOAM's overset mesh functionality, which enables the simulation of systems with both static and moving components, such as the interaction between the rotating screw and the stationary barrel in extrusion systems. The modeling work will focus on capturing the complex flow dynamics of molten plastic as it moves through the screw channels, incorporating detailed calculations of velocity, pressure, and temperature fields. The use of overset mesh facilitates a highly accurate representation of the relative motion between components, which is essential for understanding material behavior under dynamic processing conditions. By tailoring the simulations to include various geometric configurations, the modeling work aims to provide a comprehensive toolset for optimizing extrusion processes. The insights gained will enhance the understanding of the complex interactions within the extrusion system and contribute to the development of efficient, sustainable plastic recycling technologies.

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Poster: Modelling and Simulation

Paper ID: S33-374

Design of Lightweight Plastic Containers Through Optimization Analysis

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Abstract

The trend of lightweight plastic bottles is driven by environmental awareness and sustainability efforts. This includes research focused on designing and producing thinner walls and smaller caps without compromising structural integrity and functionality. Key technologies for successfully manufacturing thin-walled plastic bottles include rib structure design and optimized preform design. Rib structure design is essential for enhancing structural stiffness without significantly increasing material usage or weight. Preform design is crucial as it determines the thickness uniformity of the final product after blow molding. This study used simulations to optimize rib structures and preform shapes for lightweight containers, following four stages: [Stage 1] Rib Structure Analysis: ANSYS-based linear buckling analysis was conducted to select the optimal rib design for stiffness and aesthetics. The chosen design, a double vertical rib, targeted a 500ml PET bottle with a thickness ratio of 1.5:1:1 (Bottom, Shoulder, Body). [Stage 2] Minimum Thickness Determination: Using LS-DYNA 3D, nonlinear buckling analysis predicted the minimum thickness (0.36mm) meeting weight (26.05g ±1%) and top load (≥15kgf) targets, with a Bottom thickness of 0.54mm and 0.36mm for Shoulder and Body. [Stage 3] Preform Shape and Length: Past preform data was analyzed to finalize a preform of 84.175mm, meeting the 26.05g weight target. [Stage 4] Blow Molding Optimization: ANSYS and Polyflow analysis minimized wall thickness variation, ensuring uniformity and meeting constraints (minimum 0.1mm thickness, ≤2% weight deviation, forming rate ≥99.9%). The final preform design achieved a 500ml container weighing 26.67g with a 15kgf top load. This method was experimentally validated, indicating its potential for efficient lightweight container production.

Poster: Modelling and Simulation

Paper ID: S33-339

Designing extrusion screws using artificial intelligence

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Abstract

The interest in the issues of artificial intelligence of many different centers around the world has brought specific results that have already found practical and widespread applications. "Artificial intelligence" has become increasingly popular and more frequently used in recent years. The rapid development of electronics and computer science is conducive to the development of this field of science. "Intelligent machines" are needed by humans to create and discover new relationships, and artificial intelligence has significantly influenced various areas of technology and, above all, has achieved great implementation success in areas where a large amount of data is available. It is also increasingly used in the processing of polymer materials. The designs of screws of plasticizing systems of extruders are largely proprietary and there is very little specific information available in the literature. Our team generated a set of many extrusion screw designs using computer simulation software for the extrusion process, including the transport of solids, melting and pumping of the melt. The parameters and results obtained were entered into four machine learning algorithms. The performance of the four algorithms was evaluated by comparing the predictions of each algorithm with the corresponding simulation results. For three of the algorithms, we obtained satisfactory performance, and the best one was additionally evaluated using a previously "unseen" dataset consisting of two screws with defined diameters. It is argued that the same ML methodologies can be applied to datasets of existing real-world screw designs. Our conclusion is that the data-driven methodology presented in this paper can be used in the design of extruder screws, leveraging knowledge gained from the development of existing designs.

Poster: Modelling and Simulation

Paper ID: S33-322

A study on the design of adaptive preform temperature control system based on heat transfer analysis

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Abstract

In the blow moulding process, the temperature control of the preform has a significant impact on the quality and energy efficiency of the final product. Typically, a two-stage injection/blow molding processes are operated separately, resulting in additional energy consumption for storage/management and reheating of injection molded preforms. In this study, the process design and cooling performance of the in-line system were evaluated through simulation to develop an in-line system that integrates injection and blow molding processes to save energy. The in-line system consists of an injection, adaptive temperature control and blow system, with the adaptive temperature control system consisting of a picking, transfer, core, docking module. To design an efficient temperature control system, the cooling process of the preform was simulated using CAE analysis. The sequential cooling process in the picking module and core module was simulated using heat transfer analysis. Thermal-flow analysis was only used to calculate the heat transfer coefficients, and mainly transient heat transfer analysis was used to evaluate the preform cooling performance of the picking module and core module. Cooling performance was evaluated for five different cooling conditions for the same target cooling time. In addition, a cycle analysis was performed to predict the 'hot zone' that may occur within the adaptive temperature control system due to repeated cycles. The adaptive temperature control system shows promise for improving the energy efficiency of the blow molding process and increasing productivity by achieving uniform cooling and temperature control of multiple injection-molded preforms simultaneously. The analysis-based temperature control system design carried out in this study will be verified in the future through field demonstration and evaluation to verify its suitability for real industrial sites.

Poster: Morphology and Structural Development

Paper ID: S14-158

Water Soluble Polymer for Sulfate Scale Control in Oilfields: Cutting-Edge Synthesis, Characterization, and Performance Insights

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Abstract

The formation of sulfate scale, primarily consisting of anhydrite ($CaSO4$) and barite ($BaSO4$), poses substantial challenges in oil and gas production. Conventional methods for mitigating scales are often limited by high costs, environmental concerns, and reduced efficiency at elevated temperatures. This study explores the potential of locally synthesized water soluble polymer as a scale inhibitor. The polymer was synthesized in two steps using condensation and quaternization reactions and the chemical structure was confirmed by NMR and FTIR. Moreover, the thermal stability was measured by Thermogravimetric Analysis (TGA). The effectiveness of this polymer was tested using a static bottle test. For the scale inhibition test, the incompatibility scenario was formulated by mixing synthetic brines in a 1:1 ratio. To evaluate their inhibition potential, polymeric material was added at two different concentrations (100 and 1000 ppm), and scale inhibition tests were performed at 90°C for 7 days. The experimental results demonstrated that the polymer has considerable potential for inhibiting sulfate scale formation. In the control experiment, needle-shaped scales appeared after 24 h and continued to grow over time. To test the practical applicability of the synthesized polymer, different concentrations were prepared under the same conditions as the control. The polymer remained free of precipitation at both concentrations for 7 days and showed significantly better scale inhibition performance underscoring its superior effectiveness. At a concentration of 100 ppm, the polymer displayed negligible precipitation or scale formation and upon increasing the concentration to 1000 ppm no signs of scale or precipitation were observed, highlighting the stability and effectiveness of the polymer in sea brine. The experimental results from this study underscore the potential of polymer synthesis as a promising approach for scale inhibition in the oil and gas industry.

Poster: Morphology and Structural Development

Paper ID: S14-145

Shear-Induced Crystallization of Polypropylene Blends with Polymethylmethacrylate

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Abstract

The shear-induced crystallization of polypropylene (PP) blends with polymethylmethacrylate (PMMA) having low molecular weight was studied. The addition of PMMA greatly enhanced the shear-induced crystallization of PP. Because of the low viscosity at high temperature, the PMMA droplets dispersed in the PP were deformed to the flow direction. As the temperature decreased at cooling process, the viscosity of PMMA greatly increased prior to the PP crystallization. As a result, the deformed PMMA dispersions were hardly deformed further in the molten PP and behaved like glass fibers. It provided an increase in the actual shear rate of PP, leading to a large Rouse-Weissenberg number. They, thereby, accelerated shear-induced crystallization of the PP. Because of the pronounced shear-induced crystallization, the orientation of the PP chains, which causes high rigidity, was greatly enhanced.

Poster: Morphology and Structural Development

Paper ID: S14-127

Effect of Triethyl Citrate on water absorption for Isosorbide-Based Polycarbonate

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Abstract

Isosorbide-based polycarbonate (ISB-PC), known as a biomass-based transparent plastic, is widely recognized as an excellent candidate to replace bisphenol-A polycarbonate (BPA-PC) and poly(methyl methacrylate) (PMMA). It is known that optical and mechanical properties of ISB-PC are sensitive to the moisture content. In this study, triethyl citrate (TEC) was added to ISB-PC as a biomass-based plasticizer. It was found from dynamic mechanical properties and tensile properties that TEC acted as an antiplasticizer, i.e., the TEC addition enhanced the modulus in the glassy region. This is attributed to the decrease in the free volume fraction. We further investigated the water content in the ISB-PC/TEC blends and found that the TEC addition reduced the water content. This must be owing to the free volume reduction.

Poster: Nanotechnology

Paper ID: S15-382

Innovative use of in-situ fibrillation for the rational design of PP/EPDM/CNT nanocomposites with simultaneously high mechanical performance and thermal/electrical conductivity

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Abstract

In this study, we introduce an advanced method for enhancing carbon nanotube (CNT) dispersion in polypropylene (PP) nanocomposites, using a combination of chemical functionalization and physical confinement. Our approach involves a two-step process: initially, CNTs are chemically functionalized and dispersed into an ethylene propylene diene monomer (EPDM) rubber phase via solution mixing. This is followed by melt-blending the CNT-infused EPDM with PP, where an in-situ fibrillation process helps to achieve a refined composite structure. Morphological and rheological analyses reveal that this technique successfully confines CNTs within a network of nanoscale EPDM fibrils, uniformly distributed throughout the PP matrix. This well-organized network notably reduces the electrical and thermal percolation threshold from approximately 1.5 wt.% to just 0.25 wt.%, while also enhancing the rheological and crystallization behavior of the PP. In the rheological context, the nanocomposites display a more pronounced elastic behavior at low frequencies, indicative of a global resistance to deformation due to the interconnected network of crosslinked EPDM/CNT fibrils, while also exhibiting generally lower viscosity compared to conventional PP/CNT nanocomposites. Moreover, our nanocomposites display a more uniform crystallization behavior, with increased crystallinity and higher crystallization temperatures compared to conventional PP/CNT composites. Moreover, this tailored morphology significantly improves the mechanical properties, tripling both tensile toughness and ductility. By addressing the common challenge of reduced toughness and ductility in CNT-based nanocomposites, our method offers a comprehensive improvement, also providing better electrical and thermal conductivity.

Poster: Nanotechnology

Paper ID: S15-45

In situ growth of ZIF-67 at PAN nanofibers: influence of synthesis conditions on particle morphology

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Abstract

Metal-Organic Frameworks (MOFs) have drawn much attention from researchers due to their unique physical structures and potential applications in fields such as biomedicine, catalysis, and gas adsorption. 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 Polyacrylonitrile (PAN) nanofibers, evaluating the influence of solvents, time and linker concentration on the morphology of the particles formed. The solvent used can impact both the shape and size of the particles, thus influencing their applications. In this work, a solution of PAN and cobalt nitrate was electrospun, and from this process, mats were obtained. These mats were immersed for 0.5, 1 or 4h in a solution containing 2.0, 4.0 or 6.0 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 the time of synthesis has a major influence on the particle growth, while the linker concentration has an influence on the nucleation. The CO2 adsorption analysis showed CO2 uptake at 1 bar up to 0.4 mmol/g.

Poster: Polymer Blends and Alloys

Paper ID: S16-381

Extrusion Up-Cycling of Plastic Waste Using Atmospheric Plasma Jet Modification

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Abstract

This research aims to evaluate the capability of atmospheric plasma jet modification during extrusion to increase the miscibility of polypropylene (PP) and polyethylene (PE) blends and discuss the feasibility of the treatment as a plastic waste up-cycling solution. To evaluate the success of the plasma jet treatment, we used multiple tests to determine the mechanical, viscous, and morphological properties of each polymer blend, which allowed us to gain a significant understanding of the blend performance. Through the study, it was found that there were no significant improvements in the mechanical properties of the treated blends. However, this was likely affected by the degradation of the polymer, which was witnessed throughout testing. Promisingly, there were noticeable improvements in the morphology of treated polymer blends for low ratios of polyethylene. This indicates strong potential for future use of atmospheric plasma jet modification of polymer blends, which could offer a more sustainable approach to plastic waste treatment, especially considering the low percentages of polyethylene typically found in recycled polypropylene. To see further improvements in polymer blend performance using atmospheric plasma jet modification, it is necessary to study the plasma torch's use further and identify methods in which degradation can be minimized by adjusting variables surrounding the treatment, such as plasma flow rate, exposure time and nozzle distance. Supposing degradation can successfully be mitigated during the extrusion process, it may be possible to see the mechanical and viscous properties of polymer blends become increasingly closer to that of their virgin counterparts, enabling significant improvements in plastic waste upcycling.

Poster: Polymer Blends and Alloys

Paper ID: S16-191

Preparation of Compatibilized Blends and Foams Using Biorefinery Waste Humins and Bio-degradable Polyesters

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Abstract

Biorefineries are essential for promoting sustainability by utilizing renewable feedstocks to convert biomass into valuable chemicals and materials, thereby reducing dependence on fossil fuels and lessening environmental impact. A typical process involves the acid-catalyzed conversion of polysaccharides derived from biomass into platform chemicals such as furfural, 5-hydroxymethylfurfural, levulinic acid, and formic acid. However, a significant barrier to the widespread adoption of this technology is the formation of humins—black, tar-like by-products that can account for as much as 50% of total carbon loss. These humins feature a dense polyaromatic structure with various functional groups and exhibit high viscosity, poor solubility, and thermal instability, complicating their processing and valorization. However, the valorization of humins presents a significant opportunity for creating sustainable materials. In this poster, we report on the upcycling of the humins in preparing reinforced polyester matrices such as polylactic acid (PLA) and polycaprolactone (PCL) with enhanced properties. By optimizing the reaction conditions, particularly the humin-to-polyester ratios, we achieved micro-phase separated blends with interesting thermoplastic and elastomeric properties. At the same time, the materials exhibited foam morphology. Comprehensive characterization using FTIR, DSC, TGA, and rheological analysis demonstrated that the resulting humins-polyester blends possess superior structural and mechanical properties, including enhanced elasticity and reduced glass transition temperatures compared to pure polyester counterparts, making them ideal candidates for various applications. This study highlights the potential of humins-polyester blends as an innovative, sustainable solution for material applications by leveraging a significant biorefinery waste stream.

Poster: Polymer Composites

Paper ID: S36-356

Comparative Study of Mussel Shell-Derived and Commercial Calcium Carbonate as Low-Loading Fillers in Polypropylene Composites: Thermal and Mechanical Properties

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Abstract

Mineral-sourced calcium carbonate is widely used as a filler in polymer composites due to its abundance and property-enhancing capabilities. This study explores mollusc shells as a sustainable alternative, comparing various calcium carbonate fillers in polypropylene (PP) composites. Four fillers were investigated at 5% loading: commercial calcium carbonate (CC), raw mussel shell (MS), and two surface-modified MS fillers-maleic anhydride-grafted PP modified (MAPP) and polydopamine and MAPP co-modified (PDA/MAP).Thermogravimetric analysis revealed enhanced thermal stability for all composites, with PDA/MAPP-MS fillers showing the highest improvement (maximum weight loss at 675°C vs. 490°C for neat PP). Differential Scanning Calorimetry indicated that MAPP-MS and PDA/MAPP-MS fillers induced β-PP formation and slightly increased crystallinity. Mechanical testing showed that PDA/MAPP-MS/PP composites exhibited the highest elastic modulus (1.57GPa, 7.4% increase from neat PP) and maintained comparable tensile (23.1 MPa) and flexural strengths (35.3 MPa) to neat PP (23.8 MPa and 34.5 MPa, respectively). Other fillers showed slight decreases in strength, suggesting suboptimal bonding with the PP matrix.Scanning Electron Microscopy revealed enhanced wettability and adhesion for MAPP and PDA/MAPP modified fillers, evidenced by the absence of voids and presence of polymer fibrils on filler surfaces. Dynamic Mechanical Analysis showed elevated storage moduli for all composites, with PDA/MAPP-MS/PP exhibiting the most substantial improvement (14.5% increase at -50°C). In conclusion, mussel shell fillers, especially when PDA/MAPP co-modified, outperformed commercial calcium carbonate in enhancing thermal, mechanical, and dynamic mechanical properties of PP composites. These findings highlight the potential of modified mussel shell waste as a sustainable filler for polymer composites.

Poster: Polymer Composites

Paper ID: S36-355

Improving Performance of Harakeke Flax Fibre Composites Through Low-Temperature Plasma Treatment

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Abstract

Climate change has seen a worldwide shift towards the development of sustainable and biodegradable materials, with the use of natural fibres gaining interest in the composites sector. From a NZ standpoint, phormium tenax, or harakeke flax, has been identified as a promising fibre reinforcement material. When combined with a bioderived polymer such as PLA, a 'green' composite is generated. Despite their environmental benefits, the high variability, moisture sensitivity, and hydrophilic behaviour of natural fibres pose challenges to fibre-matrix bonding. This research explores air atmospheric plasma modification as a clean and eco-friendly pre-treatment method to improve interfacial adhesion properties of harakeke fibres, providing a replacement for environmentally harmful chemical alternatives. Plasma treatment parameters were explored, with an optimal nozzle distance of 10 mm and line speed of 30 feet/min identified. IR analysis and thermal degradation tests confirmed the removal of unwanted fibre constituents following plasma modification, with mechanical testing of fibre bundles finding the effects on tensile strength to be within acceptable limits. Microdroplet tests indicated improvements to interfacial shear strength with plasma treatment, though sample size was inadequate for statistical significance of these results. Composite manufacturing methods were explored, with a modified 3D printer effective for laboratory-scale plasma modification of discontinuous fibre tows. Hot mixing and compression moulding techniques ensured good fibre wetting and dispersion during manufacture, with the plasma-treated specimens produced exhibiting significant improvements in tensile strength. These findings prove the feasibility of plasma modification techniques as a successful fibre pre-treatment method for harakeke flax/ PLA composites, with enhanced mechanical interlocking, fibre wettability, and hydrophobic surface chemistry contributing to improved interfacial adhesion.

Poster: Polymer Composites

Paper ID: S36-353

Polymeric nanocomposite triboelectric nanogenerators for antimicrobial platforms

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Abstract

Triboelectric nanogenerators (TENGs) have attracted a lot of attention recently because they can power wearable electronics and small energy-harvesting devices. However, rigid materials are limiting the application of TENGs, especially in flexible electronic devices, and thus flexible materials are receiving more and more interest as an alternative to traditional rigid materials. This presentation introduces polymer nanocomposite thin films for the various types of TENGs by facile, simple, low-cost, reproducible, and eco-friendly layer-by-layer (LbL) method. So far, studies have shown the following results: (1) Body-patchable, antimicrobial, encodable TENGs with ultrathin, free-standing, translucent chitosan/alginate/ silver nanocomposite multilayers. As a result, this environmentally friendly chitosan/alginate-based TENG can be used as a next-generation implantable, wearable, patchable, and encodable portable electronic device. (2) Designable functional polymer nanocomposites as an electron-blocking layer for highly deformable power-boosted TENGs. An LbL assembled electron-blocking polymer nanocomposite was employed between the negative tribomaterial layer and the graphene-based LbL electrode, significantly boosting the TENG output performance. (3) Self-powered microbial inactivation and particles removal in water gelatin-based LbL TENGs. The gelatin TENG-driven electrophoresis apparatus for eliminating harmful nanoparticles and E. coli was effectively demonstrated without the necessity for an external power source of a water disinfection system. (4) Development of antibacterial film and cell stimulation platform. We described a reproducible single-electrode TENG-based composite film with chitosan/silver nitrate as an anodic triboelectric layer. This device may kill four bacterial species approximately 100% in the first cycle.

Poster: Polymer Composites

Paper ID: S35-309

Bacterial Cellulose and Fungal Mycelium-Based Polymer Composites for Multipurpose Applications

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Abstract

Polymer composites (PCs) are preferred for various applications due to their unique and advantageous properties compared to the polymer matrix. They demonstrate excellent mechanical strength and stiffness. Additionally, PCs enable rapid processing cycles, maintain consistent dimensional stability, exhibit minor thermal expansion properties, and outstanding fatigue and fracture resistance. As a result, there has been a growing interest in the preparation and characterization of bacterial cellulose and fungal mycelium-based PCs for their potential applications in healthcare and footwear. Bacterial cellulose (BC) is a carbohydrate polymer synthesized by microbes. It is well-known for its favourable physicochemical properties, including biocompatibility. The chemical network structure which consists of abundant hydroxyl groups on its surface and strong hydrogen bonds, facilitates the attachment of BC to other biomaterials. This proves its ability to form biocomposites. Consequently, the focus will be on modifying BC for various healthcare applications, such as wound dressing materials. Furthermore, the formulation of BC-based composite materials using hydroxyapatite and graphene oxide for bone tissue engineering and regeneration will be presented. Fungal mycelium (FM) is a natural polymeric composite fibrous material composed of natural polymers such as chitin, cellulose, proteins, etc. Recently, mycelium has attracted attention as a form of programmable matter, where its structural characteristics can be influenced by various factors such as growth conditions, species type, the composition of feed substrates and other factors. As a result, efforts have been made to prepare economically viable and self-growing fibrous materials based on fungal mycelium. Experiments have been conducted using lignocellulosic waste materials along with a white rot fungal strain. The microstructural analysis of this heterogeneous mycelium network will also be discussed.

Poster: Polymer Composites

Paper ID: S35-281

Preparation of Electromagnetic Interference Shielding Composite of Ethylene Propylene Diene Monomer with Electroless-Plated FeCo Hollow Fibers

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Abstract

A low-density (1.18 g/cm^3) electromagnetic interference (EMI) shielding composite was developed by incorporating electroless-plated FeCo hollow fibers into an EPDM (ethylene propylene diene monomer) polymer matrix. The aspect ratios of the fibers were precisely controlled, and their hollow structure was formed through a thermal treatment process. These FeCo hollow fibers were then mixed with EPDM to fabricate the composite material. Higher aspect ratios in the hollow fibers significantly increased the EMI shielding effectiveness of the composite, reaching 30 dB, which was attributed to the low sheet resistance (30 ohm/sq). The improved shielding properties resulted mainly from a conductive network established above the percolation threshold by high-aspect-ratio fibers. Additional enhancement was due to increased reflection loss caused by impedance mismatch, along with absorption and multiple internal reflection losses.

Poster: Polymer Composites

Paper ID: S34-234

Studies of Promoted Crystallization Kinetics and Physical Properties in Novel Multi-component Biodegradable Polymer Composites Containing Cyclodextrin Inclusion Complex

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Abstract

The novel biodegradable polymer composites of poly(L-lactic acid) (PLLA), poly(ethylene glycol) (PEG), and cyclodextrin inclusion complex were investigated in this study. The crystallization kinetics and the physical properties of the composites were deeply discussed. In the composites, the cyclodextrin inclusion complex was made by PLLA and α-cyclodextrin (α-CD), and named as PLLA-CD-IC. The isothermal crystallization was explored in depth, and the relevant results showed that with the presence of PLLA-CD-IC in the three-component PLLA/PEG/PLLA-CD-IC composites, the crystallization time tended to be shortened, which means that the addition of PLLA-CD-IC might increase the crystallization rate of PLLA in the composites. Furthermore, we found that the rate constant k evaluated by the Avrami equation was increased with the increase of PLLA-CD-IC content in the composites. This indicated that adding PLLA-CD-IC would promote the isothermal crystallization rate of the PLLA/PEG/PLLA-CD-IC composites. The number of spherulites was found to be increased with the increase of PLLA-CD-IC content in the composites. This inferred that PLLA-CD-IC can be an effective nucleation agent for the crystallization of the PLLA/PEG/PLLA-CD-IC composites. The wide-angle x-ray diffraction (WAXD) results demonstrated that the crystalline structures of PLLA was not significantly changed by PEG and PLLA-CD-IC in the composites. The TGA measurements reveled that the PLLA/PEG/PLLA-CD-IC composites displayed better thermal stability than neat PLLA. Adding hydrophilic PEG and PLLA-CD-IC will also decrease the water contact angle of the composites, indicating that the hydrophilicity of the composites can be improved by PEG and PLLA-CD-IC. With the addition of PEG and PLLA-CD-IC in the novel three-component PLLA/PEG/PLLA-CD-IC composites, the crystallization kinetics and the physical properties of the composites can be obviously promoted and influenced, respectively.

Poster: Polymer Composites

Paper ID: S34-218

Synthesis of PDMS Block and Graft Copolymers by RAFT Polymerization and Their Self-assembly Investigations

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Abstract

This study focuses on high χ value block copolymers (BCP). Phase separation in diblock copolymers occurs when $\chi N > 10.5$. Therefore, the construction of , and a nanostructure with thinner domain spacing L0 required the copolymers to possess less molecular weight ($L0 \approx \chi 1/6N2/3$). As the degree of polymerization decreases, the χ-value needs to increase, otherwise, we can only obtain the disordered phase. According to the literature, the solubility parameter of PDMS is δ=15.5 (MJ/m3)1/2, while that of P2VP is δ = 20.6 (MJ/m3)1/2, indicating a significant difference in their solubility parameters. Compared to linear block copolymers, bottle brush copolymers, owing to their densely connected brushes, were more easily constructed the unique lamellae nanostructure with asymmetric line widths. Hence, we designed a brush-like block copolymer to further enhance the conformational asymmetry between these two segments. The polymer chain transfer agent P (PDMSMA-r-St)-CTA is copolymerized in an RAFT manner to produce large molecules. 2VP is polymerized in an RAFT manner to form a brush-like structured BCP. Brush-like BCPs with different chain lengths are measured using TGA and DSC to compare the differences between their Td5% and Tg. Solid-phase self-assembly structures of brush-like block copolymers are observed using SAXS, comparing them with traditional linear block copolymers in phase separation, studying the differences at various annealing temperatures, and observing the differences in their self-assembly using a temperature-variable small-angle scattering instrument. The side chain of a brush-like block copolymer can lead to larger spacing between molecules, stronger intermolecular forces, and a more intricate structure. When studying the microphase separation of brush-like block copolymers, researchers discovered that the volume fraction may differ from that of typical linear block copolymers.

Poster: Polymer Composites

Paper ID: S17-112

Butt joint lamination of thermoplastic and thermosetting prepreg for manufacturing CFRP parts with optimized structural functions by area

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Abstract

CFRPs are widely used in various industries such as aerospace, automotive, wind energy, shipbuilding/marine, and sports/leisure due to their excellent mechanical properties and low density. The demand for these materials is expected to increase in the future. When applying CFRP to aircraft structural components, the key mechanical and functional performance requirements may vary by area. For example, in the wing structure of an aircraft, the leading edge requires tough thermoplastic carbon composites to withstand bird strikes or foreign object debris, while the skin is preferably made of stiff thermosetting carbon composites. To manufacture CFRP parts with optimized structural functions for wing structures, bonding between thermoplastic and thermosetting carbon composites is essential. However, existing bonding techniques using adhesives or rivets require separate fabrication of thermosetting and thermoplastic carbon composites, leading to increased processing steps and potential strength reduction due to hole drilling. To overcome these limitations, this study proposes a method of butt joint lamination of thermoplastic prepreg and thermosetting prepreg, followed by compression molding to manufacture the composite parts in one step. This method demonstrates excellent bonding performance that minimizes the use of adhesives or rivets while avoiding additional processing steps. This presentation will evaluate the mechanical properties of the composites based on the lamination shape of the prepregs and introduce research confirming the equivalence of experimental and computational results. Additionally, it aims to predict mechanical properties based on various lamination shapes and present results for deriving the optimal configuration.

Poster: Polymer Composites

Paper ID: S37-58

Mechanochemical carbon nanotube surface functionalization for enhanced compatibility with polymers

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Abstract

Our group has recently synthesized high aspect ratio (100 μm L x 15 nm D) multiwalled carbon nanotubes (MWCNTs) on unconventional, thin-layered catalyst supports, leading to high carbon yields and eliminating the need for purification. However, our existing work with these MWCNTs has shown poor processability and percolation behavior in thermoplastic composites fabricated by high-shear melt mixing due to MWCNT bundle shear resistance. In this work, we use planetary ball milling to impart MWCNT surface functionalities by milling the MWCNTs in the presence of a second functional species, leading to enhanced polymer-MWCNT interactions. In the first case, we mill MWCNTs in the presence of ammonium carbonate to impart oxygen- and nitrogen-containing groups to the MWCNT surface, leading to hydrogen bonding interactions with functionalized polymers. Preliminary results show improved rheological and electrical percolation behavior for mechanochemically functionalized MWCNTs compared to plain milled nanotubes, suggesting the addition of functional groups on MWCNT surfaces improves nanotube dispersion in the polymer (polycarbonate) matrix. In the second case, we mill MWCNTs in the presence of melamine to encourage pi-pi interactions, inhibiting MWCNT agglomeration and subsequently improving MWCNT dispersion in polymer composites. In the third case, we mill MWCNTs in the presence of elemental sulfur to enhance the mechanical reinforcement effects in vulcanized rubber composites with a tire tread rubber application in mind. For all cases, we report various polymer-CNT composite property changes due to the addition of functionalized MWCNTs and comment on the viability of the mechanochemical functionalization processes in an industrial setting.

Poster: Polymerisation and synthesis

Paper ID: S18-213

Synthesis of polyamides via Ugi-type multicomponent polymerization and functionalizing with α-lipoic acid for crosslinking and elastic vitrimer in application

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Abstract

This study presents the design and synthesis of multifunctional polyamides using a one-pot multicomponent reaction (MCR) strategy, specifically the Ugi reaction, to explore their potential in crosslinking and self-healing applications. MCRs involve the combination of three or more reactants to form structurally complex products in a single step. In our approach, aldehydes (A), carboxylic acids (B), amines (C), and isocyanides (D) were used to successfully synthesize polyamides with diverse structural combinations. We explored the influence of aromatic (ortho, meta, and para) and aliphatic amines, along with aromatic and aliphatic aldehydes, on the reaction outcomes. The resulting polyamides were characterized using gas chromatography (GC) and gel permeation chromatography (GPC) to determine molecular weight distribution and conversion rates. Structural confirmation was achieved through nuclear magnetic resonance (NMR) and Fourier-transform infrared spectroscopy (FTIR). The impact of different monomers on reaction order, yield, and thermal properties was thoroughly examined. At the application of the study was the use of α-lipoic acid (LA) in a Ugi reaction to introduce 1,2-dithiolane functional groups into the polyamide structures. The 1,2-dithiolane group, a five-membered ring with adjacent sulfur atoms, plays a crucial role in forming dynamic crosslinking networks through reversible ring-opening reactions. This property endows the resulting polyamides with adaptive self-healing capabilities and reusable adhesive characteristics. In addition to self-healing and reusability, the 1,2-dithiolane group offers intrinsic antioxidant activity, making these materials valuable for stabilizing quantum dots and metal nanoparticles.

Poster: Polymerisation and synthesis

Paper ID: S18-142

Synthesis of P(DMSMA-co-MMA) random copolymers by ATRP for RIMPS in epoxy thermosets

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Abstract

Epoxy thermosetting resins (ET resins) are widely recognized for their superior thermal and chemical stability, mechanical properties, and ease of processing. However, their dense cross-linked network structure inherently leads to brittleness. To address this, toughness enhancers can be introduced to improve material resilience. Although effective in toughening, these additives often induce a plasticizing effect, which can detract from the thermal stability and mechanical performance. We prepared poly(dimethylsiloxane) monomethacrylate (PDMSMA) with varying chain lengths and molecular weights, along with methyl methacrylate (MMA), which was synthesized via atom-transfer radical polymerization (ATRP) to form P(PDMSMA-co-MMA) random copolymers. The one-pot synthesis of these random copolymers offers advantages. The copolymer was selected for its compatibility with ET resins, enabling it to self-assemble into suitable microphase separation morphologies for toughening. Different volume fractions of P(PDMSMA-co-MMA) were polymerized via ATRP, and the self-assembly phenomena in bulk films were observed through small-angle X-ray scattering (SAXS). Due to the significant difference in solubility parameters between PDMSMA and MMA, phase separation occurs within the polymer structure. Random copolymers with various volume fractions were blended into epoxy thermosetting resin at different ratios to observe the phase separation morphology of the polymer in the epoxy resin, as well as its effects on thermal and mechanical properties.

Poster: Rheology and characterisation

Paper ID: S19-445

Analysis of the pressure dependent flow and shrinkage characteristics of semi- crystalline polymers

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Abstract

Injection molding is a preferred method for manufacturing plastic components. Pressure-gradients induced by the injection process promote flow within the tool, causing elevated shear of the material up to several thousand per second, while the hydrostatic pressure level rises continuously through several hundreds of bar. Control over those overlapping processes in injection molding means control over morphology, and consequently over the property profile of the final product. Boundary conditions of this magnitude have a particularly large influence on the crystallization kinetics of semi-crystalline thermoplastics. From studies using Fast Scanning Calorimetry (FSC) and pvT-analysis it is already known how the cooling rate and the pressure affect the crystallization temperature [1].However, the studies only refer to one specific variable - change of cooling rate at atmospheric pressure or variation of pressure at 10 K/min cooling rate. Studies on the influence of the cooling rate under process-relevant pressures on the crystallization temperature are hardly known to the authors so far [2,3]. Special methods are required to obtain characteristic values for the process-relevant pressure-dependent material behavior during flow and cooling. The poster presents methods used at the IPF-Dresden, which are based on the measuring principle of pvT and high-pressure capillary rheometry. These methods help to predict the process-relevant crystallization and shrinkage behavior of semi-crystalline materials.

Poster: Rheology and characterisation

Paper ID: S19-258

Revisiting a method for measuring fluid viscosity in a hermetically sealed vial

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Abstract

Some time ago, we reported on the rotational rocking of a sealed, cylindrical vial for examining phase changes of single or multi-component polymeric materials. Aside from the advantage of a hermetic seal against loss of a volatile component, gentle rocking keeps the components mixed and improves the heat transfer. Using a bifurcated optical fiber with a laser source and a PMT detector, the method could easily detect changes with time and temperature such as gelation and phase separation. Oscillation frequencies over the range of 0.01 to 1 Hz were typical. Somewhat as an aside, data using Newtonian fluids (calibration oils and sugar solutions) were gathered. In particular, the viscosity range of the oils was from 0.05 to 60 Pa s, a ratio of 1200. For all of these oils, a curious instability occurred during a frequency sweep extending to frequencies above 10 Hz. To explain this, the present simple approach was to consider the many dimensionless groups that are viscosity-free but deal with fluids. Such dimensionless groups include the Bond, Froude and Weber numbers. An additional group was based on the equation for the Seiches frequency. Of these four, the Froude number seemed to reach a critical state (kinetic vs. potential energy) close to the frequency at which the detectable motion of the fluid surface ceased to act as a smooth mirror. It is conjectured that this chaotic sloshing motion, led to the observed behavior. Thus, not surprisingly, viscosity measurements via rocking of the vial need to be confined to low frequencies. Student PCA users and co-developers should be recognized; these include Drs. Hwee-Khim Boo, Glenn Gordon, Catherine Jackson, David Moonay, and Ren-Jye Wu, among others.

Poster: Rheology and characterisation

Paper ID: S19-192

Rheological Characterization of Polymers in the Presence of Supercritical CO_2: Applications in Polymer Processing and Modification

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Abstract

This study highlights the use of Anton Paar's pressure cells in combination with an MCR rheometer to perform high-pressure rheological measurements, focusing on the effects of supercritical carbon dioxide (CO_2) on the rheological behavior of polymers. The pressure cells, which operate up to 400 bar and 300 °C, are designed to simulate industrial conditions relevant to polymer processing, oil recovery, and food technology. The study explores the influence of CO_2 as a plasticizer and processing agent, particularly its impact on the viscosity, melting point, and internal structure of polymer systems such as Polylactic Acid (PLA) and High-Density Polyethylene (HDPE). Initial results demonstrate that CO_2 significantly alters the rheological behavior of these polymers, reducing viscosity and shifting the melting point compared to tests in nitrogen. CO_2's plasticizing effect becomes evident under supercritical conditions, enhancing the flow properties and processability of the materials. Further testing is expected to provide deeper insights into how CO_2 interacts with different polymer types, influencing key processing parameters such as temperature and pressure. The findings underscore the importance of understanding rheological behavior under high-pressure CO_2 conditions to optimize polymer modification, blending, and foaming processes. This approach offers a flexible framework for further investigations into various polymer systems and the broader impact of supercritical CO_2 on industrial applications.

Poster: Rheology and characterisation

Paper ID: S19-66

Rheological Behavior of in-house Synthesized Zwitterionic Surfactant-Polymer Mixtures in High-Salinity EOR Applications

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Abstract

Water-soluble polymers play a pivotal role in various industrial applications, particularly in enhanced oil recovery (EOR) processes within the upstream oil and gas sector. Polymers such as partially hydrolyzed polyacrylamide (HPAM) and copolymers of acrylamide and 2-acrylamido-2-methylpropane sulfonic acid (ATBS-AM) are commonly used to increase fluid viscosity, improving sweep efficiency and facilitating the displacement of residual oil from reservoirs. Surfactants, another critical component in EOR, are utilized to reduce interfacial tension, but conventional surfactants often degrade in harsh environments characterized by high salinity and temperature. To address these challenges, we synthesized a series of zwitterionic surfactants with improved stability and studied their interactions with commercial polymers. This study investigates the rheological properties, focusing on the effects of surfactant concentration, salt concentration, and the molecular structure of surfactants, including tail length, head group type, and the presence of ethoxy groups. The results indicate that the rheological properties, such as viscosity and storage modulus (G'), are strongly influenced by surfactant concentration and salt content. Higher surfactant concentrations generally resulted in more pronounced viscoelastic behavior. However, salt concentration led to a decrease in both viscosity and storage modulus, attributed to the ion-induced screening effect, which weakened the network structure within the system. Additionally, longer tail lengths, different head group types, and the presence of ethoxy groups were found to enhance the viscoelastic properties of the surfactant-polymer systems. These findings demonstrate that our synthesized surfactants are fully compatible with HPAM and ATBS-AM polymers and offer tunable rheological properties suitable for EOR applications under harsh reservoir conditions.

Poster: Rubbers and elastomers

Paper ID: S20-200

TPE/Unvulcanized Rubber Bi- and Tri-Layers: Observations of Unusual Mechanical Responses and a Survey of Potential Applications

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Abstract

There is significant interest in adding value to existing high-volume polymeric materials, from commodity polyolefins through engineering plastics and elastomers. Of particular interest to our laboratories is the development of multi-layer constructs of rubbery materials systems that exhibit multi-functionality, including low gas permeability, improved tactile properties, and unique mechanical responses. Toward that end, we will discuss observations of tension-and-release properties of simple bilayers of vulcanized and unvulcanized rubbers which necessarily have different viscoelastic responses. Specifically, a vulcanized (or physically crosslinked) rubber should exhibit classical neo-Hookean behavior in tension (for example, styrenic thermoplastic elastomers), while an unvulcanized rubber, such as poly(isobutylene), should dominated by viscous flow with permanent deformation. A well-adhered bilayer strip, when stretched, held for a few seconds in tension, and then allowed to relax, shows instantaneous curling with eventual slow recovery back to original dimensions. Such dimensional recovery can be reasonably understood by combining the vulcanized rubber's response using a hyperelastic spring element in parallel with the unvulcanized rubber's response using a generalized Maxwell model. Also of interest is energy absorption behavior, with unvulcanized rubber layers acting to dissipate energy via viscous damping. Addition of a TPE surface layer to form symmetric a tri-layer leads to different mechanical responses, with evidence for strain-induced crystallization of the unvulcanized butyl center layer. Impact damping of such materials as a function of layer thickness will be discussed.

Poster: Rubbers and elastomers

Paper ID: S20-178

β-Farnesene-based copolymer Liquid Rubbers for Sustainable Elastomer

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Abstract

Abstract: Liquid rubbers have recently gained importance as essential processing aids, functioning as plasticizers and processing oils that maintain the mechanical properties of the base rubber while promoting long-term sustainability. Primarily, these rubbers are low molecular weight materials that exhibit significant viscous flow at room temperature. Significantly, during vulcanization, they form crosslinks with the primary rubber chains, thereby enhancing or preserving the performance of the final compounds. Considering factors such as cost, product durability, energy efficiency, and environmental concerns, liquid rubber-based processing aids hold promise as an alternative to the highly aromatic oils or fossil-based plasticizers commonly used in the rubber industry, offering long-term functionality through more environmentally sustainable processes. Here, the bio-based copolymer liquid rubbers were developed using β-farnesene (FA), dibutyl itaconate (DBI), styrene (Sty), and recycled styrene (rSty) via a simple and eco-friendly Diels-Alder (DA) reaction carried out at 100 °C for 24 h. The successful synthesis of a homopolymer of bio-synthon FA and its copolymer with DBI, Sty, and rSty was confirmed through nuclear magnetic resonance (NMR) and Fourier-transform infrared (FTIR) spectroscopy. Furthermore, gel permeation chromatography (GPC) was used to determine the molecular weight and polydispersity index of the synthesized liquid rubbers. Notably, the incorporation of liquid rubber into the base polymer substantially improves the physical and mechanical properties. Thus, the results demonstrate that the produced liquid rubber possesses significant properties, indicating its suitability for industrial applications. Keywords: Liquid rubber, β-Farnesene, Dibutyl itaconate, Styrene, Recycled styrene, Diels-Alder reaction Acknowledgment: This work was supported by the project from the Ministry of Trade, Industry, and Energy of the Republic of Korea (20015122).

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