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2024
Conference

Polymers for a Safe and Sustainable Future

28–31 May 2024 | Athens, Greece

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Polymers 2024—Polymers for a Safe and Sustainable Future

The War Museum
Athens, Greece
28-31 May 2024

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Prof. Dr. Konstantinos Triantafyllidis
Dr. Ioanna Deligkiozi

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Dr. Ioanna Katsavou

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You can find the last version of the Book of abstract in **here**.

Welcome from the Chairs

Dear colleagues and friends,

We are very proud and honored to announce the international conference Polymers 2024—Polymers for a Safe and Sustainable Future, organized in collaboration with the MDPI open access journal Polymers, Aristotle University of Thessaloniki and BIOMAC project, and Exelisis Co. The conference will be held in Athens, Greece, on May 28–31, 2024.

Global mass production of synthetic plastics started in the 1950s, with an estimated total number of 8.3 to 9.1 million metric tons (Mt) already manufactured, evidence that polymers have made an outstanding contribution to the development of modern society in every field. From this amount, it is estimated that only 9% has been recycled and 12% incinerated, whereas the remaining 79% has now accumulated in landfills, rivers, lakes, and the open sea. However, the high stability and non-degradability of synthetic polymers have caused serious environmental issues to living organisms, evident with “Microplastics”, which have been recognized as one of the most threatening contemporary problems. Except for polymers, many of today’s used additives (plasticizers, flame retardants, stabilizers, etc.) exhibit some toxicity and have negative impacts on human health. Due to these concerns, recent research efforts of the polymer scientific community have been focused on producing environmentally friendly, safe, and non-toxic polymers and additives that could be fully recycled or completely degradable shortly after their use. Nevertheless, the substitution of conventional polymers with newly designed polymer systems, which have similar properties to the former, poses a challenge to polymer scientists and manufacturers. The transition to climate neutrality and zero-pollution ambitions requires new polymers to be produced by employing green chemistry and engineering, sustainable chemistry, and circularity-by-design. For the fabrication of such polymers, several parameters, such as hazard assessment of the used chemicals/monomers, the human health and safety aspects in the chemical/material production and processing phase, the human health and environmental aspects in the final application phase, and finally the environmental sustainability assessment, should all be taken into account.

“Polymers 2024” is an international conference covering the latest progress and innovations in the field of polymers for the production of new materials and additives for a safe and sustainable world. The conference aims to explore the latest findings in the scientific field of polymers, with a particular emphasis on the synthesis of safe polymers with unique properties for human health and environmental sustainability. Additionally, the goal is to focus on green polymer chemistry and industrial approaches using bioresources to synthesize biobased and biodegradable polymers, in addition to exploring safe and sustainable-by-design polymers using modeling, theory, and simulation and simultaneously investigating their chemical and physical properties for different applications. Clean, green, and efficient production processes will be presented, while life cycle assessments, exposure, risk assessment, decontamination, and environmental remediation will also be discussed. The conference also aims to propose novel techniques for polymer recycling and reuse. Such an event is a unique opportunity for polymer scientists from around the world to present their works, findings, and innovations in polymer chemistry and technology with regard to sustainable development and with great respect to human life and the environment.The conference follows the previous successful meetings of Polymers 2018—Polymers: Design, Function and Application held in March 2018, Barcelona, Spain, and Polymers 2022: New Trends in Polymer Science: Health of the Planet, Health of the People held in May 2022 in Turin, Italy. We look forward to welcoming you to Athens!

Prof. Dr. Dimitrios Bikiaris
Aristotle University of Thessaloniki,
Greece

Prof. Dr. Konstantitnos Triantafyllidis
Aristotle University of Thessaloniki,
Greece

Dr. Ioanna Deligkiozi
AXIA innovation, Germany

Keynote Speakers

Prof. Dr. Damià Barceló
Catalan Institute for Water Research (ICRA), Scientific and Technological Park of the University of Girona, Spain, Water and Soil Quality Research Group, IDAEA-CSIC, Barcelona, Spain

Prof. Dr. Minna Hakkarainen
KTH Royal Institute of Technology, Stockholm,Sweden

Prof. Dr. Armando J. D. Silvestre
University of Aveiro, Portugal

Invited Speakers

Dr. Sylvain Caillol
CNRS, Institut Charles Gerhardt Montpellier, Montpellier University, France

Prof. Dr. Nathanaël Guigo
Institut de Chimie de Nice, France

Prof. Dr. Gianmarco Griffini
Politecnico di Milano, Italy

Prof. Dr. Hermis Iatrou
National and Kapodistrian University of Athens, Greece

Prof. Dr. Tadahisa Iwata
Graduate School of Agricultural and Life Sciences (GSALS), The University of Tokyo, Japan

Prof. Dr. Nadia Lotti
University of Bologna, Italy

Prof. Dr. Marco Sangermano
Politecnico di Torino, Italy

Dr. Joachim Venus
Leibniz Institute for Agricultural
Engineering and Bioeconomy,
Potsdam, Germany

Prof. Dr. Ning Yan
University of Toronto, Canada

Dr. Tobias Robert
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Prof. Dr. Youssef Habibi
University Mohammed VI
Polytechnic (UM6P),
Sustainable Materials
Research Center, Morocco

Abridged Program

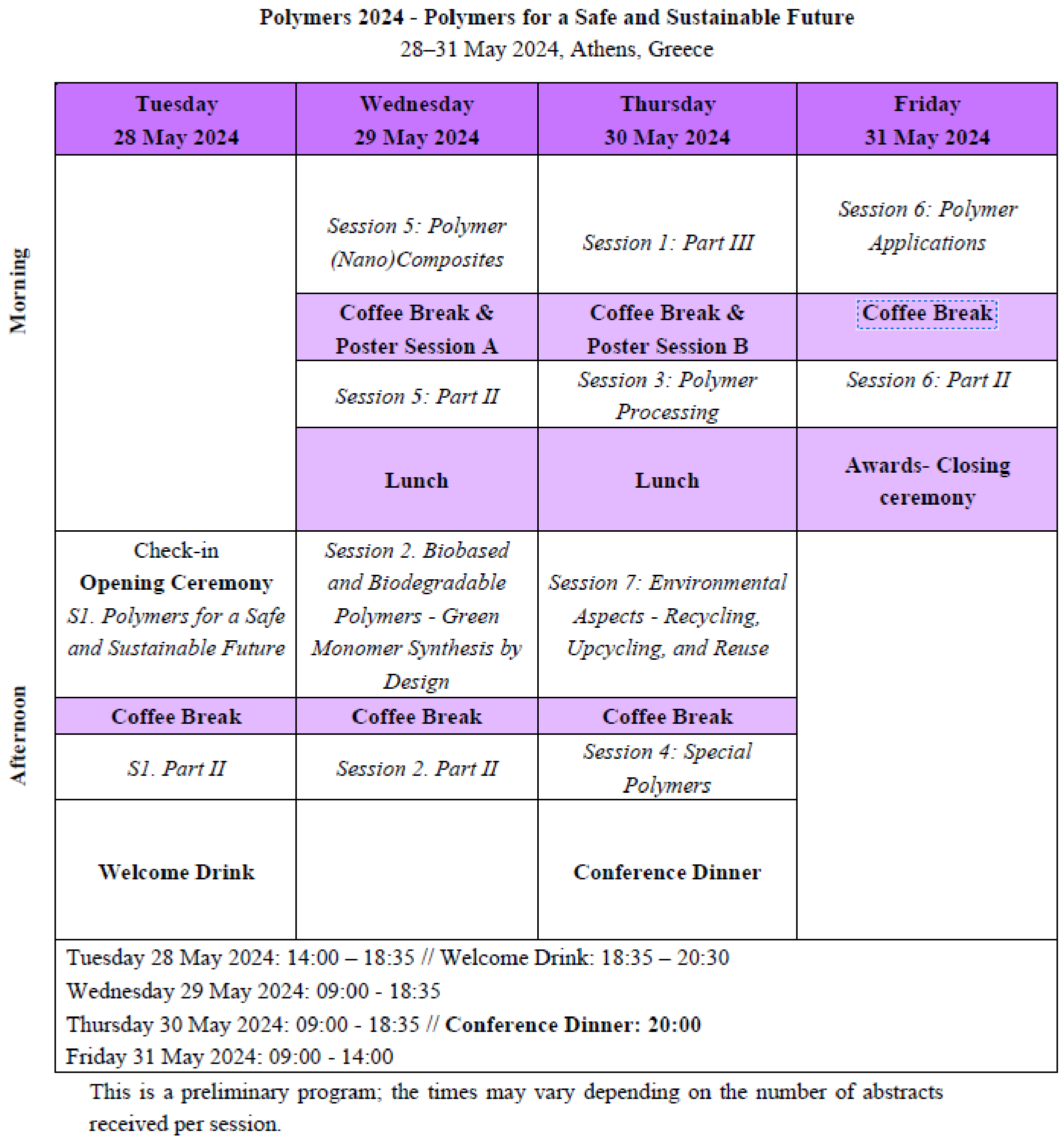
Tuesday, 28 May 2024
13:00 – 14:00 Registration
14:00 – 18:35 // Welcome Drink: 18:35 – 20:30

Wednesday, 29 May 2024
9:00 am – 18:35

Thursday, 30 May 2024
9:00 am – 18:35 (Conference Dinner: 20:00 pm)

Friday, 31 May 2024
9:00 am – 14:00 pm

9:00 am – 14:00 pm CET



Polymers 2024 - Polymers for a Safe and Sustainable Future
28–31 May 2024, Athens, Greece

	Tuesday 28 May 2024	**Wednesday 29 May 2024**	**Thursday 30 May 2024**	**Friday 31 May 2024**
Morning		*Session 5: Polymer (Nano)Composites*	*Session 1: Part III*	*Session 6: Polymer Applications*
		Coffee Break & Poster Session A	**Coffee Break & Poster Session B**	**Coffee Break**
		Session 5: Part II	*Session 3: Polymer Processing*	*Session 6: Part II*
		Lunch	**Lunch**	**Awards- Closing ceremony**
Afternoon	Check-in **Opening Ceremony** *S1. Polymers for a Safe and Sustainable Future*	*Session 2. Biobased and Biodegradable Polymers - Green Monomer Synthesis by Design*	*Session 7: Environmental Aspects - Recycling, Upcycling, and Reuse*	
	Coffee Break	**Coffee Break**	**Coffee Break**	
	S1. Part II	*Session 2. Part II*	*Session 4: Special Polymers*	
	Welcome Drink		**Conference Dinner**	

Tuesday 28 May 2024: 14:00 – 18:35 // Welcome Drink: 18:35 – 20:30
Wednesday 29 May 2024: 09:00 - 18:35
Thursday 30 May 2024: 09:00 - 18:35 // **Conference Dinner: 20:00**
Friday 31 May 2024: 09:00 - 14:00

This is a preliminary program; the times may vary depending on the number of abstracts received per session.

Conference program

13:00-14:00	Check-In	
14:00-14:15	Opening Ceremony	
S1. Polymers for a Safe and Sustainable Future (Part I) chaired by Ioanna Deligkiozi		
14:15-15:00	**Mina Hakkarainen** **Keynote Speaker**	Designed from biobased for increased circularity
15:00-15:15	**Shanmugam Thiyagarajan**	Synthesis of biobased (co)polyesters with tuneable thermal properties
15:15-15:30	**Edoardo Miravalle**	Thermoplastic-like Recycling of Biobased Thermoset Polyurethane Using Covalent Adaptable Network Mechanisms
15:30-15:45	**Stamatina Vouyiouka**	Sustainable designing and recycling/upcycling of biopolyesters
15:45-16:00	**Samara Costa**	Life cycle assessment for blends of recycled PET and Bio-PET: circular innovations
16:00-16:30	**Coffee Break**	
S1. Polymers for a Safe and Sustainable Future (Part II) chaired by Youssef Habbibi		
16:30-17:00	**Joachim Venus** **Invited Speaker**	Bioconversion of lignocellulosic hydrolysates into lactic acid
17:00-17:15	**Sofia Makri**	Ultrasound-assisted process for the production of lignin nanoparticles
17:15-17:30	**Mercedes Bettelli**	Sustainable Bio-based Foams and Bioplastics from Wheat Gluten Proteins

17:30-17:45	**Mari Cruz García-Gutiérrez**	Processing, structure, and properties relationship of silk fibroin: a sustainable biopolymer
17:45-18:00	**Nisha Middleton**	Optimising Sustainable Plastics for Food Packaging Films
18:00-18:15	**Olalla Sanchez-Sobrado**	Reinforced Polymeric material based on glass fiber from wind turbines for 3D printing technologies feedstock biomaterials
18:15-18:35	**Tobias Robert** **Invited Speaker**	Poly(ester itaconate)s as bio-based oligomers for additive manufacturing
18:35-20:30	**Welcome Drink**	

S5. Polymer (Nano)Composites

chaired by Gianmarco Griffini

09:00-09:30	**Tadahisa Iwata** **Invited Speaker**	Development and Marine Biodegradation of High-Performance Biodegradable Biomass Plastics
09:30-09:45	**Valadoula Deimede**	IL-Graphene oxide polyamide nanofiltration membranes: Preparation, performance and anti-fouling properties
09:45-10:00	**Richard Thompson**	Reinforcement of GO Composites using Rigid and Flexible Crosslinkers
10:00-10:15	**Anastassia Rissanou**	Hydrated Graphene Oxide/Polymer Nanocomposites: A Computational Study
10:15-10:30	**Giacomo Marra**	Scaling Sustainability: Nanolignin-Enhanced PLA Functionalization through Reactive Extrusion
10:30-10:45	**Kristine Aleksayan**	Biocomposites based on PLA with silver nanoparticles
10:45-11:00	**Annika Byrne**	Small Additive, Big impact—Bio(nano)materials in the BIOMAC Open Innovation Test Bed
11:00-11:30	**Coffee Break & Session Poster A**	

S5. Polymer (Nano)Composites (Part II)
chaired by Nadia Lotti

11:30-12:00	**Gianmarco Griffini** **Invited Speaker**	Lignin as a valuable tool for functional materials: coatings, composites and beyond
12:00-12:15	**Carlota Hernández Fernández**	Development of Lignin-Based Polyurethane Adhesives
12:15-12:30	**Huy Nguyen**	Evaluating the ultra-fine grinding for the continuous production of nanofibrillated cellulose
12:30-12:45	**Katerina Koshenaj**	Rheological Properties of HPP Starch-based Hydrogels Loaded with Bioactive Compounds
12:45-13:00	**Magdalena Gierszewska**	Chitosan edible food packages containing deep eutectic solvent and olive leaves extract
13:00-14:15	**Lunch Break**	

S2. Biobased and Polymers - Green Monomer Synthesis by Design (Part I)
chaired by Stamatina Vouyiouka

14:15-15:00	**Armando Silvestre** **Keynote Speaker**	Biobased polymers and (nano)cellulose based composites: a contribution to more sustainable materials
15:00-15:15	**Michelina Soccio**	Biobased and compostable multiblock copolymer of poly(L-lactic acid) and poly(pentamethylene 2,5-furanoate): design, synthesis and characterization
15:15-15:30	**Josemar Gonçalves de Oliveira Filho**	Rapid manufacturing of smart nanofibers: Solution blow spinning polycaprolactone with anthocyanins from agri-food sources
15:30-15:45	**Emine Ayşe Turhan**	Enhancing Wood Polymer Composites Performance through Carboxylation of Wood Fibers
15:45-16:00	**Flore Kilens**	Copoly(ester-ether)s from Biobased Monomers: Tunable Properties for Sustainable Packaging
16:00-16:30	**Coffee Break**	

S2. Polymer Synthesis - Sustainable (Upscale/Industrial) Production

chaired by Sylvain Caillol

16:30-17:00	**Nathanaël Guigo** **Invited Speaker**	New avenues for biobased furanic polymers
17:00-17:15	**Anne-Sophie Schuller**	Development of an electrospun bi-layer membrane of PLA nanofibers on a hydrogel film for wound dressing application
17:15-17.30	**David De Smet**	A pathway to green polyurethanes for textiles
17:30-17:45	**Wael Almustafa**	Chemical synthesis of atactic Poly-3-hydroxybutyrate (a-P3HB) by self-polycondensation: catalyst screening and characterization
17:45-18:00	**Helena Monteiro**	Environmental life cycle assessment of bio-based polymer intermediate products – identifying potential benefits and challenges
18:00-18:15	**Agata Olszewska-Widdrat**	Bioprocess optimization for succinic acid production from lignocellulosic biomass
18:15-18:35	**Youssef Habibi** **Invited Speaker**	Sweet polyesters

S1. Polymers for a Safe and Sustainable Future (Part III)

chaired by Zoi Terzopoulou

09:00-09:30	**Ning Yan** **Invited Speaker**	Developing Bio-Based Polymers with Dynamic Bonds for Recyclability
09:30-09:45	**Zhaobin Qiu**	Structure and properties of biobased and/or biodegradable polymers
09:45-10:00	**Ramin Farnood**	Application of Eco-friendly Polymers to Enhance Wet-strength Properties of Cellulosic Food Packaging Materials
10:00-10:15	**Fakhri-Eddin Lahfaidh**	Exploring and understanding the recycling of a biobased epoxy thermoset via saponification
10:15-10:30	**Loic Hilliou**	From the seaweeds' carrageenan composition to the carrageenans' gel properties: can we establish a link?
10:30-10:45	**Shreyas Aralumallige Chandregowda**	Investigating sodium carboxymethyl cellulose bio-flocculant interaction with Kaolinite: Insights from sedimentation tests, analytical techniques, and Molecular Dynamic Simulation.
10:45-11:00	**Sofia Mylona**	Thermal Conductivity Enhancement of PE-RT samples with M5 and GNRs25 fillers
11:00-11:30	**Coffee Break & Session Poster B**	

S3. Polymer Processing

chaired by Tobias Robert

11:30-12:00	**Marco Sangermano** **Invited Speaker**	Sustainable UV-Cured polymers from coatings to composites and additive manufacturing

12:00-12:15	**Georgios Bokias**	Novel composite hydrogel adsorbents for the efficient adsorption of uranyl and copper ions
12:15-12:30	**Sacha Pérocheau Arnaud**	Understanding additive degradation pathways and formation of Non-Intentionally Added Substances (NIAS) in polystyrene: impact on chemical structure and thermo-mechanical properties
12:15-12:30	**Harshada Ravindranath Chothe**	Optimizing 3D Printing Parameters for Enhancing Thermal Conductivity of Carbon Fiber-Filled Polymer Filaments
12:15-12:30	**Daniel Barker**	A bioderived CO2-responsive rigid foam as an alternative to expanded polystyrene
13:00-14:15	**Lunch Break**	

S7. Environmental Aspects - Recycling, Upcycling and Reuse

chaired by Dimitra Lambropoulou

14:15-15:00	**Damià Barceló** Keynote Speaker	Microplastics in Terrestrial and Aquatic Environments : Green Analytical Protocols, Vectors of Pharmaceuticals and Risk to Biota
15:00-15:15	**George Kyzas**	Chitosan/graphene oxide@kappa-carrageenan composites for the adsorption of hexavalent chromium, trivalent arsenic and fluoride ions from wastewaters
15:15-15:30	**Franciele Saorin**	Upcycling perfumery: a sustainable guide to recycling SURLYNTM perfume caps
15:30-15:45	**Sara Exojo-Trujillo**	Characterization of microplastics exposed to UV irradiation and their behavior as sorbents of organic contaminants
15:45-16:00	**Michail Maniadakis**	Polymer Waste Sorting Technologies to Support the Circular economy
16:00-16:30	**Coffee Break**	

S4. Special Polymers

Chaired by Andrea Dorigato

16:30-17:00	**Sylvain Caillol** **Invited Speaker**	A journey around circularity in polymers, from renewable resources to recycling
17:00-17:15	**Vicent Lapinte**	3D/4D Printed Polyoxazoline Hydrogels
17:15-17:30	**Célia Ziane**	Sustainable High Performance Self-Catalyzed Epoxy-Amine Vitrimers
17:30-17:45	**Sergejs Gaidukovs**	Synthesis and photoprinting of vegetable oil-based acrylate elastomers for energy harvesting structures
17:45-18:00	**Yana Shymborska**	Multi-Technique Surface Analysis of Smart Copolymer Brush Coatings with Composition-Dependent Temperature-Response Mechanism
18:00-18:15	**Changseop Kim**	Double-Layer Solid Polymer Electrolyte Using PEO and PVDF-HFP for All-Solid-State Batteries
18:15-18:35	**Prokopios Georgopanos** **Invited Speaker**	A way to be more efficient in polymer synthesis via the use of digital twins
20:00	**Conference dinner**	

S6. Polymer Applications

Chaired by Nathanaël Guigo

09:00-09:30	**Nadia Lotti** **Invited Speaker**	Ad hoc chemical designed furan-based polymers for sustainable monomaterial food packaging.
09:30-09:45	**Xiao Hu**	Ultrasound-Controlled Protein-Based Films and Nanofibers for Biomedical and Sustainable Applications
09:45-10:00	**Johanna Langwieser**	Investigation of the impact of single and double filtration systems on post-consumer PE-LD film waste
10:00-10:15	**Soonmi Yoo**	Phantom surface dose assessment with application of PLA (Polylactic Acid) and PBT (Polybutylene Terephthalate) elastomer 3D printed boluses for high energy photon radiation therapy of the nasal cavity
10:15-10:30	**Olena Sevastyanova**	Innovative polyester binders for the next-generation lithium-ion battery electrodes
10:30-10:45	**Andrea Dorigato**	Novel polylactide/poly(pentamethylene furanoate) blends for bioderived packaging films with multifunctional properties
10:45-11:00	**Sarawut Rimdusit**	Multi-stimuli Controlled Properties of Biobased Benzoxazine-Urethan Copolymers with Multiple Shape Memory Effects
11:00-11:30	**Coffee Break**	

S5.Polymer Applications (Part II)

chaired by Evangelos Karavas

11:30-12:00	**Hermis Iatrou** **Invited Speaker**	A novel mechanism of nanostructured materials to treat cancer, cardiovascular, kidney and autoimmune diseases
12:00-12:15	**Liudmyla Gryshchuk**	New bio-based, biocompatible, biodegradable (co)polymers to develop functional (nano)capsules with antimicrobial properties
12:15-12:30	**Giulia Fredi**	Electrospun Mats Based on Furanoate Polyesters: Processing, Characterization and Performance for Controlled Drug Release
12:30-12:45	**Nina Kulikova**	Leucine-Based Pseudo-Proteins as Perspective Biomaterials for Skin Wound Dressings
12:45-13:00	**Christian Dauwe**	Understanding Molecular Pathway from Monomer via Polymer/Biopolymer to Degradation Products using simple HPLC-System equipped with newest Chromatography Tools
13:00-13:15	**Zoé Garisoai**	Biodegradable Microparticles Of Polydepsipeptide And Polylactic Acid For Drug Delivery Applications
13:15-13:30	**Michel Habib**	4D printing of soft shape-morphing alginate hydrogels as biomedical devices
13:30-13:45	**Rafail Ionnidis**	Novel biobased poly(lactic acid)-co-poly(ethylene azelate) (PLA-co-PEAz) copolyesters as potential substrates for printing electronics (PE)
13:45-14:00	**Awards- Closing Ceremony**	

General Information

Polymers 2024—Polymers for a Safe and Sustainable Future will be held at the War Museum in Athens 28 – May 2024. This conference aims to bring together top scientists, researchers, and industry experts from around the world to share the latest findings in the scientific field of polymers, with a particular emphasis on the synthesis of safe polymers with unique properties for human health and environmental sustainability.

Conference Venue

The War Museum
Rizari 2-4, Athina 106 75, Greece

Registration Desk

The desk for registration, information and distribution of documents will be open from 13:00h on 28 May 2024.

Certificate of Attendance

Participants of the event will be able to downlod an electronic Certificate of Attendance by accessing their dashboards on Sciforum.net once the event is concluded. The certificates will be found under the “My Certificates" category.

Disclaimer

Delegates will receive a name-badge at the Information Desk, upon registration. The badge must be worn prominently in order to gain access to the congress area during the event. Admission will be refused to anyone not in possession of an appropriate badge.

Insurance

The organizers do not accept liability for personal accidents, loss, or damage to private property incurred because of participation in Polymers 2024—Polymers for a Safe and Sustainable Future. Delegates are advised to arrange appropriate insurance to cover travel, cancellation costs, medical, and theft or damage of belongings.

Athens

Athens is the historic and vibrant capital of Greece, where ancient wonders meet modern delights. Steeped in rich history and mythology, Athens is a city that beckons visitors with its timeless allure.

Explore iconic landmarks such as the majestic Acropolis, where the Parthenon stands proudly, offering breathtaking views of the city. Immerse yourself in the city's ancient past at the National Archaeological Museum, housing a vast collection of artifacts from Greece's ancient civilizations. Stroll through the charming Plaka neighborhood, lined with picturesque streets, traditional tavernas, and quaint shops. Experience the lively atmosphere of Monastiraki Square, bustling with vibrant markets and enticing street food.

For art enthusiasts, the Benaki Museum and the Museum of Cycladic Art showcase magnificent Greek art spanning centuries. Athens also boasts a vibrant contemporary art scene, with numerous galleries and exhibitions.

Indulge in Greek cuisine at the city's renowned restaurants, savoring traditional dishes like moussaka and souvlaki, accompanied by locally produced wines and spirits.

Athens' warm Mediterranean climate offers the perfect backdrop for wandering through the city, from the ancient Agora to the beautifully landscaped National Gardens. As you explore this captivating city, you'll find that Athens seamlessly blends its glorious past with its dynamic present.

The War Museum

We are delighted to host the conference at the prestigious War Museum in Athens. This historic venue offers a unique backdrop that seamlessly combines history, innovation, and knowledge. Located in the heart of Athens, the War Museum provides versatile spaces for presentations, workshops, and networking opportunities. With its central location and easy access to transportation and hotels, it ensures convenience for participants from around the world. Join us in this inspiring setting as we bring together experts and enthusiasts for an event to be remembered.

Address: [Rizari 2-4, Athina 106 75, Greece]

Access:

1. 3-minute walk from 'Evangelismos' Metro Station (M3/Blue Line);
2. 15-minute walk from 'Syntagma' Metro Station (M2/Red Line and M3/Blue Line);
3. 25-minute walk from 'Monastiraki' Metro Station (M1/Green Line and M3/Blue Line);
4. The following bus lines have routes that pass near the museum: 203, 211, 235, 550, 608, and 815.

Gala dinner

Royal Olympic
ATHENS

Thursday, 30 May 2024, 8:00 pm

Price: 60€ *Tickets must be purchased in advance, but you can ask for availability at the Registration Desk.*

We invite you to join us at the Conference Dinner at the Royal Olympic Hotel, a family run five star property in the center of Athens, which will make of your evening at the restaurant an experience to remember. The hotel lays just in front of the famous Temple of Zeus and National Garden, underneath the Acropolis and only 2 minutes walk to the new Acropolis Museum.

The dinner will be at an additional cost of **60 EUR** and will need to be booked separately in an independent registration. Please **register and pay** for it here **before 15 May 2024** and save your seat. During the registration process, please indicate any dietary restriction in the **comments**.

You are welcome to bring any accompanying persons by booking their seats. Please note that registrations onsite will not be permitted.

The restaurant will be located the top of the Royal Olympic Hotel (Address: Athanasiou Diakou 28, Athina 117 43, Grecia). You can reach the restaurant from the conference venue walking 20 minutes, by taxi or public transport (metro M2 or M3 check options here).

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- IOAP – An Institutional Open Access Program that supports its members with access to MDPI's submission system, publication data and administrative processes relating to Article Processing Charge (APC) management.

If you would like more information about open access or any of our services listed above, be sure to talk to us at the MDPI booth. See you there!

Contact persons during the event

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Emergency Information

All emergencies in Greece: 112

Ambulance and health emergencies: 166

Fire brigade: 199

National Police: 100

Abstracts – Talks

S1. Polymers for a Safe and Sustainable Future (Part I)

chaired by Ioanna Deligkiozi

Keynote Speaker Mina Hakkarainen

Designed from biobased for increased circularity

Minna Hakkarainen

[1] *KTH Royal Institute of Technology*

Biobased plastics can positively impact the environment, however, in order to make a real difference our materials need to be designed from sustainable resources and have managed and sustainable end-of-life. The most suitable end-of-life management will depend on the type of material and application. Here, some examples will be given of our recent research which focused on 1) desing of biobased materials for mechanical and chemical recyclability by utilizing dynamic covalent chemistries. For example, we fabricated series of aliphatic-aromatic polyester-imines and polyamide-imines with promising properties and facile circularity; 2) design of biobased light processable resins for digital light processing 3D printing. For example, we demonstrated the importance of resin composition and chemical functionalities on printability, mechanical properties, recyclability and biodegradability. 3) design of polymer materials with enhanced (bio)degradability through degradation promoting additives, such as embedded enzymes. For example, we demonstrated the effectiveness of embedded enzymes in triggering the degradation of aliphatic polyesters and cellulose acetate under simulated composting conditions and in aqueous environments.

Synthesis of biobased (co)polyesters with tuneable thermal properties

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Over the last couple of decades, there has been a notable surge in the commercial interest in biobased polyesters across various application areas. This interest is mainly in addressing the circularity of polymers that need to be recycled more efficiently at the end of their life, as well as the fact that their monomers are completely derived from biomass feedstocks.

In this vein, we investigated the use of 2,5-furandicarboxylic acid (2,5-FDCA) in combination with linear and rigid diols, i.e., ethylene glycol, 1,3-propane diol, 1,4-butane diol, and 2,2,4,4-Tetramethyl-1,3-cyclobutanediol-CBDO, in the synthesis of biobased (co)polyesters. Through a traditional two-step melt–polycondensation procedure, all of these polyesters were synthesized up to a molecular weight of Mn 15 kD (Scheme 1). The thermal characteristics of the resulting polymers reveal intriguing findings.

The systematic incorporation of a linear glycol in combination with a rigid diol allows for the fine-tuning of the physical and thermal properties of these polyesters. For instance, the desired glass-transition temperature (T_g), between 36 °C and 125 °C, can be achieved while using a specific combination of diols. The higher incorporation rate of the rigid CBDO diol results in amorphous materials. Thus, a toolbox is created using biobased monomers, from which polyester with the desired properties can be obtained. This strategy is beneficial for creating polymers with the required properties for specific and demanding applications.

Thermoplastic-like Recycling of Biobased Thermoset Polyurethane Using Covalent Adaptable Network Mechanisms

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Polyurethanes (PU) can be thermoplastic and thermosetting and represent 8% of the plastic produced worldwide. Due to their widespread use, increasing amounts of PU waste are generated. Therefore, all processes that involve the treatment of derived waste play a crucial role, particularly for thermoset PU, which is not compatible with direct industrial recycling. Since most current methodologies for recovering PUs are mainly downgrading paths, new processes are being developed. A new mechanical recycling path for this type of polymer has been designed and investigated based on a specific stress-relaxation behaviour first reported by Toblosky and Offenbach, which involves mechanisms of the exchange of covalent bonds capable of causing network rearrangement, defining a novel polymer class known as covalent adaptable networks (CANs).

This work investigates the reprocessing abilities of a novel synthesised biobased PU. The pristine material was obtained by combining a trifunctional polyol (Sovermol 780) and a difunctional isocyanate (Tolonate xflo100) in the presence of a catalyst, dibutyltin dilaurate. Both reagents are commercially available and have 65% and 25% biobased fractions. Reprocessing was carried out by finely grinding the initial network and then hot pressing it for 45 minutes at 170 ° C under 2 tons of pressure. Before and after the process, the material was characterised via IR spectroscopy, TGA, DSC, DMA analyses and tensile tests. No major differences in the IR spectra were observed, which was correlated with the preservation of all the pristine functional groups and the absence of any oxidative phenomena. Minor changes in the thermal properties were revealed by thermal analysis, although there were increases in elongation and strength at break and a reduction in the Young's modulus. The procedure can be considered as a possible PU recycling or upcycling method due to the small differences in the characteristics of the reprocessed materials.

Sustainable designing and recycling/upcycling of biopolyesters

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The increasing environmental pollution along with ineffective approaches, e.g., oxo-degradable polymers, have led to strict regulations on plastic waste management (PPWD–Directive 94/62/EC on the packaging reusability/recyclability by 2030). Our group has been working on eco-designing bio-based polymers and enhancing their waste management *via* different recycling approaches. Regarding eco-design, aiming for PLA stabilization and lifetime extension, readily available aliphatic and aromatic carbodiimide-based anti-hydrolysis additives were examined, and their efficiency was found dependent on the polymer structure, e.g., the aromatic carbodiimide was inefficient due to its competitive action as a nucleating agent and its deactivation through entrapment in crystalline regions. Vitrimerization has been employed as an alternative valorization approach for low-MW biopolyesters such as PBS: dynamic crosslinking with DGEBA or glycerol was achieved using a transesterification catalyst. Tunable insolubility and rheological properties were attained by adjusting the crosslink density. In parallel, a wide range of recycling approaches has been developed, including chemical, mechanical and biochemical methods (solid-state polymerization (SSP), remelting-restabilization, enzymatic depolymerization). SSP was applied as a repair tool for low-MW biopolymers, including PLA and PBS. Critical process parameters were defined to avoid undesirable thermal phenomena (i.e., sintering) and achieve a MW increase > 30%. Indicatively, SSP was effective for PLA at reaction temperatures 130°C for low initial MW (14.000 g/mol) thanks to the high end-group concentrations. Mechanical recycling, through remelting-restabilization, was applied for PBS, which is known to undergo branching during extrusion. Antioxidant incorporation in the PBS matrix ensured its recyclability and secure reprocessing, stabilizing it until the 5th extrusion cycle. Finally, enzymatic depolymerization was applied as an upcycling approach for both PLA and PBS. A psychrophilic esterase significantly decreased the polymers' MW (up to 25%), while a low mass loss was monitored (up to 5%), indicating random scission as the dominant hydrolysis mechanism.

Life cycle assessment for blends of recycled PET and Bio-PET: circular innovations

Samara Costa, Graziella Saft, Renato Reis, Cátia Zoraida, Sofia Pinto, Natália Ladeira

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The transition to a circular economy is one of the European Union's ambitions for 2030. In light of this, the plastic industry has been investing in recyclable plastics and bio-based polymers as an eco-friendly material. The study aims to offer a sustainable alternative to virgin PET using formulated recycled PET and biopolymers through the extrusion for potential applications in PET fibers. The formulation was processed using a co-rotating twin-screw extruder (Coperion ZSK 26, L/D ratio 40) with antioxidants and an epoxy-based chain extender. The Life Cycle Assessment (LCA) methodology was used as a supporting tool to compare the environmental performance of two scenarios: (i) baseline with 100% virgin PET; and (ii) formulation using recycled PET, bio-PET with 20% renewables, and additives. The LCA approach aligns with ISO 14040 (2006) and ISO 14044 (2010), enabling the evaluation of environmental impacts. This method involves four stages: (i) establishing goals and scope, (ii) compiling a life cycle inventory, (iii) conducting a life cycle impact analysis, and (iv) interpreting the findings. The LCA was carried out using SimaPro 9.5.0.1 software. The selected method was EPD (2018) V1.04, focusing on the environmental impact category of global warming. Furthermore, the application of LCA can indicate which scenario and production phase in the life cycle process has the greatest environmental impact. Therefore, by replacing virgin PET with recycled PET and bio-PET in this study, a reduction in greenhouse gas emissions is expected.

S1. Polymers for a Safe and Sustainable Future (Part II)

chaired by Youssef Habbibi

Invited Speaker Joachim Venus

Bioconversion of lignocellulosic hydrolysates into lactic acid

Joachim Venus

[1] *ATB Potsdam*

Among the 17 sustainable development goals SDG7 “Ensure access to affordable, reliable, sustainable, and modern energy for all”, SDG12 “Ensure sustainable consumption and production patterns” and SDG13 “Urgent action to combat climate change” are interrelated and have become a high priority on the research agenda. Especially for biotechnological processes, in which the carbon of various substrates should be converted into microbial products, there is an increasing interest in the use of cheap raw materials, organic residues and wastes, which are not in competition with food and feed.

The goal is to develop high performance fermentation processes based on the substitution of expensive substrates and nutrients by cheaper biogenic materials due to their main proportion of the whole costs. Many feedstocks cannot be used normally for fermentation directly because the fermentable sugars are bound in the structure especially as cellulose and several types of hemicelluloses. A pre-treatment is required when enzymes are used for hydrolysis in an enzymatic approach. Possible disturbing impurities and inhibitors (e.g. phenolic components), difficult to use components (e.g. pentoses) and partly fluctuating or relatively low concentrations of bio-available carbon sources in these materials should be considered.

The viability of the production of lactic acid from several lignocellulosic residues has been demonstrated from laboratory up to pilot scale including the entire value chain starting from the raw material and resulting with a polymer-grade product. As a result of the achievements so far the optimization of pre-treatment, hydrolysis, fermentation, and downstream processing steps in parallel together with the screening of suitable bacteria have been performed. The utilization of lactic acid in high purity and quality is one of the predominant applications for the production of biopolymers like PLA.

Ultrasound-assisted process for the production of lignin nanoparticles

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Lignin is an organic biopolymer, primarily sourced from softwood, hardwood, or non-wood, and abundantly available as a by-product of pulping industries and bio-refineries. Lignin is recognized for its structural complexity and heterogeneity. It has an aromatic backbone formed by the cross-linking of three distinct p-(hydroxypropenyl) phenols. The composition and properties of lignin are heavily influenced not only by its origin but also by the pre-treatment methods (e.g., kraft, organosolv, soda, or enzymatic hydrolysis) used during its extraction from lignocellulosic biomass. Recent advancements have demonstrated the potential of micro- and nano-lignin particles to enhance the performance of end products by virtue of the unique properties of nanostructured materials. Among various techniques for producing submicron lignin, ultrasonication (U/S) has emerged as a prominent, environmentally friendly method, and avoids the use of hazardous chemicals [1]. In this work, we employ at both the lab and pilot scale a novel ultrasound-assisted process, supplemented by ball milling, to reduce the particle size of various lignin types. We focus on chemical, morphological, and dimensional analyses of lignin particles via FT-IR, NMR, DLS, GPC, SEM, and TEM, aiming to discern and compare structural and compositional changes before and after the U/S treatment. We demonstrate that advanced physical processing techniques can effectively alter the properties of various lignin types and reduce the large starting particle size of raw lignin from above 20 μm down to 100 nm, based on TEM analysis, thereby producing lignin nanoparticles and offering tailored solutions for their utilization in niche applications.

Sustainable Bio-based Foams and Bioplastics from Wheat Gluten Proteins

Mercedes Amelia Bettelli, Mikael Stefan Hedenqvist

[1] *KTH Royal Institute of Technology (KTH)*

Polymer foams have an important role in society due to their wide range of densities, and they are extensively used as cushioning, damping, thermal, and sound insulation materials. However, foams are mainly obtained from fossil-based resources and society is striving to move towards renewable materials with a low environmental impact and less waste. Thus, there is strong motivation to develop foams using bio-polymers from renewable resources to reduce their environmental impact. We report the production of sustainable protein foams from a co-product of the ethanol/starch industry. Here, wheat gluten (WG), as a raw material; glycerol, as a plasticizer; and ammonium bicarbonate (ABC) and sodium bicarbonate (SBC), as food-grade blowing agents, were used to produce highly porous foams. Several thermal processing techniques, such as thermal treatment, compression molding, and extrusion, were used to evaluate the impact of the processing route and formulation on the microstructure of the protein foams. The extrusion of WG showed that porous WG with ABC had a low decomposition temperature, enabling extrusion of the material at a temperature as low as 70 °C, well below the protein aggregation temperature required at a higher processing temperature (120 °C) using SBC, resulting in a better foaming and energy efficiency. Further, the use of a natural and non-toxic cross-linker (citric acid) resulted in foams with lower densities, porous structures, and saline swelling properties (~1 g/g in 24 hours). The gluten foams were promising as biodegradable materials. The foams were biodegradable in soil, biodegrading into innocuous molecules for nature for up to 26 days. A hydrolytic degradation of 40% was observed in the first week at different pHs, which is of utmost importance for developing future micro-plastic-free items. These results show the potential for the scalable production of sustainable WG bio-based foams, challenging petroleum-based alternatives and competing with less sustainable petroleum-based polymer foams.

The processing, structure, and properties relationship of silk fibroin: a sustainable biopolymer

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Biobased resources have been proposed as next-generation materials for advanced applications. Among them, silk fibroin, a protein-based material generally obtained from Bombyx mori cocoons, is considered to play an increasing role in the development of a more sustainable generation of devices, electronics, photonics, and smart textiles. Silk fibroin is a block copolymer consisting of a heavy and a light chain with different amphiphilicity linked together by a single disulfide bond. Silk fibroin is semicrystalline in nature. Additionally, it displays crystalline polymorphism depending on the processing conditions. Regenerated silk fibroin can be dissolved into an aqueous solution to later be processed into a final material format. It has excellent film-forming capabilities. However, the pure silk fibroin films tend to be stiff and brittle in the dry state over time, exhibiting a high tensile strength but low elongation. Several procedures have been used to modify the physical and mechanical properties of silk films to control properties, mainly toward more flexible systems. In this context, the present contribution will cover recent research on the processing–structure–properties relationship of silk fibroin freestanding films as follows:

- The processing–structure inter-relation of films, processed from solutions in different solvents and with different additives, investigated by Fourier-transform infrared (FTIR) spectroscopy and wide-angle X-ray scattering (WAXS) using synchrotron light.
- The structure–properties inter-relation, investigated by following the emitted fluorescence in situ while simultaneously monitoring changes in the structural features by WAXS, of silk fibroin films under mechanical stretching.

Optimising Sustainable Plastics for Food Packaging Films

Nisha Middleton, Karen Johnston, Paul Mulheran

[1] *University of Strathclyde*

Polyhydroxybutyrate (PHB) is a sustainable polyester that is bio-derived, eliminating the need for petrochemical feedstocks, and biodegradable, hence will not contribute to landfills. PHB has great potential as a food packaging film, having several properties comparable to those of conventional petroleum-derived plastics. Furthermore, it can be copolymerised with polyhydroxyvalerate (PHV) or processed with plasticisers and filler particles to control the crystallinity, which, in turn, can allow control over flexibility and barrier properties. Despite numerous experimental studies published on PHB, there is a knowledge gap in linking the polymer crystal microstructure to its performance. This project uses experiments and molecular dynamic (MD) simulations to understand the structure and behaviour of PHB composites and how to tailor various properties for sustainable food packaging applications. Copolymerisation with PHV was found to improve properties by lowering the glass transition and melting temperatures. The effect of plasticisers and filler particles on the mechanical and thermal properties of solvent-cast PHB films will be presented. MD simulations and permeation experiments found that PHB acts as a good barrier against water, making it a suitable candidate for food packaging film. The results obtained from this work will not only enhance our understanding of polymer properties but also provide valuable insights for tailoring PHB-based materials, contributing to the development of more sustainable solutions for food packaging applications.

Reinforced Polymeric material based on glass fiber from wind turbines for 3D printing technologies feedstock biomaterials

Olalla Sanchez-Sobrado[1], Andrea Torre-Poza[1, 2], Gregor Luthe[3]

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The contents presented in this work have been obtained within the project LIFE: CarbonGreen (LIFE20 ENV/NL/000200), in which energy-efficient and waste-less technology (ThorSpin) was used for the treatment of waste materials from the blades of wind turbines. Through this technology, very fine powder was obtained. By the use of a ‘glue’ bio-polymer (PLA), the powder fillers were reused to manufacture filaments and pellets for 3D printing technologies. Fillers and PLA (40% wt) were blended through a double extrusion procedure. A consistent continuous flow was achieved at the die, making it possible to spool the filament. Once the extrusion steps were completed, feedstock material for 3D printing technologies was obtained in the two main commercial formats: filament and pellets. The thermal characterization of the obtained samples was carried out to study the good processability of the material and to gather data to select the optimum parameters of the posterior printability window. The DSC values obtained for glass transition temperature (Tg) and melting temperature (Tm) revealed no significant differences with respect to the neat PLA. TGA curves showed a solid content below the theoretic filler content (40%wt due to the possible presence of organic matter in the filler epoxy resin), which might be degraded with the PLA polymer. Concerning the processability observed for the obtained composite material in a 3D printing commercial equipment, a filament was deposited by the Fused Filament Fabrication (FFF) technique. Furthermore, the filament was pelletized to obtain pellets with a high aspect ratio and size like those presented by most commercial materials. These present sufficient quality to achieve a homogeneous flow during the deposition process. The processing parameters of the printing procedure were chosen taking into account the results of the thermal characterization to perform printability tests.

Invited Speaker Tobias Robert

Poly(ester itaconate)s as bio-based oligomers for additive manufacturing

Tobias Robert[1], Sacha Pérocheau Arnaud[1], Natalia Malitowski[1], Lazaros Papadopoulos[2], Francisco José Gontad Fariña[3], Dimitrios Bikiaris[2]

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Over the last years itaconic acid has drawn considerable attention as novel and renewable building block for bio-based polymers. It has been used as (co-)monomer in radical polymerization reactions to obtain polyitaconates with different fields of application. However, itaconic acid can also be used as monomer for unsaturated polyesters. Due to the higher reactivity compared to polyesters derived from maleic acid, these materials can also be used in UV-curing applications and have the potential to be a renewable alternative to polyester acrylates. In addition, by using other bio-based building blocks it is possible to obtain polymers of this type that are completely derived from renewable resources. Herein, the synthesis and properties of novel polyesters and poly(ester amide)s derived from itaconic acid will be reported. Furthermore, the application of these polymer resins as binders for conventional UV-curing additive manufacturing, as well as 2-photon polymerization will be presented. The results suggest that these bio-based resins and monomers can be an alternative to conventional materials derived from acrylic acid. These finding are very intriguing, as itaconic acid usually suffers from lower reactivity towards UV-induced crosslinking in comparison to acrylic acid. In addition, characterization of the properties of the UV-cured materials derived from itaconic acid show that they can compete or even surpass the properties of commercial materials.

S1. Polymers for a Safe and Sustainable Future (Part III)

chaired by Zoi Terzopoulou

Invited Speaker Ning Yan

Developing Bio-Based Polymers with Dynamic Bonds for Recyclability

Ning Yan

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There is a growing trend to enhance sustainability by producing chemical products using renewable bio-based feedstocks as well as by improving recyclability of materials. Thermoset polymers make up a significant portion of plastics products but typically end up in landfill due to lack of recyclability. A new alternative to thermoset materials is covalent adaptable networks, also known as vitrimers, which maintain similar high-performance properties and are recyclable. We have synthesized various novel bio-based vitrimers from starch, chitosan, and lignin as the starting material that contained different dynamic exchangeable bonds. Starch was epoxidized and mixed with a thiol crosslinker that contains exchangeable disulfide bonds. Remarkably, after many reformations, the material improved its tensile strength and young's modulus of 970 % and 8900%, respectively. We have also successfully prepared biodegradable pH responsive chitosan-based dynamic covalent framework materials through one-pot/ultrasonic-assisted amidation reaction under moderate conditions without the need of any catalyst. Moreover, a new strategy of catalyst-free direct synthesis of covalent adaptable network polyurethanes from lignin with editable shape memory effect have been developed. All these novel bio-based covalent adaptable network polymers exhibited either self-healing characteristics or recyclability, demonstrating excellent promises to reduce landfilled materials to result in a lower life cycle impact on the environment.

Structure and properties of biobased and/or biodegradable polymers

Zhaobin Qiu

[1] *Beijing University of Chemical Technology*

From both fundamental research and practical application perspectives, biobased and/or biodegradable polymers have recently attracted considerable attention. Actually, biobased and biodegradable are two different items. Some polymers are only biobased but not biodegradable, such as furan based polymers, while some polymers are biodegradable but not biobased, such as PBAT, PBST, and PCL. Some polymers are both biobased and biodegradable, such as PES, PBS, PHA, and PLLA. In our lab, we synthesized many different kinds of biobased and biodegradable polyesters, such as PES, PBS, PEA, PLLA, PBF, PPF, PHF, PNF and so on, and these polymers based copolymers, polymer blends, polymer composites. We have been modifying the chemical and physical structures and adjusting the physical properties of biobased and/or biodegradable polymers using different methods, including copolymerization, polymer blending, and polymer nanocomposite. In this topic, we will briefly introduce the recent progress of the structure and properties of biobased and/or biodegradable polymers of our lab.

Application of Eco-friendly Polymers to Enhance Wet-strength Properties of Cellulosic Food Packaging Materials

Ramin Farnood

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Developing cellulosic food packaging materials requires the addition of wet strength agents to ensure mechanical integrity in such applications. In this presentation, we will discuss the use of chitosan as a wet-strength additive for cellulosic fiber mats. Chitosan was treated with glutaraldehyde, coated on the surface of cellulose fibers in aqueous suspensions through an ion exchange reaction, and then cross-linked during drying to form a strong bridge between fibers. The absorption and distribution of chitosan-glutaraldehyde on the surface of cellulose fibers were characterized by X-ray Photoelectron Spectroscopy and Time-of-Flight Secondary Ion Mass Spectrometry. The effects of chitosan/glutaraldehyde and chitosan/fiber feed ratios on the strength properties and saturated water absorption were investigated. An increase of as high as 2400% in the wet strength of the fiber mat was detected.

As an alternative approach, the use of carboxymethyl cellulose (CMC)/chitosan polyelectrolyte complex was also investigated. Cellulose fibers were treated with CMC in fibre suspension and were further cross-linked by chitosan through dipping wet fiber mats in a chitosan solution. The structure of cellulose fiber networks cross-linked by CMC/chitosan complex was characterized by SEM. The influence of the amount of CMC/chitosan complex on fibers through the layer-by-layer method and its effect on the wet strength properties of treated fiber mat were studied.

Exploring and understanding the recycling of a biobased epoxy thermoset via saponification

Fakhri-Eddin Nadir LAHFAIDH*, Nathanaël Guigo*, Luc Vincent, Nicolas Sbirrazzuoli*

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Our world is facing unprecedented environmental challenges, with plastic waste being one of the major contributors to ecological concerns. As traditional recycling methods such as mechanical recycling are displaying limits, chemical recycling and its recent developments emerge as an interesting option to address the plastic waste issue while advancing towards a more sustainable future. Thermosetting resins are not prone to mechanical recycling, and their chemical recycling or reprocessing can be foreseen.

This study will focus on a solvolysis-based recycling method of a flexible biobased epoxy-acid cross-linked thermoset. An in-depth methodology for in situ monitoring and quantifying the solvolysis with time will also be unveiled. For this purpose, different techniques were employed such as calorimetry and spectroscopy. The temperature dependence was investigated, leading to a comprehensive kinetic analysis of the solvolysis process. The kinetic data allowed for simulation, and thus, extrapolation at different temperatures. In addition, the valorisation of the recycled product will be highlighted, shedding light on the potential of reprocessing biobased thermosets into fresh materials. The properties of samples prepared by employing solvolyzed products from the initial thermoset resins were studied, with special emphasis on their thermal and mechanical properties. Some limitations were brought to light, and solutions to address these issues will be proposed. This systematic approach not only facilitates understanding of the chemical processes involved during solvolysis but also paves the way for precise control and optimization.
By presenting these advancements, this research aims to contribute to the hot topic aimed at increasing the sustainability of biobased thermoset resins more sustainably by considering the recycling approach.

From the seaweeds' carrageenan composition to the carrageenans' gel properties: can we establish a link?

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Hybrid carrageenans (HC) are hydrocolloids isolated from seaweeds which are extensively used as texturizing agents mainly in the food industry. However, the interplay between the copolymer structure of HC and the carrageenan composition of the seaweeds used for their production is not well documented[1]. Furthermore, the relationships between the gels viscoelastic properties and the gels structure is far from being clearly established, as too few studies used molecular based theories to rationalize such relationships[2].

As a continuation of earlier studies which looked for any possible link between the carrageenan composition of model and cultivated seaweeds and the chemical structure of extracted HC[3,4], we extend here the research for possible links to a series of 12 commercial seaweeds used in the industry to produce HC with various chemical compositions. The carrageenan composition of the seaweeds is quantitatively estimated from the solid-state NMR spectra measured on grinded algal samples. HC are extracted in hot water without any modification of their natural chemical and physical characteristics. ^{1}H-NMR and FTIR showed that the chemical structure of the isolated HC varies from 5 to 80 mol% kappa-carrageenan, from 10 to 80 mol% iota-carrageenan, while they contain from 8 to 23 mol% biological precursors. These numbers are systematically compared with those computed from the solid-state NMR spectra and discussed in light of the viscoelastic properties of 1 wt% HC solutions and gels in the presence of NaCl or KCl.

Investigating sodium carboxymethyl cellulose bio-flocculant interaction with Kaolinite: Insights from sedimentation tests, analytical techniques, and Molecular Dynamic Simulation

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The mining industry produces enormous amounts of waste annually, termed as “mine tailings,” which mainly consist of colloidal-sized clay minerals. Gravity separation is impractical, necessitating the use of polymeric flocculants like Polyacrylamide (PAM). However, PAM poses toxicity risks, prompting the exploration of sustainable biopolymers. This novel study proposes using sodium carboxymethyl cellulose (NaCMC) biopolymer as a flocculant, investigating its surface interactions with Kaolinite clay mineral at macro and atomistic scales. At the macro scale, a series of sedimentation tests were conducted at 10% kaolinite content and varying concentrations of NaCMC, recorded using time-lapse technique for 24 hours. Sedimentation tests were repeated at varying pH and ionic strengths to simulate mine tailings. Analytical techniques (zeta potential and FTIR) were used to identify the interaction mechanism. At the atomistic scale, molecular dynamic simulations (MDS) were performed using the GROMACS package. From sedimentation results, NaCMC was found to be most effective at acidic pH due to electrostatic interactions, which was also validated from zeta potential measurements. However, at neutral and alkaline pH, NaCMC required divalent cations (Ca2+) to interact via divalent cation bridging. From Attenuated total reflectance–Fourier transform infrared spectroscopy (ATR-FTIR) measurements, the presence of hydrogen bonding was confirmed. At the atomistic scale, MDS results revealed electrostatic interactions and divalent cation bridging as the major interaction mechanisms between NaCMC and Kaolinite.

Thermal Conductivity Enhancement of PE-RT samples with M5 and GNRs25 fillers

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Polyethylene of raised temperature resistance (PE-RT) is a plastic high-flexibility pipe, used under high-temperature, high-pressure conditions (e.g., 13.79 bar at 23 °C and 6.9 bar at 82 °C).

Because it is safe to transport potable water, with high resistance to corrosion and chemicals, and is environmentally friendly, PE-RT has many applications in water distribution systems either indoors or outdoors.

The thermal conductivity of seven samples was measured using the GHFM-22, which operates according to the ASTM E1530 Guarded Heat Flow Meter technique, for the measurement of the thermal conductivity of solids. According to this technique, the sample is subjected to a steady-state axial temperature gradient. The sample's thermal conductivity is obtained by measuring the temperature difference across it and one additional temperature.

Each side of every sample was covered with thermal paste to ensure the device plates were attached to the sample and to reduce contact resistance. For the measurement process, the heater on the top stack was set at 40 ^{o}C, while the bottom stack was kept at 10 ^{o}C, allowing a mean temperature of 25 ^{o}C inside the sample.

The seven samples in which thermal conductivity was measured were PE-RT, mixtures with different fractions of M5, and GNRs25.

The diameter of all samples was 50.8 mm, and the thickness of each sample was between 0.62 mm and 1 mm.

The thermal conductivity of all samples was enhanced compared to the pure baseline PE-RT sample. The thermal conductivity enhancement is higher for the M5 mixed with PE-RT than the sample with the same weight fractions as GNRs25.

S2. Biobased and Polymers - Green Monomer Synthesis by Design (Part I)

chaired by Stamatina Vouyiouka

Keynote Speaker Armando Silvestre

Biobased polymers and (nano)cellulose based composites: a contribution to more sustainable materials

Armando J.D. Silvestre

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Addressing the challenges raised by the massive production and use of fossil based polymers and materials, as well as the resulting environmental impacts is a major scientific challenge to contribute to a more sustainable model of development, within the biobased and circular economy concepts.

Addressing these challenges require a broad range of novel solutions spanning from the development of new and sustainable biobased polymers and materials, their recyclability and biodegradability. In this context, cellulose the most abundant plant component, plays a pivotal role, both as a material as central source of platform chemicals, among which 2,5-furanedicarboxylic acid has been considered to play a central role.

I the last two decades we have been actively working in the development of novel polyester based on 2,5-furanedicarboxylic acid, as well as on the development of functional composite materials based on cellulose and synthetic and biobased thermoplastics as well as with other polysaccharides. The use of nanocellulose forms as bacterial BNC and nanofibrillated (NFC) cellulose as well as other active molecules enabled the development of nanomaterials with improved mechanical and functional properties and transparency, not accessible to the conventional cellulose counterparts.

An overview of recent developments in these fields will be presented in this keynote.

Biobased and compostable multiblock copolymer of poly(L-lactic acid) and poly(pentamethylene 2,5-furanoate): design, synthesis and characterization

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The exponential growth in the use of petroleum-based plastics, besides the exploitation of non-renewable resources, leads to serious ecological issues related to their dispersion in the environment. In this context, the creation of biobased and biodegradable polymers represents one of the most innovative challenges.

In this study, the ecodesign of an aliphatic/aromatic multiblock copolymer of poly(L-lactic acid) (PLLA) and poly(pentamethylene 2,5-furanoate) (PPeF) was carried out with the aim of widening the applicability of PLLA in the sustainable packaging sector.

The synthetic method followed a novel top-down approach, starting from industrial high-molecular-weight PLLA, which was reacted with 1,5-pentanediol to obtain hydroxyl-terminated PLLA, then chain-extended with hydroxyl-terminated PPeF and synthesized through solvent-free polycondansation. The final copolymer was subjected to molecular, structural and thermal characterization. Tensile and gas permeability tests were also carried out.

Compared to PLLA, the multiblock copolymer showed an improvement in thermal stability, gas barrier capability and flexibility, making the material suitable for the production of flexible films for packaging.

Moreover, the new copolymer was found to be completely compostable within 60 days: the partially degraded samples, together with those of the parent homopolymers, were studied in depth through DSC, WAXS, NMR and GPC analyses. All techniques evidenced the intermediate behavior of the copolymer with respect to PLLA and PPeF. In terms of mechanism, the PPeF and PLLA blocks were demonstrated to undergo surface erosion and bulk hydrolysis, respectively. In terms of kinetics, PPeF blocks degraded slower than PLLA ones.

Rapid manufacturing of smart nanofibers: Solution blow spinning of polycaprolactone with anthocyanins from agri-food sources

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The continuous advancement in rapid manufacturing techniques has played a crucial role in the fabrication of nanofibers intended to produce smart food packaging. This study aimed to employ the solution blow spinning (SBS) technique for the rapid production of intelligent nanofiber mats based on polycaprolactone (PCL) and red cabbage extract (CE) obtained from retail waste for application in monitoring food quality. The addition of CE to the PCL matrix increased the nanofiber diameter from 156 nm to values between 261.05 and 278.14 nm for PCL/CE10 and PCL/CE15, respectively. The addition of CE also improved the mechanical and water-related properties of the nanofibers, although it reduced thermal stability. CE-incorporated nanofiber mats exhibited visible color changes ($\Delta E \geq 3$) in response to buffer solutions with a pH range between 3 and 10, as well as when exposed to ammonia vapor. The smart nanofibers demonstrated the ability to monitor fish fillets through visible color changes during storage. Initially, at 0 hours, the PCL/CE10 and PCL/CE15 mats exhibited a lilac hue, but after 24 hours, this color became less saturated. After 48 hours, bluish-gray tones were observed, and after 72 hours, the blue color indicated the deterioration of the fish fillets with a pH of 8.01. Thus, smart nanofibers produced via the SBS technique reveal potential as intelligent food packaging materials.

The authors are grateful to FAPESP (processes 2021/13260–7 and 2023/02038-7) for their financial support.

Enhancing Wood Polymer Composite Performance through Carboxylation of Wood Fibers

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Wood-based panels play a crucial role in various industries, providing structural benefits combined with improved physical properties through advanced treatment methods. While traditional techniques like esterification offer advantages, their multi-step processes and use of radical-generating chemicals are a threat for the sustainability of the method, particularly in large-scale production methods. Despite this, esterification remains widely used due to the presence of a high amount of free hydroxyl groups on the surface of the wood fiber. This study investigated the enhancement of the reactivity of Pinus brutia wood fibers to improve the interfacial binding of wood and polymer adhesives by introducing carboxy groups to their surface through straightforward and cost-effective methods. The process involved a simple oxidative method with nitric acid, specifically applied at its decomposition temperature (130 °C), and varying treatment times of 15, 30, and 60 minutes. The resulting wood fibers, modified by an enriched surface with carboxyl groups, were thoroughly investigated and confirmed through Fourier-transform infrared (FTIR) and X-ray diffraction (XRD) analysis. The physicochemical properties of the modified wood fibers were investigated with FTIR, thermal gravimetric analysis (TGA) and contact angle, which indicated that they were thermally stable and hydrophilic compared to the unmodified fibers. Additionally, the surface morphology and color of the wood fibers were analyzed with SEM and UV reflectance, respectively. Subsequently, the modified fibers were incorporated into wood panels, and their performance was compared with panels produced from unmodified fibers. We present water resistance, mechanical properties, and internal bond strength of the composite wood panels produced and their relation to the morphological, compositional, and interfacial properties of the modified fibers.

Copoly(ester-ether)s from Biobased Monomers: Tunable Properties for Sustainable Packaging

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Aliphatic polyether polyols are polymeric intermediates largely used in the industry. A recent advance in their synthesis involved a straightforward process where polyether polyols are obtained through the self-condensation of the corresponding diol, expanding the scope to a wide range of new structures and applications [1]. In the present work, amorphous, semi-crystalline and highly crystalline polyether polyols are synthesised from three biobased diols, namely 1,6-hexanediol, 1,3-propanediol and 1,4-cyclohexanedimethanol, with molecular weight ranging from 500 to 8000 g·mol-1. These polyether polyols are used as macro-initiators in the subsequent ring-opening polymerisation (ROP) of l-lactide (LLA) to prepare a triblock copoly(ester-ether) (coPEE), namely a poly(l-lactide)-b-polyether polyol-b-poly(l-lactide). The formation of an ABA copolymer system where the polyether polyol is used as a soft B middle block and poly(l-lactide) (PLLA) as hard A blocks brings interesting features in terms of thermal and mechanical properties when compared to neat PLLA. For instance, inserting up to 30 wt% of the highly crystalline poly(1,6-hexanediol) in the copolymer leads to a certain degree of phase compatibility where both the glass transition (Tg) and melting temperature (Tm) of the PLLA are moderately affected. By contrast, using an amorphous poly(1,4-cyclohexanedimethanol) as a middle block is more likely to lead to a decrease in Tg and bring flexibility. Overall, triblock coPEE made of polyether polyols and LLA with tunable thermal and mechanical properties can be of great interest for specific packaging applications while meeting the growing need for biosourced and biodegradable plastics.

[1] Basterretxea, A.; Gabirondo, E.; Jehanno, C.; Zhu, H.; Flores, I.; Müller, A. J.; Etxeberria, A.; Mecerreyes, D.; Coulembier, O.; Sardon, H. ACS Sustainable Chem. Eng. 2019, 7 (4), 4103–4111.

S2. Polymer Synthesis - Sustainable (Upscale/Industrial) Production (Part II)

chaired by Sylvain Caillol

Invited Speaker Nathanaël GUIGO

New avenues for biobased furanic polymers

Nathanaël GUIGO

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In the biorefinery operations, sugars contained in plant biomass can be transformed into chemical building blocks via catalytic or enzymatic pathways. 5-hydroxymethylfurfural (HMF) and furfural are two platform chemicals which can be obtained from the dehydration of C6 (glucose, fructose) and C5 (xylose) sugars. They can be further converted into furanic derivatives such as 2,5-furandicarboxylic acid (FDCA) or furfuryl alcohol (FA) which are key building blocks for the preparation of biobased polymers.

This lecture aims at highlighting the great potential offered by furanic polymers [1-7]. A special emphasis will be made on polyfurfuryl alcohol (PFA) - a thermoset matrix prepared from the acid-catalyzed polymerization of FA. During PFA preparation, hydrolytic furan ring opening are occurring thus leading to the formation of carbonyl species. The formation of these side functions can be monitored and exploited to give additional means to tune the properties of these green thermoset resins. In the same vein, industrial humins formed during conversion of sugars can be also smartly valorized into thermosetting applications.

In addition, perspectives offered by furanoate polyesters will be also discussed. It will be shown how their peculiar structure/property relations can help - to a certain extent - to better understand the behavior and potentialities of semi-aromatic polyesters.

Development of an electrospun bi-layer membrane of PLA nanofibers on a hydrogel film for wound dressing application

Anne-Sophie SCHULLER, Christelle DELAITE

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Wound healing is a complex process of tissue regeneration, and a wide range of wound dressings is available on the market. Only a few are designed to facilitate and accelerate the healing process. Conventional dressings only serve to protect the wound from the outside environment to prevent infection while maintaining a moist environment to promote rapid recovery.

Therefore, a new generation of active wound dressings was designed: a bilayer wound dressing with two distinct layers offering different functionalities. This was designed to protect the wound, treat inflammation, and prevent the risk of infection. For this purpose, a bi-layer nanofibrous membrane was developed by using the electrospinning technique.

A first layer composed of gelatin (GE) and hyaluronic acid (HA) as a hydrogel film was made, and zinc oxide particles were incorporated to promote antibacterial properties. Drug-loaded polylactic acid nanofibers (ibuprofen was taken as a model drug) were then deposited on this first layer via electrospinning to increase the dressing's functionalities and provide the dressing with anti-inflammatory properties. The morphological and thermal properties of the drug/HA-loaded PLA nanofibers and the mechanical properties of GE/HA film were investigated. The mechanical and biological properties of this wound dressing, as well as the release of the active ingredient, were evaluated to optimize the properties of the final material.

A pathway to green polyurethanes for textiles

David De Smet, Myriam Vanneste

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Polyurethane (PU) is widely used in diverse applications such as coatings, foams, adhesives, sealants and elastomers. Among the organic coatings, PU coatings have unique performances, including abrasion and chemical resistance, and toughness and flexibility, explaining their use in a wide range of applications from automobile finishings to textile coatings. Recent advances are made in green PU for (textile) coatings. Currently, polymers made from renewable raw materials are experiencing a renaissance, but the application of bio-based coatings on textiles is limited. PU coatings based on renewable resources were developed to improve the environmental impact of coatings by decreasing the carbon footprint. However, at the end of life, PU-coated textiles still end up as landfill or are incinerated, since PU is not biodegradable and is not recycled at this moment. Due to the low susceptibility of PU to physical, chemical and biological factors, and the toxicity of some of the combustion products, landfilling is still the most common way to process PU waste and PU-coated textiles. Efforts need to be made to overcome the landfilling of PU-coated textiles.

Bio-based solvent-free PU coatings with excellent wash fastness and hydrolysis resistance were developed for technical and medical textile applications. Both bio-based 2K PU and PU dispersions were developed. A bio-based chain extender, based on vanillin and cystine, was synthesized and incorporated in the PU backbone to introduce self-healing properties. The healable bio-based PU coating showed a healing efficiency of approximately 80%. Biodegradable units are being examined to be incorporated in PU to improve its biodegradability. As an alternative route, the chemical recycling of PU-coated textiles is demonstrated in a 70% ZnCl2 aqueous solution. This method allowed the easy separation of the coating from the fabric. Analysis of the coating fractions after solvolysis revealed that PU was converted into the original polyol and an amine, corresponding to the isocyanate building block.

Chemical synthesis of atactic Poly-3-hydroxybutyrate (a-P3HB) by self-polycondensation: catalyst screening and characterization

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Poly-3-hydroxybutyrate (P3HB) is a biodegradable polyester produced mainly by bacterial fermentation in an isotactic configuration. Its high crystallinity (about 70%) and brittle behavior have limited the process window and the application of this polymer in different sectors. Atactic poly-3-hydroxybutyrate (a-P3HB) is an amorphous polymer that can be synthesized chemically and blended with the isotactic P3HB to reduce its crystallinity and improve its processability [1]. Ring Opening Polymerization (ROP) is the most cited synthesis route for this polymer in the literature. In this work, a new synthesis route of a-P3HB by the self-polycondensation of racemic ethyl-3-hydroxybutyrate will be demonstrated. Different catalysts were tested regarding their effectiveness, and the reaction parameters were optimized using titanium isopropoxide as the catalyst. The resulting polymers from self-polycondensation were compared for their properties with those of a-P3HB obtained by the ROP and characterized by Fourier-transform infrared spectroscopy (FTIR) and gel permeation chromatography (GPC), and the double bond content (DBC) was determined by UV-vis spectroscopy by using 3-butenoic acid as a standard. Additionally, an LCA analysis of the new synthesis method was carried out to assess the environmental impact of a-P3HB.

The project "Waste2BioComp - Conversion of organic waste into sustainable bio-based components" is funded by the Horizon Europe program. Project no.: 101058654.

Environmental life cycle assessment of bio-based polymer intermediate products – identifying potential benefits and challenges

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With the growing awareness of the environmental influence of anthropogenic activities, the plastic industry, which still strongly relies on fossil-based sources, has become a topic of concern. To contribute to the enhancement of European industrial sustainability, a common approach is to use renewable feedstocks for polymer production as well as to study and promote circular value chains (from second- and third-generation feedstocks). Within this context, the BIOMAC project is developing valuable bio-based intermediate products with potential applications in different polymeric test cases. Aiming to support such developments, this research study applies the standardized life cycle assessment methodology to estimate the potential environmental impacts along the life cycle of different products being developed in the BIOMAC bio-plastic value chain to identify potential environmental hotpots associated with the development stages. This study highlights the advantages, shortcomings and trade-offs that should be considered in the development of new safe and sustainable products, prior to the process's scale-up. A comparison with the literature benchmark is performed to complement and grow the existing knowledge of the field. Overall, bio-based product developments hold potential environmental benefits in some environmental categories while tackling several challenges associated with the improvement of product functionality and process efficiency, but also future product end-of-life scenarios.

Bioprocess optimization for succinic acid production from lignocellulosic biomass

Agata Olszewska-Widdrat

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The biotechnological production of succinic acid is a crucial step towards the transition to a bio-based economy. In this work, biotechnological methods using sustainable, cheap, and readily available raw materials bring bio-economy and industrial microbiology together via microbial production of one of the most important platform chemical - succinic acid (SA). SA was produced from a non-expensive side stream of pulp and paper industry (fibre sludge) proposing a sustainable way to valorize it towards economically important monomer for bioplastics formation. This work showed a promising new route for their microbial production which can pave the way for new market expectations within the circular economy principles. Fibre sludge was enzymatically hydrolysed for 72 h to generate a glucose rich hydrolysate (100 g·L−1 glucose content) to serve as fermentation medium for Bacillus coagulans A 541, A162 strains and Actinobacillus succinogenis B1, as well as Basfia succiniciproducens B2. All microorganisms were investigated in batch fermentations, showing the ability to produce either lactic or succinic acid, respectively. The highest yield and productivities for lactic production were 0.99 g·g−1 and 3.75 g·L−1·h−1 whereas the succinic acid production stabilized at 0.77 g·g−1 and 1.16 g·L−1·h−1. Moreover SA production was scaled up to pilot scale (50L). Additionally, SA was purified via downstream processing to meet industrial standards and high product quality.

Invited Speaker Youssef Habibi

A way to be more efficient in polymer synthesis via the use of digital twins

Youssef Habibi

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In conjunction with growing interest in developing circular economies through the substitution of fossil carbon by renewable resources, interest in biomass feedstock, including wood, does not appear to wane but will continue to attract considerable attention in society during the so-called 4th industrial revolution. Biomass is abundant, renewable, and sustainable and represents a limitless potential to supplant or at minimum complement fossil fuels resources. Therefore, the conversion of these resources into sustainable value-added chemicals, polymers, and materials is surfacing as a potential answer to face the expected scarcity of fossil resources and consequently addresses timely issues of sustainability and ecological consciousness. Herein we argue for a renewed interest in wood as a limitless resource of chemicals, polymers, and materials within the construct of the biorefinery for the processing, fractionation, and full recovery of all components to convert them to non-traditional high-added value uses. In the forest products industry, mainly pulping, cellulosic fibers are the main product, but numerous by-products are generated in the “black liquor.” The latter contains lignin and low molecular hemicelluloses. However, key challenges remain on how to increase environmental and economic stewardship through traditional and innovative pulping technologies to find competitive and higher-value applications for by-products such as black liquor. Approximately 70% of the hemicellulose contained in wood is extracted in very low molecular weight oligomers given the harsh conditions used in the pulping process. Up to today, this sugar-rich fraction is unexploited. Consequently, alternatives to add value to these low-molecular mass fractions are therefore needed. This presentation will summarize the key findings of our work on the polymerization of monomers obtained from the conversion of hemicellulose sugars. Novel polyesters with tailored architectures were synthesized and their molecular and thermal properties were determined. A few illustrative examples will be provided to show their potential for sustainable plastic materials.

S3. Polymer Processing

chaired by Tobias Robert

Invited Speaker Marco Sangermano

Sustainable UV-Cured polymers from coatings to composites and additive manufacturing

Marco Sangermano, Lorenzo Pezzana

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Biobased monomers are becoming increasingly important to develop green and sustainable polymeric products in order to substitute petroleum-based materials. In this study different biobased monomers have been synthesized and exploited both in cationic and radical UV-Curing [1]. Reactivity of curing process was investigated, and the crosslinked materials fully characterized. An easy tailoring of the properties of the final UV-cured coatings is demonstrated by varying the ratio of the monofunctional-difunctional epoxy monomer or by in-situ generation of hybrid organic-inorganic networks. The same formulations were processed in 3D-printing using the hot-lithography technique when processing epoxy monomers [2]. Finally, UV-Cured composites were achieved by exploiting the frontal induced photopolymerization process.

Novel composite hydrogel adsorbents for the efficient adsorption of uranyl and copper ions

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Since the rapid growth in human society and industrial activities, pollution of water with heavy metals has become a long-lasting environmental problem globally because of the continuous accumulation of heavy metals and its subsequent toxicological effects. For example, the presence of radionuclides (such as uranium in water above a certain limit) or copper ions (due to overuse in some applications) poses serious threats to an ecosystem's stability and living organisms.

Among the methodologies employed to address this problem, adsorption is the most widely used due to benefits like its wide applicability and facile operation processes. Therefore, the development of new, efficient, low-cost, easy-to-prepare adsorbents is a key research area. In line with this and towards the development of more eco-friendly methodologies, natural polymers like collagen and cellulose have been used to create efficient hydrogel adsorbents with a controllable crosslinking density and subsequent swelling ability and mechanical integrity. Recently, we have developed hydrogels based on collagen crosslinked with water-soluble copolymers bearing functional epoxy groups. This approach opens a wide range of options for the use of different functional copolymers, either natural or synthetic, with complementary functionalities to the epoxide reactive groups. Hereby, based on our previous knowledge on the crosslinking reaction of carboxyl or/and amine groups with epoxy groups after thermal treatment, we focus on the development of novel and low-cost composite hydrogel adsorbents with a high adsorption capacity through a simplified and water-based procedure. To this end, hydrogels composed of polyacrylic acid or gelatin and poly(sodium styrene sulfonate-co-glycidyl methacrylate) have been developed. These materials are proven as effective adsorbents of copper ions, while they exhibit a remarkable adsorption performance for uranyl ions.

Understanding additive degradation pathways and formation of Non-Intentionally Added Substances (NIAS) in polystyrene: impact on chemical structure and thermo-mechanical properties

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To meet the objectives set by the EU to recycle 50 % of packaging materials by 2025 and 30 % of recycled plastics in new materials, the scientific community will need to tackle the challenges associated with end-of-life plastic material gathering, sorting, cleaning, and recycling. One major issue is the presence of Non-Intentionally Added Substances (NIAS), of which their identities and quantities depend on the type of polymer, its application, object life, and thermo-mechanical history of processing. NIAS can result from the degradation of the polymer, additives, i.e., IAS (Intentionally Added Substances), used materials (up to 20-30 wt% of the material, including antioxidants, light stabilisers, flame retardants, etc.) and contaminants, or the interaction between these three categories. The presence of NIAS in recycled plastics raises concerns regarding the recyclability of plastics by increasing the presence of NIAS and impairing the properties of the material, human health, and environmental issues.

Studying NIAS is an analytical challenge due to the presence of numerous impurities in low quantities. This project takes a systemic approach to obtain an in-depth understanding of the interactions between polymers, IAS, and NIAS, focusing on virgin polystyrene mixed with known quantities of standard additives as model materials for a more rigorous approach. Thermoplastic was processed using a small-scale polymer mixer. From the recovered material, IAS (additives and impurities originally present in virgin polymer) and NIAS were extracted, identified, and quantified using various analytic methods: NMR, GC-FID, and GC-MS. The impacts of the process and the chemical interaction were also assessed by measuring the thermo-mechanical properties. This allowed us to identify and quantify several substances, which help us to understand how they are formed and how to adjust the recycling parameters to reduce or prevent their formation.

Optimizing 3D Printing Parameters for Enhancing Thermal Conductivity of Carbon Fiber-Filled Polymer Filaments

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Additive manufacturing, specifically fused filament fabrication (FFF) of polymers and composites, is being studied in various fields, such as aviation, where weight reduction (WR) is a key target. WR can be achieved by replacing metal with high-performance thermoplastic polymers like polyetherimide (PEI) and their composites, simultaneously providing greater design freedom. However, the inherent thermal insulating behavior of polymers can result in premature electronic device failure due to overheating. Thermally conductive fillers like carbon fibers (CFs) can be used to tackle overheating. Composite processing using FFF deserves a systematic study concerning printing parameters since the latter controls the particle distribution/dispersion and defect quantity as a porosity fraction and, hence, thermal conductivity. The current research outlines the effects of the printing parameters on the structure and properties of ULTHEM 1010 PEI and PEI-CF filaments. We identified a set of 3D printing methods that optimized the thermal conductivity of the composites. This discovery is explored through a thorough structural characterization and analysis. The results demonstrate the potential for utilizing 3D-printed PEI-CF in applications demanding heat dissipation functionality.

A bioderived CO2-responsive rigid foam as an alternative to expanded polystyrene

Daniel Barker[1]

[1] *Queen's University*

Expanded polystyrene (EPS) is neither green nor sustainable; it is derived from petroleum-based products and uses organic solvents as blowing agents, which have many environmental, health, and safety issues. EPS is one of the most common plastics around the world because of its use in packaging and insulation. However, EPS is often not recycled; when it is, it cannot be converted back into EPS. Although it is very damaging to the environment, it is still a widely accepted material because of its excellent thermal and structural properties. There is, therefore, a need for a sustainable alternative material that performs similarly to EPS while being easily recycled and reformed into new expanded foam materials.

Natural monomers like vanillin provide a route to bioderived styrene analogs with added functionalities. A helpful functionality that solves multiple problems with EPS production and recycling is CO2 responsiveness. CO2-responsive materials can reversibly switch between two properties when in the presence or absence of CO2 and water. Adding a CO2-responsive moiety to this bioderived styrene analog allows the polymer to be dissolved in carbonated water but precipitated when CO2 is removed. A carbonated polymer solution can be blown into a foam shape with similar properties to EPS using the rapid evaporation of water and CO2 as the blowing agent rather than organic solvents like in traditional EPS manufacturing. A CO2-responsive foam provides a simple recycling method for a material that is traditionally not recycled at all.

The work presented will describe the synthesis of a new bioderived CO2-responsive rigid foam. Polymer properties were analyzed and compared against commercial EPS. The rigid foam was recycled by dissolution in carbonated water and re-expanded into a new foam. This new, bioderived, CO2-responsive rigid foam addresses many issues found in EPS while demonstrating a similar performance and an improved recyclability.

S4. Special Polymers

chaired by Andrea Dorigato

Invited Speaker Sylvain CAILLOL

A journey around circularity in polymers, from renewable resources to recycling

Sylvain CAILLOL

[1] *Institut Charles Gerhardt, Montpellier University, CNRS, France*

Recent years have witnessed an increasing demand for environmentally friendly materials, particularly for polyurethanes (PU)s, which correspond to 6th polymer in the world with an annual production close to 20Mt. We have synthesized biobased polymers from renewable resources, particularly natural phenols, following a platform approach and convergent functionalization routes. Furthermore, in order to reduce the environmental impact, we have also proposed to replace some harmful substances and additives by less harmful monomers. Hence, we have proposed substitution of BPA in epoxy networks, and regarding PUs, we have developed a platform approach for the synthesis of non-isocyanates PUs. We have thoroughly investigated the reactivity, the interest and limits of this reaction leading to polyhydroxyurethanes (PHU)s, and particularly to hybrid PHUs. We have also designed self-healing polymers and coatings to improve the lifespan of polymers. In order to consider the full life cycle of materials, we also studied the recycling of thermosetting polymers especially by the synthesis of vitrimers.

3D/4D-Printed Polyoxazoline Hydrogels

Brossier thomas[1], Benkhaled Belkacem Tarek[2], Volpi Gael[1], Blanquer Sébastien[2], Vincent Lapinte[2]

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Soft materials such as hydrogels have many applications, mainly in the biomedical field with lenses, dressings, tissue engineering, etc. A recent trend has appeared with the printing of polymeric resins to build sophisticated hydrogel materials, highly porous or with eccentric morphologies, allowing the design of nanorobots or actuators for applications other than medicine. The hydrogels employed water-soluble polymers including poly(ethylene oxide) (PEO), poly(vinyl alcohol) (PVA), and poly(vinyl pyrrolidone) (PVP). A promising family of polymers is poly(2-alkyl-2-oxazoline) (POx) because they are (bio)compatible and hemocompatible, and they employ versatile chemistry.

Herein, polyoxazoline hydrogels were elaborated, layer-by-layer, using additive manufacturing–stereolithography (SLA) to build well-defined multicentrimetric samples, which were sometimes highly porous. In the last case, the observed cell proliferation promises the use of this class of polymers as bioinks after its cytocompatibility with the viability of encapsulated cells is checked. This study was extended to thermosensitive POx resins using poly(2-isopropyl-2-oxazoline) as alternatives to PNIPAM for 4D printing. Noteworthy contraction/extension morphings were measured at certain temperatures, later offering various motions and applications to actuator building.

Sustainable High-Performance Self-Catalyzed Epoxy–Amine Vitrimers

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Since 2011, vitrimers have gained popularity as a new class of cross-linked polymers that blend the benefits of thermosets (high mechanical performance and dimensional stability) and thermoplastics (repairability, reprocessability, and recyclability). Their reprocessability is mainly governed by reversible bond-exchange mechanisms based on various reactions such as transesterification (TER), transcarbamoylation, transimination, and disulfide metathesis [1]. Their sustainability is governed by their reusage and recycling, thus leading to waste reduction and efficient energy consumption. Today, the majority of TER-based vitrimers require the addition of a liquid catalyst in their composition, while the others commonly show too-low glass transition and reshaping temperatures. However, to be industrially applied, both the formulation and the properties of vitrimers should fulfil the following requirements. For formulation, monomers should be liquid at 22°C or show low melting points; the formulation should represent a liquid at T65°C and possess low viscosity h1000MPa/s; and its solidification should occur at T65°C. For vitrimers, Tg>60°C, storage modulus E'>1000MPa, relaxation time τ30min at temperatures 190°C, and a thermal stability with Tonset >200°C on air.

In this work, we suggest a novel type of high-performance vitrimers based on epoxy–amine chemistry [2]. By varying the nature of diamines and bis(epoxide)s, a series of unique vitrimers possessing outstanding properties (Tonset up to 260°C, Tg up to 145°C, τ in the range of 15-20 min at 180°C, and E' up to 3000MPa) was synthesized, making them attractive for composites and automotive industry. Finally, the tertiary amines, generated in situ during the reaction, serve as an internal catalyst for TER exchange, thus excluding the plasticizing and leaching problems associated with external catalyst utilization. This work was supported by the Luxembourg National Research Fund (FNR) via the SusPoCo (PRIDE21/16748260) project.

Synthesis and photoprinting of vegetable oil-based acrylate elastomers for energy harvesting structures

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The synthesis procedure of rapeseed oil acrylayes and epoxides is reported. The received resins can be blended with different biobased reactive diluents to prepare stable formulations. While the addition of low-content nanocellulose additives can provide a tool to control the viscosity of the resins, which are requested to be printed by light processing with a vat or syrenge 3D printers. The photorehology was used to characterize the viscosity changes during phtotocuring processing. The spatial cell-type structure of TENG devices has been printed for energy harvesting measurements. The thermal, mechanical, and thermomechanical performance of the developed and printed biopolymers was tested. The elastomeric performance and ductility of the biopolymers depend on the chosen chain extension by reactive diluents. It strongly impacts surface-charged generation and final energy harvesting performance. The accelerated weathering aging of the printed biopolymer structures showed a strong dependence on the resin formulation, while the biodegradation of the thermoset bioacrylates was evaluated, and the circularity of the approach used was also evaluated to recover the raw components. The TENG device performance can be compared with the fossil polymer analogs.

Multi-Technique Surface Analysis of Smart Copolymer Brush Coatings with Composition-Dependent Temperature-Response Mechanism

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Temperature-responsive polymer brush coatings constitute one of the most prospective materials for advanced biomedical applications [1]. The chemical nature of monomeric units that form brush chains specifies the molecular mechanism of the T-response, which, in turn, determines the transition in wettability, its extent, and its location with respect to the physiological range. A key strategy to adjust these features involves replacing the homopolymer with copolymer brushes.

Copolymer brush coatings P(OEGMA-co-AAm) [2], P(OEGMA-co-HEMA), and P(NIPAM-co-HEMA) [3] were prepared from di(ethylene glycol)methyl ether methacrylate) (OEGMA), acrylamide (AAm), 2-hydroxyethyl methacrylate (HEMA), and N-isopropylacrylamide (NIPAM). The molecular composition of the coatings was examined with X-ray Photoelectron Spectroscopy and Time-of-Flight Secondary Ion Mass Spectrometry. The T-response was studied as a function of composition for the wettability of coatings, the thickness of coatings immersed in water (examined with White Light Reflectance Spectroscopy), and the morphology imaged in air (with Atomic Force Microscopy). Furthermore, cell tests were performed to demonstrate that coatings can influence the morphology and adhesion of fibroblast cells with a change in temperature.

TOF-SIMS and XPS show copolymer composition that is homogeneous with depth in the brush coating. Hence, interactions between monomeric units of a different chemical nature can contribute to the molecular mechanism of the T-response, making it more complex than a simple transition between hydrated loose coils and hydrophobic collapsed chains. This leads to unexpected results, such as an enhanced response in wetting or its contradictory tendencies (UCST, LCST, blocked transition) switched by composition.

Double-Layer Solid Polymer Electrolyte Using PEO and PVDF-HFP for All-Solid-State Batteries

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Solid polymer electrolytes offer enhanced stability and energy density, making them promising for next-gen batteries compared to lithium-ion technology. Numerous studies have explored solid electrolytes using polyethylene oxide (PEO, (-CH2CH2O-)n) as the polymer base. However, PEO faces limitations with high-voltage cathode materials, exhibiting slow oxidation beyond 3.9V (vs. Li/Li+) [1]. This paper presents a stable double-layer solid polymer electrolyte (DLSPE) for high-voltage applications, using poly(vinylidene fluoride-co-hexafluoropropylene) (PVDF-HFP, (-CH2CF2-)x[-CF2CF(CF3)-]y)(cathode side) and PEO(anode side). For DLSPE synthesis, PEO and lithium bis(trifluoromethane-sulfonyl) imide salt (LiTFSI) were mixed at a 20:1 molar ratio, and PVDF-HFP and LiTFSI at a 2:1 weight ratio. After casting PEO/LiTFSI, a solution of LiTFSI (1g mL-1) in tetrahydrofuran (THF, C4H8O) solvent was homogenously sprayed for enhanced Li+ transference number and reduced interfacial contact resistance. Subsequently, PVDF-HFP/LiTFSI layers were cast on the cathode side polymer electrolyte to firmly bind two layers together via H-F hydrogen bonding. The DLSPE's effectiveness was demonstrated by a comparison of three samples, (PEO/LiTFSI):(PVDF-HFP/LiTFSI) with thickness ratios of 4:1, 2:1, and 1:1. The results show that the 2:1 ratio exhibited a 53% increase in Li+ transference number (0.49), outperforming the PEO single layer (0.32), and ion conductivity also improved over twofold at room temperature (30°C). Additionally, during 30 cycles at 0.1 C, the DLSPE showed electrochemical oxidation stability beyond 4.2V (vs. Li/Li+). In conclusion, the DLSPE design is expected to be applicable for high-voltage solid-state batteries.

Invited Speaker Prokopios Georgopanos

A way to be more efficient in polymer synthesis via the use of digital twins

Prokopios Georgopanos, Felix Kandelhard, Emil Pashayev, Juliane Schymura

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Polymers are present all around us and are employed in a wide range of daily activities. Laboratory polymer synthesis was frequently predicated on doing numerous trial experiments to determine the ideal process parameters and produce a polymer with the necessary characteristics (such as molecular weight and dispersity) for subsequent applications [1, 2]. Methods for establishing a more efficient process include reaction kinetic modeling and experiment design. It is now more important than ever to integrate experimental work with digitalization, or modeling and simulation, in order to become more efficient and sustainable while also consuming fewer raw materials and producing less waste.

Our research on digital twins in polymer synthesis (Figure 1) tackles the problem of being efficient and sustainable both in the laboratory and during the process of scaling up. Modeling and simulation have been used in a range of controlled polymerization techniques, from synthesis in continuous flow reactors [3], large batch reactors, as well as well as on laboratory-scale glass vials. Examples of these techniques include anionic polymerization and reversible addition-fragmentation chain transfer polymerization. [4-7]

Critical synthesis parameters, such as the concentration, the experimental temperature, the external heating applied, and the particulars of each process, such as the flow for continuous flow reactors or the type of stirrer used for batch reactors, could all be identified in every instance. By using the digital twin methodology, these factors were implemented into actual studies in the laboratory on both smaller and bigger scales. Crucial process variables that affect the process's safety were also taken into account. In every instance, this work indicates that there is a more effective way to produce polymers more efficiently and sustainably with the desired qualities

S5. Polymer (Nano)Composites

chaired by Gianmarco Griffini

Invited Speaker Tadahisa Iwata

Development and Marine Biodegradation of High-Performance Biodegradable Biomass Plastics

Tadahisa Iwata

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To establish a sustainable material production system and preserve the beautiful global environment forever, it is desirable to develop “biomass plastics” that are made from renewable biomass instead of petroleum, and “biodegradable plastics” that are completely degraded into carbon dioxide and water by enzymes secreted by microorganisms in the environment. This paper presents a series of studies on microbial polyesters and polysaccharide ester derivatives, including the synthesis of novel polymers, development of new processing techniques for high-performance films and fibers, elucidation of the relationship between structure and properties using synchrotron radiation, control of the rate of enzymatic degradation and environmental degradation. Furthermore, development of self-degradable aliphatic polyesters in sea-water environment by embedding lipases via melt extrusion will be presented. More recently, we succeeded to confirm microbial decomposition of representative biodegradable plastics (polyhydroxyalkanoates, biodegradable polyesters, and polysaccharide esters) at diverse deep-sea floor locations ranging in depth from 757 to 5552 m. The rate of degradation slowed with water depth. We analyzed the plastic-associated microbial communities by 16S rRNA gene amplicon sequencing and metagenomics. Several dominant microorganisms carried genes potentially encoding plastic-degrading enzymes such as polyhydroxyalkanoate depolymerases and cutinases/polyesterases. Our results confirm that biodegradable plastics can be degraded by the action of microorganisms on the deep-sea floor, although with much less efficiency than in coastal settings.

IL-Graphene oxide polyamide nanofiltration membranes: Preparation, performance and anti-fouling properties

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Membrane-based technologies play a key role in water purification and desalination, as they produce superior water quality and have a much smaller footprint compared with conventional water treatment technologies. In addition, membrane-based desalination technologies are inher-ently more energy efficient than thermal processes. In particular, thin-film composite (TFC) polyamide membranes consist the dominant technology for nanofiltration (NF) and reverse osmosis (RO) applications. Thin film nanocomposite (TFN) nanofiltration membranes were prepared via the surfactant-assembly interfacial polymerization (SARIP) between low concentrations of piperazine (PIP) and organic trimesoyl chloride (TMC) in the presence of neat or amide functionalized graphene oxide (GO) nanosheets on a porous support. This substrate is based on a pyridine containing aromatic polyether prepared via the phase inversion method. The prepared TFN membranes were studied by FT-IR, SEM, XPS, contact angle measurements and it was revealed that polyamide layers with rougher surfaces, increased hydrophilicity and higher cross-linking degrees were formed via embedding neat or amide functionalized GO nanosheets. Moreover, they exhibited a moderate water permeability and high salt rejections. In particular, the membrane containing the neat GO (TFNGO50) displayed a water permeability of 4.2 L m-2 h-1 bar-1 and excellent Na2SO4 rejection (98.8%) and MgSO4 rejection (99.5%). The NaCl rejection was 47.0%, among the highest reported in the literature. When the amide functionalized GO nanosheets were embedded in the PA layer, the water permeability was slightly improved while the salt rejections were significantly reduced compared to TFNGO50. Lastly, the incorporation of GO enhanced the anti-fouling properties of the prepared membranes due to increased hydrophilicity of the PA surface.

Reinforcement of GO Composites using Rigid and Flexible Crosslinkers

Richard Thompson, Purneema Kaur

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Crosslinkers are important for graphene oxide (GO) plates in filtration applications because they help to define and maintain the integrity of the nanoscale structure. Flow stress analysis of three different types of reinforced GO composites shows significant increases in the elastic modulus of the GO composites, compared to non-crosslinked GO. Crosslinkers were Octaammonium POSS (rigid cage), and two variants of a polymer crosslinker described elsewhere, https://doi.org/10.1016/j.desal.2019.114079. Crosslinking with either of the flexible polymers increases the yield stress of GO composites up to 20 times more than with the rigid crosslinker. The 'one pot' synthetic route employed in this work shows that levels of reinforcement are relatively insensitive to crosslinker concentration. The yield stress of all three types of composites increases sharply as a function of crosslinker concentration, reaching a broad plateau, before decreasing slightly. The decrease in reinforcement at high concentrations may be attributed to the saturation of available sites on GO nanosheets inhibiting crosslinking. Composites crosslinked in-situ included a significant fraction of water which was excluded under compression. Crosslinked GO samples under compression showed an increase in the elastic modulus consistent with an increase in the effective concentration of composite. GO-coated membranes showed high rejection (up to ~90%) of Rhodamine WT, and the resilience of these membranes was visibly improved with very low crosslinker loadings, 0.2% w/w with respect to the mass of GO.

Hydrated Graphene Oxide/Polymer Nanocomposites: A Computational Study

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Graphene-based nanocomposite membranes are considered among the most promising materials for nanofiltration purposes, including water purification and desalination. However, there are many challenges to address before commercialization becomes possible. Apart from issues related to thermal and mechanical stability, selectivity of the membranes to different pollutants appears to be crucial for the optimization of their performance. To this end, we studied graphene oxide (GO)-branched poly(ethyleneimine) (BPEI) hydrated mixtures by means of fully atomistic molecular dynamics simulations to assess the effects of the size of the polymers and the composition, in the morphology of the complexes; the energetics of the systems; and the dynamics of water and ions within the composites. The presence of the cationic polymers of both generations hindered the formation of stacked GO conformations, leading to a disordered porous structure. The smaller-in-size polymer was found to be more efficient in separating the GO flakes due to its more efficient packing. The variation of the relative content of the polymeric and the GO moieties provided indications for the existence of an optimal composition in which the interaction between the two components was more favorable, implying more stable structures. Both water diffusivity and ionic transport were enhanced in the systems with the larger-in-size branched polymers, particularly at lower polymer content, due to the higher availability of free volume for the respective moieties. The detail afforded by the present work provides new insight for the fabrication of BPEI/GO composites with controlled microstructure, enhanced stability, and adjustable water transport and ionic mobility.

Scaling Sustainability: Nanolignin-Enhanced PLA Functionalization through Reactive Extrusion

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Poly(lactic acid) (PLA) composites incorporating 0.5 wt% lignin or nanolignin were synthesized via in situ ring-opening polymerization (ROP) by reactive processing in a lab-scale torque rheometer.

Extensive characterization using SEM, DSC, mechanical tests, DPPH assays, and UV-Vis spectroscopy was performed. Additional analyses via GPC, ATR, and NMR determined the molecular weight, structure, and lactide content.

Both lignin and nanolignin reduced UV transmittance and improved antioxidant activity. Enhanced dispersion, crystallization, mechanical strength, and optical properties were observed, attributed to efficient dispersion through reactive processing and interfacial covalent bonds. Furthermore, nanolignin significantly improved cold crystallization and mechanical properties.

Given the reduced reaction time of 15 minutes obtained by adjusting the amount of catalyst, the in situ ROP was successfully scaled up by reactive extrusion (REX) in a pilot plant twin-screw extruder (TSE) at a production rate of 8 kg/h, yielding nanocomposite pellets suitable for the cast film extrusion process.

Funding was provided by the European Union’s Horizon 2020 Research and Innovation Program under Grant Agreement No. 952941 (BIOMAC Project).

Biocomposites based on PLA with silver nanoparticles

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Nowadays, urgent environmental problems concerning plastic waste can be solved using polymers of natural origin. Among them, PLA is occupying one of the leading positions, since its properties can be on a par with those of synthetic polymers. This work presents biocomposites based on PLA containing an antibacterial agent (silver nanoparticles). The systems were produced using a twin-screw extruder. In order to improve the PLA elasticity, a plasticizer poly(ethylene glycol) (PEG) of different molecular weights was used. The investigation of the mechanical and thermal properties showed that the introduction of stabilized silver nanoparticles led to their enhancement. The morphological tests via SEM revealed that the nanoparticles were uniformly distributed in the PLA matrix. The exploration of its antibacterial activity was performed using Gram-positive and Gram-negative bacteria. In addition, biodegradability tests using mold fungi from the All-Russian Collection of Microorganisms (VKM) were carried out. The obtained results showed that these materials are promising for producing biodegradable packaging.

This work was supported by the Russian Science Foundation, project no. 23-73-00076.

Small Additive, Big impact—Bio(nano)materials in the BIOMAC Open Innovation Test Bed

Annika Byrne

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To address global climate goals while reducing consumption and dependency on fossil resources, the European Sustainable BIObased nanoMAterials Community (BIOMAC) was established within the EU’s Horizon2020 framework. This community, organised as an open innovation test bed (OITB) of 29 core partners, cooperates closely to cover the entire value chain of bio(nano)materials—from biomass to final product. When it comes to polymers, the BIOMAC team provides a unique set of application expertise in native states as well as valorised with bio-nanocomponents such as nanocellulose, nanolignin and biochar. Industrial and academic clients may employ the OITB to address aspects of their bionanomaterial-based production processes or even revisit their entire value chain.

More enterprise than project: While founded as part of the Horizon framework, BIOMAC goes beyond a regular research project. The OITB is designed as a one-stop shop for clients wishing to scale up and improve their bio(nano)material products. Thoroughly validated with internal and external test cases from areas as diverse as agriculture, automotive, packaging, energy and functional textiles, BIOMAC will become self-sustained and accept clients at the end of 2024.

One SEP to coordinate them all: making complex value chains efficient and accessible is key to the OITB principle. Dealing with multistep product logistics and partnering networks in process chains is time consuming and has a negative impact on products' time to market, cost and sustainability. For BIOMAC, one single entry point (SEP) with representative rights thus serves as the client’s gateway to all of its test-bed services:

Seventeen pilot lines covering the value chain from feedstock to product;

Thre transversal service hubs for innovation and knowledge management, decision support tools, IP, exploitation and dissemination support.

The BIOMAC team now looks forward to the challenges and opportunities of supporting exciting bio(nano)material products for sustainable markets!

S5. Polymer (Nano)Composites (Part II)

chaired by Nadia Lotti

Invited Speaker Gianmarco Griffini

Lignin as a valuable tool for functional materials: coatings, composites and beyond

Gianmarco Griffini

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Lignin represents the most abundant naturally occurring source of aromatics on Earth. Currently, most of produced lignin is used as low-cost fuel for energy and heat recovery, while only a minor fraction is employed in low-value niche markets. Such limited range of applications calls for effective approaches to enhance its full utilization as renewable component in material platforms of increased commercial and technological interest.

Within this context, various approaches for lignin valorisation will be discussed in this contribution, demonstrating some novel pathways for its direct exploitation in high value-added multifunctional polymeric materials. In particular, different chemical derivatization strategies will be introduced based on the reaction of the hydroxyl groups present in lignin with suitable functional moieties, so as to obtain polymeric precursors that find application in the fields of bio-based coatings, composites and advanced manufacturing. Similarly, physical approaches relying on size reduction of lignin particles will be presented, leading to the formation of large surface-to-volume ratio functional nano-entities to be used as bio-based fillers in polymer-based nanocomposite materials.

Development of Lignin-Based Polyurethane Adhesives

Carlota Hernández, FernándezMaría del Pilar Carbonell Blasco, Víctor Manuel Serrano Martínez, Henoc Pérez Aguilar, Elena Orgilés Calpena

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Polyurethanes are one of the most widely used polymers today due to their versatility and properties. To obtain these polymers, a condensation reaction takes place using raw materials from fossil sources: polyols and isocyanates. Thus, the emission of greenhouse gases and the environmental impact associated with these polymers are very significant.

To reduce the carbon footprint of polyurethanes, more sustainable synthesis routes are being investigated. In this case, materials based on lignin, a biopolymer of natural origin present in plants, are used to develop reactive polyurethane hotmelt (HMPUR) adhesives to be used in the footwear industry.

HMPUR adhesives combine the characteristics of hotmelt adhesives with the chemistry of polyurethanes. These adhesives are synthetized from polyols that come from non-renewable sources, in this case, polypropylene glycol and polyadipate of 1,4-butanediol. However, there are several alternative ways to obtain polyurethane adhesives from renewable resources; in this case, lignin-based polyols were used to carry out the synthesis.

In the process performed, lignin-based polyols were used to synthesize HMPUR adhesives. To evaluate their properties, we started from a reference formulation developed by INESCOP where different percentages of polypropylene glycol were replaced by lignin-based polyols, using 4.4 -diphenylmethane diisocyanate (MDI) as isocyanate.

The influence of using lignin-based polyols on the final properties of the synthetized adhesives was analysed using different experimental techniques such as Thermogravimetric Analysis (TGA), Differential Scanning Calorimetry (DSC) or rheological analysis. In addition, the properties of the adhesives were evaluated by T-peel tests to determine whether they complied with the peel strength values required for footwear, as specified in the UNE-EN 15307:2007 standard.

Therefore, the development of reactive polyurethane hotmelt adhesives with lignin-based raw materials can be considered a technological and sustainable alternative to traditional adhesives.

Evaluating ultra-fine grinding for the continuous production of nanofibrillated cellulose

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Our research explores the modification of a Masuko Supermasscolloider for the continuous production of nanofibrillated cellulose (NFC), a sustainable and versatile nanomaterial derived from cellulose fibers. NFC finds applications in many sectors, ranging from packaging to food additives, hygiene, and absorbent products, but the economical production of large volumes of NFC with a minimal ecological footprint remains challenging.1, 2 Limitations in scaling up NFC production have prompted our efforts to transition from a traditional batch process to a system capable of the continuous mechanical milling of an aqueous suspension of cellulosic feedstock. This upgrade incorporates a pump-controlled circulating system, an inline viscosimeter for real-time viscosity monitoring, and a power meter to assess energy consumption.

In this study, we aim to better understand the composition–processing–property relations associated with NFC production. Specifically, we investigate the effects of process conditions (including gap sizes and milling times) and feedstock type (ranging from byproducts of the wood industry to commercial microfibrillated cellulose) on the final properties of the obtained NFC. A range of analytical techniques have been used to assess the size distribution, crystallinity, specific surface area, and morphology of the obtained NFC. In parallel, attention has been paid to factors affecting the sustainability of the production process (including solid content and power consumption). Overall, this study provides insights into the applicability of continuous ultra-fine grinding for the scalable production of high-quality nanofibrillated cellulose.

Rheological Properties of HPP Starch-based Hydrogels Loaded with Bioactive Compounds

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Natural hydrogels based on renewable and inexpensive sources, such as starch, represent an interesting group of biopolymeric materials with a wide range of applications in food and non-food sectors. Starch-based hydrogels produced by high-pressure technologies (HPPs) can be used as smart carriers for encapsulating natural bioactive compounds derived from agrifood byproducts. This study aimed to investigate the rheological properties of rice starch HPP hydrogels loaded with green tea extract and demonstrate the effect of extract additions on network strength. Rice starch (20% w/w) and green tea extract (2% w/w), suspended in distilled water, were treated with HPPs to process the conditions that enable starch gelatinization, namely 600 MPa for 15 min at room temperature. Rheological measurements (flow curves, frequency sweep tests, and stress sweep tests) were carried out to assess the mechanical properties of the samples. Loaded hydrogels retained the typical creamy appearance of rice starch HPP hydrogels with low flow resistance, suitable for the design of innovative products. The results showed that the mechanical profiles of HPP hydrogels after extract addition were typical of well-structured cross-linked gel networks. In the perspective of industrial exploitation of HPP starch-based hydrogels, an investigation of the stability of HPP hydrogels loaded with bioactive compounds with time and environmental conditions is needed.

Edible chitosan food packages containing a deep eutectic solvent and olive leaf extract

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The two largest world plastic markets, based on the data from 2021, are packaging, building, and construction. Almost 44% of the world's plastic production (390.7Mt in 2021) is devoted to packaging application, while only ca. 1.5% of produced plastics are bio-based materials and 8.3% of plastics are obtained from post-consumer recycled substrates. The global awareness of plastic pollution has led to the development of environmentally friendly technologies for food packaging, such as biodegradable polymers, edible films and coatings, and active or smart packaging [1].

One of the most common ways to apply natural polymers in food packaging is represented by edible coatings. In this food packaging method, the polymer constitutes the outer thin surface of the food and comprises a protective layer against oxygen, water vapor, microbes, etc. It can also play a role of support for the valuable active additives, such as antimicrobials, antioxidants, and plasticizers, strongly affecting and extending the shelf-life of the packaged food. Among the polymers tested for food packaging purposes, polysaccharides (starch, cellulose, chitin, chitosan), proteins, and their derivatives can be found.

In the presented research, new biopolymer films based on chitosan containing a novel plasticizer (a mixture of citric acid and choline chloride, i.e., a deep eutectic mixture, DES) and an extract from olive leaves (OLE) were developed. The impact of the OLE on the mechanical properties and antimicrobial and antioxidant activity was assessed. Moreover, the effect of the OLE content on the overall migration in three different food simulants (10% ethanol, 3% acetic acid, and isooctane) was evaluated. The migration process was discussed in the context of the swelling phenomenon, the film's molecular structure, the possible crosslinking process, and the hydrophilic/hydrophobic nature of the additive and the external medium.

[1] "Plastics – the Facts 2022", https://plasticseurope.org/knowledge-hub/plastics-the-facts-2022/ [access: 17.02.2024]

S6. Polymer Applications

chaired by Nathanaël Guigo

Invited Speaker Nadia Lotti

Ad hoc chemical designed furan-based polymers for sustainable monomaterial food packaging

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Although plastic packaging is often considered one of the main responsible of plastics environmental impact, in case of food packaging some valuable effects must be considered. Indeed, packages protect food, extending its shelf life and reducing food waste, which is one of the main plagues of the modern era (Brennan et al. 2021). Another current concern is the accumulation of wastes in the environment, which is pushing governments and society towards an efficient management of plastic and to the transition towards the circular economy. However, recycling is not always a cost-effective or a feasible alternative, due to the lack of proper recycling policies (in developing countries) and, in case of food packaging, to organic matter contamination and multilayer structure. Thus, biodegradable plastics represent the only alternative to landfill. In this scenario, 2,5-furandicarboxylic acid (FDCA) can be consiered an interesting chemical building block to realize sustainable mono-material packaging, with excellent mechanical and gas barrier properties. Of particular interest, the eco-design of novel furan-based polyesters for the realization of flexible films. It has been indeed demonstrated that flexible packaging is more sustainable than rigid one and very effective in protecting food with the minimum amount of material and waste, helping to reduce food waste by offering optimum protection (Flexible Packaging Europe, 2021).

This contribution aims to present an overview of the most important results obtained by the research group coordinated by me which have allowed the extrapolation of important property-structure correlations with particular attention to functional properties, i.e. mechanical properties and gas barrier properties.

Ultrasound-Controlled Protein-Based Films and Nanofibers for Biomedical and Sustainable Applications

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There has been significant progress in the development of protein-based films and nanofiber materials that are enhanced by ultrasound assistance. This technology allows for the physical manipulation of biocompatible and environmentally friendly protein biopolymer materials in a highly efficient, repeatable, and controlled manner.

Through our recent comprehensive studies, we have demonstrated the ability of ultrasound to regulate the structure of silk biopolymers during the assembly phase, resulting in the acquisition of desirable properties for protein-based materials. Notably, our studies have shown that ultrasound-regulated silk films exhibit a heightened thermal stability, an improved biocompatibility, an enhanced breathability, and a favorable mechanical strength and flexibility. Additionally, by altering the ultrasound parameters, we have successfully adjusted the rate of enzymatic degradation and biological response (including cell growth and proliferation) of silk protein materials. Moreover, the application of ultrasound-assisted air-jet spinning has facilitated the creation of silk-soy protein nanofibrous materials with customizable properties and a remarkable biocompatibility. These advancements hold vast potential in the fields of wound dressings and drug-carrying systems.

To ensure accurate characterization of the ultrasound-assisted protein-based materials, we employed a range of techniques, such as Fourier transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), scanning electron microscopy (SEM), differential scanning calorimetry (DSC), thermogravimetric (TG) analysis, dynamic mechanical analysis (DMA), gas permeability measurements, water contact angle measurements, enzymatic degradation assays, and cytotoxicity assays. The comprehensive examination of these materials through diverse analytical tools highlights their immense promise in fostering sustainable development and advancing healthcare outcomes.

In conclusion, the use of ultrasound-assisted technology in biopolymer-based materials showcases a remarkable ability to manipulate their structure and properties effectively. With its tremendous efficiency, absence of chemical intervention, and potential for reusability, ultrasound holds substantial potential for sustainable development and improved healthcare.

Investigation of the impact of single and double filtration systems on post-consumer PE-LD film waste

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Due to the diversity of plastic film waste streams available on the market and the associated variety of contaminants' size and amount, the use of melt filtration is necessary. Currently, single and double filtration systems are the state of the art in the plastic recycling industry, and their use depends on the application of the produced post-consumer recyclate (PCR). Using PCR for thin-walled films demands small contamination sizes, which are easier to reach using a second filtration step. In the case of relatively clean post-consumer input materials, it must be investigated whether the additional load from the second filter on the material has a counterproductive effect and whether single filtration would be sufficient. For this paper, PE-LD film waste stemming from a separate post-consumer collection in Austria was processed using an industrial-sized recycling machine with different combinations of filter sizes and systems. Melt flow rate (MFR), ash content, and oxidation temperature measurements, as well as optical contaminant detection, were performed to investigate the influence of single and double filtration systems. The investigation showed that even though the contamination amount and size were reduced, the second filter had a negative effect on specific properties.

Phantom surface dose assessment with application of PLA (Polylactic Acid) and PBT (Polybutylene Terephthalate) elastomer 3D-printed boluses for high-energy photon radiation therapy of the nasal cavity.

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When a bolus is applied to a patient's irregular skin surface, air gaps may occur between the skin and the bolus, reducing the dose at the skin surface and causing inaccurate dose delivery to the patient. In this study, we self-made various 3D-printed boluses using PLA, which is commonly used for 3D printing, and PBT elastomer (PBT-E), which has flexible properties, and applied them to phantoms to target the nasal cavity, where the skin surface is highly curved. We analyzed the volume of air gaps caused by the application of the bolus material to evaluate the reproducibility of positioning and to analyze the error between the planned and measured dose on the phantom surface. We measured the dose depth of each type of bolus using a linear accelerator to analyze its physical characteristics. CT images were acquired by applying different types of boluses to the nasal cavity of the phantom, and CBCT images were acquired after 20 phantom settings to analyze the air gap. In this study, we were able to increase the surface dose by an average of 12.6% by applying boluses when the tumor was located on the surface. The Wilcoxon signed-rank test analysis of planned dose and measured surface dose showed a statistically significant ($p < 0.05$) dose difference for conventional boluses. We concluded that patient-specific 3D-printed boluses reduce the incidence of air gaps and that the more flexible the material, the greater the effect. We expect that 3D-printed boluses made of flexible materials that are easy to apply to the patient, have high positional reproducibility, and have an easy-to-maintain shape will be best suited for accurate dose delivery.

Innovative polyester binders for the next-generation lithium-ion battery electrodes

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We introduce a series of novel polymer binders for battery electrodes, based on polyesters derived from renewable feedstock. The performance of the battery electrodes such as high capacity silicon (Si) anodes for advanced li-ion batteries, relies on the design of the polymer binder integrated within the electrode. Finding a high-performance and sustainable solution for anodes in lithium-ion batteries with a substantial Si content remains a persistent challenge. We demonstrate that the in-situ cross-linked networks of a range of green polyesters can perform as superior binders for Si anodes in li-ion batteries. The innovative binders deliver outstanding battery performance, produced from renewable feedstock, adopting water-based or solvent-free fabrication processes, and enabling easy removal and electrode recycling at the end of the battery's life. The presence of the polar groups in the polymer chain promotes Li ion solvation and transport, resulting in a high ionic conductivity of the binder. Moreover, the inherent flexibility in the formulations of the polyesters enables fine-tuning of properties such as adhesion, elasticity, and self-healing, all of which can be customized to improve the batterie's performance. The utilization of low-value feedstock from bio-refineries in synthesizing the polyesters renders them potentially appealing for various applications beyond batteries.

We will present the result on the formulation, synthesis, chemical and thermomechanical analysis of the polyesters, and additionally, the performance evaluation of the binder in batteries. The performance of the polyester binder, when tested with the Si anode in li-ion cells, appears to be superior to that of the benchmark binders across several tested polyester binder formulations. The application of the investigated binders extends beyond Si anodes to include other emerging electrodes for next generation batteries.

Novel polylactide/poly(pentamethylene furanoate) blends for bioderived packaging films with multifunctional properties

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Polylactide (PLA) is a promising biopolymer from renewable resources, but its brittleness and poor gas barrier properties limit its flexible packaging applications. Therefore, in this work, PLA was blended with a biobased rubbery poly(pentamethylene furanoate) (PPeF), acting as a toughening agent, and a commercial epoxy-functionalized compatibilizer was added to improve the interfacial interactions. The effect of PPeF loading (1-30 wt%) on the morphology, mechanical properties, oxygen permeability, and degradability in compost was characterized. All blends displayed a sea–island morphology with refined PPeF domains upon compatibilization. Incorporating PPeF induced tensile ductility enhancements from 5% strain at break for neat PLA up to 200% for the blend with 30 wt% PPeF, accompanied by progressive stiffness and strength declines. Through the application of the essential work of fracture (EWF) approach to the prepared films, the specific essential work of fracture (we) was seen to increase from 6.2 to 40.0 kJ/m2 with rising PPeF contents, confirming its effectiveness as a toughness enhancer. PPeF contributed to improving the UV and gas barrier properties of PLA. Moreover, compost burial tests also revealed 26% weight loss of PPeF after 60 days, proving its biodegradability.

Multi-stimuli-Controlled Properties of Biobased Benzoxazine–Urethane Copolymers with Multiple Shape Memory Effects

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Biobased shape memory polymers (SMPs) were developed from copolymerization of bio-based benzoxazine (BZ) monomers and urethane prepolymer (PU-prepolymer), both derived from biobased raw materials. Polybenzoxazine is known to act as an effective rigid molecular segment in shape memory polymer formulation, whereas the soft molecular segments in this work are based on flexible polyurethane. The biobased BZ monomer (V-fa monomer) was synthesized through a Mannich condensation reaction using vanillin, paraformaldehyde, and furfurylamine, whereas the biobased PU-prepolymer was prepared from reacting palm oil polyol (MW = 1400 Da) and toluene diisocyanate (TDI). The curing behaviors of poly(V-fa/Urethane), with a mass ratio of 50/50, were examined using differential scanning calorimetry, and the obtained structure of the resulting poly(V-fa/Urethane) copolymer was confirmed via Fourier transform infrared spectroscopy. The V-fa/Urethane copolymers with weight ratios of 70/30, 60/40, 50/50 and 40/60 were observed to exhibit shape memory behaviors induced by heat as well as near-infrared laser irradiation (808 nm). The poly(V-fa/Urethane) copolymer, specifically with a mass ratio of 50/50, demonstrated an outstanding shape memory performance. It reveals a remarkably high shape fixity to retain the temporary shape up to 90%, achieves 99% shape recovery, and exhibits a recovery time of 25 s. The shape memory behaviors were further enhanced with the addition of 3wt% graphene nanoplatelets (GNPs), leading to an improvement in the shape fixity value to 94% and reducing the shape recovery time value to 16 s. Finally, our findings also reveal that poly(V-fa/Urethane) reinforced with GNPs possesses favorable characteristics for applications as multiple SMPs.

S6. Polymer Applications (Part II)

chaired by Evangelos Karavas

Invited Speaker Hermis Iatrou

A novel mechanism of nanostructured materials to treat cancer, cardiovascular, kidney and autoimmune diseases

Hermis Iatrou[1], Foteini Arfara[2], Pandora Thimi[2], Iro Kyroglou[2], Dimitrios Skourtis[2], Kostantinos Dimas[3], Dimitrios Vlassopoulos[4, 5], Iordanis Mourouzis[6]

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Novel, multifunctional nanoparticles and hydrogels that exhibits a unique set of properties for the effective treatment of cancer are presented. The materials are comprised of polypeptidic and polyethylene oxide polymers that are a non-cytotoxic polymer. The amphiphilic hybrid materials assemble in aqueous media to form micelles or vesicles, comprised of an outer hydrophilic corona, and a pH- and redox- responsive hydrophobic layer. Dynamic Light Scattering, Static Light Scattering and Transmission Electron Microscopy were utilized to obtain the structure of the NPs. The ability of the synthesized polymers to mimic natural proteins was examined by Circular Dichroism, while the study of zeta potential revealed the “stealth” properties of NPs. The anticancer drug doxorubicin (DOX) was efficiently encapsulated in the hydrophobic core of the nanostructures and released under conditions that simulate the healthy and cancer tissue environment. It was found that the topology of PCys significantly altered the structure as well as the release profile of the NPs. Finally, in vitro cytotoxicity assay of the DOX-loaded NPs against three different breast cancer cell lines showed that the nanocarriers exhibited better activity as compared to the free drug and commercially available chemotherapeutics due to the novel targeting mechanism, rendering these novel NPs very promising materials for drug delivery applications.

Hybrid-polypeptidic materials formed injectable in situ forming quickly self-healing hydrogels, responsive to alteration of pH and increase of temperature. The connection between the alteration of secondary structure of the polypeptides with the viscoelastic behavior was revealed by means of Rheology and Circular Dichroism. Small-Angle Neutron Scattering and Scanning Electron Microscopy were employed to shed light to the structure of the polymers and how it affects their rheological properties. The results suggest that these biomaterials have the potential to be used in a number of bioapplications like drug delivery.

New bio-based, biocompatible, and biodegradable (co)polymers to develop functional (nano)capsules with antimicrobial properties

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Infectious diseases pose a significant threat to both human health and the global economy, causing more than 20 % of deaths worldwide.

It is very important to develop new antimicrobial (AM) additives that can be included in coatings for textiles (including those that come into direct contact with human skin, such as bed sheets, insoles for shoes, etc.), various plastic and metal surfaces, walls, etc., in hospitals, schools, fitness centres, etc.

The development of bio-based (nano)capsules (NCs) with AM activity can satisfy the need for antimicrobial additives, and realize this with the help of bio-based, biocompatible, and biodegradable materials. Various essential oils were used as the active core as renewable materials and as materials with well-known AM properties.

The encapsulation of active materials in polymer capsules can protect them from degradation and prolong their activity. Various bio-based, biocompatible, and biodegradable (also newly developed) (co)polymers, such as (co)polyesters and chemical modified proteins, were tested as shell building materials. The "design-by-synthesis" of (co)polymer chains with the incorporation of new functional side groups can improve the encapsulation efficiency and release profile of AM substances. The synthesis/modification of polyesters/proteins is carried out using bio-based compounds in green solvents and at ambient conditions.

Due to the full biodegradability of NCs, which can be used in all of the above-mentioned applications, abrasion during washing, wearing, or decomposition by weathering produces polyester/protein microplastics that are fully biodegradable and do not remain in the soil or water for long periods of time.

The synthesised NCs were tested for their AM activity and the most promising NCs are selected for antimicrobial applications in coatings.

Electrospun Mats Based on Furanoate Polyesters: Processing, Characterization, and Performance for Controlled Drug Releas

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Sustainable and bioderived furanoate polyesters are emerging as promising substitutes for petrochemical-derived polyesters in diverse applications including packaging, textiles, and biomedicine. This work presents the successful production, for the first time, of electrospun nanofibrous mats using two furan-based polyesters: poly(butylene 2,5-furanoate) (PBF) and poly(pentamethylene 2,5-furanoate) (PPeF). While PBF and PPeF have very similar chemical structures, they exhibit remarkably different physical and mechanical properties. The feasibility of electrospinning these polymers into non-woven mats was systematically investigated by optimizing polymer solubility, solution viscosity and concentration, spinning rate, and applied voltage. A detailed morphological analysis using field-emission scanning electron microscopy identified optimal processing conditions for generating electrospun PBF and PPeF mats.

Subsequently, the optimized mats were characterized from a thermal and mechanical point of view, and their drug delivery potential was also assessed. In fact, controllable drug delivery through nanostructured systems can enhance treatment efficacy, safety, compliance, and quality of life. While traditional methods have bioavailability and release limitations, biobased nanocarriers like PBF and PPeF nanofibers offer high loading efficiency, precise distribution, and tunable release kinetics. This study evaluated the potential of electrospun PBF and PPeF mats to administer anti-inflammatory dexamethasone treatments, using UV-Vis spectroscopy to monitor release over 7 days. Thermal and mechanical properties were characterized before and after the conditioning of mats in physiological conditions, providing insights into material performance in implant applications. The results demonstrated different mechanical properties for PBF versus PPeF after conditioning, biocompatibility for both polymers, fibroblast adhesion to mats for both polymers, and sustained dexamethasone release. Overall, this work establishes PBF and PPeF electrospun mats as promising biobased platforms for advanced drug delivery systems and disease treatment.

Leucine-Based Pseudo-Proteins as Perspective Biomaterials for Skin Wound Dressings

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Recently, we demonstrated the excellent cell-friendly/cell-supporting properties of 2D films prepared from a relatively new family of biomimetics—Leucine-Based Pseudo-Proteins (LPPs). When settled onto the surface of three different artificial LPP films, primary mouse skin fibroblast and murine monocyte/macrophage RAW 264.7 cells demonstrated prominent adhesion and perfect cell spreading, as revealed via a Scanning Electron Microscopy (SEM) analysis. Simultaneous analysis of actin cytoskeleton organization and distribution via Laser Scanning Microscopy revealed a high number of focal adhesions and motility-associated structures in the case of both cell types. A certain stimulation of cell proliferation was detected for all three LPPs, and two of them promoted macrophage migration. Thus, our data suggest that the LPPs used in this study can be considered as potential cell-friendly scaffolding materials.

In the next stage of our research, based on the previous results, we decided to investigate whether the abovementioned LPPs can be considered as possible biomaterials for skin wound dressings. We performed experiments using an in vitro wound-closure model. Wound closure is a complex process, which requires not only extensive proliferation of skin cells, but also a careful regulation of the process by immune cells. The interplay between macrophages and fibroblasts is crucial for successful skin closure. These two types of cells communicate with each other via secreted cytokines. Our data have shown that all three LPPs promote extensive wound closure compared to the control. Also, it has been detected that all three types of LPPs modulate the profile of secreted cytokines in the case of both skin fibroblasts and macrophages. Our data suggest that the investigated LPPs possess a certain immunomodulatory action, as well as a stimulatory effect on fibroblast proliferation and macrophage migration. Overall, our in vitro experiments demonstrated that the studied LPPs promote wound closure and can be considered as perspective biomaterials for skin wound dressings.

Understanding Molecular Pathway from Monomer via Polymer/Biopolymer to Degradation Products using simple HPLC-System equipped with newest Chromatography Tools

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Since liquid chromatography was invented 1850 by Prof. Runge in Oranienburg this technology has continued to several innovations. Saccharides, oligosaccharides for vacination process, polysaccharides like chitosans, important in pharmaceutical applications must get purified, analysed and determined to get a product that is economic and safe. Ligand exchange, ion exclusion and size exclusion chromatography (SEC) respective gel permeation chromatography (GPC) are tools for analysation and determination, in special cases also for purification.

GPC respective SEC has been all well established method for polymer characterisation. Its primary and oftentimes only use is to measure the molecular weight and to qualitatively compare different polymer samples. There are still 2 challenges - 1: molecular weight, size, determination

However, adding a viscometer and light scattering detector to a GPC creates new and challenging dimensions in polymer characterization. Tripel Detection and especially Volume Matched In situ Tripel Detection yields data of unsurpassed correctness. Its not only molecular weight, size (radius of gyration Rg) and structure (branching) but also enter the copolymer analysis.

Challenge 2 – pure SEC method for chitosans:

Size Exclusion Chromatography (SEC) analysis of polycations like chitosan is not easy to handle and this is further compounded by less the optimum reliability of the methods. Solution: Through a complete re-invention of the stationary SEC phase, it is now possible to access an entire line of SEC columns to carryout analysis of polyaminic/cationic sugars like chitosan. This new SEC line covers the range from oligomers up to 20 million Daltons with high recovery. This novel SEC packing media shows superior performance with high recovery rates even at low salt concentrations, and for even very large molecular sizes. High resolution is obtained from small size molecule up to + 20 million Dalton. The SEC media is even suitable for systems where polycation blocks are combined with polyanion (e.g. carboxylic) blocks from partial oxidized product.

Biodegradable Microparticles of Polydepsipeptide and Polylactic Acid for Drug Delivery Applications

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Polydepsipeptides (PDPs) have recently regained interest as biocompatible and biodegradable polymers used for biomedical applications. PDPs contain alternated amide and ester bonds, combining the mechanical properties of polyamides with the degradation capacities of polyesters. They are highly attractive polymers for drug delivery, owing to their slow degradation rate (several weeks) in aqueous environments. Depending on the amino acid used to synthesize the starting monomer, i.e., morpholine-2,5-diones (MDOs), PDPs' mechanical and biodegradable properties can be tuned to fit the requirements of a desired application. This study aims to synthesize phenylalanine-based PDP's (PDP(Phe)) and to subsequently use microparticles as drug delivery systems. Since MDOs are not commercially available and are usually obtained via a two-step synthetic pathway, a rapid and solvent-free synthesis has been developed via mechanochemistry for the first step. PDPs were then synthesized using the organocatalyzed ring-opening polymerization (ROP) of MDOs with DBU and thiourea as catalysts. To optimize the formulation and to achieve precise molecular weight control, various amounts of the thiourea co-catalyst were tested. A range of PDP(Phe)s with average molecular weights between 2.5 and 10 kg.mol-1 were produced with narrow distributions (Đ = 1.1−1.3). Because the introduction of poly(lactic acid) (PLA) units into the PDP chains represents a very interesting solution to modulate the degradability of the polymer, the ROP of MDO and lactide has also been studied and the P(MD-co-LAs) of different average molecular weights have been obtained. Microparticles of PDP(Phe) and P(MD-co-LA) were prepared using an emulsion solvent evaporation technique with microfluidics. The size, morphology, and texture were analyzed using SEM. Microspheres with diameters in the 10-100 µm range were obtained, allowing for the use of conventional needles for various administrations. Microparticle degradation and toxicity have also been studied. These microparticles can be used as drug delivery systems thanks to their loading active pharmaceutical ingredients.

4D printing of soft shape-morphing alginate hydrogels as biomedical devices

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Additive manufacturing plays a crucial role in the elaboration of patient-specific medical devices. For soft tissue implants, it is crucial to have a soft biocompatible device capable of adapting to a typical anatomy under non-intrusive surgery. To address this challenge, we have developed 4D printed alginate devices that display significant programmed shape deformation in the presence and absence of ions.

Alginate-based devices were fabricated by Digital Light Processing (DLP) technology and their response to environmental stimuli in terms of shape deformation was examined. The analysis included assessing volumetric deformations under various crosslinking conditions within both PBS and CaCl2 media, focusing on both chemical and dual-crosslinked networks.

The influence of the crosslink degree on the mechanical properties was evaluated by compression testing and rheological measurements. Improvement of mechanical resistance have been significantly highlighted by incorporating Pluronic blocks at various concentrations into the network, without compromising the shape morphing performance.

Several geometrical devices have been manufactured (porous scaffold, tubular shape representative for a tube-like cavity, wound healing devices…). The devices were engineered to shrink in CaCl2 solution and expand in physiological media to reveal the programmed anisotropic architecture, perfectly fitting a specific anatomical cavity. The device's compatibility with biological systems in the presence of calcium was established.

Additionally, apart from its programmed shape deformation capabilities, the specific swelling effect of the device was also used as a local short-term drug delivery for an anti-inflammatory drug loaded within the dual-crosslinked structure.

In summary, the alginate's ability to complex with calcium ions was used as an external stimulus enabling shape deformation for 4D printed medical devices intended for implantation. In addition, the device serves as a carrier for a local short-term release of anti-inflammatory medication.

Novel biobased poly(lactic acid)-co-poly(ethylene azelate) (PLA-co-PEAz) copolyesters as potential substrates for printing electronics (PE)

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The accumulation of fossil-based, non-biodegradable and non-recyclable polymers to the environment constitutes one of the most severe issue the modern society is facing, and it estimated that by 2050 the generated plastic wastes will surpass 10 billion tons [1]. Among the polymers from renewable resources, poly(lactic acid) (PLA) has gained the interest of the academic community and industrial factors due to its comparable thermal properties with the conventional fossil-based polymers along with its green up-scale production [2]. The goal of the present work is to produce non-toxic, eco-friendly polymers for the replacement of the fossil-based materials used for printing electronics (PE) where the electronic wastes can be considered the fastest growing solid waste stream worldwide [3].

To tune the properties of PLA, copolymerization was selected as an effective method to synthesize novel biobased copolyesters based on poly(ethylene azelate) (PEAz) for flexible PE. So PLA-co-PEAz copolyesters were synthesized via ring opening polymerization (ROP) of l-lactide. The mechanical performance of the copolyesters were investigated in detail and all copolyesters exhibited enhanced elongation with high young's modulus values, meaning that the copolymers were rather tough and flexible materials concurrently. Initially, to evaluate their performance for printing electronics, PLA blown and cast films were developed and different inks were printed on top of each sample with promising results. To enhance the performance of the PLA sheets, annealing and biaxial stretching experiments were performed.

S7. Environmental Aspects - Recycling, Upcycling and Reuse

chaired by Dimitra Lambropoulou

Keynote Speaker Damià Barceló

Microplastics in Terrestrial and Aquatic Environments: Green Analytical Protocols, Vectors of Pharmaceuticals and Risk to Biota

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Plastic pollution is nowadays a global and ubiquitous problem everywhere: marine environment, sand beaches, wastewaters, surface waters, soils, sludges, sediments, biota, food and air. Plastic is part of our daily life and worldwide we use 4 trillion plastic bags annually and 1 million plastic bottles every minute. Microplastics (MPs) are directly released into the water or formed by degradation of Macroplastics. Plastic litter enters the marine environment from diverse points and diffuse sources and it can be transported through rivers long distances before being deposited in the bottom of seas. Few studies suggest that river litter can contribute up to 40% of all marine litter input, being estimated over 1.2-2.5 million tonnes of plastic every year (1,2). MPs amount in soils globally is estimated between 1.5 to 6.6 Million Tons, being China with 660 KiloTons of MPs in soils the number one in the list. The main reason has been attributed to the irrigation of the agricultural fields with wastewater. The estimation of MPs in soils of Spain and Italy is 38 and 28 KiloTons respectively due to the increasing reuse of water for agriculture as a consequence of water scarcity in the Mediterranean region . The total amount of MPs present in soils and solid organic wastes around the globe is probably higher than the amount of MPs present in the surface of the oceans (2,3). MPs, as many other contaminants, can percolate through the agricultural soils and reach the groundwater table (4). This presentation will cover different aspects of MPs and MacroPlastic litter pollution in terrestrial environment as well coastal waters , rivers ,sediments and lakes . Case studies of MPs pollution in several coastal environments, sediments and catchments of China,. Saudi Arabia, India, Europe and Australia will be reported (2,5,6). Green Analytical Chemistry (GAC) protocols for the analysis of MPs in water (7) as well as applied to ecotoxicology (8) will also be discussed. GAC issues will be discussed in all steps of the method (i) sampling, (ii) sample preparation and (iii) identification and quantification measures can be taken to make the method more environmentally friendly and sustainable, safer for the operator by assessing their greenness through Analytical Eco-scale and AGREE metrics among others (7). In-vitro and in-silico ecotoxicological methodologies are proposed instead the use of fishes and vertebrates in general(8). The following part of this lecture will describe as well MPs as vectors of pharmaceuticals such as non-steroidal anti-inflammatory drugs (NSAIDs) or, psychiatric drugs that can sorb to MPs surface (9). Lastly, It is expected that MPs will affect communities, biological diversity, and ecosystem processes (10). As regards to toxicity of MPs that is expected that, smaller MPs and NPs particles will be more toxic to organisms. Many aquatic organisms are used for biomonitoring programs being possible to obtain quantitative information about the state of health of the ecosystem. Bivalves such as Mytilus galloprovincialis were used (11).This is part of the so called “mussel-watch” program for MPs but we will mention its presence and effects in lakes too (12).

Chitosan/graphene oxide@kappa-carrageenan composites for the adsorption of hexavalent chromium, trivalent arsenic and fluoride ions from wastewaters

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It is known that urbanization and industrialization are responsible for water pollution and the accumulation of heavy metals. Therefore, the need to remove heavy metals and ions from wastewater is imperative because they threaten public health and the ecosystem. Hexavalent chromium and fluorine anions cause cancer and affects the smooth functioning of vital organs such as the kidneys and lungs. Also, arsenic trivalent is one of the five most toxic heavy metals, which can bioaccumulate in the organisms and cause diseases. For this reason, the removal of Cr6+, As3+ and F- from wastewaters is necessary. One of the most widely applied techniques for pollutant removal is adsorption, which has a lot of advantages: it is low-cost, eco-friendly and can be reused. Chitosan is a unique biomaterial that can be defined as a renewable, high-cationic-charge-density, antibacterial, biodegradable, biocompatible, and non-toxic biomaterial with high compatibility with cellulose structures, where it can be used in different applications. Kappa-carrageenan is an abundant, nontoxic and ionic cross-linker that can be combined with chitosan. Chitosan cross-linking with kappa-carrageenan could be an excellent adsorbent for the removal of pollutants from aqueous solutions. Graphene oxide is a material that it is widely used in the treatment of water/wastewater containing pollutants because of their high surface areas, excellent mechanical strength and adaptability to different functional groups. In this work, a synthesized composite of chitosan/graphene oxide/kappa-carrageenan has been tested for the removal of Cr6+, As3+ and F-. All of the materials were characterized with FTIR, SEM, XRD and porosimitery (BET analysis). Batch adsorption experiments were carried out for the determination of the optimum conditions in terms opH, temperature and contact time. The results presented the potential of the prepared materials that can even be used in industry for the removal of various pollutants.

Upcycling perfumery: a sustainable guide to recycling SURLYNTM perfume caps

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In 2022, the global perfume market stood at USD 45.85 billion, increasing to USD 48.05 billion in 2023, with a projected growth to USD 69.25 billion by 2030 [1]. Within this expansive market, numerous perfume bottle caps utilize SURLYNTM ionomers, which are ethylene acid copolymers that have been partially neutralized. Renowned for its superior transparency, abrasion resistance, and lower mass compared to conventional glass, SURLYNTM poses recycling challenges. This study consists of developing a method to mechanically recycle used perfumery caps made of SURLYNTM via Grupo Boticário's reverse logistics program, which has more than 4,000 collection points. This initiative allows for packaging returned by consumers to be repurposed for testing the recycling process to guarantee the technical validation of the recycling process for these caps. Subsequently, various concentrations of SURLYNTM post-industrial recycled (PIR) and post-consumer recycled (PCR) were injected into perfume caps, assessing processability and mechanical properties. Four scenarios underwent evaluation via the Life Cycle Assessment (LCA) tool, comparing Carbon Dioxide-equivalent (CO2-eq) emissions for different concentrations of SURLYNTM virgin, SURLYNTM PIR, and SURLYNTM PCR in caps produced by the injection molding process. The LCA adopted a cradle-to-grave approach with a functional unit of 1 kg of packaging, utilizing SimaPro 9.1.1 software for carbon footprint assessment. We considered the 100-year GWP method (IPCC 2013) and EcoInvent version 3.5 database. Results indicated successful application of up to 20% SURLYNTM PCR without compromising the functionality of perfume caps, preserving visual and quality aspects for consumers as contributing to a circular economy. Grupo Boticário's plans enlarge the sustainable possibilities for perfume caps in future projects. Alongside the mechanical recycled SURLYNTM PCR, they aim to introduce the new SURLYN™ REN and SURLYN™ CIR grades. These ionomers are derived from hard-to-recycle mixed plastic waste and bio-waste like used cooking oil (UCO), respectively. Both grades maintain the performance, appearance, and texture of virgin SURLYNTM.

Characterization of microplastics exposed to UV irradiation and their behavior as sorbents of organic contaminants

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Pollution by microplastics poses a risk to both human health and that of aquatic organisms. These microscopic-sized materials can be generated directly through the production of granules/powders or microbeads, or through the degradation of larger plastics. The degradation of plastics is due to aging processes that can be carried out through hydrolysis, mechanical abrasion, biodegradation or UV photodegradation, the latter being the most common process to which materials are subjected in nature. In this study, the behavior of 7 polymers (PA, PA MXD6, HDPE, LDPE, PP, PLA and PET) under photoinduced aging conditions was investigated. The aging process was followed by quantification of surface carboxylic acids (TBO assay) and an increase in the number of these substituents was observed as the time of exposure to UV light increased until equilibrium was reached. This was confirmed by FTIR analysis, following the increase of a peak at 1700 cm-1 assigned to the carbonyl. When comparing virgin and aged polymers, in general, a significant loss of crystallinity and an increase in polarity measured by the atomic ratio (O+N)/C, were observed. Also, a microplastic identification test was carried out by fluorescent microcopy using the DANS fluorophore (4-dimethylamino-4'-nitrostilbene). Interestingly, the fluorescence color emitted by irradiated materials was different than that of the correspondent virgin polymers, so an error can be made when identifying polymer particles found in nature, since they are surely aged. Finally, the sorption behavior of pyrene and fluoranthene, two polycyclic aromatic hydrocarbons frequently present in fresh water, was analyzed. The sorption kinetic and isotherms models confirmed that the sorption capacity of both contaminants was greater in the aged polymers. This indicates the need to study the behavior of real microplastics, aged in nature, when exposed to emerging contaminants.

Polymer Waste Sorting Technologies to Support the Circular economy

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Recycling post-consumer packages is a key component of the circular economy. Currently, there are two main approaches for identifying and sorting polymer waste packages. The first regards the processing of high quality RGB images which are fed into deep neural network models that identify and categorize waste objects. The second regards hyperspectral imaging, which focuses on classifying the material piece associated with a single pixel as being composed of a specific type of material. Understanding the difference between these methods is crucial for optimizing recycling processes.

RGB (Red, Green, Blue) images sample and encode the information available in the visible domain. Computer vision based on Deep Neural Networks (DNNs) enable machines to interpret and understand the visual world. After describing the problem with a large dataset of problem-solution images, a deep neural network is trained to recognize patterns and features of interest and learns to identify and categorize polymers in subclasses (PETE, HDPE, LDPE, etc), based on appearance.

Near-infrared (NIR) hyperspectral imaging enhances waste sorting by enabling the separation of materials based on chemical composition. Each pixel of hyperspectral images captures a wide spectrum of wavelengths. By contrasting the recorded spectrum against known spectral signatures used as references, we categorize the corresponding material as a member of certain category. Main difficulties on HSI imaging relate to materials that are dirty, wet, and most commonly have on them labels made of other materials.

Following the above, there is a need to merge the two technologies, devising a novel strategy that mitigates their weaknesses while amalgamating their advantages into a robust approach with significantly enhanced success rates. The current presentation will discuss alternative options and will present early results on the combined sorting of polymer waste using RGB and HIS data.

Abstracts – Poster Exhibition

Poster Session A – Wednesday 29 May

A1. Impact of Monomer Type on Poly(Ethylene Furanoate) Synthesis and Its Properties

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Next-generation industrially valued, 100% recyclable, bio-based poly(ethylene 2,5-furan dicarboxylate) was synthesized using 2,5-furan dicarboxylic acid (FDCA) or its derivative Dimethyl 2,5- Furan dicarboxylate (DMFD) as a monomer with the aim of producing a high-molecular-weight polymer suitable for food packaging applications. The intrinsic viscosity and color intensity of the PEF samples were analyzed concerning monomer type, molar ratios, catalyst, polycondensation time, and temperature. The structure–property relationships of the prepared PEF samples were studied using various characterization techniques in both their semicrystalline and amorphous states. The glass transition temperature (Tg) of amorphous PEF samples increased with increased intrinsic viscosity due to chain entanglement and segmental mobility. Similarly, the annealed PEF samples showed a decrease in the degree of crystallinity (Xc) with increasing intrinsic viscosity due to chain entanglement and constrained chain mobility, causing a low recrystallization rate. Dielectric spectroscopy results showed moderate effects on both the local and segmental dynamics. The ionic conductivity varied at temperatures well above Tg and was enhanced for FDCA-based samples. The nucleation density and spherulite size of the DMFD-based samples were enhanced with respect to increases in intrinsic viscosity and melt crystallization. The contact angle values and oxygen transmission rate (OTR) of the PEF samples decreased with an increase in intrinsic viscosities due to an increase in the rigidity of molecular chains. The nanoindentation test showed that FDCA-based samples exhibited low hardness and elastic modulus values due to increased diethylene glycol (DEG) content.

A2. Thermal Characterization of PLA-Based Copolymers via Reactive Extrusion with Oligo(butylene succinate) as a Macroinitiator

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This study investigates the thermal properties of poly(lactic acid) (PLA) synthesized via the reactive extrusion ring-opening polymerization of L-lactide in the presence of oligo(butylene succinate) (PBSu) as a macroinitiator. Two distinct molecular weights of PBSu (Mn=6100 and 16300 g/mol) were utilized, ranging in concentrations from 1 wt% to 15 wt% relative to the L-lactide mass in the premix.

Thermal characterization encompassed comprehensive examinations using differential scanning calorimetry (DSC), thermogravimetric analysis (TGA), and nanoidentation. The incorporation of flexible PBSu chains affected the glass transition temperature, revealing a singular transition. Both DSC and XRD analyses suggested the crystallization of both components when the PBSu premix content exceeded 5 wt%.

The thermal stability was sustained and displayed dependence on the copolymer composition and molecular weight. This investigation provides valuable insights into customizing the mechanical properties of PLA-based copolymers and establishes a groundwork for the scalable production of high-performance materials through reactive extrusion.

This work was funded from the European Union’s Horizon 2020 Research and Innovation Programme under grant agreement no. 952941 (BIOMAC Project).

A3. Market applications study of reversibly cross-linked Polyethylene (rPEX) using green additives

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This study examines the feasibility, demand dynamics, and potential challenges associated with the market uptake of two groundbreaking polymer-based products, pipes for the construction and utilities sector and cables for the photovoltaic market, both made from reversibly cross-linked polyethylene (rPEX) in combination with green additives.

The work is conducted in the framework of the REDONDO project, which aims to adopt Safety-by-Design and Sustainability-by-Design frameworks by incorporating safety and sustainability assessments already at the design stage of the polymer formulation process. The analysis integrates key elements to delve into market dynamics, technological advancements, and potential challenges thanks to the active collaboration with industry stakeholders.

The market description and relative segmentation provide insights into the target market's volume, size, and characteristics. Special emphasis is placed on segments such as cross-linked polyethylene, and green additives applied to pipes and cables. A competitive analysis is undertaken to evaluate existing alternatives, ascertain market shares, and identify both opportunities and challenges for the application of and rPEX. Furthermore, a risk assessment offers an overview of the primary risks linked to the development of OPEX products, spanning from polymer formulation to final product manufacturing and applications. This study proposes risk mitigation strategies to address identified challenges and uncertainties. Finally, a preliminary patent analysis in the field of rPEX, green additives (i.e. nanolignin and nanocellulose), will be conducted to identify existing patents and provide an overview of the potential limitations or openings for innovation within the patent landscape.

The findings of this preliminary market feasibility study contribute to understanding the potential of using the rPEX as an alternative to non-reversible PEX, supporting stakeholders in making informed decisions and facilitating the sustainable integration of rPEX across diverse industries.

This project has received funding from the European Union's Horizon Europe Framework Program under Grant Agreement No 101058449.

A4. Utilizing Bio-based Coatings to Address PFAS Concerns – A Strategic Analysis Using PESTLE and SWOT Tools

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Per- and polyfluoroalkyl substances (PFAS) are known for their excellent water and oil-repellency properties and are utilized in a wide range of everyday products. However, these artificial chemicals are persistent and can severely impact the environment and human health. To overcome the use of PFAS in coatings, the BIO-SUSHY project aims to replace them by using bio-based alternatives comprising sol-gel precursors, polymers, and bio-additives.

To guarantee efficient exploitation and the market uptake of the project, a PESTLE (Political, Economic, Social, Technological, Legal, Environmental) and SWOT (Strengths, Weaknesses, Opportunities, Threats) analyses have been conducted.

While the PESTLE examines the macro external factors, the SWOT analysis considers both internal and external factors. In the BIO-SUSHY project, it was preliminarily identified that policy frameworks such as the Chemical Strategy for Sustainability and the thriving biobased market offer economic opportunities, complemented by societal preferences for sustainable and healthier alternatives. Ongoing technological trends with sol-gel coatings also support the project's goals. Meanwhile, BIO-SUSHY's SWOT analysis identified internal strengths like innovative bio-based coatings and robust methodologies. Moreover, the project consortium seems to benefit from social acceptance tools, a certification program, and market demand driven by PFAS restrictions. However, foreseen challenges include market price competitiveness, funding limitations, and compliance issues.

Therefore, this work aims to provide an overview of the project concept and the use of business tools to facilitate the assessment of the strategic project planning process in the bio-based field.

The BIO-SUSHY project is funded by the European Union under the Grant Agreement Number 101091464. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Health and Digital Executive Agency (HaDEA). Neither the European Union nor the granting authority can be held responsible for them.

A5. Synthesis of chemically modified nanolignins as flame retardants

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Lignin is the second-most-abundant biopolymer after cellulose with an approximate annual production of 100 million metric tons per year [1]. Being a by-product of the paper and pulp industry, most of this biomass fraction is incinerated to produce steam for process energy. In the past few decades, however, due to its low cost and natural abundance as a renewable organic carbon source, the potential it has in numerous applications as a raw material for valuable products is being unraveled [2]. For example, its high thermal stability and char-forming capability have been of increasing interest for flame retardant (FR) applications. The potential toxicity of traditionally used halogenated FRs and the urge to develop sustainable environmentally friendly alternatives have led to research into the possible modifications and applications of lignin-derived flame retardants for polymeric materials. Therefore, modifications of lignin to tune its FR properties, such as incorporation of nitrogen- and phosphorous-containing intumescent flame retardants, have become very attractive alternatives. Herein, we present our ongoing work on lignin modifications to tune its FR properties, thermal stability and dispersibility in polymeric matrices. More specifically, nitrogen and phosphorous reagents were incorporated into the lignin backbone using different synthetic routes, thus altering its thermal and physical properties. Reactions were performed on a 40 g scale each, and solid-state nanoparticles of the resulting N,P-modified lignins with an HDD < 500 nm were produced using Creative Nano's Ultrasound-assisted pilot line. The structure and properties of the modified lignin nanoparticles were investigated using FT-IR, DLS, TGA and SEM.

This project has received funding from European Union's horizon program under GA no 101058449, REDONDO.

A6. Recyclable Pla-peaz Copolymers For The Replacement Of Fossil-based Substrates In Printed Electronics

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Printed electronic (PE) technologies have witnessed a massive and sustaining expansion in recent decades. According to estimates, 30 billion devices were connected to the Internet in 2020, covering solutions from smart cities to smart wearables and from domestic life to industries. This growth has been driven by numerous advances in the fields of electronics, polymer processing, printing, etc. [1] Currently, PE technologies are entering their commercial phase, which has obliged research teams in academia to deal with challenges and issues that have not been considered until recently [2]. Typically, flexible hybrid electronic devices can be fabricated on substrates like numerous thermoplastic polymers, such as poly(ethylene terephthalate) (PET), poly(ethylene naphthalate) (PEN), and thermoplastic polyurethane (TPU). These conventional plastics offer their individual performance advantages, such as high flexibility and low cost; however, they derive from rapidly depleting non-renewable petroleum resources and require incineration or landfilling at the end of life [3]. Employing greener materials and fabrication processes will encourage sustainability and aid meeting eco-design directive regulations and European Green Deal objectives. Amongst bio-based polymers, poly(lactic acid) (PLA) has been lately investigated as a potential candidate for thin film PE [4]. Nevertheless, commercial PLA exhibits poor heat resistance and inherent brittleness, but its copolymerization with biobased aliphatic monomers may overcome this challenge. Such a polymer is poly(ethylene azelate) (PEAz) produced from biobased ethylene glycol and azelaic acid.

In the current work, a series of flexible, biobased, biodegradable, and recyclable PLA-PEAz copolymers were successfully synthesized by a combination of the two-stage melt polycondensation procedure for PEAz synthesis, followed by a ring opening polymerization (ROP) reaction in the presence of lactide. The recyclability of prepared polymeric substrates was evaluated using microwave-assisted hydrolysis and 1H NMR spectroscopy. Enzymatic hydrolysis and UV degradation were also tested for the evaluation of the polymers degradability in the environment.

A7. Zwitterionic Functionalized Chitosan With Antibacterial Property For Hemostatic Applications

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Wounds are disruptions to the integrity of the skin caused by a variety of causes, including trauma, surgery, diabetes, and burns. A suitable wound dressing should be flexible, have sufficient mechanical strength, and not adhere to the wound or surrounding tissue. Although there are many biomaterials suitable for hemostatic agents, chitosan was chosen to create a sponge-like material.

Chitosan is one such polymer, as it has unique mucoadhesive properties due to its amino and hydroxyl functional groups compared to other natural polymers such as starch and cellulose, and its high membrane permeability.However, CS has some drawbacks: Limited mucoadhesion, low chemical purity, poor swelling properties, and poor water solubility at neutral pH. To adapt these, various attempts have been made to prepare chitosan derivatives using suitable monomers containing multiple reactive groups.

2-Acrylamido-2-Methylpropane Sulfonic Acid (AMPS) has been repeatedly used in drug delivery due to strongly ionizable Sulfonic Acid ($SO2$) functional groups. It is a hydrophilic monomer which presents low toxicity, anti-bacterial properties and can improve the salt tolerance of non-ionic groups increasing the swelling capacity of the hydrogel.

The aim of this study was to evaluate the efficacy of pure chitosan (CS) and its derivatives including 2-acrylamido-2-methyl-1-propanesulfonic acid (CS-AAMPS). This modified chitosan was synthesized by radical polymerization, and its structure was detected by Fourier transform infrared spectroscopy (FT-IR) spectroscopy. Additionally, it showed from biological analysis, low cytotoxicity, improved mucoadhesive properties and antibacterial activity against S. aureus and E. coli.

A8. Valorization Of Sugar-derived Polyols As Plasticizers Of Poly(lactic Acid)

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Polylactic acid (PLA) stands out as a highly promising material for the production of eco-friendly packaging due to its compostable nature, non-toxic properties, and derivation from renewable sources such as corns, sugar beets, and potatoes. Recognized as safe by the US Food and Drug Administration (FDA) for food packaging applications, PLA, however, faces limitations such as embrittlement, low thermal stability, and suboptimal barrier properties against gases and UV rays, along with lacking antimicrobial characteristics. Addressing these drawbacks is crucial to enhance PLA's suitability for packaging applications. The selection of non-toxic additives and fillers is paramount in this pursuit.

This study explores the potential of sorbitol, derived from glucose-rich feedstock streams through catalytic hydrogenation/hydrogenolysis, as well as commercially available glycerol, as plasticizers for PLA. The melt compounding of PLA with 0.5, 1, or 2.5 wt% of either glycerol or sorbitol was conducted in a lab-scale compounder. Tensile properties were assessed to understand the plasticization impact, while FTIR and XRD were employed to examine the structural properties. Additionally, DSC measurements were employed to investigate thermal transitions and crystallinity. The findings revealed a reduction in the glass transition temperature, particularly pronounced with glycerol as the plasticizer. Moreover, crystallinity exhibited an increase with higher plasticizer content, contributing to enhanced elongation at break. This research thus presents a promising avenue for optimizing PLA-based packaging materials by leveraging glucose and sorbitol as effective plasticizers with potential applications in sustainable packaging solutions. Finally, the impact of the plasticizers on enzymatic hydrolysis was evaluated via mass loss measurements and microscopy observations.

Acknowledgement: This work was funded by the European Union’s Horizon 2020 Research and Innovation Programme under Grant Agreement No. 952941 (BIOMAC Project).

A9. Development Of Multifunctional And Innovative Hemostatic Products Using New Polymeric Carriers And Nanoparticles

Katerina Papadopoulou, Ioanna Koumentakou, Despoina Meimaroglou, Dimitrios N. Bikiaris

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Despite advances in medicine and the advancement of technology in protective equipment, lethal hemorrhage caused by trauma remains one of the most difficult problems in medicine and military medicine.

The new trend in hemostasis is the use of natural polymeric materials. It is evident that most pharmaceutical companies have turned their interest towards polymers, since they offer a huge range of properties at very affordable prices. Such products include HemCon, Chitoflex, Chitosea and Hemostatic Granules. They are based on the natural chitosan polymer and are currently commercially hemostatic products that provide rapid hemostasis but with several disadvantages such as the large amount of product required for adequate action and high price, as well as incomplete hemostatic action in some cases leading patients to death. It also does not provide antimicrobial activity, resulting in significant wound infection.

To achieve these goals, chitosan hemostatic powder with antimicrobial properties was prepared by chemical modification. The efficacy was enhanced by vitamin K, protamine sulfate and iron sulfate, which accelerate thrombosis, as well as heparin (anticoagulant), which was encapsulated in polymer nanoparticles to avoid thrombosis at undesirable points. The obtained hemostatic product was fully characterized for its successful synthesis by FT-IR and for crystallinity by XRD, showing reduced crystallinity compared to CS alone. Furthermore, swelling studies were conducted with the hemostatic product showing extensive swelling capacity (maximum degree of swelling up to 4000%).

Acknowledgement

The authors wish to acknowledge co-funding of this research by European Union-European Regional Development Fund and Greek Ministry of Education, Research and Religions/EYDE-ETAK through program EPANEK 2014- 2020/Action “EREVNO-DIMIOURGO-KAINOTOMO” (project T2EΔK-00275).

A10. Synthesis And Study Of Biochar-doped PLA Bio-nanocomposites.

Katerina Papadopoulou, Dimitrios N. Bikiaris

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The global demand for alternative materials that are biobased as well as fully biodegradable highlights that they are a viable pathway to deal with the issues related to plastic production. Poly(lactic acid) (PLA) is one of the most attractive thermoplastic polyesters of recent years. PLA is a promising biobased, biodegradable, non-toxic and biocompatible polymer which can contribute towards a circular economy. It is mainly produced via ring-opening polymerization of lactide or via polycondensation of lactic acid. Theese materials have already found applications in different fields such as agriculture, automotives, printed electronics, etc.

In the present work, samples of PLA and its bio-nanocomposites containing 1, 2.5, and 5 wt% biochar (BC) were prepared via ring-opening polymerization. Biochar is a byproduct of biomass pyrolysis in a zero-oxygen environment at high temperatures (300–800 ◦C). Biochar can be used as a filler in PLA polymeric matrixes in order to improve the performance of PLA composites, as well as reduce their price. The biochar that we incorporated in the PLA composites is derived from soft wood pellets (SWPs). The successful synthesis of PLA and its bio-nanocomposites was confirmed via Fourier Transform Infrared Spectroscopy (FTIR). The fine dispersion of BC in nanosize form into the polymer matrix was confirmed via Transmission Electron Microscopy (TEM). Furthermore,measurements of the mechanical properties of the bio-nanocomposites were carried out, and the influence of the BC on the rate of enzymatic hydrolysis of the materials was evaluated via Scanning Electron Microscopy (SEM).

Acknowledgements

This work was funded from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No. 952941 (BIOMAC Project).

A11. Chitosan Dressings Containing Inorganic Additive And Levofloxacin As Potential Wound Care Products With Enhanced Hemostatic Properties

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Nowadays, the research is focused on designing products that can stop bleeding quickly and without side effects. The characteristics of an ideal hemostatic material are: rapid arrest of arterial and/or venous bleeding with no thermal effect (a sharp rise in temperature in the wound), non-toxicity, flexibility, adaptability to the wound's shape, easy to remove without leaving residues, and stability in extreme temperatures.

Despite the progress in the development of hemostatic products, efficient treatment solutions to control hemorrhage upon wounding are still necessary. Hemostatic products with the ability to create gels when in contact with water and/or blood without being dissolved exhibit unique advantages. The gel can form an active coating that protects the wounded area from germs, absorbs and retains water within its structure, while removing excess exudates from the wound surface, and allows proper gaseous exchange.

Chitosan (CS) is a natural hydrogel-forming polysaccharide, easy to modify for specific applications. Inorganic compounds in turn possess documented hemostatic properties. In this study, innovative hemostatic products based on CS, containing the inorganic additive iron(III) sulfate, at different concentrations, and the antibiotic Levofloxacin were prepared, and their potential use as hemostatic materials was investigated. Structural characteristics, physical state and drug loading/release properties were examined. Strong interactions developed between CS and the additive, the pore size in the resulting products was affected, swelling increased up to 2500% and the stability of the wound dressings improved. The crystallinity of Levofloxacin reduced, and its release was immediate. The materials showed biocompatibility upon contact with cultured keratinocytes, hemocompatibility and hemostatic efficacy in vitro and in vivo.

Acknowledgement

The authors wish to acknowledge co-funding of this research by European Union-European Regional Development Fund and Greek Ministry of Education, Research and Religions/EYDE-ETAK through program EPANEK 2014- 2020/Action “EREVNO-DIMIOURGO-KAINOTOMO” (project T2EΔK-00275).

A12. Development Of Biosourced Surfactants Based On Chitosan Oligomers (Cos): Epoxy–amine Chemistry

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Surfactants are amphiphilic molecules that stabilize and homogenize emulsions containing two immiscible phases. These properties make them indispensable in many industrial applications and in everyday life. However, today, almost 50% of surfactants on the market are petroleum-based and of fossil origin. It is therefore necessary to find biosourced alternatives to replace these surfactants.

Chitosan is a polysaccharide of interest in the literature due to its amine and alcohol functions, opening the door to different chemistries of functionalization[1]. Due to its high molecular weight, native chitosan is practically insoluble in common solvents and cannot be used as a surfactant. It is then depolymerized to form chitosan oligomers (COs) with low DP. Their hydrophilic and functionalizable structure allows the subsequent grafting of biosourced fatty chains through epoxy–amine chemistry, thus providing a hydrophobic part to these COs.

After several characterizations of these CO-based surfactants such as CMC and surface tension, a study of their behavior in an O/W emulsion was carried out. The destabilization mechanisms were described and evaluated through various tests including rheological evaluation and droplet size measurements[2]. As a result of these studies, it is clear that these new biobased systems can compete with the surfactants currently found in the market and could replace them in some applications.

[1] Chapelle Camille, Ghislain David, Sylvain Caillol, Claire Negrell, and Myriam Desroches Le Foll., “Advances in chitooligosaccharides chemical modifications”, Biopolymers 112, no 9 (2021). https://doi.org/10.1002/bip.23461

[2] Berthalon Steve, David Ghislain, Negrell Claire, Azema Nathalie, Frugier Jérémy, “O/W emulsion stability of non-ionic chitosan oligomer surfactants modified by epoxidized fatty chains at pH7: influence of formulation and emulsification conditions“, not submitted yet.

A13. Reactive Extrusion Synthesis of Poly(lactic acid)-Poly(butylene succinate) Block Copolymers: Towards Enhanced Mechanical Properties and Process Scalability

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This research focuses on the innovative synthesis of poly(lactic acid) (PLA) through reactive extrusion ring-opening polymerization of L-lactide in the presence of oligo(butylene succinate) (PBSu) as a macroinitiator. Two different molecular weights of PBSu (Mn=6100 and 16300 g/mol) were employed, with concentrations ranging from 1 wt% to 15 wt% relative to the L-lactide mass in the premix. The copolymers, exhibiting number average molecular weights between 30 and 100 kg/mol, demonstrated a decrease with the increasing PBSu content in the feed.

Characterization involved a thorough investigation using spectroscopic techniques, gel permeation chromatography (GPC), X-ray diffraction (XRD), and nanoidentation.

Remarkably, the nanoidentation results indicated that PLA-PBSu 2.5% copolymers displayed a superior elasticity modulus and strength compared to other compositions. This could be attributed to a complementary effect of their high molecular weight and crystallinity, making them promising candidates for continuous reactive extrusion, a novel, rapid, and economically viable method for commercial PLA-based polymer production.

This study offers valuable insights into tailoring the mechanical properties of PLA-based copolymers and establishes a foundation for the scalable production of high-performance materials through reactive extrusion.

This work was funded by the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No. 952941 (BIOMAC Project).

A14. Synthesis, Characterization, and Crystallinity studies of Poly (lactic acid-co-ethylene adipate) Copolymers

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The escalating demand for sustainable materials to replace traditional plastics in diverse applications has stimulated a growing need for biodegradable polymers. Biodegradable polymers are designed to degrade naturally in the environment, reducing the amount of plastic waste that accumulates in landfills and oceans [1]. However, the mechanical properties of biodegradable polymer-based plastic materials are often inferior to those of traditional plastics, which can limit their use in certain applications [2]. Therefore, there is a need for biodegradable polymers that can provide plastics with both mechanical performance and environmental sustainability [3], [4], [5]. In this work, we focused on the synthesis and characterization of relatively novel biodegradable copolymer poly (lactic acid-co-ethylene adipate) (PLEAd). Lactic acid is a rigid and crystalline material that can improve the stiffness and strength of this copolymer [6]. Ethylene adipate, on the other hand, is a flexible and amorphous material that can enhance the toughness and ductility of the copolymer [7]. By copolymerizing PLA with ethylene adipate, the resulting material combines the rigidity of PLA with the flexibility introduced by the ethylene adipate segments. The combination of these two materials is thus anticipated to yield a copolymer with a unique balance of their properties. L-lactide and poly (ethylene adipate) prepolymer were used as starting components in the ring-opening polymerization process, and the structure of the resultant copolymer was confirmed using Fourier transform infrared spectroscopy (FTIR) and nuclear magnetic resonance (NMR) spectroscopy. The thermal properties of PLEAd were studied using thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC), and crystallinity was studied using X-ray diffraction analysis (XRD). Our results indicate that PLEAd has a high degree of crystallinity and is thereby anticipated to have good mechanical properties, including high stiffness and strength. These properties make PLEAd a promising material for various applications, such as packaging, biomedical devices, and tissue engineering.

A15. Nanocellulose functionalized with oligomers of aliphatic polyesters for increased compatibility with biopolymeric matrices

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Poly(3-hydroxybutyrate) (PHB), the most representative member of the polyhydroxyalkanoates family, is a natural polyester obtained by bacterial fermentation. Its natural origin, biodegradability, and biocompatibility along with its satisfactory mechanical properties promote PHB as a valuable substitute for synthetic petroleum-based polymers in packaging applications, medicine, and even for industrial purposes. However, its high price, relatively low thermal stability, and high brittleness limit its widespread application. A common way to improve the properties of PHB is via blending with cellulose nanofibers (CNFs), a reinforcing agent of natural origin, which is also characterized by biodegradability and biocompatibility. Nonetheless, CNFs are characterized by a high hydrophilicity, totally opposite to the hydrophobicity of the PHB matrix, which makes good dispersion of CNFs in PHB quite impossible. Therefore, to ensure good compatibility between the PHB matrix and the CNFs, surface functionalization of cellulose is crucial.

In this work, CNFs were surface-modified with oligomers obtained by the thermal degradation of PHB. The influence of the grafted oligomers on the structure, morphology, crystallinity, size, surface hydrophobicity, and thermal stability of CNFs was studied by using Fourier-transform infrared spectroscopy, atomic force microscopy, X-ray diffraction, laser diffraction, contact angle, and thermogravimetric analysis. The results showed that the chemical treatment of CNFs with oligomers derived from PHB determined an increase in the surface hydrophobicity of CNFs, while the good thermal stability characteristic of cellulose remained generally unchanged. The functionalized CNFs can be used as suitable reinforcing agents in biopolymeric matrices such as PHB.

Acknowledgments: This work was financially supported by a grant of the Ministry of Research, Innovation and Digitization − UEFISCDI, project number PN-III-P4-PCE2021-0435 (CELGAS) within PNCDI III and project PN 23.06.01.02/2022 AQUAMAT within PN 23.06 Core Program-ChemNewDeal.

A16. Pickering emulsions stabilized using curcumin-loaded TEMPO-oxidized nanocellulose

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Pickering emulsions, two-phase systems stabilized using particles, are becoming attractive candidates in the food, pharmaceutical, and cosmetic industries. Organic and inorganic micro- and nanoparticles have been employed for stabilizing Pickering emulsions containing vegetable, essential, and mineral oils, as well as lipids, hydrophobic monomers, or polymers as an oil phase. Among the aforementioned particles, nanocellulose is the most attractive due to its natural provenience sources, high surface area, biodegradability, biocompatibility, good mechanical properties, and great possibilities for surface chemical modification. Nanocellulose is composed of β-D-glucopyranose units linked by β (1➔4) glycosidic bonds abundantly connected by intra- and intermolecular hydrogen bonds. This structure endows nanocellulose with a high degree of crystallinity, good mechanical properties, and a wide range of possibilities to tailor its adherence to different media following chemical modification.

In this work, cellulose nanofibers (CNFs) were obtained from microcrystalline cellulose via mechanical defibrillation and surface modification with TEMPO oxidation. Cellulose functionalization and the treatment influence on the CNF properties were characterized using Fourier transform infrared spectroscopy, atomic force microscopy, contact angle, and thermogravimetric analysis. Unmodified and TEMPO-oxidized CNFs were tested as stabilizers for curcumin-loaded Pickering emulsions. Optical microscopy, rheology, and laser diffraction highlighted the influence of CNFs/curcumin on the droplet size distributions, creaming index, and emulsion stability in time. The resulting emulsions are promising formulations for ulterior use in biomedical and food applications.

A17. Bio-based adhesives from pristine lignin: combining performance and sustainability

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In the context of phenol-formaldehyde (PF) resins, lignin can be regarded as a promising alternative to fossil-based and toxic phenols due to its natural polyphenolic structure. Currently, chemical modification is one of the most investigated strategies aimed at increasing lignin reactivity towards PF systems. This approach involves the use of hazardous chemicals and high temperatures. As a result, in this work, phenolic adhesives were developed using chemically unmodified lignin, micronized via a facile ball milling procedure, combined with a cardanol bio-derived polyol, an additional natural source of phenols, to produce nearly formaldehyde-free adhesives with high lignin contents.

Bio-based lignin-cardanol phenolic (LCP) adhesives were formulated by employing a 90 wt.% combination of lignin with a novolac pre-polymer powder at 0/100, 5/95, 10/90, 20/80, and 30/70 kraft lignin/novolac weight ratios and 10 wt.% of a polyether polyol-based cashew nutshell liquid. The reference commercial material consisted of a bicomponent resin prepared by using 90 wt.% of the novolac pre-polymer and 10 wt.% of liquid resole. In LCP resins, the cardanol-based polyol was added to the formulation to improve its ability to wet the substrate, fully substituting the liquid resole component in the adhesive formulation. Resins thus obtained were analyzed via differential scanning calorimetry to design the optimal curing process. Once cured, LPC resins displayed excellent gel content values (>97%). All resins showed glass transition temperatures between 160 °C and 180 °C. Thermogravimetric analysis showed excellent thermo-oxidative responses up to 220 °C. The adhesive performance of the LPC adhesive was compared to the commercial formulation via metal-to-metal lap shear tests and wood-to-wood adhesion tests. In both cases, the lignin- and cardanol-derived component combination enabled high bio-content nearly-free formaldehyde adhesive production, exhibiting optimal performance when 20 wt.% of lignin was used to replace the novolac component.

Acknowledgments: project BIOMAC; grant agreement no. 952941

A18. Different outer membrane proteins of Escherichia and Salmonella form polymeric amyloid assemblies

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Insoluble protein aggregates with a fibrillar morphology called amyloids and β-barrel proteins both share a β-sheet-rich structure. Correctly folded β-barrel proteins can not only function in a monomeric (dimeric) form, but also tend to interact with one another—followed, in several cases, by the formation of higher-order oligomers or even aggregates. Different β-barrel proteins have been shown to form amyloid fibrils in vitro (Sulatskaya et al., Int. J. Mol. Sci., 2021). Outer membrane proteins (Omps) of Gram-negative bacteria represent porins involved in a wide range of virulence- and pathogenesis-related cellular processes, including transport, adhesion, penetration, and colonization of host tissues. Recent data suggest that Omps from several bacterial species are able to adopt an amyloid state different to their β-barrel structure. We investigated the amyloid properties of the OmpC and OmpF porins from two species belonging to the Enterobacteriaceae family: Escherichia coli and Salmonella enterica. We demonstrated that these porins form toxic fibrillar aggregates in vitro. These aggregates exhibit birefringence upon binding Congo Red dye and show characteristic signals under X-ray diffraction. Thus, we confirmed the amyloid properties of OmpC of E. coli and demonstrated bona fide amyloid properties for three novel proteins, OmpC of S. enterica and OmpF of E. coli and S. enterica, in vitro. For all these proteins, amyloid properties were also demonstrated across a whole range of parameters, including detergent and protease resistance, thermal stability, interaction with specific amyloid dyes under polarization microscopy, and characteristic images via transmission electron microscopy, as well as in studies in the curli-dependent amyloid generator system (Belousov et al., Int. J. Mol. Sci., 2023). These data are important in the context of understanding the structural dualism of Omps and its relation to pathogenesis.
The work was supported by the Russian Science Foundation (grant no. 24-26-00124).

A19. Nanocellulose isolated from agro-industrial residue for biopolymers reinforcement

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Bio-based polymeric materials are conveniently sourced from a wide variety of agro-industrial wastes. Lignocellulosic biomass, the largest renewable resource on Earth, is regarded as the most suitable source of cellulose, with the latter being isolated by bleaching and alkali treatments along with high-pressure homogenization. Wheat straw is one of the most abundant agricultural wastes, which is usually burned, thus creating environmental issues. Therefore, finding ways to valorize this waste is important for environmental protection.

In this work, starting from lignocellulosic waste, cellulose nanofibers were extracted by two alternative methods: i) several bleaching and alkaline hydrolysis treatments followed by mechanical defibrillation (NCI); ii) alkaline hydrolysis treatments and hydrogen peroxide, followed by mechanical defibrillation (NCII). Both NC I and NC II were characterized by Fourier-transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), thermogravimetric analysis (TGA) and transmission electron microscopy (TEM) to assess their morpho-structural and thermal properties and to confirm the removal of lignin, hemicelluloses, and other impurities. The isolated cellulose nanofibers was tested as modifiers to improve poly(lactic acid) (PLA) properties. The results show the great potential of these cellulose nanofibers to be used as reinforcing agents in biopolymers.

ACKNOWLEDGMENT

This work was financially supported by a grant from the Ministry of Research, Innovation and Digitization − UEFISCDI, project number PN-III-P4-PCE2021-0435 (CELGAS) within PNCDI III and project PN 23.06.02.02/2022 InteGral, within PN 23.06 Core Program-ChemNewDeal.

A20. Layered dressings from biopolymers and natural antibacterial products

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Aliphatic polyesters such as poly(3-hydroxybutyrate) (PHB) and poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV) are microbially synthesized polymers that stand out for their biodegradability, non-toxicity, and biocompatibility. Some properties of PHB and PHBV are similar to those of polypropylene, a conventional petroleum-based polymer. PHB and PHBV biopolymers are promising alternatives to petroleum-derived polymers in biomedicine, agriculture, and packaging applications.

Layered dressings may provide a suitable environment for wound healing, depending on their structural characteristics and composition. Usually, they are composed of an inner drug-release layer in contact with the skin and an outer mechanical support layer. The outer layer may be made from aliphatic polyesters such as PHB or PHBV, which are hydrophobic polymers, and the inner layer from a biopolymer loaded with the drug. Cellulose may function as a good drug-release matrix, provided that its adhesion to the outer layer is ensured.

In this work, a PHBV film was plasma-treated at atmospheric pressure to increase its surface hydrophilicity and then sprayed with a nanocellulose suspension containing an antibacterial drug. The PHBV film before and after the plasma treatment and the layered structures were characterized by contact angle determination, X-ray photoelectron spectroscopy, thermogravimetric analysis, scanning electron microscopy, and dynamic mechanical analysis. The antibacterial activity of the dressings was also characterized. The results emphasized the effect of the plasma treatment on the hydrophilicity and thermal and mechanical properties of biopolymer films and the good prospects of these layered dressings for biomedical applications.

A21. Superior Recyclability in Ultra-light Bio-based Polyurethane Foams

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In recent years, there has been notable growth in the polyurethane (PUR) market, driven by a consistent rise in demand for products in the construction, automotive, and packaging industries. Currently, PUR foams dominate the market as the primary product category, contributing to over 50% of the global revenue [1]. However, an ongoing challenge lies in effectively recycling PUR foams.

This study presents an innovative approach to enhance the recyclability of PUR foams by incorporating hydrolysable ester units into their structure. Three series of bio-based, low-functional poly(ester-ether) polyols derived from succinic acid (SA) were synthesized. These SA–polyols were successfully employed in producing ultra-low-density polyurethane foams, acting as a complete (100%) or partial (80%) substitute for high-functional polyols, petrochemical (commercial), or bio-based (tall oil-based). All resulting PUR foams demonstrated a semi-rigid nature with partially open cellular structures and an advantageous, very low, apparent density of 16 kg·m-3[2].

The impact of SA–polyols containing hydrolysable ester linkages on the chemical recyclability of PUR foams was assessed. The study revealed that the introduction of SA–polyols significantly enhanced the recyclability of the PUR foams via glycolysis, underscoring their potential to contribute to a circular economy and address concerns related to plastic waste.

A22. Fabrication of chitosan microneedle patches for transdermal delivery of active ingredients.

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Transdermal drug delivery is successful in a number of applications, including hormone replacement therapy, smoking cessation, and pain management; however, it is limited to a narrow range of compounds that easily pass through the skin. Several challenges have been encountered in expanding use of the technology to the delivery of hydrophilic macromolecules, such as peptides, proteins, and vaccines. These biopharmaceuticals cannot permeate the outermost layer of the skin, the stratum corneum, at sufficient levels to achieve a considerable therapeutic effect. Although chemical enhancers and mechanical abrasion can increase drug permeation, they may irritate or cause damage to the skin. Therefore, the challenge of creating an effective transdermal delivery system involves breaking the skin barrier for drug transport without irritating the skin.

This study developed a biodegradable microneedle patch made of chitosan for efficient and sustained transdermal delivery of macromolecular drugs. As a drug delivery system, chitosan has attracted increasing attention because of its excellent biocompatibility, degradability, and nontoxicity. Drugs loaded in chitosan carriers can be released through swelling and degradation of the chitosan matrix, leading to a clear sustained-release effect.

Specifically, hydrogels with different amounts of chitosan were prepared. The viscosity of prepared hydrogels was investigated and then we researched the ability of hydrogels to fabricate patches with microneedles with high stability. The structure of the fabricated chitosan patches was studied with a microscope and SEM. Finally, the swelling capacity and hydrolysis of patches with microneedles were researched in different conditions.

A23. Bio-based Sustainable Coatings with Lignin Resins for Enhanced Performance and Environmental Impact

Michele Ponzelli, Raquel Moreno, Idoia Etxeberria, Arantxa Artola, Aitor Barrio, Nour Mattar, Walter Pitacco, Leo Staccioli, Omar Reyes, Jose Gallego, Claudio Pagella, Ioanna Deligkiozi

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Coatings play a crucial role in our daily existence by offering protection, enhancing aesthetics, and providing functionality to different surfaces. Nevertheless, the environmental repercussions associated with coatings derived nowadays from fossil fuels and the emission of volatile organic compounds (VOCs) have prompted concerns. Accordingly, regulations have been introduced to reduce the usage of these coatings.

Towards the road of defossilization and the creation of a sustainable bioeconomy, the LIGNICOAT project is developing innovative lignin-based resins and coatings. Lignin, a by-product of lignocellulosic biomass, is a natural polymer that can be used as a building block for producing biobased resins. LIGNICOAT particularly targets biobased coating with enhanced properties in terms of fire, corrosion, and antimicrobial resistance.

This work aims to provide an overview of the project concept, the methodology, and the most recent results obtained in the development and application of the biobased coatings and their performance. Moreover, the potential market applications of these innovative coating solutions are also analyzed.

The LIGNICOAT project has received funding from the Bio-based Industries Joint Undertaking (JU) under the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101023342. The JU receives support from the European Union’s Horizon 2020 research and innovation programme and the Bio-based Industries Consortium.

Poster Session A – Wednesday 29 May

A24. Eugenol as a natural building block for functionalized polymers: Controlled radical polymerization to preserve the allylic group

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Biomass-derived monomers have emerged as attractive alternatives to non-renewable starting materials in the development of sustainable polymers, reducing our reliance on fossil-based raw materials. Eugenol, a natural product that can be extracted from essential oils or obtained from lignin depolymerization, exhibiting properties such as antioxidant and antimicrobial activity, represents an interesting building block for biobased polymers [1-2]. Polymerization via ARGET-ATRP of the methacrylic derivative of eugenol, eugenyl methacrylate (EuMA), was studied aiming at preserving the unsaturated group. This type of polymerization was selected for its living character and for the possibility to use a low amount of metal catalyst and organic solvent [3].

Catalyst systems based on CuBr2 with three different amines (BiPy, PMDETA and HMTETA) were studied. First-order kinetics occurred for reaction times shorter than 2 h, whilst prolonged times led to deviations from the linear trend, suggesting the direct involvement of the allylic group in the termination reactions. The highest degree of allylic group preservation was observed with the PMDETA-based catalysts, while the CuBr2/BiPy system proved the least effective. A comparison between EuMA and the corresponding dihydrogenated monomer (DEuMA) clearly evidenced the influence of the allylic group on the kinetics of polymerization.

Electronic structure calculations supported experimental evidence, indicating the energetics of intermediates deriving from all the possible side reactions and suggesting the mechanism preserving the allylic group in the controlled radical polymerization ARGET. Hence, this study demonstrates that modulating the kinetic polymerization by ligands can be useful for preserving the eugenol allylic group for further polymer post-functionalization.

A25. Valorisation of lignocellulosic biomass-derived glucose-rich streams for the production of bio-based sugar-alcohols as monomers

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Most chemicals and fuels are produced from non-renewable fossil carbon sources. Their extensive use poses issues such as future resource availability and already recognized serious and detrimental environmental impact. A prominent alternative would be the use of renewable and abundant natural resources, such as lignocellulosic biomass from agricultural/forestry residues. To this end, sustainable and efficient (bio)chemical processes need to be developed for a cost-competitive valorisation of biomass and its fractions. The first important process step is the pretreatment of biomass and the selective fractionation towards its main structural components, consisting of cellulose, hemicellulose and lignin. Cellulose can be depolymerized via enzymatic (bio-chemically) or acid (chemically) hydrolysis to glucose, which can act as the base chemical to produce a variety of platform chemicals (i.e., sorbitol, glycols, etc.), with high potential in the solvent, polymer, pharmaceutical, food and fuel ind*ustry.*

In this work, we studied the performance of Ru and Pt catalysts supported on micro/mesoporous activated carbon, in the hydrogenation and hydrogenolysis of glucose-rich streams produced from lignocellulosic biomass pretreatment, at a range of hydrogenation temperatures (120–180oC), at a relatively low hydrogen pressure of 3MPa and for different reaction times (1–5h). Also, the scale-up from lab (100mL) to semi-pilot-scale (5L) unit was also addressed. It was shown that Ru is significantly more selective towards sorbitol compared to Pt. For example, the 5wt.% Ru/AC catalyst afforded a sorbitol yield of over 90wt.% (at 99.9wt.% conversion) compared to 60wt.% (at 90.2wt.% conversion) obtained by the corresponding Pt catalyst, at the optimum condition, the latter also being selective towards glycerol and propane-1,2-diol.

A26. Syringaldehyde as building block for the synthesis of bio-based polymers via ARGET-ATRP

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Syringaldehyde is one of the aromatic molecules deriving from the depolymerization of lignin, a natural and plentiful compound. Because of this, syringaldehyde methacrylate derivative has been polymerized for the development of sustainable polymers with glass transition temperature (Tg) comparable or higher than that of poly(styrene), a ubiquitous and fossil-derived thermoplastic [1,2]. In addition, the aldehydic group of syringaldehyde, if preserved during the polymerization process, would confer antimicrobial activity to the final material as already reported for vanillin methacrylate, allowing for the synthesis of added-value, sustainable thermoplastic. [3]

Free radical polymerization produces poly-(syringaldehyde methacrylate) (PSAMA) with a yield of 98% but a very large Đ (4.07), indicating the presence of many termination processes during the polymerization. [1]

The aim of this work is the synthesis of PSAMA via controlled radical polymerization techniques. To this end, ARGET-ATRP was carried out in presence of copper-based catalysts to study the influence of few amino-ligands (PMDETA, Me6TREN and BiPy) and initiators (EBiB, EBPA and TsCl) on the kinetic of polymerization, yield, and polydispersity of the molecular masses.

Polymerization were carried out at different temperatures, monomer concentrations, time, metal-ligand ratio. Preliminary results indicate that PMDETA gave the higher monomer conversion over Me6TREN and BiPy; in particular, with PMDETA a yield of 70% was obtained while with the other ligands the values were always under 10%. As it concerns initiators, EBiB and EBPA performed similarly and both better that TsCl.

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A27. Properties of poly (butylene furanoate-co-dilinoleic furanoate) film obtained via cast extrusion

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The aim of this work was to obtain film from poly(butylene furanoate-co-dilinoleic furanoate (PBF_DLF 70:30) with two different thicknesses (ca. 120, thinner, and 400 µm, thicker) via solventless continuous CAST extrusion and investigate its mechanical (tensile test: puncture resistance), barrier (oxygen transmission rate—OTR) and thermal properties (DSC and DMTA). The results for the thinner films were compared to poly(butylene succinate) (PBS) and polyethylene (PE) film obtained via the same method. The biobased polymer was easily processable and the obtained film was homogenous and elastic. Tensile tests results revealed that PBF_DLF 70:30 exhibited similar properties to PE and commercial PBS but puncture resistance was higher for the copolymer (4.16 N). Moreover, PBF_DLF 70:30 films were characterized by higher OTR (thinner, 83, and thinner, 189 cm3/m2/24 hr) than PBS (228 cm3/m2/24 hr) and much higher than PE (more than 3000 228 cm3/m2/24 hr). This biobased material is intended for packaging materials production, so sealing tests were performed with excellent results.

This work has received funding from the European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie grant agreement no. 872152 (GREEN MAP). An international project co-financed by the program of the Minister of Science and Higher Education entitled "PMW" in the years 2000-2023, contract No. 5091/H2020/2020/2, is acknowledged.

A28. Cr6+ and Pd-Free Electroless Plating on Plastics

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Plating on plastics (PoP) remains a pivotal technology in industries like the automotive, electronics, and home appliance industries, as it improves the mechanical strength, corrosion resistance and aesthetic appeal. Pretreatment of the polymeric surface is required to chemically deposit (electroless plating) an initial conductive metallic layer prior to electroplating. Current industrial processes employ carcinogenic and toxic-to-the-environment hexavalent chromic acid solutions during the etching process. Moreover, they rely on Critical Raw Materials such as palladium/stannous chloride colloidal solutions for surface activation. Surface pretreatment is followed by electroless plating to produce a Ni-P alloy. This work presents the development of a sustainable and cost-effective PoP approach by eliminating chromic acid and palladium, respectively, from the etching and the activation of ABS, PC-ABS and Nylon-12 polymeric surfaces. The chemical modifications and the morphological properties of the polymeric surfaces were investigated via FT-IR, Water Contact Angle measurements, SEM-EDX and Optical Microscopy. Our results demonstrate the successful electroless plating of a uniform, approximately 5 μm-thick Ni-P conductive layer on the polymeric surfaces with excellent adhesion. This breakthrough not only enhances the overall sustainability of the PoP process but also underscores its practicality, marking a significant stride towards environmentally conscious practices in surface coating applications.

This research work has received funding from the FreeMe project, financed by the European Union, under the GA number 101058699.

A29. Modification of PET chain to improve its solubility in a solvent suitable for the wet phase inversion process

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Membrane methods are gaining popularity as sustainable alternatives due to their chemical-free separation process, low environmental impact, and energy efficiency compared to traditional methods. Membrane techniques are already key elements of the technological process in many applications and industrial sectors. Therefore, developing materials from which new membranes will be produced is essential to implementing highly effective wastewater treatment technologies. An interesting material from which membranes can be made is poly(terephthalate ethylene) PET. Its high uniformity, mechanical strength, and resistance against chemicals make PET a promising material for membrane applications. Despite the many advantages of PET, there are limitations in its adaptation to the most commonly used method of membrane production, i.e., phase inversion. Phase inversion immerses a thin film of polymer dissolved in a solvent into a non-solvent coagulation bath. Removing the solvent creates a porous membrane. Using an effective solvent for dissolving PET while preparing the membrane is very important because it affects the properties of the finished membrane, such as hydrophilicity. The high chemical resistance of the polymer makes it challenging to find a solvent (or mixture of solvents) that will be miscible with water. The toxicity of commonly used PET solvents (e.g., trifluoroacetic acid/dichloromethane, chloroform, phenol, m-cresol) excludes their use in a sustainable economy. This work aimed to change the properties of PET by chemically modifying the polymer chain to increase the hydrophilicity of the polymer. Depolymerization of the PET chain was carried out via glycolysis. Diol functional groups were introduced into the polymer structure during the transesterification reaction. Structures of new PET, molecular weights, contact angles, surface analysis, and solubility in a new solvent were identified by Fourier-Transform Infrared (FTIR), Gel Chromatography (GC), Goniometr, and Scanning Electron Microscope (SEM), respectively.

A30. A Decision Support Tool for the simulation, design and optimization of emerging Plating on Plastics (PoP) technologies

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The current Plating on Plastics (PoP) process is challenged by the use of toxic Cr6+ and Pd, a Critical Raw Material, to form metallic nucleation sites that enable the metallization of non-conductive plastics. These issues raised concerns about replacing existing practices with REACH-compliant compounds. A novel PoP technology is proposed by the FreeMe EU-funded research project using acidic solutions and Ni-salts instead of Cr6+ and Pd, respectively. As a result, Decision Support Tools (DSTs) were employed to propose best practices for the adaptation of the new technologies to existing plating shops. The alpha version of the FreeMe-DST is formulated as a process design and optimization model to simulate the stages of an ABS polymer PoP process using (i) piranha solutions for etching plastics, (ii) Ni-acetate to activate etched polymers, (iii) NaBH4 for nickel site reduction, and (iv) metallization (Ni-P electroless deposition).

The FreeMe-DST is equipped with unit operation models, experimental data, and property estimation models. The reactions' mechanisms were described with higher-order kinetics and equilibrium models, while new regression models were built from scratch to predict and relate the physicochemical properties of plastic surfaces with process operating conditions. Studying the etching phenomena enabled the identification of the property patterns driving the development of a new model to estimate the Contact Angle of etched polymers as a function of the etching time and solution concentrations. As a step further, a new model-based concept was proposed to predict the adhesion of metallized polymers (key end-user specification) as a function of operating conditions and physicochemical characteristics, like the hydroxyl groups' surface density.

The DST receives inputs from end users (item dimensions, type of polymer, equipment design, specifications) and returns the best options for the design and operation, ensuring end-user specifications (use cases for the automotive, aerospace, and home appliance sectors) and securing Safe-and-Sustainability-by-Design principles by optimizing economic, environmental, and safety objectives.

A31. Rheological Characterization of Deep Eutectic Solvent after Delignification Process

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Deep eutectic solvents (DESs) have been used for lignocellulosic biomass fractionation and lignin extraction due to their simple procedure, selective solubility of lignin, low cost, and recyclability. After the delignification process of wood chips with DES, the initially transparent DES turns into a dark liquid with high viscosity that resembles a tar-like structure once the reaction is cooled down. The remaining highly viscous DES loaded with separated hemicellulose, cellulose and lignin is of great interest for further processing, e.g. to form biodegradable nanocomposite films, however, its rich structural and rheological features remain unexplored. In this study, we aim to provide insight into how the Hydrogen Bond Donors (HBD) and Hydrogen Bond Acceptors (HBA) forming the DES structure interact with lignin and cellulose dissolved in DES by performing thermo-rheological characterization and structural analysis by small-angle x-ray scattering. The results are correlated with the complex ion interactions with lignocellulosic biomass and are used to understand the viscoelastic behavior of the resulting complex fluids. Understanding the rheological characteristics of this material enables precise control over the mechanical properties of the final lignocellulosic nanocomposites.

A32. Production and characterization of hydrolyzed bacterial cellulose for extrusion-based 3D-Printing applications

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Bacterial cellulose, obtained through kombucha tea fermentation, is a promising renewable biomaterial and is purer than plant-derived cellulose. Hydrolyzed bacterial cellulose is widely used in research due to its crystallinity. This research focuses on assessing the mechanical and rheological properties of hydrolyzed bacterial cellulose, aiming to unveil its potential for extrusion-based 3D Printing.

Bacterial cellulose sheets were bio-synthetized from three different kombucha tea starters and, after a cultivation of 7 days, underwent an alkaline washing. Untreated cellulose sheets were dried and mechanically tested with uniaxial tensile tests. A blend of bacterial cellulose from the different cultures was subjected to 30%(v/v) H2SO4 hydrolysis (4 hours, 70°C). Hydrolyzed bacterial cellulose was dried in sheets and underwent uniaxial tensile testing. Hydrolyzed cellulose suspensions at different concentrations (5%(w/v), 9%(w/v), 13%(w/v), 17%(w/v)) were produced. Rheological analysis, including flow and oscillatory tests, was conducted on these suspensions to evaluate their suitability for extrusion-based 3D Printing.

The tensile properties of hydrolyzed bacterial cellulose sheets were aligned with those of untreated cellulose; therefore, hydrolyzation preserved microstructures. Rheological analysis showed a shear-thinning behavior of hydrolyzed bacterial cellulose suspensions, thus a suitability for extrusion-based 3D-Printing techniques. Thixotropy tests showed a prompt recovery after high deformations, typical of extrusion during 3D Printing, ensuring a high shape retention ability. In conclusion, these findings on the mechanical and rheological properties of a blend of hydrolyzed bacterial cellulose unlock avenues for its utilization in advanced applications, particularly in the field of additive manufacturing.

This study was carried out within the MICS (Made in Italy–Circular and Sustainable) Extended Partnership and received funding from the European Union Next-GenerationEU (PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR)–MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.3–D.D. 1551.11-10-2022, PE00000004). This manuscript reflects only the authors' views and opinions; neither the European Union nor the European Commission can be considered responsible for them.

A33. Modification of thermosensitive poly N-isopropylacrylamide derivatives intended for use as drug carriers

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The development of new or improved forms of drug delivery to affected sites is expected to improve pharmacotherapy. An innovative drug carrier should possess unique properties and respond intelligently, reversibly, and in a controlled manner to specific external stimuli. Modifying the structure and physicochemical properties of 'smart' drug delivery systems during synthesis can enhance the safety of drug distribution in the body, limit adverse effects on healthy tissues, and maintain appropriate drug concentrations. One potential candidate is the polymer N-isopropylacrylamide (PNIPA), which exhibits desirable thermosensitive properties for targeted drug delivery applications. PNIPA undergoes a phase transition at 32˚C, which can be modified by altering the polymer structure, such as through cross-linking. Cross-linked polymeric structures are commonly used as drug carriers due to the range of possible modifications to their structure. The physicochemical properties of these structures are also affected by the degree of cross-linking. This research evaluates the influence of an established type of cross-linking agent with different chain lengths on the characteristic physicochemical parameters of the obtained thermosensitive polymeric structures. The project aims to synthesise, by precipitation polymerisation without surfactants, a series of thermosensitive PNIPA derivatives using polyethylene glycol dimethacrylate with different carbon chain lengths as a cross-linking agent. The physicochemical properties of the polymers will be evaluated to select the most suitable one as a potential carrier for therapeutic substances. Physicochemical studies on the synthesised cross-linked polymers will provide information on the effect of the chain length of the cross-linking agent on parameters such as the particle size, phase transition temperature, and stability of these thermosensitive polymer structures. This research will contribute to the development of safer and more effective drug delivery systems.

A34. Crystallization, Molecular Dynamics, Electrical and Heat Transport in Complex Systems based on Semicrystalline Renewable Polyesters

Panagiotis Klonos[1, 2], Nikolaos D. Bikiaris[1], Lazaros Papadopoulos[1], Eleftheria Xanthopoulou[1], Zoi Terzopoulou[1], Alexandra Zamboulis[1], Apostolos Kyritsis[2], Dimitris N. Bikiaris[1]

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Various renewable biobased semicrystalline polyesters (PLA [1], PCL [2], furan-based [3,4], succinic acid-based [5], vanillic acid-based [6], etc.), in bulk form and in nanocomposites (PNCs), are studied using calorimetry, dielectric spectroscopy, and light flash analysis, in combination with other spectroscopic and microscopy techniques. Many structural aspects, e.g., the composition, molar mass, chain–chain associations, and polymer–nanoparticle (NP) interactions, are connected to the thermal transitions (crystallization, glass transition) and local and segmental molecular dynamics [7]. Next, the role of such direct and indirect structure effects are connected to the micro- and macroscopic performance. As expected, for moderate and high crystal fractions, the existence of crystals, their size, number, distribution, and interconnectivity dominate the heat transport, the ion and small molecular permeation, and the mechanical performance. The crystal nucleation memory [2,5] aspects are investigated in special homopolymers, whereas in PNCs, the nucleation and crystal growth are associated with the existence/absence and the strength of the formed polymer–NP interfacial interactions [4]. Novel models are proposed on the latter issues [4], as well as on the thermal conductivity in semicrystalline polymeric materials [1,8].

A35. Synthesis of multifunctional, innovative immediate-acting hemostatic patches based on chitosan with enhanced antibacterial properties and coagulative additives

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The restoration of hemostasis after an injury is still an ongoing challenge, despite numerous studies in this area. Massive blood loss can be a consequence of a transport accident or may occur on the battlefield. Hemorrhage also appears during surgeries and as a result of certain diseases. Despite modern surgical techniques and new hemostatic materials, bleeding is one of the most common causes of death in surgery.

In the present research, a hemostatic product of modified chitosan with poly(butylene succinate) (PBSu) nanoparticles containing the encapsulated active substance heparin is proposed. The modification of chitosan was prepared with zwitterion [2-(N-morpholino) ethanesulfonic acid (MES)], which gives the hemostatic products improved antibacterial properties. Protamine sulfate and vitamin K, which play a crucial role in blood coagulation, and iron sulfate, which creates a barrier by coagulating proteins and prevents the outflow of blood from vessels, were added to the hydrogel of the modified chitosan in small amounts. The FT-IR results confirmed the modification of chitosan with MES and its interaction with PBSu nanoparticles with heparin. The size and morphology of the nanoparticles were studied by DLS and SEM. Moreover, the morphology of the modified chitosan with the hemostatic additives was observed with SEM. The crystallinity of the prepared products was measured with XRD analysis. In addition, the swelling capacity and hydrolysis of the chitosan hemostatic product were studied, showing satisfactory results regarding high water adsorption and stability. Finally, in vivo hemostatic studies confirmed the aggregation of blood platelets and the successful hemostatic action using the chitosan hemostatic product compared to medical gauze.

A36. Comprehensive Investigation of Thermal Degradation and Non-Isothermal Crystallization Kinetics in High-Density Polyethylene Tannic Acid Composites

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The integration of natural additives into polymer matrices has become a focal point in contemporary materials research, driven by the pursuit of sustainable and enhanced-performance materials. Among these additives, tannic acid (TA), a natural polyphenol sourced from various plants, has recently garnered attention for its potential to modify polymer properties. This study explores the novel combination of HDPE with TA, aiming to investigate the potential reinforcement effects and property enhancements within the polymer matrix. The thermal degradation behavior and non-isothermal crystallization of HDPE/ TA composites were systematically investigated via thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC), respectively. The TGA results revealed multiple distinct mass loss stages during the decomposition process of HDPE/TA composites. A notable increase in the maximum decomposition temperature was observed in the derivative thermogravimetric plot. To elucidate the degradation mechanism, the conversion degree and kinetic parameters were calculated using isoconversional and model fitting methods. Various heating rates (5, 10, 15, and 20 °C/min) were employed, and both the differential isoconversional method of Friedman and the integral isoconversional method of Vyazovkin were utilized. The consistency between the Eα values obtained from these methods indicated the complexity of the thermal degradation mechanism, regulated by different processes at the initial and final stages. The Sbirrazzuoli model demonstrated remarkable accuracy in predicting crystallization kinetics, showcasing its efficacy in simulating non-isothermal crystallization processes under varying cooling rates. This comprehensive investigation contributes valuable insights into the thermal and crystallization behaviors of HDPE/TA composites, advancing our understanding of their complex kinetics under real-world processing conditions.

A37. Structural and Mechanical Properties of Poly(lactic acid) (PLA) and Poly(butylene succinate) (PBS) Blends through Nanocellulose Incorporation and Compatibilization

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This research explores the combined impact of nanofibrillated cellulose (NFC) reinforcement and compatibilization on the performance of blends comprising poly(lactic acid) (PLA) and poly(butylene succinate) (PBS). Blends with an 80/20 ratio of PLA to PBS were formulated through melt blending and subsequently enriched with 1 wt% NFC, either in its original state or acetylated. To improve miscibility, the blends were compatibilized using a PLA-co-PBSu copolymer, as verified by scanning electron microscopy (SEM) analysis.

In addition to this, mechanical properties were assessed through tensile testing, revealing improved tensile strength and elongation in the compatibilized blends compared to neat PLA.

This thorough examination offers valuable perspectives on enhancing the mechanical properties of PLA/PBS blends by introducing nanofibrillated cellulose and implementing compatibilization. These discoveries contribute to the progression of knowledge in sustainable polymer blends.

This work was funded from the European Union’s Horizon 2020 Research and Innovation Programme under Grant Agreement No. 952941 (BIOMAC Project).

A38. Thermal Properties and Biodegradation of Poly(lactic acid) (PLA) and Poly(butylene succinate) (PBS) Blends through Nanocellulose Incorporation and Compatibilization

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This study investigates the synergistic effects of nanofibrillated cellulose (NFC) reinforcement and compatibilization on the performance of poly(lactic acid) (PLA) and poly(butylene succinate) (PBS) blends. Blends with an 80/20 ratio of PLA to PBS were prepared using melt blending and further enhanced with 1 wt% NFC, either in its pristine form or acetylated. The blends were compatibilized with a PLA-co-PBSu copolymer to enhance miscibility.

The thermal and crystallization characteristics were investigated using differential scanning calorimetry (DSC), X-ray diffraction (XRD), and polarized light microscopy (PLM). The results indicated an enhanced crystallization of PLA in the presence of nanocellulose. Additionally, the impact of nanocellulose on enzymatic hydrolysis was evaluated by mass loss measurements and microscopy observations.

This comprehensive investigation provides valuable insights into improving PLA/PBS blends' mechanical, thermal, and enzymatic properties through the incorporation of nanofibrillated cellulose and compatibilization. These findings contribute to advancing our understanding of sustainable polymer blends for various applications, particularly in the context of enhanced performance and biodegradability.

This work was funded by the European Union’s Horizon 2020 Research and Innovation Programme under grant agreement no. 952941 (BIOMAC Project).

A39. Ultra-high-Molecular-Weight Polyethylene/Graphene Nanoplatelet Composites

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In recent years, in the global chemical industries, there has been a transition away from metallic-based infrastructure to non-metallic based infrastructure. This represents a huge challenge due to the dramatically different properties of polymer-based engineering materials over metals. One serious challenge is that polymer-based materials suffer from disadvantages such as creep, deformation under continuous load, and relatively low tensile strength. Using nanomaterials such as graphene nanoplatelets (GNPs) to form polymer nanocomposite materials is one strategy that may mitigate some of these presented issues. However, graphene nanoplatelets (GNPs) can also suffer from low compatibility or efficient dispersion in a polymer matrix due to their agglomeration. This study investigates and examines the use of a novel innovative polymeric compatibilizer to target and enhance the dispersion of graphene nanoplatelets (GNPs) into the ultra-high-molecular-weight polyethylene (UHMWPE) matrix as well as study the resulting improved mechanical and thermal properties that are obtained.

A40. The effect of keratin extracted from chicken feathers by different methods on the properties of bio-polyamide nanocomposites

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In order to comply with the 2015 EU directive on the end of life for cars, which stipulates the obligation to reuse and recycle 85% of the vehicle, increasing emphasis has been placed on the development of polymer composites based on bio polymers reinforced with natural (nano) fillers. Bio-polyamide from 100% bio sources (bio-PA) is a high-performance plastic with better mechanical properties, chemical stability and/or thermal stability than the most used polyamides, polyamides 6 or 6,6. The waste generated by the poultry industry, such as chicken feathers, has attracted the attention of many researchers. Chicken feathers have a multifunctional, self-assembled structure that contains over 90% keratin, an insoluble protein with high resistance to biodegradation, tightly packed either in an α-helix or a β-sheet into keratin supercoiled polypeptides. Different methods have been developed for the treatment of chicken feather waste and the recovery of keratin and amino acids. The mechanical properties and thermal behaviour of chicken feather keratin depend on the chemical composition and structural arrangement, resulting from the keratin extraction methods.

In this paper, the morphological/structural (SEM, XRD, FTIR), thermal (TGA, DSC), mechanical (tensile and impact tests), dynamic mechanical (DMA) and nanomechanical (nanoindentation and nanoscratching) properties of the nanocomposites based on the bio-PA and keratin extracted from chicken feathers were studied. Keratin extracted by thermal hydrolysis (KT), by alkaline hydrolysis (KA) and by chemical hydrolysis in combination with enzymatic treatment (KC) was used. In dynamical conditions using the melt processing method, nanocomposites with 5 wt.% keratin were obtained. The best properties were obtained by the uniform dispersion of KT in the bio-PA matrix (an improvement of approx. 15-30% compared to the virgin polymer).

A41. Lignin/Carbon nanotubes hybrids for conductive inks applications

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Conventional electronic parts are based on non-renewable resources and have a negative impact on the environment. Research has focused on sustainable alternatives by examining the potential use of biomass products in printed electronics applications. Lignin, an organic, abundant, and biodegradable polymer, is an attractive choice for “green” electronics. The integration of lignin in conductive inks can promote printability, without significantly affecting the electrical conductivity. In addition, carbon nanotubes (CNTs) are well documented regarding their very good electrical and thermal conductivity and mechanical strength, making them suitable as conductive fillers in inks formulations [1]. The combination of lignin and CNTs is expected to produce hybrid materials with good electrical conductivity and mechanical performance with lignin serving as a dispersing agent to improve the stability and uniformity of CNT-based formulations. In the present work, Lignin/CNTs hybrids were synthesized using an eco-friendly process that avoids the use of organic solvents. We experimented with different types of CNTs, including functionalized and oxidized varieties, to optimize the electrical conductivity of the resulting hybrids. These were prepared by directly dispersing CNTs and Lignin in water with the aid of Ultrasonication. The hybrids’ properties were investigated via DLS, TEM and SEM. The electrical conductivity was determined via Broadband Dielectric Spectroscopy (BDS), yielding values ranging from 10-4 to 10-2 S/cm in all samples. This indicates free electrons transport and thereby the potential use of Lignin/CNTs hybrids as bio-based alternatives in electronic applications.

A42. Production of cellulose nanoparticles towards functional polymer additives

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Biomass exploitation towards renewable materials via greener and more sustainable technologies has recently been in the scientific and technological spotlight. Recently, natural fibers are drawing increasing attention as an alternative to traditional nanofillers, such as glass and carbon fibers, clays, or carbon nanotubes. Special focus is recently placed on nanocellulose. Owing to its exceptional features such as high crystallinity, large surface area, and good thermomechanical properties, cellulose nanoparticles can serve as excellent polymer reinforcing agents. However, due to their hydrophilic nature, nanocellulose is often surface-modified with various organomodifying agents to achieve improved dispersion into the polymeric substrates or to enhance the final materials' hydrophobicity.

In this work, cellulose was extracted from poplar by an integrated biorefining process, comprising of a first organosolv fractionation step, followed by bleaching of the remaining cellulose-enriched biomass. In the optimized organosolv step, both high delignification of biomass and almost complete solubilization of hemicellulose take place, thus making these two important "side-streams" also recoverable for downstream utilization in various applications. The isolated cellulose was then used to produce cellulose nanofibers (CNFs) and cellulose nanocrystals (CNCs) via ultrasonication and a typical sulfuric acid hydrolysis procedure, respectively. Finally, they were surface-modified with 3-Aminopropyltriethoxysilane, 1H,1H,2H,2H-perfluorooctyltriethoxy and (pentafluorophenyl)triethoxy-silane. All cellulose nanoparticles were characterized as to their structure and crystallinity using FT-IR and XRD, while their size and thermal stability were determined by DLS and TGA, respectively. Their surface modification was confirmed by means of XPS and elemental analysis. The results demonstrate the successful production of highly crystalline CNFs and CNCs promising thermal properties, highlighting the great potential of waste biomass utilization to high-added value products through biorefinery pathways.

A43. Rapid manufacturing of smart nanofibers: Solution blow spinning of polycaprolactone with anthocyanins from agri-food sources

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The continuous advancement in rapid manufacturing techniques has played a crucial role in the fabrication of nanofibers intended to produce smart food packaging. This study aimed to employ the solution blow spinning (SBS) technique for the rapid production of intelligent nanofiber mats based on polycaprolactone (PCL) and red cabbage extract (CE) obtained from retail waste for application in monitoring food quality. The addition of CE to the PCL matrix increased the nanofiber diameter from 156 nm to values between 261.05 and 278.14 nm for PCL/CE10 and PCL/CE15, respectively. The addition of CE also improved the mechanical and water-related properties of the nanofibers, although it reduced thermal stability. CE-incorporated nanofiber mats exhibited visible color changes ($\Delta E \geq 3$) in response to buffer solutions with a pH range between 3 and 10, as well as when exposed to ammonia vapor. The smart nanofibers demonstrated the ability to monitor fish fillets through visible color changes during storage. Initially, at 0 hours, the PCL/CE10 and PCL/CE15 mats exhibited a lilac hue, but after 24 hours, this color became less saturated. After 48 hours, bluish-gray tones were observed, and after 72 hours, the blue color indicated the deterioration of the fish fillets with a pH of 8.01. Thus, smart nanofibers produced via the SBS technique reveal potential as intelligent food packaging materials.

The authors are grateful to FAPESP (processes 2021/13260–7 and 2023/02038-7) for their financial support.

A44. Dissolution Enhancement of Aprepitant Drug in Polymer Solid Dispersions

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In the present study, ternary solid dispersions (SDs) of Aprepitant (APT) were developed and evaluated for the first time. Specifically, ternary SDs of APT with Poloxamer 188 and Soluplus® (SOL) were prepared via melt mixing and compared to binary APT/Poloxamer 188 and APT/SOL SDs. Pre-weighed (a total of 10 g) binary (APT/Poloxamer 188 and APT/SOL) and ternary (APT/SOL/Poloxamer 188) SDs were prepared via melt mixing using a Haake–Buchler Reomixer at 150oC and 15 min mixing time with roller blades. Three different drug concentrations (10, 20, and 30 wt%) were used.
Differential scanning calorimetry combined with wide angle X-ray diffraction studies showed that crystalline API was dispersed in both binary and ternary SDs, while Fourier transformation infrared spectroscopy studies revealed no molecular interactions among the components.
Scanning electron microscopy combined with EDAX element analysis showed that the API was dispersed in nano-scale within the polymer matrices, while increasing APT content led to increasing API nano-crystals within the SDs.
Dissolution studies of both binary and ternary SDs showed that Poloxamer 188 strongly affected the release profile of APT, since an initial burst effect leading to high percentages of the dissolution rate were observed in all ternary SDs. In all prepared solid dispersions, the drug dissolution was substantially enhanced, compared to neat drug, proving that the chosen polymer matrices are appropriate to produce immediately released formulations.

A45. Chitosan-Based Hemostatic Sponges with Antibacterial Properties: Synthesis and Characterization

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In ancient years, different processes were sought to effectively control bleeding, especially when the normal coagulation of the human body was insufficient to achieve satisfactory hemostasis. The application of traditional dressings with the purpose to stop a hemorrhage is effective only in the case of superficial wounds. Any skin tissue damage associated with excessive bleeding requires the use of a hemostatic agent. Currently, there are a few types of hemostatic agents, such as physical agents, resorbable agents, biological agents, synthetic agents and dressings. The most popular ones are biodegradable gelatin and collagen foams, fibrin sealants as well as chitosan granules, sponges, and dressings. Hemostatic agents may be used in hospitals and by individuals. Thus, the environmental conditions of their application can be very diverse. Some injuries may occur under non-sterile conditions. Traumatic wounds that are exposed to dirt and pathogens are susceptible to infections. Therefore, an ideal hemostatic agent should have antimicrobial properties. This can be achieved by applying a dressing containing antibiotics or metallic nanoparticles that are effective against most bacterial species.

In this work, we try to modify chitosan with zwitterion [2-(N-morpholino) ethanesulfonic acid (MES)]. The modification of chitosan was achieved by introducing new functional groups under mild reaction conditions through its reactive amino groups and hydroxyl groups. The chemical construction of the new chitosan derivative (CS-MES) was studied via FTIR, and the water solubility of CS-MES was studied under different conditions. Additionally, we investigated the morphology and crystallinity of CS-MES via SEM and XRD analysis. Finally, we chose S. aureus and E. coli. to study the antibacterial properties of CS-MES.

A46. The potential of fucoidan as an effective carrier of natural antimicrobial agents

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Biopolymers, the so-called 'building blocks of nature', are found in all organisms of animal, microbial, or vegetable origin. They have received a lot of interest in various applications where sustainable and biodegradable solutions are needed. Biopolymers have been widely exploited in medicine, pharmaceutical engineering, the food industry, and other bioengineering fields.

Fucoidan is a water-soluble sulfated polysaccharide commonly isolated from brown algae. As a natural polymer with its antioxidant, antibacterial, antiobesity, antiallergy, anticancer, antibacterial, antiviral, anticoagulant, and antitumor properties, fucoidan has also received widespread attention in various fields, particularly for its use as a coating material.

This work aims to use fucoidan for the encapsulation of the natural antimicrobial agent K2 toxin produced by the food yeast Saccharomyces cerevisiae. Encapsulation protects K2, which is a protein, from adverse environmental factors, proteolysis, or interactions with other substances in food. The K2–fucoidan particles were synthesized by a simple complexation method at pH values 3.8, 4.2, and 4.8. The fucoidan concentration was 0.1 or 0.4 mg/mL and the K2 concentration was 2.6 or 4.0 µg/mL. FT-IR and DLS methods were used to confirm the interaction of components. The morphology of particles was determined by SEM. The resulting particle size was typically 180–280 nm at all pH values. Particles containing K2 usually had a less negative surface charge compared to fucoidan. In addition, stability studies were performed that were based on the measurement of the particle size and zeta potential during storage. After the storage of the particles for 4 weeks at +4 °C, the zeta potential changed insignificantly, while the size tended to decrease.

To conclude, fucoidan has potential as a carrier for the development of a K2 toxin delivery system.

A47. A smart coating with enhanced antibacterial properties based on pH-sensitive modified chitosan for dental implant applications

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Tooth loss is very common due to various causes; therefore, the use of dental implants is a widely followed strategy for tooth replacement. Till now, commonly used dental implants were susceptible to bacterial colonization, and, subsequently, to the formation of a bacterial biofilm. Peri-implantitis is defined as an inflammatory condition, induced by this biofilm, that affects the tissues surrounding the implant and leads to the loss of supporting bone, thus compromising the effectiveness of implant therapy. Our vision is to provide a proactive option to deal with peri-implantitis by developing a functional implant coated with a pH-sensitive material, which would aid in the prevention of bacterial colonization and simultaneously have an advanced regenerative potential.

In the present study, the structure of chitosan (CS) was modified with 2-sulfobenzoic acid cyclic anhydride (SBA), and the new CS derivative was further crosslinked with vanillin through the formation of Schiff-base C=N bonds that are sensitive to acid hydrolysis, thus tuning the pH-responsive behavior of the material and enhancing the antimicrobial activity of chitosan. The modification of the chitosan structure with the SBA zwitterion was confirmed spectroscopically using FTIR and NMR, the semicrystalline character of the CS derivative was evaluated by means of XRD, the swelling ability was investigated under neutral and acidic conditions, and the shear-thinning behavior was assessed via rotational viscometer studies. In a further step, solution blending of neat CS and the CS-SBA derivative was performed, whilst cerium oxide nanoparticles (Ce-NPs) and mesoporous cerium-doped silicate nanoparticles, both reported as having an antibacterial potential, were introduced into the CS/CS-SBA matrix. The obtained dispersion was then used for injection coating upon titanium implants. Scanning electron microscopy revealed the fine dispersion of the NPs in the smart CS blend, whereas stereomicroscopy was employed to examine the coating efficiency in terms of the layer thickness, homogeneous deposition and consistency.

A48. Comparison of Biodegradable Packaging Materials Containing Berberine and Quercetin

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Introducing additives that change the composition and the properties of the atmosphere inside packaging or compounds characterized by antibacterial and antioxidant properties allows us to obtain active packaging and extends the shelf life of most food products. Natural compounds with antibacterial properties include flavonoids, among which berberine and quercetin deserve particular attention. Published works devoted to packaging materials based on polylactide with the addition of berberine and quercetin [1,2] resulted in biodegradable materials that have antibacterial properties, while being thermally and mechanically stable. The desired properties of packaging materials also include resistance to water vapor permeability and antioxidative properties that extend the shelf life of stored products. Moreover, in the case of packaging containing various types of additives, it is very important to meet the EU standards regarding the migration of active ingredients into food simulants. Therefore, our research focused on the analysis of the above-mentioned parameters. The properties of polymer films containing from 0.5 to 2% wt. of particular flavonoids were examined and compared. Based on the obtained results, it was determined that materials containing quercetin have excellent antioxidative properties, while films with the addition of berberine have practically no such properties. Interestingly, the addition of quercetin increases the water vapor permeability of polylactide-based films, while the introduction of berberine leads to increased resistance to water vapor transmission. It was found that both types of packaging extend the freshness of blueberries. Moreover, based on migration tests for the food simulants including isocatane, 10% ethyl alcohol, and 3% acetic acid, it was established that the obtained materials meet the EU standards and the migration does not exceed 10 mg per kg of stored food. The obtained results lead to the conclusion that the studied materials, containing quercetin and berberine, constitute promising active packaging.

A49. Novel functional biobased esters used as plasticizers for polymeric materials

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Many studies on active packaging materials are related to polymers modified with essential oils or pure terpenes used as active additives due to their antimicrobial properties. However, essential oils have some drawbacks such as high volatility, intense fragrance, or irritating properties. Thus, some of the main neutralization methods are chemical reactions, e.g., esterification. In our work, we chose two commercial additives (with different alkyl chain lengths between functional groups) with two end ester groups and functionalized them with selected terpenes (enzymatically and without any catalyst). The highest reaction yield was obtained in the case of geraniol and citronellol. Four esters based on these additives and two terpenes were characterized (e.g., FTIR, DSC, TGA, and NMR) were added to commercial poly(butylene succinate) (PBS) for a preliminary study exploring the plasticizing effect on the films obtained via the casting method. Homogenous, flexible, and slightly opaque films were obtained, and mechanical and thermal (DSC and DMTA) tests, as well as microbiological (antibacterial and antiviral) tests, were performed. After esterification, the fragrance of the terpenes had lower intensity and the esters exhibited thermal stability higher by ca. 100 °C than pure terpenes. Modified PBS films inhibited Streptoccocus aureus strain growth. Such materials can be used as packaging materials, e.g., in medical and food sectors.

This work has received funding from the European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie grant agreement no. 872152 (GREEN MAP). An international project co-financed by the program of the Minister of Science and Higher Education entitled "PMW" in the years 2000-2023; contract no. 5091/H2020/2020/2 is acknowledged.

A50. Electrospun nanofibers with pomegranate peel extract as a new concept to treat oral infections

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Pomegranate peel extract is known for its potent antibacterial, antiviral, antioxidant, anti-inflammatory, wound healing, and probiotic properties, making it useful in the treatment of oral infections.

This study focused on optimizing an electrospinning process for a combination of polycaprolactone (PCL) and polyvinylpyrrolidone (PVP) nanofibers loaded with the optimized pomegranate peel extract. The preliminary studies of the process involved the time of system mixing prior to electrospinning, the mixture flow rate, and the rotation speed of the collector. The characterization of the nanofibers was confirmed using XRPD diffractograms, SEM pictures, and FTIR-ATR spectra. The composition of the nanofibers can control the release; in the case of PVP-based nanofibers, immediate release was achieved within 30 minutes, while in the case of PCL/PVP, controlled release was achieved within 24 hours. All systems showed antibacterial activity against oral pathogenic bacteria. Analyzing the effect of different scaffold compositions on the obtained electrospun nanofibers showed that those based on PCL/PVP had better wound healing potential.

The proposed strategy to produce electrospun nanofibers with pomegranate peel extract is an innovative approach to better use the synergy of the biological action of active compounds present in extracts and patient-friendly pharmaceutical form, especially useful for the treatment of oral infections.

A51. Biodegradable PLA-PEG-PLA triblock copolymer microbeads using microfluidics technique for cosmetic applications

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The global production of plastics continues to rise, and it is estimated that more than 10 million tons of plastic wastes enter the oceans every year. As such, microplastics pose a considerable threat especially considering the growing body of evidence concerning the impacts of plastic waste. Microplastics are classified into two major categories, primary and secondary microplastics, depending on their origin. Natural weathering processes yield secondary microplastics from macroplastic wastes after use. In contrast, primary microplastics are intentionally produced in small sizes for specific applications. Microbeads (MBs) are primary microplastics and are approximately 1 mm or less in diameter; they are extensively used in cleansing health products such as personal exfoliants and toothpastes. Consequently, the industry of cosmetics must develop formulations and processes based on sustainable alternatives such as biodegradable microparticles from natural feedstock to replace the plastic MBs. In the past decades, the microfluidic technology has proven to be extremely beneficial in the successful preparation of micro- and nanoscale particles. This technique has attracted much attention due to it allowing the exact control of reaction conditions and fluid flow, since it enables the precise and homogenous mixing of the polymer solution with the antisolvent solution, in contrast to the manual bulk mixing method. In the current work, the successful ring opening polymerization (ROP) of amphiphilic triblock PLA-PEG-PLA copolymers using various [PLA]/[PEG] molecular ratios is reported. The fabricated materials were characterized using FT-IR, XRD, and DSC techniques in order to investigate their physicochemical properties. A 3D flow focusing microfluidic device with 100 μm channels was used for the preparation of the PLA-PEG-PLA microparticles. The morphology and size of the obtained microbeads was observed using a scanning electron microscope (SEM). Their biodegradability in the environment was tested via soil degradation and degradation in various aquatic environments, as well as under UV exposure

A52. Eletromagnetic Interference and Shielding Numerical Simulations of Electronic Packages for Automotive Industry

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Numerical simulations are becoming of extreme importance to study the Electromagnetic (EM) behaviour and the interaction of certain devices with the surrounding environment. In the automotive industry, this necessity arises with particular relevance as there has been an increasing amount and complexity of electric and electronic systems over the past years [1]. A great part of the current industries, including the automotive one, is conducting the replacement of metal parts with polymeric and composite parts to a major trend that allows, among others, the reduction of the weight [2,3], what is, for battery-powered vehicles, a great asset as it increases the autonomy. Obviously, this material exchange must be properly studied regarding mechanical (structural), thermal and the associated EM constraints. This work presents the development of a polymeric lightweight material(s) packaging for batteries based on iterative numerical simulations, with a focus on the EM behaviour. The numerical simulations are performed aiming to assess the effect and feasibility of using some polymeric and composite packages, by predicting the propagation and intensity of EM fields inside the enclosure when subjected to external interferences. Therefore, it is understood whether the material EMI shielding is effective (over 20 dB for electronic devices; ideally over 40 dB) [4,5]. It also depicts a comparison between the actual case study, that is a metallic package (aluminium and stainless steel). The influence of parameters such as incident waves direction, magnitude and polarisation are also evaluated. Finally, considerations of the geometry and materials properties are proceeded, suggesting the best geometric and material approach to be followed.

This article was developed within the scope of the “Agenda/Alianças Verdes para a Inovação Empresarial” by the Consortium “NGS New Generation Storage” co-financed by NextGenerationEU, through the 'Business Innovation Agendas' investment from the Recovery and Resilience Plan (RRP).

A53. Exploring the potential of Rosin and its Derivatives for Innovative and Environmentally Friendly Materials

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Polymers are an integral part of our modern lifestyle, with most polymeric products being derived from fossil fuels. Considering the continuous consumption of oil reserves and the adverse environmental effects of their uses, new alternatives are being sought in renewable and natural resources. Nature is a source of raw materials with important properties and applications, which have recently captured more and more interest due to their abundance, cost, and easy chemical modification.

Within this context, the RN21 project intends to enhance and mobilize research and innovation on the natural rosin extracted from pine trees and its derivatives, as a “bio” raw material. Through this project, we expect to enhance the range of ready-to-market applications and increase the value chain of the rosin exploitation sector. Thus, the opening of the application field of this raw material is envisaged in sectors such as packaging, textile, automotive, shoes, among others, and it leads to an increase in the bio content and sustainability footprint of the final structure, as well as the valorization of a national resource.

In the present study, rosin derivatives are incorporated into biobased polymeric matrices. The experimental design includes the formulation, compounding, and production of samples and their performance evaluation. The efforts aim to maintain or enhance their mechanical performance, processability, and compatibility when compared with the currently used materials.

The RN21 project has received funding from the Environmental Fund through Component 12 – Promotion of Sustainable Bioeconomy (Investment TC-C12-i01 – Sustainable Bioeconomy No. 02/C12-i01/2022), of European funds allocated to Portugal by the Recovery and Resilience Plan (PRR), within the scope of the European Union (EU) Recovery and Resilience Mechanism, framed within Next Generation EU, for the period 2021–2026.

A54. Enhancing Clay-Based 3D Printing Mortars with Polymeric Mesh Reinforcement Techniques

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Additive manufacturing (AM) technologies have garnered significant attention in the construction field in recent years. Specifically, AM technologies such as 3D mortar printing (3DMP), 3D concrete printing (3DCP), and Liquid Deposition Modeling (LDM) that utilize 3D printing machines for working with various building materials offer noteworthy advantages over conventional construction methods. Building with 3D-printing technologies has the potential to eliminate project time, costs, and overall resource requirements while at the same time providing free design possibilities. Moreover, it contributes to the automation of the construction process, leading to a reduction in workplace accidents. However, AM in construction presents challenges in achieving superior results in total mechanical performance compared to traditional building methods. These challenges include limitations such as poor interlayer bonding and the presented anisotropies of the extruded mixtures. Therefore, it is imperative to conduct research aimed at enhancing the structural properties in AM building construction. This study aims to provide a comprehensive investigation showcasing the potential of embedding 3D-printed polymeric meshes in clay-based mortars to enhance their performance. Clay-based materials are selected for their reduced environmental impact and recyclability compared to cement-based materials. One of the optimal geometries identified in the literature was chosen for the 3D-printed meshes, which were then printed using three of the most widely used polymeric materials in 3D-printing applications (PLA, ABS, PETG). To reinforce the mechanical properties of the printed specimens, the meshes were strategically placed in the interlayer direction during the 3D-printing process. The outcomes of adding polymeric meshes show that, with polymeric meshes and a small addition of cement, the 3D-printing specimens exhibit improved mechanical characteristics in terms of compression and tension performance. Furthermore, the successful integration of the printed reinforcements into clay-based mortars has been valid

A55. Poly(L-lactic acid)-co-poly(butylene adipate) block copolymers as long acting injectable microparticles of Aripiprazole drug

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Microparticulate-based long acting injectable (LAI) formulations is an emerging technology of drug delivery systems. That is because they promote sustained drug release, where extended times varying from a few weeks up to 2-3 months can be achieved. The greatest benefit of LAIs, compared to traditional formulations, is that less frequent dosing is required, yet improved therapeutic efficacy is accomplished due to the higher patient adherence. Aliphatic polyesters, such as poly(lactic acid) (PLA) and its copolymers with glycolic acid (PLGA), are the most used polymers for such applications.

In the present study, a series of new poly(L-lactic acid)-co-poly(butylene adipate) (PLA/PBAd) block copolymers of different weight ratios (90/10, 95/5, 75/25 and 50/50 ww/) have been synthesized by a combination of melt polycondensation (PBAd) and ring opening polymerization of L-lactide in the presence of PBAd. The chemical structure of all prepared copolymers was assessed using FTIR and NMR spectroscopies, while their molecular weight was determined by Size-exclusion chromatography (SEC). It was found that by increasing the PBAd content, the molecular weight in copolymers decreases, whereas the addition of PBAd accelerates the enzymatic hydrolysis of the polymer matrix.

Due to their low cytotoxicity, these copolymers can be utilized in drug delivery applications. In this study, the microencapsulation of Aripiprazole (ARI) drug, via a typical emulsification/solvent evaporation technique, and its release rate was investigated. SEM micrographs showed the formation of well-shaped, spherical MPs, while DSC and pXRD data revealed that ARI drug was encapsulated in amorphous form. In vitro dissolution studies suggested a highly tunable biphasic extended release, for up to 30 days, indicating the potential of the synthesized copolymers to act as promising LAI formulations, that will maintain a continuous therapeutic level for an extended time period.

A56. Application of a polymer ultrafiltration membrane made of polyacrylonitrile to close the water circuit in the metal industry

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Achieving climate and raw material neutrality by 2050, i.e. implementing the assumptions of the New Green Deal, requires transforming the entire system of production and consumption in such a way as to eliminate the concept of waste. The value of raw materials, including water, should be maximized in accordance with the 7xR hierarchy, i.e. rethink, reduce, reuse, repair, refurbish, recycle and recover. Applying this principle in water and wastewater management requires the development of system solutions, primarily in the recovery and reuse of water contained in wastewater, as well as their immediate implementation in enterprises. Technologies that will provide not only a positive ecological effect but also bring economic benefits to the entrepreneur are being sought.

Membrane filtration is currently increasingly used in the industry (including in the production of food, beverages, and pharmaceuticals) due to its low cost and ease of production, as well as ensuring high efficiency, effectiveness, and selectivity of filtration. Intensive research and development in the area of using membrane techniques for closing water circuits is closely related to the rapid development of polymer technologies and the production of specialized filtration membranes.

The presented work concerns the possibility of using a polymer membrane made of polyacrylonitrile for the treatment of post-industrial wastewater produced by metal industry enterprises. Wastewater generated during vibroabrasive machining of zinc-aluminum alloy details was examined. The tests were conducted on a laboratory scale (membrane with an area of 140 cm2). An ultrafiltration process and a transmembrane pressure of 4 bar were used. Filtration through a bag filter (5 µm pore diameter) was used as the initial purification step. The possibility of reusing reclaimed water in the original industrial process was assessed.

A57. Development of Safe Nano-Enabled Bio-Based materials and bionanocomposites for advanced applications – Open Innovation Test Bed (OITB)

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The development of biomaterials with functional properties can be valuable for new applications and has been proven a sustainable alternative to fossil-based materials. BIONANOPOLYS is a 48 month-project granted by the European Commission, which aims to bring to the market safe nano-enabled bio-based materials and polymer bionanocomposites for multifunctional and new advanced applications. In order to achieve this goal, high lignocellulosic feedstocks are used for the production of cellulose nanofibers (CNF), cellulose nanocrystals (CNC) and nanolignin (NL) as well as high sugar content feedstocks are used for the production of building blocks, organic acids, PHA and active compounds.

BIONANOPOLYS Open Innovation Test Bed (OITB) offers state-of-the-art technologies in upgraded pilot plants as well as technical services such as quality control and process optimization, modelling and simulation, and monitoring. In addition, non-technical services are also offered such as life-cycle assessment, food safety, evaluation of biomaterial, compostability and recyclability analysis, business and legal support, and techno-economic assessment.

More specifically, there is a network of 14 pilot plants involved in BIONANOPOLYS, 5 pilot plants are developing bionanomaterials from biomass, 3 pilot plants are focusing on polymer bionanocomposites as well as 6 pilot plants are involved in the manufacturing process of the bio-based nanoproducts. BIONANOPOLYS OITB aims to develop bio-based materials and bionanocomposites for a large range of applications in different sectors such as packaging, food, pharmaceuticals, textile, and additive manufacturing.

This project has received funding from the European Union’s Horizon 2020 Research and Innovation programme under grant agreement No. 953206.

A58. Development of Nanoparticulate Drug Delivery Systems for Endoplasmatic Reticulum Aminopeptidase Modulators for the Treatment of Cancer or Autoimmune Diseases

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Endoplasmatic reticulum aminopeptidases (ERAPs) are key enzymes in the generation of antigenic epitopes that bind the Major Histocompatibility Complex class I. Therefore, they modulate the immunopeptidome presented at the cell surface that triggers the immune response via T- or NK-cells. Thus, they are potential targets for viral infections, cancer, or autoimmune diseases. However, the discovery of potent and selective ERAP inhibitors as well as their controlled and selective delivery at pathological sites is highly challenging. To overcome this, hybrid amphiphilic pH-responsive polymeric materials were synthesized to form nanoparticles with encapsulated ERAP inhibitors. They are pH-responsive in order to be delivered selectively at pathological sites and tissues where there is a lower pH. The polymeric materials are poly(ethylene oxide)-b-poly(L-histidine) copolymers. Since the ERAP inhibitors are negatively charged, they interact with the positively charged poly(L-histidine) amino acids to form spherical core–shell nanoparticles. The nanoparticles were extensively characterized by static and dynamic light scattering, Zeta potential, and UV and NMR spectroscopy. Their drug loading efficiency and capacity were be obtained. Their release profiles were measured at buffers exhibiting different pH values, mimicking healthy as well as cancer cell environments. The results show that the nanoparticles are promising ERAP inhibitor delivery systems to treat cancer as well autoimmune diseases.

A59. Molecularly Imprinted Poly(2-oxazoline) for the Selective Recognition of Ibuprofen

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Ibuprofen is a non-steroidal anti-inflammatory drug used as a mild analgesic that has been detected in wastewater, surface water, groundwater, and even drinking water. Thus, there is an urgent need for the development of methods that are suitable for the extraction of such a pollutant from water. Among the various remediation alternatives, molecularly imprinted polymers (MIPs) have emerged as a promising candidate for water treatment due to their high affinity and specificity for a target template. Indeed, MIPs are cross-linked functional polymer materials that are prepared in the presence of a specific template, thereby creating cavities with a certain spatial distribution of functional groups that selectively recognise the template molecule. Herein, we present the successful preparation of polyoxazoline-based MIPs for the recovery of ibuprofen. The advantage is that poly(2-oxazoline)s have high biocompatibility, stealth behaviour, and high synthetic versatility. The structure of both the molecularly imprinted polymer (MIP) and its non-molecularly imprinted counterpart (NIP) has been analysed using Fourier-Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM), and Atomic Force Microscopy (AFM). Template adsorption on MIP and NIP was studied in batch experiments and the determination of the residual target analyte in solution was performed on an HPLC-DAD system. Adsorption isotherms were calculated to understand the adsorption interaction mechanism of the template with the MIP surface. The obtained adsorption isotherm equilibrium data were analysed using the Langmuir and Freundlich isotherm models for both MIPs and NIPs. We investigated the influence of several parameters on the template adsorption as well as the reusability of the MIPs. We also tested our MIPs for the selective removal of ibuprofen in real samples, such as water from Lake Albano in Italy.

A60. Design and synthesis of Poly(2-oxazoline)s for wastewater treatment

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Over the last decades, governmental organizations have become increasingly aware of the chemical pollutant crisis and the resulting severe threats to humankind and environmental health. Taking into account the possibility of remediating wastewater, poly(2-alkyl/aryloxazoline)s (PAOxs) have undoubtedly been recognized as a valuable polymer class, characterized by uncommon synthetic versatility and good biocompatibility, features that give straightforward access to highly functionalized and adaptable materials.

Considering that, we devoted several efforts to the preparation of polymers capable of exploiting electrostatic and hydrophilic interactions with a predetermined cargo (heavy metal ions, organic pollutants, and active principles). In particular, (a) PiPOx, which establishes weak intermolecular interactions due to the carbonyl group, easily coordinates heavy metal ions, as well as (b) pAmOx, decorated with aminic moiety, which could interact with small acidic compounds such as pharmaceutical products, and (c) PolyPhOx, bearing a diphenyl substituent, is able to install π-π stacking interactions and is suitable for removing organic pollutants from aqueous solutions. Moreover, we embarked on the task of optimizing the CROP reaction conditions with the objective of formulating a protocol for the Gram-scale production of various POxs. Simultaneously, we made several attempts to bind these polymers to a range of biocompatible substrates, including graphene oxide, lignin, and cellulose, with the aim of creating an insoluble, well-dispersed material suitable for water filtration. Specifically, the newly synthesized polyPhOx was directly employed in pharmaceutical adsorption batch experiments using prepared aqueous solutions. In contrast, for pAmOx, a “grafting to” approach was adopted. The prepared and characterized polymer was covalently bonded via an amidic bond to prepared graphene oxide, thereby enabling it to interact with acidic organic compounds such as pharmaceutical products in aqueous solutions.

A61. Synthesis, photophysical characterisation and microbiological activity of a novel blue fluorescent polyamidoamine dendrimer modified with 1,8-naphthalimide units

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In recent years, fluorescent dendrimers containing chromophore fragments at specific, predetermined positions on the molecule have been investigated, leading to new properties and fields of application in chemistry, biology, pharmaceutics, genetic engineering, nanomedicine, etc. This study synthesised and characterised a new second-generation PAMAM dendrimer modified with 4-N,N-dimethylaminoethoxy-1,8-naphthalimides units emitting blue fluorescence. The influence of the polarity of the solvents on its photophysical characteristics has been investigated and a hypsochromic shift in the absorption and fluorescence maxima was found upon the transition from non-polar to polar solvents. The fluorescence quantum yield also shows a significant dependence on the type and polarity of the solvents. The change in the fluorescence intensity of the dendrimer as a function of pH in a water–alcohol solution at a ratio of (4:1 v/v) was studied. It was found that in the interval pH = 10.0 – 5.5, the fluorescence intensity increased more than 50 times, indicating excellent pH fluorescence switching and control of photoinduced electron transfer, which is due to the protonation of the tertiary nitrogen atom of the receptor fragment of the 4-N,N-dimethylaminoethoxy substituent. The antimicrobial activity of the dendrimer was tested in vitro against Gram-positive B. cereus and Gram-negative P. aeruginosa in a meat peptone agar medium in the dark and after light irradiation. It was established that after light irradiation, the dendrimer's antibacterial activity increased due to the generation of singlet oxygen that attacked the bacteria's cell membranes. In this case, B. cereus appears slightly more sensitive than P. aeruginosa.

Funding
This study is financed by the European Union Next Generation EU, through the National Recovery and Resilience Plan of the Republic of Bulgaria, project № BG-RRP-2.004-0008-C01.

A62. Cotton fabric modified with chitosan for controlled release of diclofenac

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Wound dressings are an essential segment of the medical market. Today, the dressing is expected to actively support the healing process, providing a moist environment, absorbing the excess exudate, protecting the wound from secondary infections, and releasing biologically active substances as necessary. In medical textiles, the application of chitosan hydrogel as a wound dressing is due to its advantages: biocompatibility, biodegradability, non-toxicity, antimicrobial properties, biological activity, etc. Chitosan-based hydrogels support wound healing at various stages (such as excessive inflammation and chronic wound infection) and can also alleviate anti-wound-healing factors. Its biological properties allow for its application as an antimicrobial wound dressing, gradually releasing a biologically active substance. This research aims to obtain a new antimicrobial composite material that releases an anti-inflammatory biologically active substance (diclofenac sodium) by modifying cotton fabric with cross-linked chitosan to varying degrees. The structure of the obtained samples was characterized by optical microscopy, contact angle measurement, and thermal and FTIR analysis. The antimicrobial activity of the cotton samples was evaluated against Gram-positive and Gram-negative model bacterial strains. A chitosan and diclofenac synergistic antimicrobial effect and a uniform release of diclofenac in vitro under physiological conditions were established.

Acknowledgements: The authors gratefully acknowledge the financial support by the European Union-NextGenerationEU via the National Recovery and Resilience Plan of the Republic of Bulgaria, project № BG-RRP-2.004-0002, „BiOrgaMCT".

A63. Fast Production of Intelligent Nonwovens using Solution Blow Spinning: Potential of Zein/Gelatin with Anthocyanins from Purple Sweet Potato Agri-Food Waste

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The efficient manufacturing of intelligent packaging based on nonwovens represents a promising alternative to enable the application of these materials in food quality monitoring. The objective of this study was to rapidly produce intelligent nanofiber nonwovens made of zein/gelatin (Z/G) functionalized with various concentrations (5–15% w/w on the matrix) of anthocyanin-rich extract from purple sweet potato agri-food waste (PE) using the solution blow spinning (SBS) technique for use in food quality monitoring applications. The addition of PE to the Z/G matrix reduced the viscosity of the solution from 0.242 to 0.209–0.175 Pa s−1. The mixed gelatin/zein solution formed uniform and smooth nanofibers irrespective of the incorporation of PE, and the nanofiber diameter was reduced from 999 nm to between 867 and 653. Mats composed of Z/G nanofibers with added PE, especially at concentrations of 15%, exhibited visible color changes (ΔE ≥ 3) that were rapidly altered in response to pH (3–10) and when exposed to ammonia vapor. These Z/G nanofiber mats were successfully used to monitor the deterioration of fish fillets through visible color changes. The use of these nanofiber mats to monitor changes in food quality highlights the significant potential of the SBS technique and the use of anthocyanins from agro-industrial waste to produce new smart packaging materials for use in food applications. The authors are grateful to FAPESP (processes 2021/13260–7 and 2023/02038-7) for financial support.

A64. REDONDO Reversibly cross-linked Polyethylene

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Polyethylene (PE) is a commodity plastic and one of the most widely used synthetic polymers. To improve its properties, PE is chemically cross-linked. During cross-linking, new intra-chain bonds are formed between the linear chains of PE, linking the chains together in a network. Cross-linked PE (PEX) exhibits superior properties compared to non-cross-lined polyethylene. Nevertheless, due to the formation of cross-links, PEX cannot be melted and recycled/reused, but it is downcycled as a filler in other composite materials. This is a significant drawback, especially in the present context of intense reflection on more environmentally friendly practices.

REDONDO is a Horizon Europe funded project that aims to achieve a fully reversible cross-linking process. This will enable the synthesis of reversibly cross-linked polyethylene (rPEX), that will be inherently recyclable and thus sustainable by design. Additionally, innovative biobased and green additives, such as nanolignin and nanocellulose, will be used to confer novel/improved properties to rPEX. The successful synthesis of rPEX will be demonstrated in two applications: pipes and cables for photovoltaic applications. In the present presentation, the REDONDO concept and strategies to achieve its goal will be discussed.

A65. Circularity assessment of materials and products from lignocellulosic biomass: the case of the BIOMAC project

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BIOMAC (Grant Agreement No 952941) is a Horizon 2020-funded project aimed at establishing an Open Innovation Test Bed (OITB) ecosystem to upscale processes and technologies for the conversion of lignocellulosic biomass into high-added-value nanomaterials and polymers. Materials and products developed within the project are targeted to applications in high-market-share sectors, and are demonstrated as "test cases" in the automotive, agriculture, food packaging, construction, and printed electronics fields.

Within this framework, sustainable end-of-life management strategies for the biobased (nano)materials and products within the OITB were evaluated from a Circular Economy perspective. A stepwise approach was followed, focusing on three main successive actions, namely (1) the mapping of existing end-of-life management chains for plastic wastes within the European Union; (2) the definition of end-of-life management practices within the Consortium; (3) the definition of technical and management guidelines to extend BIOMAC products life-cycle. A test case-oriented methodology was adopted, encompassing an extensive literature review aimed at framing legislation and regulation in force on end-of-life management for plastic waste within the European Union. Currently available technologies for plastic waste processing, reuse and/or recycling were characterized as well, regardless of their development scale (i.e., industrial, pilot, or laboratory). Based on a well-established methodology reported in the literature, a key performance indicator was identified to assess the level of circularity of each of the biobased products under development within the project framework. Commercially available analogous items produced by the partners were taken into account as well, and considered benchmarks.

The analysis showed promising results, emphasizing the higher level of circularity of BIOMAC products with respect to the reference ones. Based on data provided by the partners and gathered from the literature, different scenarios were hypothesized to define optimal strategies that might be implemented with the aim to further increase the sustainability of BIOMAC products from a Circular Economy perspective.

A66. Modified chitosan adsorbent materials for removal of b-blockers from aqueous samples

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The current study investigated the synthesis, characterization, and efficacy of three chitosan-based materials for removing pharmaceutical mixtures from aqueous solutions. The target mixture consisted of three b-blockers: atenolol, propranolol, and metoprolol. By incorporating poly(ethylene imine) and poly(acrylamide), the physical properties of chitosan could be finely tuned. Adsorption kinetics analysis indicated that the adsorption process of the drug mixture involves both physical and chemical mechanisms. Isotherm tests revealed that the Langmuir model accurately described the adsorption process for CS and CS-PEI, while CS-AMI followed the Freundlich model, suggesting the presence of heterogeneous adsorption sites in multilayers. Characterization of the polymers was performed using FT-IR, SEM, and XRD techniques. Based on these findings, the three materials demonstrate high effectiveness as adsorbents for removing drug residues from aqueous environments.

Poster Session A – Wednesday 29 May

A67. Development of novel post-consumer PLA and PCL blends for antioxidant food packaging

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The detrimental impact on the environment derived from the incorrect management of conventional plastics has promoted the use and development of biobased and biodegradable materials for food packaging. They guarantee greater sustainability since they come from renewable sources, including agroindustrial byproducts and residues, in addition to maintaining the quality and safety of its products. Specifically, poly(lactic acid) (PLA) is characterized by its compostable nature, its availability, and its easy processing by melt extrusion, becoming one of the most used biopolymers in the industry. The interest in the incorporation of biopolymers into the market has led the Cabreiroá company to recently launch water bottles made of PLA. Because PLA is a valuable polyester, its recyclability should be an alternative in addition to its compostability. Thus, in this work, the use of the post-consumer PLA from these water bottles will be used to developed new active packaging systems. For this purpose, we started with these commercial bottles subjected to a prior accelerated aging and washing process to simulate real post-consumer recycling conditions. Polycaprolactone (PCL), a polyester known for its excellent deformability, was added in order to mitigate the deterioration of this biopolymer during recycling. PCL can improve the loss of mechanical properties of PLA after recycling, modifying aspects such as its crystallinity. Likewise, the addition of quercetin (Q), a natural polyphenolic antioxidant, to the polymer matrix intrinsically increases the interaction between both polymers and will allow for greater preservation of food sensitive to oxidation via its progressive release.

In this work, active films of PLA and PCL blends at different ratio (85/15 and 70/30) incorporating Q at 3 %wt. were melt extruded and thermo-pressed. Structural (FTIR), thermal (DSC and TGA), optical, and morphological (SEM) properties were analyzed, in addition to their capacity antioxidant and Q release profiles.

A68. BIOMAC—Decision Support Tool for assessing Value Chains of nano-reinforced bio-polymers

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In the biobased industry, where biomass serves as a raw material, there are numerous pathways to achieve polymer end products, and the possibilities expand even more when nanotechnology is incorporated in the production process. In this complex landscape, the challenge is to find the optimal value chain path, considering economic and environmental impacts. The BIOMAC project tackles this challenge with a Decision Support Tool (DST) that strategically evaluates sustainability and feasibility across different value chains, guiding users throughout.

The web-based DST displays a user-friendly interface fostering efficient communication with computational tools in the backend. The backend integrates customized data repositories and optimization models considering various biobased processes with their mass and energy balances along with techno-economic and environmental factors.

This tool allows for key operations. In the "Step-by-Step" mode, users can construct value chains towards biopolymers gradually, understanding the impacts of each process. The "Optimal Path" feature allows a systemic review of the entire value chain tree, enabling the user to adjust variables and perform optimizations subjected to single or multiple criteria.

Case studies explore the utilization of alternative types of biomass (e.g., beechwood sawdust and Miscanthus Giganteus) in producing the project’s five final products (PU-based automotive parts, PLA-based barrier coatings, PU-based bridge modules, and PE-based agriculture applications). The optimization model prioritizes environmental and economic factors, and identifies the most efficient production path through biomass fractionation, nanocomposite production (nanolignin, nanofibrilated cellulose, nanocellulose), downstream processing, and final polymer formulation. Users can assess various options (different biomasses, alternative processes), conduct hypothetical studies (market fluctuations, biomass availability, product demand), and identify the most beneficial paths tailored to their specific requirements.

The DST strives to empower stakeholders to navigate the challenging landscape of nano-enabled biopolymers. Its user-friendly interface allows for easy and accessible studies, without requiring expertise in optimization or data collection, enabling decision-making in this field.

A69. Impact of plastics from daily fluid intake on blood pressure

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The global issue of microplastic pollution, as a result of its indispensable usage in building materials, packaged food, medical products or consumer goods, poses significant health problems for the population. These small particles can penetrate intact cell barriers in the intestines and alveoli, thereby entering the bloodstream.

The aim of this pilot study was to investigate the effects of reduced plastic consumption on blood pressure.

Eight healthy adults and participants abstained from consuming commercially produced bottled beverages and restricted their primary fluid intake to tap water. Their blood pressure was measured after 14 days and after 28 to 30 days of this partial plastic diet.

Our findings from a gender-unrelated analysis reveal a tendency toward decreased systolic blood pressure after two weeks, with a subsequent further decline after four weeks. Significant findings are evident even at the two-week mark for diastolic blood pressure. Considering blood pressure separately for women only, a significant decrease can be seen after two and four weeks.

The results of the study suggest, for the first time, that a reduction in plastic use could potentially lower blood pressure, probably due to the reduced volume of plastic particles in the bloodstream. To confirm these results, a larger sample of male and female participants must be examined, ideally with the monitoring of plastic concentration in the blood.

A70. Depolymerization of End-of-Life Poly(lactic acid-co-ethylene adipate) Copolymer via Sn-Catalysis

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The (re)use of polymeric materials derived from either renewable resources or bio-based or biodegradable materials follows the European strategy for a circular economy. There is a need to improve the performance of recycled materials and accelerate the development of renewable raw materials, renewable energy, and production technologies [1]. Novel polymer materials used in packaging applications, biomedical devices, and implants include aliphatic polyesters such as poly(lactic acid) (PLA). PLA is a bio-based and compostable polymer material, but due to its inherent brittleness and slow degradation rate, which have limited its wider application, several aliphatic polyesters such as (poly(ethylene adipate), poly(propylene adipate), and poly(butylene adipate) have been synthesized to overcome this problem [2]. Although many aliphatic polyesters have been developed, there is no reported work on the chemical degradation of the novel biodegradable copolymer poly(lactic acid-co-ethylene adipate) (PLeA). From an environmental perspective, the crucial role of the end-of-life PLeA copolymer is highlighted by its potential for recycling,

Several chemical degradation methods of PLA-based materials are currently being developed and investigated, including thermolysis, hydrolysis, and alcoholysis, which yield lactide or other products [3], are used in further copolymer synthesis. Therefore, the main objective of this work was to further investigate the effect of catalysts and reaction conditions, including catalyst loading, temperature, and pressure, on the overall product rate of PLeA copolymer degradation. With this in mind, a preliminary study of the chemical depolymerization of the PLeA copolymer was carried out using tin-based catalysts, Sn(Oct)2 or zinc(II) acetate (Zn(OAc)2). This novel study of the chemical depolymerization of PLeA copolymer involves the combination of the following complementary techniques to examine the resulting (degraded) product, including attenuated total reflection–Fourier transform infrared spectroscopy (ATR-FTIR), differential scanning calorimetry (DSC), thermal gravimetric analysis (TGA), nuclear magnetic resonance (NMR), and X-ray photoelectron spectroscopy (XPS)

A71. Strategies for the Circular Economy transition in the manufacturing of novel bio-based materials

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The meaning of the words “Circular economy” (CE) has been explained using different definitions for several applications and industrial scenarios. The CE framework addresses global challenges such as climate change, biodiversity loss, waste, and pollution by emphasising the circular goals of recycling, reuse, repair, and shared use. Specifically, in the bio-based industry, a circular economy approach involves designing products to minimize waste and enhance resource efficiency.

The GREEN-LOOP project focuses on bio-based material solutions produced through innovative manufacturing techniques. Employing smart manufacturing technologies like artificial intelligence, microwave, and ultrasound, the project optimizes three value chains from raw materials to final products. These techniques ensure efficiency and sustainability, reducing waste and minimising resource consumption.

The transition to a circular economy necessitates technological, economic, and social changes. Implementing reuse, recycle, and repair concepts requires modifications to production lines, representing a step toward technological change. The adoption of circular business models (CBMs) plays a pivotal role in achieving economic transformations, aligning with circular goals. Social innovation, encompassing emergent needs and new solutions to meet social goals, also supports this transition.

This work aims to analyse three value chains from a circular perspective, emphasising waste minimization techniques at the source, the reduction of raw materials, and the optimization of recycling and reuse. The approach involves identifying circular business goals, technological and social innovation enablers, and applying the most suitable CBM to the GREEN-LOOP project's use cases.

In conclusion, this study contributes to understanding the circular economy's practical application, emphasising the importance of circular business models in realising a transition towards a more resource-efficient and circular economy. This study serves as a valuable case study to implement tailored circular business models in the field of novel bio-based material manufacture.

The GREEN-LOOP project has received funding from the European Union's Horizon Europe Framework Program under Grant Agreement No 101057765.

A72. Market feasibility study for mycelium-based material production

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This research includes a comprehensive market feasibility study to assess the sustainability of mycelium-based material production for the fashion and automotive sectors in the framework of the MY-FI EU-funded project. Mycelium-based material can be seen as an alternative to leather and synthetic leather , which are well known to have a negative environmental impact due to the use of hazardous chemicals and the significant amount of water use. Synthetic leather, indeed, contains material from plastics such as polyvinyl chloride (PVC) or polyurethane (PU), thermoplastic polymers that depend on chemicals derived from fossil fuels and therefore cannot be considered sustainable.

This study integrates key elements to analyze market dynamics, technological advancements, and potential challenges in introducing mycelium-based materials to the market as an alternative to the existing products. The investigation begins by outlining the mycelium-based material's unique properties and production processes, emphasizing the circular economy principles of recycling, reuse, and sustainability, aligning mycelium-based material production with global initiatives addressing environmental concerns.

The market description and relative segmentation provide insights into the target market's volume, size, and characteristics. The competitive analysis evaluates existing alternatives and their market shares, identifying opportunities and challenges for mycelium-based materials. This study also delves into the economic feasibility aspects and a patent analysis will assess the intellectual property landscape related to mycelium-based materials. This includes identifying existing patents, evaluating their scope, and understanding potential constraints or opportunities for innovation within the patent landscape.

The findings of this market feasibility study contribute to a comprehensive understanding of the potential for mycelium-based material production. The insights derived from this research will guide stakeholders in making informed decisions, thus fostering the sustainable integration of mycelium-based materials into diverse industries.

MY-FI has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 101000719.

A73. Evaluation of the Industrial Separation Process of Solar Cables: Sieve Analysis of Plastic Regranulate

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In the rapidly evolving field of solar energy, efficient recycling of solar cables, composed of a copper conductor with insulation (white particles) and a jacket layer (black particles), is crucial for sustainable development. This study aims to evaluate the industrial separation process of these cables, focusing on the segregation efficiency of the constituent materials. Understanding the distribution and characteristics of the separated materials, particularly the plastic regranulate, is vital for optimizing recycling methods and supporting the environmental sustainability of solar energy infrastructure.

Employing R10 series standard sieves (100 µm to 2500 µm), a sieve analysis was conducted on plastic regranulate derived from solar cables. High-resolution image analysis (9600 dpi) categorized particles into "black" (jacket layer) and "white" (insulation layer), alongside copper conductor identification based on RGB red values. The median particle size was 1655 µm, with black particles predominant in smaller sizes, suggesting material differences like brittleness. White particles were more frequent in larger sizes. The copper content, identified through maximum RGB red values, was found to be larger, indicating less fragmentation during separation.

A74. Microplastics in the Landfill Area of Kefalonia, Greece: Sampling, Laboratory Techniques, and Identification Methods for Soil Samples

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Empirical research, crucial for assessing the risk of microplastics (MPs) in diverse environmental matrices, emphasizes the primary importance of developing protocols for methods and measurement procedures. As the complex nature of soils, including those from landfill areas, presents a challenge, a suitable and efficient standardized method for microplastic analysis in the soil matrix has yet to be found. In this study, we assessed MP presence on the Pallosti landfill area and the neighbor Agia Kyriaki beach, in the north part of Kefallonia island, Greece. Eleven samples were collected from pre-defined sites inside and around the landfill area and one along the road of the Agia Kyriaki beach. To evaluate the dispersion of microplastics, surface (0-5 cm) and depth sampling (20 cm) were carried out with a specific protocol using metallic equipment. For the recovery of microplastics, it is essential to digest the organic material and subsequently separate soil fractions. As part of the sample pretreatment process, sieves with dimensions of 2mm, 400μm, and 50μm were utilized. For the degradation of organic particles, a Fenton reagent with 30% H_2O_2 and $FeSO_4Cl$ catalyst in a temperature-controlled bath was used during the exothermic reaction. Mineral particle removal contained density separation with a supersaturated NaCl solution, followed by centrifugation and filtration to retain MPs. A multi-method approach for identifying and characterizing MPs involved analysis with an optical microscope and FTIR spectroscopy, while the recovered MPs were examined using SEM-EDS for both elemental mapping and morphological study. Using FTIR spectroscopy, microplastics were identified in some of the samples, while the most frequently detected polymers were PE, PP, and PS, with chemical analysis revealing the presence of titanium additives in some samples. In conclusion, this work highlights the importance of standardized protocols for microplastic recovery and analyses, emphasizing ongoing methodological advancements, particularly in soil matrix.

A75. An overview of market and technology landscape on sustainable Printed electronics

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In the European Union (EU), Electronic Wastes (End-of-Life Electronics or e-wastes) has become an important environmental issue. It is remarkable that according to Eurostat, in 2021 an average of 11 kg per inhabitant was created in the EU. To tackle this issue, there is a need to explore new options for electronics that are designed for reuse, repair, and high-quality recycling. Printed electronics (PE) is an additive manufacturing method characterized by its versatility, scalability, and low material usage, making it an ideal candidate for the circular production of electronics, especially when it is aligned with the Safe & Sustainable by Design (SSbD) Framework, defined by the EC.

The Sustain-a-Print (SaP) project, an EC funded research initiative, targets the development of sustainable materials and formulation for the PE industry. More specifically, it focuses on the production of bio-based polymeric materials (poly-ethylene azelate and polylactic acid) and additives (lignin based conductive nano-particles and biobased copolymers). These novel technologies offer new, sustainable substrates for the flexible electronics industry and ink components. In this study insights based on the results of an extensive market search and of the technology landscape, based on patent analysis, are presented. Data related to bio-based polymers, the development of conductive materials from renewable sources and their integration on printed electronics for various applications (smart packaging, wearables) have been collected and analysed. As the industry evolves, understanding these trends becomes of paramount importance for stakeholders seeking to navigate the evolving landscape and contribute to the development of environmentally conscious electronic solutions.

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.

A76. Circular Strategy for Epoxy Composite Recycling: Bisphenol-A (BPA) Recovery from Lignin-Epoxy composites via Fast Pyrolysis

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Lignin is one of the three main structural components of lignocellulosic biomass and is considered as the most abundant natural source of aromatic/phenolic compounds. Its functionality as well as its aromatic/phenolic structure renders lignin as a highly versatile resource with huge potential in polymer design and materials. Epoxy resins are a class of thermosetting polymers produced from diglycidyl ethers of bisphenol-A (DGEBA), a material that is based on the toxic bisphenol-A (BPA). Lignin's hydroxylated surface is prone to functionalization via epoxy rings (glycidylation) that enhances its affinity with polymers like epoxy resins, partially replacing DGEBA and thus resulting in green and bio-based epoxy composites with promising properties. However, the environmental impact of polymer waste is still present, highlighting the need to apply circular economy strategies for their recycling.

Fast pyrolysis (FP) represents a promising depolymerization process for both lignin and polymers, which when coupled with catalytic upgrading can lead to the production of added-value chemicals and the recovery of monomers/oligomers (or monomer precursors) like BPA and phenol monomers. In this approach, DGEBA precursors (original monomers) can be obtained following sustainable manufacturing and circular economy models, thus establishing a closed-loop circular and fossil-independent path towards epoxy resin composites.

In this work, we investigated the functionalization of kraft lignin via the attachment of epoxy rings (glycidylation). Glycidylized lignin (GKL) was fully characterized using NMR andthe epoxy content was determined via titration, GPC, TGA/DSC, etc. GKL was further used as a bio-based epoxy prepolymer, aiming to achieve up to 50 wt.% replacement of fossil-based diglycidyl ethers of bisphenol-A (DGEBAs). The thermo-mechanical and thermal properties of the bio-composites were evaluated, revealing enhanced properties. Following this, selected bio-composites were depolymerized via fast pyrolysis to test the effectiveness of thermochemical recycling towards obtaining valuable chemicals. GC-MS and HSQC NMR analyses testified to the successful depolymerization of bisphenol-A (BPA) and phenolic compounds.

A77. Environmental and Economic Impacts of Substituting Single-Use Plastic Straws: A Life-Cycle Assessment for Greece

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The usage of more than 30 billion straws a year has been reported in the European Union (EU), in 2020, one year before the official ban of single-use plastics in Europe. The impacts of this plastic waste on the environment and on our health are global and can be drastic. Since 2021, single-use plastics, including straws, have been banned in the EU Member States. Since then, many different types of straws have been proposed and are available on the market. This study attempts to assess their effectiveness, mainly from an environmental point of view, and identify the best alternative amongst the selected examined options (metallic, glass, bioplastic, organic, etc.) available on the market.

Life-Cycle Assessment (LCA) was implemented for eight different available straw types (apart from conventional polypropylene one) for Greece, aiming to reveal the best available option regarding environmental impact. Apart from LCA, a preliminary cost analysis and consumer preferences survey were conducted. For this purpose, LCA, utilizing ReCiPe 2016 methodology and following ISO 14040/44, was performed. Appropriate questionnaires were developed and shared with a representative sample of consumers.

The findings indicate that (reusable) metal straws exhibit a lower overall environmental impact over one year. More than 85 percent of the environmental impact from metal straws stems from washing, emphasizing the role of human behavior in it. Among single-use straw types, the standard plastic straw demands less than 50% of the energy and nearly one third of the amount of CO2 compared to paper and bioplastic straws. From a socio-economic point of view, cost seems to play a minor role. However, the consumer's acceptance of and preference for the new products, and their awareness of health and environmental risks, are very significant factors influencing single-use plastic straw elimination.

A78. Micro-Actuators with pH-Responsive Hydrogel via Two-Photon Polymerisation

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The integration of additive manufacturing in micro-robotics has showcased high potential for the development of miniature smart devices.1 These microscale tools exhibit precise control for object manipulations. The key element for the movement and actuation of such micro-systems is stimuli-responsive material.

This works presents the fabrication of a multi-material 3D micro-actuator by direct laser writing via two-photon polymerisation (2PP). It allows for the building up of complex 3D microstructures by moving focused femtosecond laser beams across the polymer hydrogel. Based on the fabrication parameters, we can tune chemical and mechanical properties of such microdevices for the intended application.

The actuation of 2PP microstructures is activated by pH-responsive polymer hydrogels, inspired by artificial muscles that contract and expand in response to pH changes of the environment.2 The response takes only a few seconds due to their miniature size. The selection of the monomer identifies the stimuli to which the microstructure reacts. Two types of pH-responsive polymer hydrogels can be incorporated in a single design to fabricate a pH sorter microsystem. The morphological features and performance of pH-responsive microstructures were evaluated by optical microscopy, atomic force microscopy (AFM), and scanning electron microscopy (SEM). We investigated the effect of design, hydrogel composition and fabrication parameters on the performance of such micro-actuators.

These 2PP-fabricated micro-actuators offer numerous potential applications, including cell manipulation, sensing, microfluidic devices, and drug delivery.3 The presented approach demonstrates the controlled fabrication of novel programmable 4D micro-tools integrated with stimuli-responsive materials, creating opportunities for advanced micro-tool applications.

A79. Advancing the European Sustainable BIO-based NanoMAterials Community (BIOMAC): A Pioneering Open Innovation Test Bed

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The European Sustainable BIO-based NanoMAterials Community (BIOMAC) is embarking on a groundbreaking initiative to accelerate the market integration of Nanostructured Bio-based Materials. At the core of this endeavor is the establishment of an Open Innovation Test Bed (OITB), dedicated to upscaling processes and ensuring the market readiness and production viability of these innovative materials.

The BIOMAC OITB, designed as a collaborative effort within a multidisciplinary consortium, operates as a One-Stop-Shop (OSS) with fair accessibility conditions and costs. This OSS serves as a Single Entry Point, providing common access to physical facilities, capabilities, and services essential for the development, testing, and upscaling of nanotechnology and advanced materials in industrial settings.

The primary focus of BIOMAC lies in the creation and demonstration of novel manufacturing supply and value chains. Technologies developed up to Technology Readiness Levels (TRL) 4-5 underwent upscaling and validation to TRL 7. This strategic approach expedites the journey from innovation to market entrance.

The OITB extends its services beyond upscaling, encompassing critical aspects such as regulation and safety assessments, sustainability evaluations, circularity considerations, and market potential analyses. These services, including modeling, process control, standardization, and characterization, are offered at fair conditions and costs.

BIOMAC's initiatives are poised to significantly benefit European midcap enterprises by fostering collaboration among technology developers. This collaborative environment enables the exploration of novel applications across various end-use markets, contributing to the increased awareness and knowledge of potential avenues. Moreover, BIOMAC is committed to enhancing the European industry's understanding of regulations, safety measures, and sustainability aspects, ultimately driving the successful integration of Nanostructured Bio-based Materials into the market.

This work was funded from the European Union’s Horizon 2020 Research and Innovation Programme under Grant Agreement No. 952941 (BIOMAC Project).

A80. Reviving mixed plastic waste through chemoenzymatic recycling

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Poor waste management worldwide leads to a constant increase in environmental pollution; if current production and waste management trends continue, roughly 12bn tons of plastic waste will end up in landfills or the natural environment by 2050. Even though recycling plastic packaging waste is the most sustainable solution for the circular plastics economy, a minor part of packaging waste is recycled; 8% of plastic waste was recycled from 1950 to 2019. The main obstacle to viable mechanical recycling is the presence of different polymer types in end products (mixed-plastic waste), hampering the recycling process and reducing the recyclates' quality. The EnZyReMix project aims to develop innovative methodologies to separate complex packaging waste streams, i.e., mixed plastics, and valorize the depolymerized oligomers from post-consumer materials via upcycling approaches. Specifically, we will focus on mixtures of PLA/PET since PLA is a new source of polymeric contamination for rPET, and their separation is not easily feasible due to their similar appearance and densities. Commercially available grades will be identified through mapping the polymer market, focusing on bottle-grade PLA and PET, characterized and processed via cryogenic milling into mixtures of different ratios based on the estimated PLA occurrence in the bottle household waste. The initial materials will be submitted to hydrolysis to prepare oligomers of controlled characteristics for the screening, identification, and structural characterization of degrading enzymes. In parallel, PLA and PET films will be prepared via compression molding and submitted to accelerated laboratory weathering to simulate improper waste disposal in soil and sea. Ageing kinetics will be studied at different temperatures, and the aged single-type materials/mixtures will serve as model waste to be subjected to selective enzymatic degradation. Overall, different polymeric substrates will be prepared to be tested on a real case study of an upcoming type of waste, i.e., PLA/PET bottles.

A81. Enzymatic polymerization meets scalability: poly(butylene succinate) production process and a case-study encapsulation application

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Enzymatic polymerization is a promising method for producing polymers that can be used in food packaging applications since it is a green method that avoids using chemical catalysts; according to the compostable and biodegradable polymer packaging standards, heavy metals should not exceed the maximum allowable level of 150 mg/kg on dry substances. However, in most works, various solvents are used (e.g., diphenyl ether for solution polymerization, chloroform for filtration, and methanol for precipitation), impeding the scaling up of the enzymatic polymerization processes. At the same time, high vacuum and temperatures (>90°C) are required for prolonged reaction times, thus leading to increased molecular weights (MWs) while opposing the green chemistry principles (e.g., high energy consumption). In this context, PBS was herein enzymatically synthesized via a solventless, two-stage process, and the most critical parameters (i.e., reaction temperature, pressure, and time) were evaluated regarding the MW, thermal properties, and morphology of the prepolymer. Thanks to the process's simplicity, scaling up was achieved based on the optimized conditions, resulting in 20 g of enzymatically synthesized PBS for the first time. Different sustainable post-polymerization methods (i.e., SSP, low-temperature melt post-polymerization) were then examined to increase the MW of the scaled-up prepolymer reaching ΔMn and ΔMw values of up to 76 and 93%, respectively. The enzymatically synthesized and upgraded PBS was used as a carrier for polymeric encapsulation systems via the emulsification–solvent evaporation technique. Naringin, a plant secondary metabolite, is a flavonoid with antioxidant activity; thus, it was selected as the model active compound for encapsulation, and preliminary in vitro release experiments were conducted to roughly assess the system's relevant profile.

A82. Understanding the solvent dissolution of styrene-acrylonitrile (SAN) employing calorimetry, FTIR and rheometry for envisioning the physical recycling of acrylonitrile-butadiene-styrene.

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The recycling of plastics has been a major issue to tackle for the past 50 years. Indeed, the pollution of the environment has been reinforced by plastic landfilling. Acrylonitrile-butadiene-styrene (ABS) is a commonly used plastic in the automotive and electronic industries that is formulated with different additives such as pigments, flame retardants, and fillers. Hence, finding a recycling strategy leading to a recycled ABS material with virgin-like mechanical and thermal properties is of great interest. According to the complexity of and the variety in ABS compositions, physical recycling is a promising solution. Indeed, it would enable the removal of polybutadiene rubber (PBR) particles and additives from the styrene-acrylonitrile (SAN) matrix via dissolution/precipitation. Thus, the dissolution of the SAN was performed in various solvents selected from their Hansen solubility parameters. In situ monitoring of the polymer dissolution by calorimetry, Fourier Transform Infrared Spectroscopy (FTIR), and dynamical mechanical analysis (DMA) allowed the investigation of thermodynamic and kinetic aspects of the dissolution process. Rheometric measurements were performed on SAN solutions to find the best-suited range of concentrations to be targeted during the recycling process. The main steps in the dissolution process of SAN were identified and quantified, and the results will be used to aid the ongoing investigations of physical solvent-based dissolution for plastic recycling.

A83. CO2 Adsorption on Chitosan Aerogel Beads

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Enzymatic polymerization is a promising method for producing polymers that can be used in food packaging applications since it is a green method that avoids using chemical catalysts; according to the compostable and biodegradable polymer packaging standards, heavy metals should not exceed the maximum allowable level of 150 mg/kg on dry substances. However, in most works, various solvents are used (e.g., diphenyl ether for solution polymerization, chloroform for filtration, and methanol for precipitation), impeding the scaling up of the enzymatic polymerization processes. At the same time, high vacuum and temperatures (>90°C) are required for prolonged reaction times, thus leading to increased molecular weights (MWs) while opposing the green chemistry principles (e.g., high energy consumption). In this context, PBS was herein enzymatically synthesized via a solventless, two-stage process, and the most critical parameters (i.e., reaction temperature, pressure, and time) were evaluated regarding the MW, thermal properties, and morphology of the prepolymer. Thanks to the process's simplicity, scaling up was achieved based on the optimized conditions, resulting in 20 g of enzymatically synthesized PBS for the first time. Different sustainable post-polymerization methods (i.e., SSP, low-temperature melt post-polymerization) were then examined to increase the MW of the scaled-up prepolymer reaching ΔMn and ΔMw values of up to 76 and 93%, respectively. The enzymatically synthesized and upgraded PBS was used as a carrier for polymeric encapsulation systems via the emulsification–solvent evaporation technique. Naringin, a plant secondary metabolite, is a flavonoid with antioxidant activity; thus, it was selected as the model active compound for encapsulation, and preliminary in vitro release experiments were conducted to roughly assess the system's relevant profile.

A84. Oxylignin isolated from aqueous solution as a biobased alternative for preparation of polyurethane coatings

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Coatings play a crucial role in safeguarding, enhancing aesthetics, and augmenting functionality across a diverse array of materials. These protective layers are classified into distinct categories based on their composition, including polymer-based, solvent-based, water-based, and powder coatings. Widely employed in the automotive, aerospace, marine, and construction sectors, among others, coatings serve multifaceted purposes.

Polyurethanes, among the most versatile synthetic polymers, exhibit an expansive range of applications encompassing foams, adhesives, elastomers, and coatings. However, a growing environmental apprehension surrounds their use as coatings, prompting industrial initiatives to diminish reliance on traditional fossil fuel-based materials. Instead, there is a concerted exploration of renewable and biobased alternatives. Lignin, a byproduct from the pulp and paper industry, has emerged as a sustainable substitute for petroleum-based chemicals due to its unique properties—such as its aromatic structure, high reactivity, and abundance—making it an appealing choice for various industrial applications, including coatings.

Lignin, derived from industrial black liquor at different pH levels (pH 2 to pH 5), serves as an environmentally benign component in the production of novel polyurethane coatings. Characterization of lignin samples was conducted using UV-Vis, FTIR, SEC, TGA, and NMR methods. The resulting coatings underwent comprehensive analysis, including spectroscopy, microscopy, and thermogravimetry, to assess their physical properties. Ongoing studies aim to establish structure–property relationships, particularly concerning the mechanical stability of these innovative biobased coatings. This endeavor represents a significant stride in mitigating the environmental impact of coatings while exploring sustainable alternatives in the realm of materials science.

A85. Synthesis and characterization of thermosetting resins based on isosorbide

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Thermosets and especially epoxy resins occupy a large share of the polymer market as they find a variety of applications in adhesives, insulating materials, coatings, and composites. Bisphenol A (BPA) is predominantly used as raw material for the synthesis of epoxy resins. However, due to the fact that BPA is a fossil-based material associated with adverse health effects when used in plastic products, extensive research has been carried out in recent decades to develop bio-based epoxy polymers from alternative and renewable bio-based precursors [1]. Vegetable oils have been well described in the literature for their high yield upon epoxidation of double bonds; however, their long aliphatic chains limit their properties and their ability to effectively replace conventional epoxy networks [2]. On the other hand, sugar-derived monomers, which are low-cost and abundant, have also gained attention for epoxy prepolymer synthesis.

Focused on the development of bio-based epoxy resins, this study explores the synthesis and potential application of isosorbide-derived epoxy resins. Isosorbide, obtained from starch industry by-products and second-generation biorefining, serves as a promising and sustainable alternative, while also possessing structural similarity to BPA. The synthesis of bis-isosorbide diglycidyl ether was achieved through a base-catalyzed reaction between isosorbide and epichlorohydrin. Optimization studies determined the optimum reaction conditions, while the identification and characterization of the epoxy monomers wereconducted by NMR, FTIR (ATR), and EEW titration. Thermal and UV photopolymerization showcased the potential for crosslinked networks, as evidenced by DSC, TGA, and FTIR analyses.

A86. Nanocellulose-Based Dynamic Hydrogels: Phase Behavior, Rheology and Fire Prevention Performance

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Flame-retardant composite hydrogels offer many advantages over conventional flame retardants, such as high water retention capacity, enhanced fire resistance, and mechanical tunability. However, existing hydrogel formulations face limitations such as reliance on non-biodegradable components and the need for periodic rehydration. In response to the pressing need for sustainable flame retardants, we explore the use of cellulose nanocrystals (CNCs) crosslinked with boronate ester bonds derived from borax, a naturally occurring mineral, to serve as bio-renewable hydrogel flame retardants. CNCs, obtained through the acid hydrolysis of wood-based cellulose, exhibit unique properties for effective fire prevention, including high thermal conductivity and gradual decomposition yielding char residue. Borax, on the other hand, enhances the fire-retardant properties of CNC-based hydrogels through its endothermic decomposition and the formation of glassy barrier for heat and mass transport. These synergistic effects result in significant improvements in ignition delay, flameout time, and char formation when applied on wood substrates. Rheological investigation shows a liquid-to-soft-solid transition of CNC--borax dispersions with tunable network elasticity ranging between ≈ 0.2 kPa to 3.5 kPa and an immediate self-healing ability. We correlate the microstructure and rheological behavior with fire prevention mechanisms used for the rational design of sustainable fire-retardant hydrogels. These results showcase the circular use of plant-based dynamic hydrogels to prevent wood fires, in both wet and dry states, a feature lacking in conventional hydrogel suppressants. (This work is supported by TÜBİTAK 1001 program grant no: 222Z106.)

A87. Hyaluronate-based Nanocapsules as Carriers of Lipophilic Active Substances with Synergistic Effect

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Recently, there has been a growing interest in the field of co-delivery of lipophilic drugs using nanoparticle systems. Co-delivery of different active substances has proven effective, among others in anticancer therapy, where a single anticancer drug may not be able to cope with the complex nature of cancer cells.1,2 Efficient and effective drug carriers can prevent the toxic effects of a substance on healthy tissues and cells, which can significantly improve the effectiveness of therapy.3,4

The subject of the presented research are polymer nanocapsules built of a liquid-oil core and the hydrophobically modified polysaccharide. The systems were prepared by an ultrasound-assisted emulsification procedure combining an aqueous phase consisting of hyaluronic acid modified with a 12-carbon alkyl chain (HyC12) dissolved in an aqueous solution and an oil phase.5,6

Nanocapsules were tested for their ability to effectively encapsulate several active compounds inside the capsules to enable their synergistic therapeutic action. Biological studies include cytotoxicity assay on human colorectal adenocarcinoma cells (Caco-2) and human fibroblast cells (WI-38). The results obtained confirm the synergistic effect of several selected compounds.

A88. Towards effective self-healing coating systems for metal protection: from microcapsule synthesis to performance evaluation

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Self-healing systems have attracted research interest as they are able to autonomously detect and repair damage, without external intervention. The risk of material failure is significantly reduced, and the need for maintenance and associated costs decrease. In this context, the use of poly(urea-formaldehyde) (PUF) microcapsules with an encapsulated epoxy resin (DGEBA)was investigated for self-healing applications in protective coatings on metallic surfaces. Accordingly, microcapsules with the desired properties were produced via in situ polymerization. Alkyd-based coatings were developed by incorporating microcapsules along with the appropriate curing agent (ethylenediamine, EDA) for the encapsulated epoxy resin. Morphological characteristics along with surface properties (roughness, gloss, and König hardness) were studied and correlated to the microcapsule content in the coatings (5, 10, and 15% w/w). The introduction of microcapsules led to increased surface roughness, while in the case of the highest concentration (15% w/w), the formation of microscopic pores was observed through SEM. As a result, its protective properties were inferior compared to the reference coating without capsules, as supported by electrochemical impedance spectroscopy (EIS), which was used to assess the self-healing properties. Lower concentrations (5, 10 % w/w) led to a slowdown in corrosion, especially in the case of 5% w/w, where SEM confirmed the formation of a protective layer at the site of the initially exposed substrate. Additional tests were conducted on both alkyd-based and epoxy-based coatings, where the incorporation of microcapsules into the topcoat layer, primer layer, and a combination of both (multilayer) was examined. The most promising results were evidenced in the case of the epoxy multilayer system, which demonstrated superior performance in salt spray conditions. After 400 hours, the reference sample showed significant corrosion, while the self-healing system effectively protected the substrate. EIS confirmed the delayed corrosion, and SEM verified the formation of a protective layer in the exposed areas.

A89. Thermoresponsive functional polymers for the recovery of lithium

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The recent developments in the electric car industry have led to an over-consumption of non-renewable resources such as lithium. Furthermore, it has been estimated that 200 to 500 million tons of spent lithium-ion battery (LIB) waste was generated in 2020. The current industrial battery recycling processes, mainly pyrometallurgy and hydrometallurgy, are rather polluting, energy-consuming and onerous. Lithium-selective inorganic materials are available but limited to laboratory-scale studies due to their synthesis and processability drawbacks. Furthermore, organic molecules that are capable of selectively and efficiently interacting and bonding with lithium ions have been abundantly reported in the literature. Notably, crown-ethers (CEs) provide lithium-ion selectivity over other alkali ions, mild-condition synthesis and great adaptability.

In this context, we report the design of a CE-based material able to reversibly and selectively complex lithium ions. Grafted onto a polymeric support, CEs could serve as an efficient and selective tool for the recovery of lithium from LIB leachates (aqueous solutions that are produced during the recycling of waste LIBs). Firstly, an original monomer functionalized with a crown-ether moiety was developed, namely 2-(benzo-12-crown-4-ether)ethyl methacrylamide (BCEEM). Then, free radical polymerizations of BCEEM, BCEEM/N-isopropylacrylamide (NiPAAm) and BCEEM/acrylic acid (AA) mixtures were carried out (Scheme 1), leading to P(BCEEM), P(BCEEM-st-NiPAAm) and P(BCEEM-st-AA) polymers, respectively. PNiPAAm moieties inferred thermoresponsive properties to the final materials, while PAA moieties were introduced to improve the stability of Li+ ion binding to the CEs.

The critical solution temperatures were found to be around room temperature and will be exploited for an improved processability of the material. Preliminary sorption experiments were also carried out using ionic chromatography (IC) in order to determine the complexation capacity of the synthesized polymers. Preliminary results proved that lithium ions were efficiently sorbed onto the developed materials, with a preference for AA-containing copolymers.

A90. Influence of the incorporation of graphite and Cloisite powder on the properties of an epoxy thermoset

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The permeability of a material represents its ability to allow the permeate to pass through it. The transmission gradient of a polymer material is based on the product of two factors: the diffusion gradient (D) and the solubility (S) of the permeate in the matrix. D depends on the size of the permeate and the porosity of the material, while S depends on the chemical affinity between the two compounds. To increase the gas impermeability of a polymer material, it is possible to influence its tortuosity by adding fillers that affect the D factor of permeability. Fillers frequently found in the literature include clays, graphene and graphite powders, fly ash, etc. These fillers can be added to both thermoplastic and thermoset matrices. The work presented here was carried out on an epoxy-amine type thermosetting matrix. It presents results on the impact of the addition of graphite powder and Cloisite on the physicochemical properties such as viscosity and Tg. Mechanical properties such as elongation at break, Young's Modulus, tensile strength and toughness are studied. The diffusion, solubility and therefore the permeability of the final material are also investigated.

A91. Investigating Secondary Crystallisation of Pa-12 Using Fast Scanning Calorimetry

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Polyamide 12 (PA-12) is a strong and durable thermoplastic commonly used in advanced polymer processing techniques, such as powder bed fusion (PBF). The property profile of PA-12 is dependent on its ability to form highly crystalline structures, as well as the morphology, size, shape, and stability of the resulting crystals. Similarly, the crystallisation process, which causes concurrent volume shrinkage effects, is crucial to the dimensional precision of PBF parts. Secondary crystallisation, a process rarely studied in PA-12 literature, causes further developments in crystallinity that could alter material properties. As such, this study investigates the mechanism and rate of secondary crystallisation, across a wide isothermal crystallisation temperature (Tc) range, using fast scanning calorimetry (FSC). At Tcs between 100°C and 130°C, PA-12 crystallises into the hexagonal γ phase and displays significant secondary crystallisation. For extended crystallisation times (tc), the melting endotherm related to the crystal population formed during isothermal crystallisation progressively shifts to higher temperatures; this is indicative of a slow yet continuous lamella-thickening process. The melting enthalpy and melting temperature increase linearly as functions of the logarithm of tc, suggesting that lamella thickening occurs via a chain-sliding or melt-recrystallisation mechanism. However, for Tc's > 135°C, PA-12 crystallises into the α′ phase, whereby hydrogen bonding can be more easily attained and larger, more thermodynamically stable crystal structures develop. Due to the increased thickness of primary lamella, the secondary thickening rate reduces and grows dependent on the square root of tc. This supports the Hay model, whereby lamellar thickening is controlled via chain diffusion. Consequently, the crystalline structure of PA-12, the rate and extent of secondary crystallisation, and the mechanism of lamellar thickening are all related to tc and Tc. These insights into the crystallisation behaviour of PA-12 could be useful to help predict the properties and performance of the final PBF parts.

A92. Innovative ultrafast in-situ forming hydrogels with intrinsic properties for immediate hemostasis and tissue regeneration for wound healing applications in the oral cavity

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Chitosan (CS) is a positively charged, natural hydrogel-forming polysaccharide with remarkable biological properties such as biocompatibility, non-toxicity, antimicrobial activity, and the ability to facilitate hemostasis. Gelatin (GEL), which is a product of partial hydrolysis of collagen, can ionically crosslink with CS, via its negative charge, forming a polyelectrolyte complex (PEC). Moreover, Gel obtains the ability to promote cell adhesion and regeneration due to Arginine-Glycine-Aspartic acid (RGD) sequence. Cellulose is one of the most abundant biodegradable materials produced by plants or bacteria. TEMPO-oxidized nanocellulose (OCNC) is the most valuable derivative of nanocellulose that can promote the formation of hydrogel with CS via its aldehyde groups, developed via oxidation. OCNC is completely bioresorbable and easily degradable under physiological conditions. Added to that, OCNC shows excellent hemostatic effects and bactericidal properties against a wide range of Gram-positive and Gram-negative organisms and most importantly can present a high crosslinked CS-hydrogel with great hemostatic, antibacterial antioxidant properties. The antibacterial properties of CS-GEL-OCNC can be enhanced with the addition of nanoparticles with antibacterial properties. Cerium oxide ($CeO2$) and cerium-based nanoparticles have attracted considerable interest in recent years due to their inherent antioxidant properties.

The aim of the present study was to propose innovative solutions for faster hemostasis, control of bacterial invasion and simultaneous enhancement of tissue regeneration, providing painless wound healing in the oral cavity. In detail, nanoparticles with the nominal composition of 70SiO2-27CaO-3CeO2 (27CaO), 70SiO2-28CaO-2CeO2 (28CaO), 70SiO2-29CaO-2CeO2 (29CaO), 70SiO2-30CaO (30CaO) were added in different concentrations (0.5%, 1%, 2%) to CS-GEL-OCNC. The successful synthesis of the composite materials was confirmed by FTIR spectroscopy, their crystallinity was analyzed by XRD, their thermal properties were studied with DSC, the morphology of patches was evaluated with SEM , while water swelling was also investigated. Finally, their biocompatibility was analyzed with the MTT assay on human periodontal ligament cells (hPDLCs).

A93. T. arjuna Incorporated Polycaprolactone Nanofiber for Antimicrobial Matrix

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Current significant major challenge is to resolve the drug-resistant bacteria, imposing a threat to humanity. Overuse of antibiotics declines their fighting efficiency. Henceforth, new solution is needed for the eradication of infection-causing microbes. This study aims to develop infection-resistant Polycaprolactone nanofiber by incorporating hydroalcoholic T. arjuna (TA) extract. PCL nanofiber is modified by co-electrospinning agent surfactant to modify its physiochemical properties and promote the loading of TA extract.

In this study, 5%, 10%, and 15% of surfactants (AOT and Triton X 100) were used to modify PCL nanofiber. The modified PCL nanofiber was characterized by SEM, EDX, AFM, XRD, and contact angle. The bioactive T. arjuna was incorporated in optimized PCL/ Surfactant nanofiber (in the concentration of 5, 10, 20 and 30%). The nanofiber morphology and its diameter were characterized by SEM analysis. The bioactivity, including antioxidant and antimicrobial activity against S. aureus and E. coli, was characterized to analyze the potential of developed nanofiber. The T.arjuna-loaded PCL nanofiber exhibited more than 90% antioxidant activity, even at the lowest concentration. Also, it possesses more than 99% effectiveness against both bacterial strains. Conclusively, it shows potential to be used for antimicrobial matrix

A94. Instrumented mini-scale extruder prototypes for the in-line monitoring of melt mixing and extrusion of biopolymer based materials

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The environmental benefits brought by the substitution of oil-based plastic packages by bio based and biodegradable ones is often offset by the poor melt processability of biopolymers. The conversion of biopolymers into e.g. packages using industrial methods such as melt extrusion requires a better understanding of the relationships between process parameters and biopolymer properties and the development of new formulations, possibly using small quantities of experimental biopolymers.

Contributions to such understanding encompass the development of miniature extrusion lines equipped with tools enabling the in-situ measurements of biopolymer properties. In-line characterization is imperative as these materials are thermo-mechanically sensitive and thus degrade along the extruder or during the sample preparation for post-extrusion characterization. A set of miniature extruder prototypes equipped with sampling ports and rheo-optical dies will be presented. Outputs range from grams per hour to hundreds of gram per hours, whereas the development of the morphology and the viscoelasticity of biopolymer composites is assessed during the extrusion. Application examples with poly(lactic acid)/clay nanocomposites or PHA will be presented [1,2] whereas a new prototype dedicated to filaments extrusion for 3D printing application will be introduced [3].

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Acknowledgement

This research was funded by the Portuguese Foundation for Science and Technology (FCT), grant number PTDC/BII-BIO/5626/2020 (http://doi.org/10.54499/PTDC/BII-BIO/5626/2020). Additional funding from the FCT in the framework of the Strategic Funding of the IPC (projects UIDB/05256/2020 and UIDP/05256/2020) and contract CEECINST/00156/2018 (https://doi.org/10.54499/CEECINST/00156/2018/CP1642/CT0012) is also acknowledged.

A95. Decoration of planar surfaces by conjugated polymer brushes containing poly(ethynylpyridine) chains

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Conjugated polymer brushes attached covalently by one chain end to a substrate may exhibit interesting optoelectronic properties as well as better stability compared to physiosorbed polymer films. Therefore, they can be potentially used in nanoelectronics or photovoltaic solar cells.

In this work, we present a facile route to modify selected planar surfaces (e.g., indium tin oxide or quartz) through the synthesis of homopolymer brushes with poly(ethynylpyridine)-based chains. Poly(5-[2-(trimethylsilyl)ethinyl]pyridin-2-yl) 2-methylprop-2-enate) (P(m-MTEP)) and poly(6-[2-(trimethylsilyl)ethinyl]pyridin-3-yl) 2-methylprop-2-enate) (P(o-MTEP)) precursor brushes were prepared by an innovative organocatalyzed surface-initiated atom transfer radical polymerization (O-SI-ATRP) providing the layers with thicknesses reaching 30 nm. In the next step, pendant acetylene groups in the precursor P(m-MTEP) and P(o-MTEP) brushes were deprotected and subjected to self-templating polymerization that enabled the formation of a conjugated bond system. Self-templating polymerization was initiated just by the quaternization of pyridine groups in the brushes, allowing the formation of ionic conjugated surface-grafted polymer chains. The nanostructures obtained in this way were examined after each modification step, e.g., by FT-IR, UV–VIS spectroscopy, and atomic force microscopy (AFM). Conjugated P(m-MTEP) brushes were doped by selected compounds in order to increase the conductivity of these nanostructures.

Poster Session A – Wednesday 29 May

Poster Session B – Thursday 30 May

B1. Exploring the potential of tannic acid as a natural filler for HDPE

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The valorisation of renewable resources and waste streams is a popular approach to reduce the environmental footprint of materials production. In this context, natural fillers are extensively investigated. Depending on their structure, fillers can act as reinforcing agents, nucleating agents, endow the matrix with higher degradability or hydrophilicity, or confer new properties. Overall, with a careful filler selection, materials with tunable properties, improved performances and lower cost can be obtained.

After lignin, tannin has recently attracted significant interest as an inexpensive biobased renewable resource. Tannic acid, the main component of tannins, is non-toxic and features numerous phenolic OH groups in its structure. Amon other various interesting properties, it is an excellent antioxidant.

In the present work, tannic acid was used as a biobased filler to confer, among others, antioxidant properties to HDPE. Tannic acid/HDPE composites were prepared through melt-mixing and characterised via infrared spectroscopy, differential scanning calorimetry, X-ray diffraction and thermogravimetric analysis. The antioxidant activity of the composites was evaluated by monitoring the reduction of the DPPH• radical via UV-Vis spectroscopy, and promising results were obtained.

B2. Novel recyclable mono-polypropylene-based multilayer films for sustainable packaging applications

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Conventional plastic flexible packaging systems are cheap, light-weight, and exhibit numerous other properties, serving often-complex needs and prolonging the lifetime of food. Compared to other conventional packaging like paper, glass, and metal foil, it has a positive contribution in carbon footprint reduction [1]. However, the complicated design of multi- materials, frequently based on a combination of polyester and polyolefins, hinders the recycling of the used packaging materials via common mechanical recycling technologies. Moreover, the recycled mixture has worse properties than its virgin base materials [2]. Therefore, a new packaging system which can serve all the needs of current multi-material-based solutions but produced via mono-materials is desirable. This study focuses on a new polymer concept designed for mono-polypropylene-based multilayer flexible packaging, reducing the relative fraction of non-polyolefin components necessary for barrier performance to a minimum [3,4]. Compared to conventional polypropylene, the newly designed packaging materials have better stiffness/impact balance and high thermal resistance. This type of new packaging materials can be produced by the Borstar™Nextension Technology.

B3. Mechanical properties and higher-order structure analysis of curdlan propionate fiber

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Bio-based plastics have received increasing attention in recent years as sustainable materials.
Polysaccharide derivatives are also a type of biomass-derived plastic. Curdlan, used in this research, is a type of polysaccharide derivative and is also known as β-1,3-glucan. Curdlan is a polysaccharide that is produced in large quantities as a food additive and becomes a thermoplastic by replacing hydroxyl groups with propionyl groups.
In this research, after analysing the thermal properties of curdlan propionate, the curdlan propionate fibres were produced by melt-spinning. And the optimum melt spinning conditions of curdlan propionate were determined. The tensile strength of the melt-spun curdlan propionate fibres was improved from 20 MPa to 210 MPa. High-speed DSC results showed a positive correlation between collection speed, tensile strength and crystallinity of curdlan propionate fibres.
Real-time synchrotron X-ray measurements were performed to observe the formation of higher order structures during the melt spinning process of this fibre. Based on these results, a model for the formation of higher order structures in the melt spinning process of curdlan propionate was proposed.

B4. Polymers and additives from renewable sources for sustainable products and processes

Antonella Moramarco, Matteo Righetti, Valentina Brunella, Marco Zanetti, Pierangiola Bracco

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The increasing demand for innovative materials with tailored properties has promoted the research of new polymers. High-value-added materials can be obtained by blending and reinforcing existing polymers, however several polymers are immiscible, hence the properties of polymer blends, defined as mixtures of at least two different polymers, are usually poor.

To enhance the affinity, compatibilizing agents (e.g. copolymers, ionomers…) are added to polymer blends since they can reduce the interfacial energy by arranging at the interface between polymers. Among the different classes of compatibilizers, nanoparticles are receiving considerable research interest, since they are non-specific and multifunctional: these nanosized systems can be added to several polymers, enhancing not only the compatibility between polymers but also the reinforcing, flame retardant and gas barrier properties.

Historically, cellulose has been used as a reinforcing agent in polymer composites, whereas its compatibilization properties have been poorly investigated. To fill this gap, we have prepared blends of polylactic acid (PLA) and polybutylene adipate terephthalate (PBAT) and evaluated the compatibilization effect of cellulose. The choice of these materials is related to their sustainability: cellulose is a natural polymer and can be collected from agricultural waste, whereas PLA and PBAT are two immiscible biodegradable polymers having complementary mechanical properties.

The blends were prepared by hot melting using a mini twin-screw extruder, varying the relative amount of the two polymers (PLA/PBAT wt% = 90/10, 70/30, 50/50, 30/70, 10/90). All the blends showed poor tensile properties in comparison with the plain polymers, regardless PLA/PBAT ratio, due to the poor compatibility between the two polymers. To improve the properties of the blends, unmodified and modified cellulose were added during melt blending. Tensile tests and SEM analysis highlighted that cellulose particles need to be reduced to nano-dimensions to arrange at the interface and act as compatibilizer.

B5. Development of Biosourced Surfactants Based on Chitosan Oligomers (Cos): Selective Acylation and Quantification

Steve Berthalon

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Surfactants are amphiphilic molecules that stabilize and homogenize emulsions containing two immiscible phases. These properties make them indispensable in many industrial applications and in everyday life. However, today, almost 50% of surfactants on the market are petroleum-based and of fossil origin. It is therefore necessary to find biosourced alternatives to replace these surfactants.

Chitosan is a polysaccharide of interest in the literature due to its amine and alcohol functions, opening the way to different chemistries of functionalization. Through its high molecular weight, native chitosan is practically insoluble in common solvents, and can not be used as a surfactant anyway. It is then depolymerized to form chitosan oligomers (COS) with low DP. Their hydrophilic and functionalizable structure allows the subsequent grafting of biosourced fatty chains through epoxy-amine or anhydride chemistry, thus providing a hydrophobic part to these COS.

The COS-based surfactant synthesis with anhydride chemistry was carried out by the acylation of chitosan using cyclic anhydrides. We have set up a versatile and controlled method to target the grafting only on alcohol or amine function of chitosan by using a protection/deprotection pathway. These N-acylated COS and O-acylated COS were characterized by 1H NMR, and quantified by 13C NMR. To the best of our knowledge, we describe here the first example of selective acylation of COS using anhydrides, and most of all the first example of 13C quantitative NMR spectroscopy performed on COS and its derivatives.

After several characterizations of these COS-based surfactants such as CMC and surface tension, the study of their behavior in O/W emulsion have been carried out. The destabilization mechanisms have been described and evaluated through various tests including rheological and droplet size measurements. As result of these studies, it is clear that these new biobased systems can compete with the surfactants currently found in the market.

B6. Photocatalytic Functionalization of Isotactic Polypropylene Using N-Oxyl Radicals under extremely Mild Conditions

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The incorporation of polar functionality into C(sp3)-H bonds in polyolefins without compromising their molecular weight has long been a prominent objective in polymer research [1], [2]. This pursuit is driven by the prospect of synergizing the versatile thermomechanical characteristics of polyolefins with desirable engineering thermoplastic attributes. Here, we report the functionalization of polyolefins in a gel state under mild conditions with no chain scissions enabled by a photocatalytically mediated C-H bond activation followed by the enchainment of the functional group. The use of a supported α-Fe_2O_3 immobilized on a surface of glass beads in combination with N-hydroxyphthalimide enabled a generation of stable N-oxyl radicals that provide the possibility to functionalize the polyolefin at temperatures as low as 40 ºC, where chain degradation reactions are suppressed. Tunable functionalization and chain length control was demonstrated via the use of molecular oxygen and maleic anhydride as functional groups. Systematically, a range of studies for structure–property relationships was conducted, including synthetic, structural, rheological, surface, and mechanical. Advancing this photo concept further, its application was extended towards direct low-temperature surface treatments, thereby unlocking superior surface functionalization capabilities across a broader spectrum of polyolefin compositions while preserving the characteristics of the parent polyolefin. The ability to selectively modulate chain scission reactions opened up an efficient route to low-energy upcycling pathways for polyolefins. We demonstrate that by amplifying the chain degradation reactions, high-molecular-weight polyolefins can be deconstructed into high purity low-molecular-weight linear (oxo)alkanes (chain lengths from C16-C32, temperatures 45 to 135 ºC).

B7. Transforming Humin Biorefinery Waste into Valuable Resources: A Dual Strategy via Chemical Modification and Polyester Blending

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Biorefineries are pivotal in advancing sustainability by converting biomass into valuable chemicals and materials and utilizing renewable feedstocks to reduce reliance on fossil fuels and minimize environmental impact. One representative process involves the acid-catalyzed treatment of polysaccharides from biomass, yielding platform chemicals like furfural, 5-hydroxymethylfurfural, levulinic acid, and formic acids. However, a significant factor complicating the process from both economical and technological perspectives is the formation of humins, black tarry by-products comprising up to 50% of total carbon loss. Humins arise from side reactions such as aldol condensation and transesterification and feature a dense polyaromatic structure with various functional groups. Due to their macromolecular and multi-functional character, they are highly viscous and temperaturesensitive, and therefore are difficult to process.
Recognizing the importance of humin side streams in terms of the economy and sustainability, this presentation introduces a strategy to repurpose them into useful building blocks for making new materials. This study introduces a synthetic strategy to manipulate the chemical composition of humins and in this way alter their physical state and the processability. Using a set of esterification reactions with reagents of different steric size and functionality, we demonstrate a selective transformation of humins into fine powders and low-viscosity liquids. Expanding on this approach, our study includes reactions with polyesters allowing humins to be incorporated into the polymer matrix. Specifically, we present a one-step synthetic approach to prepare high-strength thermoplastic elastomers using significant fraction of the humins. These materials exhibit foam morphologies and possess excellent mechanical performance. This study employs extensive analytical techniques to comprehensively investigate and characterize the transformed materials, including spectroscopy, calorimetry, rheology, mechanical analysis, and microscopy.

B8. Chitosan/chitosan modified with zwitterions pH-sensitive materials for dental implant application

Georgia Michailidou[1], Evi Christodoulou[1], Georgia Pouroutzidou[2, 3], Ioannis Tsamesidis[2], Maria Bousnaki[2], Dimitrios Giliopoulos[4], Eleana Kontonasaki[2], Dimitrios Bikiaris[1]

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Dental implants are artificial tooth root substitutes, surgically positioned into the jawbone to replace missing teeth. They are a popular and widely accepted solution, especially in countries with advanced dental care infrastructure. However, peri-implantitis is a site-specific inflammatory condition, affecting the surrounding dental implant tissues. It is characterized by inflammation and infection of the gingival tissues and bone around the implant, compromising the success of implant therapy. Treatment of peri-implantitis is challenging, mainly due to difficulties in decontamination of the roughened and threaded surfaces of exposed implants, however is mainly performed through mechanical debridement combined with antibiotics and surgical treatment. Within this context, a functional implant coating with a pH-sensitive material with innate antibacterial properties would aid in the prevention of bacterial colonization.

In the present study, the structure of chitosan (CS), a natural polysaccharide, was modified with three different zwitterions i.e. [2-(methacryloyloxy)ethyl)]dimethyl-(3-sulfopropyl) ammonium hydroxide), 2-acrylamido-2-methyl-1-propanesulfonic acid and 2-sulfobenzoic acid cyclic anhydride. The new derivatives were further crosslinked with vanillin through the formation of Schiff-based bonds while blends of the CS-derivatives crosslinked with vanillin were performed with neat CS. The final materials were further reinforced with nanoparticles with innate antibacterial properties.

All the materials were characterized through FTIR while the pH-sensitive character of the smart derivatives was established. The added nanoparticles' ratio is critical concerning the viscosity of the formulated gels. Consequently, through rotational viscometer studies the shear-thinning behavior of the materials was assessed while the effect of the added nanoparticles on the gels' viscosity was examined. In a further step, the biocompatibility of all the materials was examined. Results revealed the successful preparation of smart pH-sensitive materials, composing shear-thinning hydrogels with exceptional biocompatibility.

B9. Amphiphilic PCL-g-Dextran and PCL-g-hyaluronan nanoparticles for the development of hybrid hydrogel/nanoparticles dual-cancer drug delivery system

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Triple-negative breast cancer (TNBC) is a prevalent and challenging subtype of cancer due to the absence of targeted therapy options, its aggressive nature, and its high recurrence risk. Researchers are exploring combination treatments using multiple modalities to enhance anticancer therapies and develop innovative dual-action drug delivery systems to improve efficacy, reduce side effects, and overcome drug resistance. In this frame, we aim to design a novel biodegradable polymeric hydrogel/nanoparticle hybrid system as a dual-drug delivery system of hydrophobic anticancer drugs and hydrophilic antibodies for enhanced cancer treatment. The originality comes from the use of a single family of amphiphilic polyester-g-polysaccharides to generate both hydrogels and nanoparticles (NPs) and ensure enhanced retention of the latter.

In this contribution, we focus on paclitaxel (PTX)-loaded NPs based on graft copolymers of poly(caprolactone) with dextran (PCL-g-Dex) or hyaluronan (PCL-g-HA). PCL-g-Dex and PCL-g-HA copolymers were synthesized by azide-alkyne Huisgen 1,3-dipolar cycloaddition between propargylated PCL, and an azido-dextran or azido-hyaluronan synthesized via reductive amination of the chain ends. Copolymers with DEX(or HA)/CL ratios of 2 and 1.5 are obtained using PCL16k or PCL35k as backbone and either Dex3k or HA5k as side chains. The copolymers were used to prepare PTX-loaded NPs via thenanoprecipitation process. NP sizes were characterized by DLS, showing diameters from 100 nm to 200 nm. An encapsulation efficiency of around 40% and drug loading on average of 10% were determined by HPLC. Comparative release kinetics and in vitro cytotoxicity towards the cancer cell lines MCF-7 and MDA-MB-231 are presented.

B10. Conductive hydrogels based on collagen and reduced graphene oxide promote the wound-healing process

Luisbel Gonzalez Perez de Medina, Katherina Fernández Elgueta, Claudio Aguayo

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Conjugated polymer brushes attached covalently by one chain end to a substrate may exhibit interesting optoelectronic properties as well as better stability compared to physiosorbed polymer films. Therefore, they can be potentially used in nanoelectronics or photovoltaic solar cells.

In this work, we present a facile route to modify selected planar surfaces (e.g., indium tin oxide or quartz) through the synthesis of homopolymer brushes with poly(ethynylpyridine)-based chains. Poly(5-[2-(trimethylsilyl)ethinyl]pyridin-2-yl) 2-methylprop-2-enate) (P(m-MTEP)) and poly(6-[2-(trimethylsilyl)ethinyl]pyridin-3-yl) 2-methylprop-2-enate) (P(o-MTEP)) precursor brushes were prepared by an innovative organocatalyzed surface-initiated atom transfer radical polymerization (O-SI-ATRP) providing the layers with thicknesses reaching 30 nm. In the next step, pendant acetylene groups in the precursor P(m-MTEP) and P(o-MTEP) brushes were deprotected and subjected to self-templating polymerization that enabled the formation of a conjugated bond system. Self-templating polymerization was initiated just by the quaternization of pyridine groups in the brushes, allowing the formation of ionic conjugated surface-grafted polymer chains. The nanostructures obtained in this way were examined after each modification step, e.g., by FT-IR, UV–VIS spectroscopy, and atomic force microscopy (AFM). Conjugated P(m-MTEP) brushes were doped by selected compounds in order to increase the conductivity of these nanostructures.

B11. Solid-state cooling by Natural Rubber: evaluation of the effect of crosslinking density on the elastocaloric performance

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Elastocaloric cooling is recognized as a promising alternative to current vapour compression cooling systems, which often rely on environmentally hazardous refrigerants. Natural Rubber (NR) stands out among elastomers exhibiting elastocaloric behaviour due to the combination of several favourable characteristics, such as nontoxicity, low cost, sustainability, softness, long-life fatigue and high caloric potential. Despite these properties, research on the refrigeration potential of NR is still in its early stages, and several aspects require attention. This work investigates, for the first time, the effect of crosslinking density on the elastocaloric properties of NR. Samples with three different crosslinking densities (2.9, 4.0 and 5.2 mol·104/cm3) were produced by internal compounding and hot pressing and thermo-mechanically characterized. The assessment of the elastocaloric effect of the produced samples revealed that reducing the crosslinking degree significantly enhanced the elastocaloric performance, obtaining a coefficient of performance (COP) of 2.4 with the least cross-linked sample. These results underscore the significance of crosslinking density as one of the primary factors to be considered to enhance the refrigeration potential of NR.

B12. Optimizing Cellulose-Based Biocomposites for Sustainable Fibre Production through Melt Spinning

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Plastic is the most used material in packaging, as well as in single-use products. Although this material has a relatively short history, the ease of its production, as well as the associated speed and low cost, have led, in the last century, to the massification of its production and the consumption of the most varied products. Due to plastic's low recyclability rate and increased utilization, most of these products end up being landfilled. Consequently, the development of alternatives to materials derived from fossil resources, like plastics, that possess the same functionalities as these products have been increasingly incentivized, both at national and international levels.

From Fossil to Fossil intends to develop cellulose-based raw materials that can adequately be used to replace fossil resources in packaging solutions. Cellulosic fibres, when combined with other materials (thermoplastic matrices, preferentially bioplastics) can give rise to new biocomposites that can be used to produce, through injection moulding, thermomoulding, extrusion, lamination or 3D printing, new products in the most varied sectors, including products for rigid packaging, films and filaments; these biocomposites, in the form of monofilaments, can also be combined with/produce sustainable textile products and create new products for flexible or rigid packaging.

However, the incorporation of cellulosic fibres presents challenges in composite processing, particularly in melt spinning, due to issues related to fibre dimensions, dispersion and inherent viscoelasticity. Therefore, this study aims to develop and optimize biocomposites based on cellulosic fibres with viscoelastic properties, enabling the production of mono- or multifilament fibres through melt spinning. The experimental design includes the addition of compatibilizers, the enhancement of melt strength and the optimization of the cellulose filler percentage.

This work was developed within the scope of Agenda “From Fossil to Forest” [C644920945-00000036], financed by PRR – Plano de Recuperação e Resiliência under the Next Generation EU from the European Union.

B13. Carboxymethyl cellulose films activated with resveratrol and berberine

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Novel films based on carboxymethyl cellulose containing active substances, resveratrol, and/or berberine were prepared so they could be used as cosmetic masks or active packaging.

Carboxymethyl cellulose (CMC) films contained glycerin as a plasticizer and berberine and/or resveratrol as active ingredients in 1% or 5% (w/w). Physicochemical, mechanical, antioxidant, and antibacterial properties, as well as water vapor permeability (WVTR) and moisture content (Mc), were investigated for the prepared films.

The amount and type of added substances influenced the properties of the CMC films. Berberine acted as a plasticizer as, with its addition, the films were characterized by lower Young's modulus and stress values at break and higher strain values at break, as well as by barrier properties that were worse than those of the neat CMC film. Films with berberine did not show antioxidant capacity but had good antibacterial properties. However, the CMC films with a higher amount of resveratrol (mixture with berberine) could stretch to a lesser extent, had lower moisture content, constituted a better barrier to moisture due to their more compact structure, and possessed an excellent antioxidant capacity, but they did not show antibacterial properties. The film with a higher content of both components revealed good antimicrobial, antioxidant, and barrier properties, making it suitable for packaging applications.

B14. Reversible Bonding in Polyurethane Adhesives Through Diels–Alder Chemistry

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The development of covalent adaptive networks (CANs) represents a major advance in the field of polymer engineering, introducing a level of flexibility never before seen in materials manufacturing. Unlike traditional adhesives that form fixed bonds, CAN-derived polyurethane adhesives have a remarkable feature: they can alter their chemical structure by means of bonds that can be reversibly formed and broken. This is usually achieved by modifying the polyurethanes with Diels–Alder (DA) adducts.

Utilizing the reversible aspects of DA reactions, these adhesives can undergo controlled processes of bonding and debonding. This attribute is especially beneficial in applications where the ability to redo or recycle is crucial, as it allows for the effortless disassembling and rejoining of parts without degrading the material's overall integrity.

This research focuses on the development of a type of solvent-based polyurethane adhesive. For this purpose, a polyurethane prepolymer with DA diene and dienophilic components is improved. To evaluate the adhesive, a series of tests were carried out including Nuclear Magnetic Resonance Spectroscopy (NMR), Differential Scanning Calorimetry (DSC), Thermogravimetric Analysis (TGA) and T-peel strength tests on leather, adhesive and rubber composite structures. These tests were designed to determine the behaviour of the adhesive under various conditions after being subjected to external forces.

The study confirmed the effectiveness of both the DA and the reverse DA (r-DA) reactions through 1H-NMR analysis. The introduction of these functional groups into the adhesive prepolymer did not detract from its properties. The adhesive maintained its thermal stability and showcased efficient flow and bonding characteristics. These qualities were found to meet, and in some cases exceed, the rigorous standards required for bonding shoe uppers to soles. Notably, when exposed to specific thermal stimuli, the bonded materials could be separated easily and without any damage, highlighting the potential for their efficient separation, reuse and recycling.

B15. Cell viability and antimicrobial capacity of chitosan-pluronic F127 and reduced graphene oxide hydrogels as wound healing dressings

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The aim of this work was to extract chitin from black soldier fly (BSF) larvae exuviae and to convert it into chitosan, to be used to develop a bioplastic. Bioplastics are among the most sustainable materials that will contribute to the resolution of new and pressing environmental challenges. In this work, we will show the chitin extraction process, as well as deacetylation to synthesize chitosan-based bioplastics from black soldier fly (Hermetia illucens) exuviae, to achieve an environmentally sustainable product with low production costs. The use of mechanochemistry and the ability to control the size of the biomass produce different products during this study. The characterization of chitin and chitosan obtained from this natural source will be performed by X-ray Photoelectron Spectroscopy.

B16. MIDs go sustainable: An overview of improvements for the next generation of sustainable mechatronic integrated devices

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Mechatronic Integrated Devices (MIDs) appeared in the last decade as a promising alternative to commonly used printed circuit boards. MIDs allow the integration of electrical and mechanical functions, as the electronic circuit is placed directly on the surface of the polymeric part, which reduces weight and the number of components. Laser Direct Structuring (LDS) is one technology, among others, for building and developing MIDs. Several examples illustrate the practical adoption of this technology in many fields such as automotive, wearables and telecommunications, from sensors to lighting and antennas to be placed in mobile phones. At same time that the miniaturization and integration level of electronics is increasing, recent trends call for more sustainable aspects, such as designs for disassembly and recycling, their correct disposal at their end of life and e-waste reduction. A big challenge is to find a balance between the technical and sustainability requirements so neither compromises the other. Improving the energy efficiency of the systems is only one of the technical points to be tackled, as well the use of more sustainable materials and processes to manufacture products in an environmentally friendly way is another good perspective. An alternative is designing products taking into consideration eco-design principles from the very start. What is certain is that there is a need to adapt and adjust the way that electronic products are developed. So far, no great focus has been given to sustainability applied to mechatronic integrated solutions. In this sense, this work seeks to provide an overview regarding the current sustainability aspects in MIDs, more specifically those produced by LDS technology. The prominent aspects to be developed are analyzed and evaluated, with the objective to provide a roadmap for the development of more sustainable mechatronic integrated solutions in the coming years.

B17. Surface coatings of L-DOPA-modified oligo(ethylene glycols)

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Mussel Foot Proteins (MFPs), enriched with the amino acid derivative L-DOPA (L-3,4-dihydroxyphenylalanine), exhibit remarkable adhesion to virtually any surface. We previously reported MFP-inspired L-DOPA-modified bifunctional oligo(ethylene glycol)s, OEG-DOPAs[1]. Here, we extend this approach to methoxy-terminated monofunctional oligo(ethylene glycols), mOEG-DOPAs. The synthesized derivatives (OEG400-DOPA, OEG1000-DOPA, mOEG400-DOPA, mOEG1000-DOPA) were studied via FTIR/NMR spectroscopies and thermal analysis, confirming the expected chemical structures.

Surface coatings were obtained by dip-coating glass and stainless steel (SS) coupons in 2 mg/mL solutions in Tris HCl buffer (pH 8.5) for 18 h, with and without subsequent thermal annealing (120 °C, 6 h). Water contact angle (WCA) measurements showed the increased hydrophilicity of the as-coated substrates, which was reduced considerably after annealing due to pronounced indole ring formation. X-ray photoelectron spectroscopy (XPS) also confirmed the attachment of OEG-DOPAs and mOEG-DOPAs on the substrates, with increased C and N abundance and reduced substrate signals. Coatings on glass appeared to be of a lower thickness (»2 nm) compared to SS (»10 nm). XPS also suggested increased nitrogen contents from secondary amine species after annealing, consistent with indole formation. Adsorption isotherm studies suggested a higher deviation from a Langmuir monolayer for all adsorbates on SS, possibly due to the enhanced multilayer formation potential via catechol complexation around dissolved Fe+3/Cr+3 metal centres.

B18. Radical–Radical Coupling Investigation Allows for Efficient Bottlebrush Polymer Demulsifiers

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The direct-growth technique was used to synthesize several macromonomers (MMs), employing reversible addition–fragmentation chain transfer (RAFT) polymerization, by growing them directly from a norbornene-functionalized chain transfer agent (CTA). We aimed to investigate the formation of bisnorbornenyl species resulting from radical termination by combination (i.e., coupling) during RAFT polymerization at different monomer conversion values in four types of monomers: styrene, tert-butyl acrylate, methyl methacrylate and N-acryloyl morpholine. Flash chromatography proved to be an efficient method to purify polymer mixtures compared to the wasteful precipitation method. Ring-opening metathesis polymerization (ROMP) of these MMs using a Grubbs 3rd generation catalyst (G3) at an MM:G3 ratio of 100:1 resulted in the formation of bottlebrush polymers. Analysis by size-exclusion chromatography (SEC) revealed high-molar-mass shoulders of varying intensities attributed to the incorporation of these bisnorbornenyl species to generate dimeric or higher-order bottlebrush polymer oligomers. The monomer type in the RAFT step heavily influenced the amount of these bottlebrush polymer dimers and oligomers, as did the monomer conversion value in the RAFT step. This protocol facilitates the synthesis of high-purity amphiphilic bottlebrush block copolymers, enabling a detailed investigation of their efficacy in the separation of crude oil emulsions.

B19. Thermal Conductivity Enhancement of PE-RT samples with M5 and GNRs25 fillers

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Polyethylene of raised temperature resistance (PE-RT) is a plastic high-flexibility pipe, used under high-temperature, high-pressure conditions (e.g., 13.79 bar at 23 °C and 6.9 bar at 82 °C).

Because it is safe to transport potable water, with high resistance to corrosion and chemicals, and is environmentally friendly, PE-RT has many applications in water distribution systems either indoors or outdoors.

The thermal conductivity of seven samples was measured using the GHFM-22, which operates according to the ASTM E1530 Guarded Heat Flow Meter technique, for the measurement of the thermal conductivity of solids. According to this technique, the sample is subjected to a steady-state axial temperature gradient. The sample's thermal conductivity is obtained by measuring the temperature difference across it and one additional temperature.

Each side of every sample was covered with thermal paste to ensure the device plates were attached to the sample and to reduce contact resistance. For the measurement process, the heater on the top stack was set at 40 oC, while the bottom stack was kept at 10 oC, allowing a mean temperature of 25 oC inside the sample.

The seven samples in which thermal conductivity was measured were PE-RT, mixtures with different fractions of M5, and GNRs25.

The diameter of all samples was 50.8 mm, and the thickness of each sample was between 0.62 mm and 1 mm.

The thermal conductivity of all samples was enhanced compared to the pure baseline PE-RT sample. The thermal conductivity enhancement is higher for the M5 mixed with PE-RT than the sample with the same weight fractions as GNRs25.

B20. Examining the adsorption of a drug complex mixture on virgin and aged polypropylene microplastics in various water matrices

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The main scope of this study was to investigate the adsorption efficiency of polypropylene (PP) microplactics (MPs) in a complex mixture of drugs. PP particles were milled and sieved through 75 – 200 µm mesh-sieves, while a quantity of them were aged with UV irradiation. Concerning pharmaceuticals, seven widely used compounds were selected, namely, Trimethoprim, Metronidazole, Indomethacin, Isoniazid, Diclofenac, Ketoprofen, and Valsartan. The experimental procedure was designed (i) to examine the kinetic data, (ii) to investigate the effect of initial concentration of drugs, (iii) to study the ionic strength, (iv) to evaluate the effect of the aqueous matrix, and (v) to examine the desorption of the drugs at different pH values. The results showed that PP MPs can adsorb pharmaceutical compounds with different physicochemical characteristics. The kinetic and isotherm studies revealed the possible interactions that occurred among the functional groups of polymers and those of drug molecules. Among the studied pharmaceuticals, diclofenacDiclofenac and Indomethacin showed the highest uptake due to their hydrophobic nature. Moreover, the aged particles showed higher adsorption efficiency. Regarding the other factors examined, pH appears to affect the adsorption of the target compounds on PP-MPs considering that electrostatic forces played a dominant role in the process. Wastewater and seawater also affected the adsorption capacity of MPs, since the high load of organic matter or salinity reduced the uptake of the target compounds. Desorption studies were also conducted at three different pH values, indicating a higher release of the target compounds at alkaline conditions.

B21. Multivariate Evaluation of Newly Synthesized Non-Porous Chitosan-based Nanobeads for Trace Analysis of Contaminants of Emerging Concern in Wastewater

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This study explores the application of newly synthesized, cheap, non-porous, chitosan-based nanobeads as a novel sorbent for dispersive solid-phase extraction (d-SPE) for the analysis of contaminants of emerging concern (CECs) in complex matrices. Nanobeads were synthesized by modifying chitosan using 2-hydroxyethyl acrylate and cross-linking with triethylene glycol dimethacrylate. The beads underwent extensive characterization: (a) scanning electron microscopy revealed an average diameter of 300 nm; (b) Fourier-Transform InfraRed spectroscopy confirmed the successful acrylation of chitosan; and (c) nitrogen adsorption indicated the non-porous nature of the material (class II Brunauer-Emmett–Teller isotherm) and a surface area of 5.8 m2g-1. The extraction efficiency of the nanobeads was assessed using dispersive solid-phase extraction (d-SPE) applied to the effluent of the municipal Wastewater Treatment Plant Ljubljana (Slovenia) enriched with common wastewater CECs (Estrone, 17-beta-estradiol, 17-alpha-ethynyl estradiol, Progesterone, Diclofenac, Ibuprofen, Naproxen, Benzophenone, Triclocarban, Triclosan, Bisphenol A, Bisphenol AF, Bisphenol F, and Bisphenol S) ranging in concentration from 17 to 67 µg L-1. Following d-SPE, separation was achieved employing liquid chromatography with a C18 column and analysis using Quadrupole-Ion-Trap Mass Spectrometry operating under electrospray ionization in negative and positive mode and multiple reaction monitoring. A multivariate approach (Plackett–Burman robust model design) was applied to understand the interaction between the nanobeads and the analytes. The results revealed the influence of sample pH and adsorbent amount on analyte recovery, with optimum results obtained at pH 4 with 40 mg of nanobeads and 6 mL of sample (recovery ranging from 82% to 122%, with a relative standard deviation ≤ 6 %). These findings suggest that non-porous chitosan-based nanobeads have the potential to be an effective sorbent for both trace analysis and environmental monitoring.

B22. The Life Cycle Assessment of Nano-lignin Production in an Ultrasonication-Assisted Reactor from Lignin

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Driven by the increased pressure to advance green and sustainable processes, several valorisation techniques are being developed to convert lignocellulosic wastes into valuable products. Pulp and paper-making industries alone account for around 70 million tons of lignin burnt for energy recovery, and only a small percentage is recovered. With the help of novel technologies such as ultrasonication, it is possible to transform this aromatic biopolymer into a nanomaterial with cross-field applications. Aiming to support decision making, this work applies life cycle assessment (LCA) to estimate the cradle-to-gate environmental impact of the nano-lignin powder produced via an ultrasonication-assisted process developed and exploited via BIOMAC and REDONDO projects. The functional unit selected is 1 kg of dried nano-lignin powder, and primary life cycle inventory data were collected from lab-scale experiments. The process developed at Creative Nano starts by grounding and drying lignin and then storing it. Afterwards, the lignin is mixed with water (from reverse osmosis) and undergoes an ultrasonication step; the resulting dispersion is frozen below -53ºC and separated via freeze drying. From this process, nano-lignin is obtained at 0% water content. The LCA results using ReCiPe methodology analyse 18 impact categories and show the most significant hotspots are the cooling and pumping systems of the ultrasonication reactor (accounting for over 70% of total average impacts), mainly due to the pilot systems' low energy efficiency. Efforts should be focused not only on yields but also on improving energy efficiency and usinglow carbon energy sources for scale up since these may jeopardize the environmental performance of innovative processes when compared to other routes of nano-lignin production. Regarding the two steps before the storage, they represent the residual impact compared to the subsequent steps, contributing to less than 1% of total average impacts.

B23. Plasma-treated lignin for improved compatibility in lignin–polypropylene compounds

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Polypropylene (PP) is one of the most widely used polymeric materials on a global scale, whose production reached 80.7 MT in 2023. Considering that 22-43% of it is currently landfilled, its use in combination with materials from renewable resources may represent a valuable strategy to reduce the environmental burden associated with its end-of-life fate. In particular, using lignin in polyolefin–lignin blends can be an excellent approach to limit the environmental impact of fossil-based polyolefin products while improving their thermo-oxidative stability. However, given the strong polarity of lignin and the absence of any polar group in the PP structure, almost no synergistic interactions can be established between the two polymers.

In this work, soda lignin was subjected to plasma treatment with the aim of increasing its compatibility with PP. A gliding arc tornado device was specially designed for treating lignin powders. Lignin–PP blends were produced by means of a twin-screw extruder by incorporation of 5, 10 and 20 wt.% (plasma-treated or pristine) lignin to PP. All the blends were extensively characterized with respect to their thermal, thermo-oxidative and mechanical properties.

In particular, electron paramagnetic resonance (EPR) spectroscopy demonstrated a notable increase in phenoxy radical species in lignin samples after plasma treatment, while a concurrent reduction in phenolic hydroxyls was detected by 31P-NMR analysis. Accordingly, tensile tests indicated superior performance of the blends containing treated lignin with respect to reference blends with pristine lignin. Considering the context of the current literature, significant values of elongations at breaks were found for lignin–PP blends that incorporated plasma-treated lignin. Additionally, thermogravimetric analysis showed that the introduction of lignin in PP blends contributed to a remarkable increase in their thermo-oxidative stability.

This work presents an effective and solvent-free strategy to incorporate lignin into polyolefin blends, achieving higher thermo-oxidative stability while maintaining excellent thermo-mechanical responses.

B24. Bacterial Cellulose Composite Films with Adjustable Properties for Sustainable Food Packaging Applications

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The widespread use of plastic materials, particularly in the food packaging industry, poses environmental challenges due to both the sourcing of these materials and their non-biodegradable nature. Cellulose, the most abundant renewable biopolymer, is gaining traction in the food packaging sector, with bacterial cellulose (BC) offering numerous advantages across various industries. BC properties can be tailored, making it a potential alternative to non-biodegradable synthetic plastics. However, challenges such as limited elasticity and production scalability hinder their widespread use in food packaging.

This study, performed in collaboration with Bioniks srl (Verona, Italy), focuses on innovatively producing BC films for food packaging, utilizing an efficient technique that enables the large-scale manufacturing of films with adjustable properties. Composite films of BC, polyvinyl alcohol (PVA), and chitosan were developed through a mechanical wet mixing technique, offering advantages like the simultaneous addition of fillers, reduced production time, and broader additive concentration ranges. Experimental testing covered various properties, including chemical, thermal, morphological, mechanical, optical, antimicrobial, and biodegradability.

Microstructural analysis showed that BC morphology remained unaffected by the wet mixing process. The interaction between BC, PVA, and chitosan was confirmed through chemical and thermal analyses. Increasing PVA content resulted in higher water-related properties, while adding chitosan decreased them and improved thermal stability. Tensile tests indicated that adding PVA reduced stress and strain at break, as well as stiffness, while adding chitosan increased the elastic modulus. Optical, antimicrobial, and biodegradability tests demonstrated the feasibility of altering film properties by varying composition. This research highlights the potential of BC composite materials and the flexibility of the wet mixing process in tailoring film characteristics, expanding applications in the food packaging sector.

B25. Cellulose nanocrystal and Pluronic L121-based thermo-responsive composite hydrogels

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Cellulose nanocrystal (CNC) emerges as a promising sustainable material, characterized by its biocompatibility, high aspect ratio, and impressive mechanical strength, making it an ideal candidate for various applications in biosensors, packaging, coatings, energy storage, and pharmaceuticals. However, the transition of CNCs into smart systems poses challenges due to their lack of stimuli-responsiveness, limited compatibility with hydrophobic matrices, and tendency to agglomerate. In this study, a thermo-responsive hydrogel is constructed with CNCs and temperature-responsive and reversible vesicle-forming PEO-PPO-PEO block copolymers, specifically Pluronic L121 (L121). This investigation delves into the phase behavior, morphology, and mechanical properties of the resulting nanocomposite, exploring the influence of unimers and polymersomes on the CNC system (4% and 5%) with the addition of varying L121 concentrations (1-20 %). The results showed that the addition of diluted and concentrated L121 produced different effects both on the CNC gelation and the resulting gel properties. At lower L121 concentrations (1–5%), the nanocomposite system exhibits increased softness but high fragility below the transition temperature. Contrastingly, higher L121 concentrations (10–20%) yield a much stronger composite with the formation of a gel network above the transition temperature. Intriguingly, the inclusion of large polymersomes imparts a soft and deformable nature to the system, enhancing its resistance to microstructural breakdown at large strains. Overall, this study reveals the thermo-reversible rheological behavior and tunability of the gelation temperature for hydrogels with increasing L121 concentration, making them promising stimuli-responsive materials for biomedical applications.

B26. Fabrication and Characterization of 3D printable bio-composite filament by reinforcing PLA with flax fibre

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Additive Manufacturing (AM) technology is used to fabricate complex structures by depositing the material layer-by-layer. AM is advantageous at short design cycles, suitable for manufacturing complex structures, and high material utilization compared to subtractive manufacturing. Also, AM has been widely used in manufacturing lightweight parts and devices for aerospace, aviation, automobiles, and medical devices. Fused Filament Fabrication (FFF) is the most widely used AM process because of its low cost and simplicity of operation, which allows printing a range of materials, multiple materials, and in multiple directions. AM of only polymer parts through FFF has resulted in lower mechanical properties. However, polymer matrices can be reinforced with continuous and short fibres to enhance the mechanical performance of FFF parts.

The present research focusses on developing and characterizing 3D printable bio-composite filaments of flax fibre-reinforced polylactic acid (PLA). Initially, composite filaments are manufactured through micro-compounding by incorporating short flax fibre into the PLA matrix. Subsequently, the composite filament undergoes characterization through thermal analysis and mechanical testing. The thermal analysis comprises TGA and DSC of the composite filament, while tensile testing is conducted to assess its mechanical properties. Additionally, DMA is performed to evaluate the damping of composite filaments. With these results, we aim to produce sustainable 3D printable composites with enhanced damping performance.

B27 Exploring the Therapeutic Synergy: Comprehensive Assays Reveal Sericin and Chelidonium Majus L.'s Potential for Wound Dressing Innovation

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Described as a "silent epidemic," wounds impose a considerable social and economic burden, severely impacting the well-being of millions globally. Promising natural compounds such as Sericin and Chelidonium majus L. (C. majus) have demonstrated potential in wound management. Sericin, derived from silk, expedites wound recovery by fostering cell growth, collagen production, and blood vessel formations. Conversely, C. majus, a medicinal herb, possesses anti-inflammatory properties and aids in tissue renewal. Combining these substances in wound dressings could concurrently address various facets of the healing process. This study aimed to explore the potential synergistic effects of Sericin and C. majus on wound healing. Through cytotoxicity, anti-inflammatory, antimicrobial, and wound healing assessments at different concentrations, we sought to understand how the collaboration between Sericin and C. majus influences the healing trajectory. The investigation of these natural substances as components of wound dressings offers a promising avenue for developing sustainable, effective, and biocompatible materials that could revolutionize wound care practices.

B28. Thiol-ene Uv-curing Of Biobased Monomers for A Green Development

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Biomass feedstocks are playing a key role toward the development of new sustainable materials with the aim to replace the fossil-based ones limiting the emissions and waste. Among the other, cellulose is gaining interest as a source of new bio-based building blocks. The necessity to limit energy consumption and time lead to the innovation of production processes and the UV-technologies have gained interest to provide a valid alternative to traditional thermal curing in the production of thermosets. In this framework thiol-ene chemistry can fruitfully combine the use of green monomers and UV to develop new bio-derived formulations. Levoglucosenone, a derivative of cellulose, is a promising candidate for creating more sustainable materials. We develop a new set of bio-based tailored monomers suitable for thiol–ene UV-curing and to test the resulting resins in DLP printing, thus increasing their possible applications. A new class of bis-allyl monomers has been synthesized from LGO through different chemical synthesis, including oxa-Michael addition, catalyst- and solvent-free Baeyer–Villiger oxidation, and enzymatic transesterification with several bio-sourced diesters. The eco-friendliness of this pathway was characterized through E-factor and EcoScale calculations. Furthermore, the monomers' back bone can be varied to fine-tune material properties, and the ester bonds can be susceptible to degradation at the end of the material's life in order to embrace the principles of the circular economy. The photo-crosslinking between bis-allylated monomers and the selected thiol, trimethylolpropane tris(3-mercaptopropionate) (TMPMP) was investigated through different techniques (i.e., real-time FTIR, photo-DSC and photo-rheology) and proved very efficient. The new materials were characterized through DSC, DMTA, tensile tests and TGA prior to successful assays of 3D printing. The degradability of the bio-based resin was investigated by hydrolytic degradation to prove its potential for chemical recycling.

B29. Sustainability in Construction: Transforming Waste Plastics into High-Value Composites

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Amidst growing environmental concerns regarding plastic waste and the disposal of glass fibres in various engineering applications, i.e., turbine blades, thermoplastic polymers are gaining traction due to their sustainable and recyclable nature. This study investigates the utilization of waste mixed plastics (wMPs) obtained from film packaging waste reinforced with short, randomly oriented waste glass fibres (wGFs) to create laminates with customisable properties. Coupon specimens were extracted from flat laminates with two different types of binders: a) acrylic and b) melamine-formaldehyde. The tensile, flexure, and compressive performance, along with the fibre volume fraction (FVF), of the two different types of specimens was evaluated following standard test methods. The incorporation of fibre reinforcement significantly enhanced the mechanical properties of the composites compared to available data on unreinforced waste mixed plastics (by approximately 40-50%). These findings suggest that the use of wMP/wGF composites as structural elements (e.g., C-section members) is promising, providing an alternative sustainable solution.

B30. Bio-based and Biodegradable Foams from Wheat Gluten Proteins

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Polymer foams have an important role in society due to their wide range of densities, and they are extensively used as cushioning, damping, thermal, and sound insulation materials. However, foams are mainly obtained from fossil-based resources with low composting and recyclable properties. Thus, there is a strong motivation to develop foams using bio-polymers from renewable resources to combat their environmental impact. We report the production of sustainable protein foams from a co-product and the ethanol/starch industry. Here, Wheat gluten (WG) as raw material, glycerol as a plasticizer, ammonium bicarbonate (ABC), and sodium bicarbonate (SBC) as a food-grade blowing agents were used to produce highly porous foams into several thermal processing techniques such as oven expansion, compression molding, and extrusion used to evaluate the impact of the processing route and formulation on the microstructure of the protein foams. The foams' swelling properties and their biodegradability herein are potential properties for their use in applications relying on single-use foams. Furthermore, the production of WG foams by extrusion showed that porous WG with ABC had a low decomposition temperature enabling extrusion of the material at a temperature as low as 70 °C, well below the protein aggregation temperature compared to a higher processing temperature (120 °C) using SBC, resulting in better foaming and energy efficiency. Damping properties were obtained, using multifunctional additives (e.g., citric acid) resulting in foams with low densities, high porous structures, lower compression set (~40%), and high energy absorption. The gluten foams were promising as biodegradable materials in innocuous molecules (soil and hydrolytic degradation) for nature, with bio-assimilation and fertilization properties. The results pave the potential for scalable production of sustainable WG bio-based foams, challenging petroleum-based alternatives to compete with less sustainable petroleum-based polymer foams.

B31. Maltodextrin-based electrospun mats as suitable precursors for the one-step in situ production of gold nanoparticles supported on carbon sub-micrometric fibers

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Thanks to the combination of their low price, water solubility, and bioderived nature, starch-derived maltodextrins have been exploited to obtain polysaccharide-based fibers via the electrospinning technique. The addition of citric acid with maltodextrins has also proven to enable the creation of cross-linked fibrous materials, by taking advantage of post-processing curing treatments carried out at mild temperatures. Furthermore, when subjected to a high-temperature pyrolysis process, the same spun mats behaved as carbon precursors, giving well-defined sub-micrometric porous carbon fibers as the product.

Over the last few decades, nanotechnology has gained significant interest in scientific and industrial realities, with nanoparticles being considered a bridge between homogeneous and heterogeneous catalysis. In this context, gold nanoparticles have attracted growing attention due to their unique features. However, their catalytic activity strongly depends on their size and shape, making controlled synthesis a vital step. After their formation, nanoparticles are commonly immobilized on a support that plays a key role in heterogeneous catalysis, by providing, e.g., acidic/basic sites or metal–support interactions. In this regard, carbonaceous materials represent an ideal choice.

In the present work, a commercial maltodextrin has been electrospun from water solutions previously added with chloroauric acid as a gold precursor. Subsequently, the dry fibers were subjected to pyrolysis treatments to obtain sub-micrometric carbon fibers. In parallel, the formation of the carbon products induced the reduction of chloroauric acid to gold nanoparticles. The yield in carbon and the size and number of nanoparticles were dependent on the pyrolysis temperature and quantity of chloroauric acid added to the maltodextrin solution, respectively. The reported approach represents a novel and unique one-step in situ strategy to obtain gold nanoparticles supported by porous carbon sub-micrometric fibers, produced from sustainable materials, avoiding the use of organic solvents or toxic compounds.

B32. Polylactic acid depolymerisation by metal complex catalysts and an organocatalyst

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Chemical recycling is an alternative to mechanical recycling or composting for end-of-life plastics. This process involves breaking down the polymer to recover monomers or valuable chemicals. Although chemical recycling methods such as hydrolysis, acid–base depolymerisation and pyrolysis have been demonstrated previously, these processes require high temperatures up to 260 °C. In this study, two zinc-based metal complex catalysts and an organic catalyst were used to degrade polylactic acid (PLA) into alkyl lactates, which are considered green solvents. The catalysts have a simple preparation process and are suitable for large-scale production. It was possible to achieve high-yield degradation reactions at temperatures as low as 30 °C. The design of experiments methodology was used to identify the main operating parameters affecting the PLA transesterification reaction. A kinetic model was proposed to explain the degradation of PLA into methyl lactate, which was also applicable to the formation of other alkyl lactates. The temperature-dependent kinetics follow Arrhenius and non-Arrhenius models.

B33. Using Safe and Sustainable by Design (SSbD) Thermoplastic Powder Coatings to Address PFAS Concerns

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Per- and poly-fluoroalkyl substances, PFAS, are widely used in paper and cardboard to provide resistance to water, oil, and other fats. They have been associated with several adverse health effects. To overcome the use of PFAS coatings in food packaging, the BIO-SUSHY project aims to replace them by using bio-based alternatives comprising safer polymers and bio-additives. To guarantee the safe and sustainable development of novel thermoplastic powder coatings for the packaging sector, a detailed assessment including toxicological and exposure analysis is conducted. This is implemented early on in the R&D phase, both for powder coating formulation development as well as for individual components. Thus, following the SSbD framework, BIO-SUSHY develops different compounds based on bio-based polyesters like polyhydroxyalkanoates (PHAs) and polybutylene succinate (PBS), combining them with green additives like lignin and carnauba wax, targeting grease resistance and the water repellency of the paper. This work covers current results on PBS- and PHA-based powder coatings applied via spraying onto paper substrates suitable for the hot forming process. Contact angle measurements, grease resistance measurements and Cobb tests were conducted for all prepared coated papers. In parallel, rapid identification of in vitro cell toxicity using an electrochemical membrane screening platform was performed to study the potential toxicity of individual powder coating components from the design phase.

The BIO-SUSHY project is funded by the European Union underGrant Agreement Number 101091464. University of Leeds is funded by the UKRI Horizon Europe Guarantee Fund: Grant Number 10056199. Views and opinions expressed are, however, those of the author(s) only and do not necessarily reflect those of the European Union or the European Health and Digital Executive Agency (HaDEA). Neither the European Union nor the granting authority can be held responsible for them.

B34. One-step isolation of sub-micro organosolv lignin: A sustainable polymer additive

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Lignocellulosic biomass from agricultural/forestry residues is considered to be an alternative to petroleum as well as a renewable source of fuels, chemicals, and polymers. Lignin, one of the main components of lignocellulosic biomass, is considered to be the most abundant natural source of aromatic/phenolic compounds. Lignin properties depend on the biomass nature/type and the isolation process, which affect their reactivity, functionality, molecular weight, and homogeneity. Its structure renders lignin an excellent alternative resource for current petroleum-derived materials, like polymers, due to the aromatic structure and presence of various functional groups like phenolic and aliphatic hydroxyls, carboxyls, etc. Organosolv lignin is a technical lignin, isolated from lignocellulosic biomass within the biorefinery schemes . This type of process is very promising since it can selectively isolate organosolv lignins with desirable properties, such as decreased molecular weight (Mw), low polydispersity (PDI), appreciable amounts of β-O-4 bonds, and also increased functionality. The tailoring of lignin properties and characteristics is crucial towards achieving increased affinity, dispersion, and ultimately enhanced properties, especially when used in polymers and composites like PLA, epoxy resins, etc. In this work, beechwood biomass organosolv (OB) lignin was isolated via hydrothermal treatment using a mixture of EtOH/water and H2SO4 (acid catalyst). The isolation process was optimized, and the obtained OB lignin had a submicron particle size. The obtained OB lignin was further characterized using 2D-HSQC and 31P- NMR, GPC, and TGA/DSC analysis. The influence of lignin's properties and characteristics provides valuable information into the structure--property correlation towards the development of bio-based polymers (i.e., epoxy resins etc.) with enhanced properties, like mechanical, thermal, and antioxidant properties. This research was funded by the "European Sustainable BIObased nanoMAterials Community" (BIOMAC) project of the European Union's Horizon 2020 Research and Innovation Programme under grant agreement no. 952941.

B35. Effect of Bio-polycarbonate grafted Maleic Anhydride(Bio PC-g-MAH) Compatibilizer on the Properties of Isosorbide-based Bio polycarbonate/CNF Composites

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Recently, due to increasing environmental regulation in the automotive manufacturing industry, the demand for the development of sustainable and eco-friendly material is increasing. In accordance with this trend, research on automotive parts using Bio plastic is expanding. In this study, an eco-friendly Bio PC/CNF composite was manufactured by melt-extrusion Isosorbide based bio-polycarbonate (Bio-PC) and CNF (Cellulose nanofiber), which will be applied as automotive parts. To compensate for the insufficient mechanical properties of the Bio PC/CNF composite, Bio PC-g-MAH, a compatibilizer, was prepared by melt grafting in a micro-compounder injection molder. It was confirmed that the tensile strength increased by about 5% and the heat resistance was improved by comparing the Bio PC/CNF manufactured with Bio PC-g-MAH and the Bio PC/CNF manufactured without Bio PC-g-MAH. Through SEM and X-ray 3D CT analysis, it was confirmed that the interfacial adhesion between Bio PC and CNF was excellent due to the addition of Bio PC-g-MAH, thereby improving the CNF dispersibility in the Bio PC.

B36. pH-Responsive Microparticles Derived from Novel PDPA-Containing Copolymers: Synthesis, Characterization, and Potential Applications

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This study investigates the physicochemical properties and potential applications of novel random copolymers for manufacturing "smart" pH-responsive microparticles (MPs). The copolymers, namely poly(2-(diisopropylamino)ethyl methacrylate))-rand-poly(methyl methacrylate) (PDPA-rand-PMMA) and poly(2-(diisopropylamino)ethyl methacrylate))-rand-butyl methacrylate (PDPA-rand-PBMA), were synthesized via reversible addition-fragmentation chain transfer (RAFT) polymerization. These copolymers were then used to fabricate highly monodisperse pH-responsive MPs using microfluidic droplet generation techniques. The manufactured MPs exhibit pH-responsiveness due to the PDPA segment containing tertiary amino groups with a pKa of ~6.8. When the pH is lower than the pKa of the PDPA segment, the amine groups become protonated, rendering the PDPA segment soluble in acidic environments. This solubility change leads to alterations in the chain properties of MPs, consequently resulting in the release of potentially encapsulated cargo molecules. Furthermore, this phenomenon can be exploited for attaching negatively charged molecules or biological entities such as gram-negative bacteria. To demonstrate this potential, we examined the interaction between MPs and negatively charged latex resin beads (as models of gram-negative bacteria) using confocal microscopy imaging. We observed the attachment of model bacteria to the MPs in a concentration- and pH-dependent manner. Importantly, when the pH exceeds the pKa of PDPA, no significant interaction between the beads and MPs is observed. This comprehensive approach provides valuable insights into the pH-responsiveness of PDPA-containing copolymers and their behavior in biological environments, offering promising avenues ranging from targeted drug delivery to bacteria entrapment.

B37. Functionalized self-assembled amphiphilic nanoparticles for targeted drug delivery

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Functionalized self-assembled nanoparticles exhibit promising characteristics as drug delivery platforms, capable of enhancing the bioavailability of therapeutic agents while enabling precise control over their release kinetics. The combination of alkyl-fluorinated and hydrophilic chains yields amphiphilic molecular structures, amenable to modification with various functional groups. Tailoring the functionalization of these self-assembled nanoparticles facilitates targeted drug delivery. Our preliminary investigation involves leveraging such constructs as drug delivery systems, centered on tailored self-assembled nanoparticles poised for translation into nanomedicine applications. Moreover, multimodal functionality of our systems allow us to track the impact of polyfluoroalkylated compounds that are gaining more attention for theirs increasing environmental contend due to its low reactivity. In vitro studies underscore the significance of the overall surface charge of nanoparticles in influencing the rate of cellular internalization and subsequent cytotoxicity. Employing confocal microscopy across various cell lines suggests that alkyl-fluorinated molecules may undergo active uptake and accumulation within the endoplasmic reticulum. Our methodology presents a novel and versatile approach for investigating self-assembled alkyl-fluorinated compounds endowed with distinct functional properties.

B38. Chitin–glucan Complex Films Obtained Via A Shock-wave-assisted Chemical Method: Novel High-voltage-dependent Electrical Resistivity And Other Physicochemical Properties

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Chitin–glucan complex (CGC), a natural copolymer extracted from fungi, merges the mechanical roughness of chitin with the flexibility of glucan, rendering it a compelling choice for film formation. In this study, a CGC film extracted from Aspergillus niger was developed using a sustainable chemical method assisted by shock waves to enhance the deproteinization process. A thin film (thickness ~10 µm) was formed from the extraction without dissolving the CGC. Such a film presented inherent triboelectric properties that were further studied by measuring its electrical resistivity, resulting in a nonlinear variable response (~177 – 24 MΩ) as a function of an applied high voltage (10 – 18 kV). While this phenomenon is known in metal oxide varistors (at relatively low voltages), it is uncommon in biopolymers. This rarity creates opportunities to explore potential applications for such films in the field of green electronics. The physicochemical properties of the CGC film were also analyzed using FTIR spectroscopy, XRD, TGA, and SEM, and the viscosity-average molecular weight (Mv) was determined, employing a rheometer. The differences in properties when using shock waves for CGC extraction were also assessed. Our results revealed that the use of shock waves in the extraction process decreases Mv by 540.52 Da. Furthermore, FTIR and TGA showed that the CGC film consists of β-1,6 and β-1,3 glucans, as well as chitin, with a 52.9% degree of acetylation (DA) using shock waves, exhibiting a higher DA than the control. XRD revealed a β chitin polymorphic type in the crystalline arrangement of chitin, as well as the preferential orientation at a 9.2° diffraction angle. In conclusion, the CGC film obtained offers interesting electrical and other physicochemical properties to develop biodegradable electronic components and devices which could help to mitigate the problems that electronic waste presents. Acknowledgements to PAEP-UNAM, CONAHCyT (A1-S-21130), PAPIIT (IG100122; IT103123) and PAIP (5000-9078; 5000-9167) grants.

B39. Alginate–based Thermo–induced Networks: A Remarkable Impact Of Ph To The Hydrogel Thermoresponsiveness

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In recent decades, hydrogels derived from natural macromolecules sourced from polysaccharides have attracted significant attention owing to their intrinsic biocompatibility, biodegradability, and nontoxicity, rendering them appropriate choices for use in biomedical applications and additional applications in healthcare. Polymers that undergo changes on their physicochemical characteristics, upon exposure to external stimuli such as pH, temperature, ionic strength etc, are known as “smart” materials. Many studies report the potential biomedical applications of hydrogels based on stimuli–responsive derivatives of the natural polysaccharide alginate.

In this research study, we explore the rheological properties of a heterograft copolymer with an alginate backbone, grafted by two different types of polymer pendant chains: (a) poly(N–isopropylacrylamide) (PNIPAM) homopolymer and (b) poly[(N–isopropylacrylamide)–co–(N–tert–butyl acrylamide)] (P(NIPAM–co–NtBAM)) random copolymer chains, displaying different Lower Critical Solution Temperatures (LCSTs).

Aqueous copolymer solutions with a polymer concentration fixed at 4 %wt. and different pH values (pH 3.5, pH 4.5 and pH 5.5) were prepared and studied through rheometry. Oscillatory as well as steady state measurements were performed. Due to its thermoresponsive side chains, the Alg–g–P(NIPAM86–co–NtBAM14)–g–PNIPAM copolymer forms hydrogels with thermo–induced sol–gel transition, above a critical temperature, Tgel (thermo–thickening). However, by lowering pH of the aqueous media in acidic regime, a remarkable increase of the elasticity of the polymer solution was observed in low temperatures. This effect induces significant changes in the hydrogel thermoresponsiveness, transforming the sol–gel transition to soft gel–strong gel. Moreover, the onset of thermothickening shifted to lower temperatures followed by broadening of the transition zone. This implies intermolecular interactions between the uncharged alginate backbone with the PNIPAM side chains, likely through H–bonding. The shear–thinning behavior of the soft gel in low temperatures provides injectability, which allows 3D–printing potential applications.

B40. Cationic hyper-branched water-soluble polymers obtained from alpha-beta- and gamma-cyclodextrins

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The possibility of exploiting cyclodextrins as building blocks for the synthesis of polymer structures has been largely reported in the literature. Both cross-linked and hyper-branched products have been obtained following different synthetic routes. Among the most common linking agents, carbonyldiimidazole is associated with the formation of carbonate bridges holding together the cyclodextrin units composing the polymer. This aspect is of great importance when the polymer is supposed to be applied, e.g., in pharma or medical applications. The reason for this is mainly related to the safety of its degradation products, released once it fulfills the intended scope, i.e., the starting cyclodextrin and carbon dioxide. Additionally, the polymer structures can be properly functionalized to strengthen the intended purpose. For instance, cyclodextrin-based polymers, studied as transfecting agents, will benefit from the presence of cationic sites in the formation of electrostatic interactions with plasmids. In this context, choline chloride represents an ideal candidate, being safe and bearing functionalities capable of allowing its anchor to the polymer chain. Also, alkyl alcohols can be used to modulate the resulting amphiphilicity.

In this work, alpha-, beta-, and gamma-cyclodextrins have been studied as suitable building blocks for the synthesis of water-soluble hyper-branched cationic polymers. Carbonyldiimidazole was used as the linking agent, choline chloride to impart cationic functionalities, and alkyl alcohols to modulate the resulting amphiphilicity. The optimization of the synthesis and purification was followed via FTIR-ATR, NMR, and elemental analysis, while GPC was employed to study the molecular weight. Finally, the complexing ability of the synthesized structures was screened with dextran sulfate and monitored via DLS and Zeta potential.

B41. Effect of utilizing recycled concrete aggregate on the thermal properties of self-compacting lightweight concrete

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It is known that the destructive effects of earthquake forces on the structure are reduced as the weight of the structure decreases as a result of the use of lightweight concrete. In addition, in today's conditions where energy is desired to be used more efficiently, it was understood that interest in the use of lightweight concrete with superior performance in terms of thermal insulation properties has increased. However, it was emphasized that the workability performance of lightweight concrete mixtures is low. It is known that one of the most common methods used in the production of lightweight concrete is the use of lightweight aggregate in cementitious systems. It is envisaged that the negative properties of lightweight concrete can be improved by adding self-compacting properties. Encouraging the use of recycled concrete waste and efficiently disposing of construction and demolition waste is of great importance for the European Green Deal. In this study, the effect of using recycled concrete aggregate on the compressive strength and thermal performance of self-compacting lightweight concrete mixtures was examined. For this purpose, a self-compacting control lightweight concrete mixture containing 100% pumice aggregate was prepared. Two different self-compacting lightweight concrete mixtures were produced by substituting 25% and 50% pumice aggregate for recycled concrete aggregate. The compressive strength and high-temperature resistance properties of the produced mixtures were examined. It was determined that as the pumice aggregate content increases in self-compacting lightweight concrete mixtures, the strength performance decreases, but high-temperature resistance improves.

B42. A highly conductive and stable Polymer-V2O5 Electrolyte for All-Solid-State Li Batteries

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Among various solid electrolytes of all-solid-state batteries (ASSBs), a polymer electrolyte is promising due to its excellent interface contact with electrodes, together with good viscoelasticity, lightweight, low-cost processing, and electrochemical stability. However, there still remain serious problems of low Li+ conductivity and electrochemical stability to achieve high-performance ASSBs. To address these challenging issues, this paper describes a highly conductive and stable poly(ethylene oxide) (C2nH4n+2On+1, PEO)-based polymer electrolyte (PPE) by incorporating V2O5 nanoparticles as inorganic filler. For the proposed PPE synthesis, PEO and lithium bis(trifluoromethane-sulfonyl) imide salt (LiTFSI) were mixed at a ratio of 20:1 (EO:Li), and appropriate amounts of poly(ethylene glycol) diacrylate (PEGDA) and V2O5 nanoparticles were also added. Finally, PPE was prepared by UV irradiation curing with a photo-initiator. Experimental results show that the proposed PPE exhibits a Li+ transference number of 0.29 which is about 59% higher than conventional PEO-based polymer electrolyte [1]. This implies that V2O5 nanoparticles help to form a stable network structure to reduce the crystallinity of PPE and facilitate hopping transfer of Li+ due to the improved crosslink between PEO and PEGDA. In the galvanostatic charge/discharge cycling test, it was confirmed that LiCoO2/PPE/Li cell operates stably for 20 cycles at a current of 0.1C. This suggests that V2O5 nanoparticles can be applied as inorganic filler in a PEO-based polymer electrolyte.

B43. A Hyaluronic-acid polymer-supported Vanadium Electrolyte Solution for VRFB-capacity fading inhibition

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A large-scale energy storage system (ESS) is needed to provide the stable energy from the unstable renewable energy sources. Vanadium redox flow batteries (VRFBs) are a noticed chemical-based ESS, which is the most technically matured RFB using vanadium ions as active species. However, VRFBs have the drawbacks of low energy density and capacity fading during cycling operations [1]. In this paper, we proposes the hyaluronic acid ((C14H21NO11)n, HA), one of a glycosaminoglycan polymer as additive to inhibit VRFBs capacity fading attributed to the reduction of active species in electrolyte with increasing cycling. Both the posolyte and negolyte were prepared by mixing 2.0 M VOSO4(VO2+) and 5 wt% HA. The prepared electrolyte was in the form of a gel having high viscosity. In the galvanostatic charge/discharge cycling test, the result show 99.85% of the capacity retention ratio at 40 mA/cm2 for 230 cycles indicating very stable capacity stability. This improves the transfer of vanadium ions by the abundant negative charge of carboxyl (-COOH) and hydroxyl (-OH) groups present in HA and the hydrophilic properties in HA are provided the stable condition because of H- bond network by interacting with H2O. In addition, HA effectively provides stable capacity preservation at high energy density by providing higher solubility than electrolyte of existing VRFBs. This suggests a breakthrough insight for the development of new types of VRFBs.

B44. Conductive Polymeric Nanocomposite Based On Carbonaceous Fillers For Integrated Metal-Free Cabling And Sensing

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In recent years, the aim to develop new classes of multi-functional materials to reduce component complexity and enhance their recyclability has become one of the main driving forces in several industrial applications. The extraordinary electrical properties of graphene-based fillers lead to a big interest in the production of a new class of nanocomposites with both excellent mechanical properties and innovative electrical behaviours.

When the graphene-based filler concentration is below a critical value, called the percolation threshold, the electrical properties of these composites are dominated by the insulating polymer matrix and the material acts as an insulator. However, if the filler concentration is above the percolation threshold, the formation of a three-dimensional conductive network leads to a change in the electrical properties of the nanocomposite, and the material acts as a conductor.

Concerning this class of materials, an interesting and promising technology consists in the functionalization by laser treatment of nanocomposites, in which the filler concentration is below the percolation threshold. The interaction between the material and the laser beam leads to the formation of a V-shaped track where the filler concentration is locally above the percolation threshold resulting in a local electrical conductivity. This innovative type of laser-functionalized nanocomposites could pave the way for a new technology for the production of metal-free electrical circuits and sensors.

In our research, we used a CO2 laser to obtain conductive tracks on polypropylene-based nanocomposites. Across all compositions, a linear correlation between track length and electrical resistance was observed with resistivity values lower than 2 Ohm/sq. This promising result allows us to further optimize this technology by developing new types of nanocomposites using different polymer matrices, including recycled polymers, and different types of nanocarbons, including environmentally friendly fillers like biochar.

B45. Nanocellulose Reinforcement of Urea-Formaldehyde Adhesives for Sustainable Polymer Composite Applications

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The increasing awareness of the detrimental effects of formaldehyde emissions on human and environmental health has increased demand for low-emission, environmentally friendly, and biobased products. Cellulosic materials, known for their high aspect ratio, mechanical strength, and biocompatibility, show promise in strengthening wood panels while reducing reliance on traditional adhesives. The inherent ability of cellulose chains to self-assemble at the nanoscale via hydrogen bonding creates a hierarchical structure that spans from the polymer chain to the fiber level. While different cellulose structures have been incorporated into adhesive formulations, the results on physical characteristics are often contradictory due to the lack of fundamental understanding of the interaction of cellulose superstructures with polymer adhesives. From this perspective, this project aims to explain the interactions between different cellulose structures, namely cellulose nanocrystals (CNCs), cellulose nanofibrils (CNFs), and cellulose microfibrils (MFCs), with industrially relevant urea-formaldehyde (UF) adhesives and investigate the chemical and physical properties of the composite systems. We investigated the formulations' dispersion, stability, phase behavior, rheology, and curing behavior with a series of well-defined and well-controlled samples. Optical images and DLS measurements showed that the dispersion and stability of UF–cellulose composites and agglomeration limits were determined. Rheological measurements showed that all cellulose forms increased the viscosity and moduli of the UF solution. Although the agglomerated suspensions increased UF, their reinforcement decreased compared to their neat forms due to long-range network disruptions. The curing kinetics of the composites were studied using DSC isotherms, showing the distinct roles of cellulose nanocrystal structures compared to nano- and micro-fibrils. These physicochemical characteristics reflect well on the adhesion behavior characterized by lap shear and tact tests. These findings provide valuable insights into developing tailored cellulose-adhesive composites to eco-friendly products in response to the growing concerns pertaining to formaldehyde emissions.

B46. Research on Chitosans,Carbohydrate Vaccines and Saccharides;Purification, Analysation and Determination II

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Since liquid chromatography was invented 1850 by Prof. Runge in Oranienburg this technology has continued to several innovations. Saccharides, oligosaccharides for vacination process, polysaccharides like chitosans, important in pharmaceutical applications must get purified, analysed and determined to get a product that is economic and safe. Ligand exchange, ion exclusion and size exclusion chromatography (SEC) respective gel permeation chromatography (GPC) are tools for analysation and determination, in special cases also for purification.
GPC respective SEC has been all well established method for polymer characterisation. Its primary and oftentimes only use is to measure the molecular weight and to qualitatively compare different polymer samples. There are still 2 challenges - 1: molecular weight, size, determination
However, adding a viscometer and light scattering detector to a GPC creates new and challenging dimensions in polymer characterization. Tripel Detection and especially Volume Matched In situ Tripel Detection yields data of unsurpassed correctness. Its not only molecular weight, size (radius of gyration Rg) and structure (branching) but also enter the copolymer analysis.
Challenge 2 – pure SEC method for chitosans:
Size Exclusion Chromatography (SEC) analysis of polycations like chitosan is not easy to handle and this is further compounded by less the optimum reliability of the methods.
Solution: Through a complete re-invention of the stationary SEC phase, it is now possible to access an entire line of SEC columns to carryout analysis of polyaminic/cationic sugars like chitosan. This new SEC line covers the range from oligomers up to 20 million Daltons with high recovery. This novel SEC packing media shows superior performance with high recovery rates even at low salt concentrations, and for even very large molecular sizes. High resolution is obtained from small size molecule up to + 20 million Dalton. The SEC media is even suitable for systems where polycation blocks are combined with polyanion (e.g. carboxylic) blocks from partial oxidized product.

B47. Development of a crystalline curing agent for highly thermally conductive epoxy composites

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A crystalline curing agent, benzene-1,3,5-triyl triaminobenzoate (BTAB), was synthesized to create a thermally conductive epoxy matrix of BTAB–epoxy and its composites, which facilitates π–π stacking and tight packing between molecules when cross-liked with epoxy resin, thereby contributing to an improvement in thermal conductivity owing to the formation of crystalline structures. Surface-treated boron nitride (BN) was also incorporated into the epoxy resin to form efficient heat paths along the through-plane direction. The resultant composite demonstrated remarkable characteristics, including an impressive thermal conductivity of 3.21 W/mK along the through-plane direction, a substantial tensile strength of 47 MPa, and an excellent lap-shear stress of 16MPa. Employing this composite in a light-emitting diode (LED) application enables effective heat management, resulting in a 64 °C reduction in the operating temperature. Through the introduction of functional groups onto the filler surface, a conducive environment for hydrogen bonding is established between the fillers and the epoxy matrix, leading to a substantial augmentation in the thermal conductivity and mechanical characteristics of the composites. The suggested manufacturing method and the ensuing epoxy composites, characterized by innovative crystalline curing agents, are predicted to expedite the evolution of advanced TIM composites.

B48. Iterative Development of a Sustainable Coffee Capsule, Using Eco-Friendly Materials

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Today, it is common to find that balancing mechanical performance and sustainability influences product design. Numerical models are considered a crucial tool for enhancing product design and understanding how novel materials impact product characteristics over time. For this project, we started with an already functional product, a coffee capsule made of Polypropylene (PP), and gradually improved its design and engineering to decrease its weight while it can still withstand the forces it will encounter throughout its service life.

The simulation approximates the coffee production process at a domestic level using a machine compatible with the capsule under study. The model takes into account internal pressures and boundary conditions, which represent the metal walls surrounding the capsule inside the machine. The iterative process focused on modifying the product geometry, and structural simulations were conducted to assess the condition of the capsule before and during use. Mechanical and physical properties of more sustainable plastics like Recycled Polyethylene Terephthalate (rPET) and Polyhydroxyalkanoate (PHA) were also added to the Abaqus software database to predict their structural behaviour in real-world applications.

In this work, reducing the weight of the geometry and using bio-based or recycled plastics (with food contact approval) are the two main ways of achieving a more sustainable product. After several iterations, it was found that the properties obtained from the structural simulations could be improved by modifying the internal and external structure of the capsule. This modification would result in a weight reduction of approximately 20% compared to the baseline. The use of rPET enables a reduction in the thickness of the final product while maintaining the same load-bearing capacity or even improving it. Likewise, the use of PHA results in behaviour similar to that of PP. However, both materials have a higher density than the baseline, resulting in heavier final capsules.

B49. Numerical and experimental investigation of wrap-around effect of electrostatic powder deposition on a powder epoxy tapeline

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Electrostatic spray powder deposition methods have the potential to be utilised in commercial towpregging lines (tapelines) for producing low-cost epoxy towpreg. The process involves the introduction of continuous carbon fibre tow into a deposition chamber, where powder epoxy is electrostatically applied onto the fibres. Subsequently, the coated tow undergoes sintering and consolidation under infrared heating. The process is a highly effective technique for tapelines because it allows for the “wrap-around effect”, which ensures effective coating of the top and underside of the fibre tow, where the processing conditions are correct.

Within the deposition chamber, the spray gun is oriented perpendicular to the fibre direction, with an extraction unit attached to the underside of the chamber. The constant extraction maintains a consistent negative pressure, preventing powder dispersion outside the deposition area. The collected overspray can be reclaimed for potential reuse, contributing to the economic viability of the process. This feature not only highlights operational efficiency, but also aligns with sustainable practices by reducing material wastage.

In this study, electrostatic spray powder deposition was investigated via numerical modelling of the electrostatic field in the chamber, thus proving the presence of a wrap-around effect. Additionally, an experimental investigation was conducted to quantify the amount of powder deposited on each side of the fibre tow. Samples of fibre tows were subjected to the electrostatic spray gun in the deposition chamber under stationary conditions, where the ‘holding’ period within the chamber was varied. This served to mimic the effects of altering production rate (tow velocity) in the operating tapeline. Results demonstrate that on average, 46 % more powder is present on the top side of the tow, as opposed to the underside—with the current deposition chamber setup and operating conditions. Correlations also show that the percentage difference in powder mass increases with higher speeds.

B50. Replacement of PVC Electrical Pipes with Recycled HDPE and LDPE: A Sustainable Solution

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Polyvinyl chloride (PVC) is the third most extensively employed plastic, following only polyethylene and polypropylene in usage. Its versatility extends across various sectors, including building and construction, piping and cable, packaging, electronics, and consumer goods, due to its advantages such as being a strong, durable, and lightweight material. Although being a versatile and vastly used polymer, PVC has been known as one of the three worst polymers, along with polystyrene and polycarbonate. Concerns persist regarding the potential hazards to human health and the environment associated with PVC throughout its entire life cycle, encompassing its production at the factory, presence in our homes, and disposal. RECY.TUBE is a project that aims to develop safer products (electrical pipes/tubes) that rely less on fossil-based raw materials, specifically PVC, by introducing recyclable polymers from post-consumer recycled materials, such as PCR-HDPE and LDPE. Additionally, non-halogenated flame retardants (HFFRs) based on organic and inorganic materials will be incorporated into the composites. Flame retardants are usually incorporated into polymers since polymer exposure to a heat source with oxygen gas causes hydrocarbon bonds to break into smaller units, resulting in intense heat release, as well as flames, smoke, and toxic gases, which can jeopardize human health and the environment. Moreover, a Life Cycle Assessment, conducted following ISO 14040:44, will analyze the environmental impacts of conventional PVC pipes in comparison to the innovative solution developed within the project. This assessment aims to pinpoint the primary areas of concern (hotspots) and opportunities for enhancing environmental performance in the new formulations. By replacing PVC with recycled material, which will be used in the new formulations in this study, a reduction in greenhouse gas emissions and overall impacts is expected.

B51. The Design of a Successive Self-Nucleation and Annealing (SSA) thermal protocol for the assessment of the impact of manufacturing procedures on the molecular structure of biomedical UHMWPE

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Ultra-High-Molecular-Weight Polyethylene (UHMWPE) used in arthroplasty is commonly treated with high-energy radiation (gamma or e-beam) for sterilization and/or cross-linking purposes. However, it is well known that the generation of free radicals following irradiation triggers an oxidative process that deteriorates the mechanical properties of the material; for this reason, cross-linking processes generally include a thermal treatment (annealing or remelting) following irradiation to remove free radicals.

To evaluate the effect of oxidation and that of irradiation and remelting procedures on the morphology of UHMWPE, a Successive Self-Nucleation and Annealing (SSA) thermal protocol was developed, and the resulting thermal fractionation profile of virgin UHMWPE was compared with those of oxidized, irradiated, and remelted UHMPWE specimens. The oxidation extent was monitored via Micro FTIR analysis and quantified in terms of Oxidation Index (OI) values.

The thermal fractionation of oxidized UHMWPE samples revealed that different levels of oxidation can generate different thermal fractionation profiles and that the differences compared to virgin material are more pronounced in the case of low (OI=0.51) rather than medium–high levels of oxidation (OI=0.69 – 1.41). The thermal profile of irradiated UHMWPE samples revealed that γ-rays do not significantly alter the lamellar thickness distribution but reduce the level of the most stable crystalline phase that the material can develop.

Following the remelting process, the material shows negligible levels of oxidation, and its thermal fractionation profile revealed that irradiation and remelting processes can generate changes to the UHMWPE molecular structure that reduce the overall crystallinity and broaden the lamellar thickness distribution.

B52. Recycled Extruded Fibre-Reinforced Thermoplastics for a Sustainable Future: Investigating Structural Performance and Damage Accumulation

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The extrusion of fully recycled short-fibre-reinforced thermoplastics provides an effective solution for manufacturing environmentally sustainable structural composites. With increasing fibrous waste from the renewable energy, automotive, and aerospace markets, and the continued mass generation of thermoplastic waste, this approach enables materials potentially deemed for landfill to be recycled into useful products. Though the implications of such techniques are promising, the mechanical performance, manufacturing parameter dependencies, and physical/material characteristics are insufficiently understood. Consequently, a comparative study is presented in which various extruded recycled glass fibre (rGF)-reinforced recycled high-density polyethylene (rHDPE) materials are evaluated. Mechanical performances were analysed via tensile and flexure testing to facilitate modulus and strength comparisons, where digital image correlation (DIC) obtained strain distributions and served to highlight potential consolidation issues. Both polymer type and inputted fibre volume fraction were demonstrated to significantly influence performance. For tested samples, fractography analysis—from scanning electron microscope (SEM) imaging—provided qualitative insight into consolidation, fibre length, and failure mechanisms. Furthermore, glass transition temperatures were obtained via dynamic mechanical analysis (DMA), and for each material variation, fibre volume fractions (FVFs) and densities were also acquired. Overall, the results of this study demonstrate that rGF/rHDPE can be extruded to produce high-performing structural materials, which, with additional study, optimisation, and uptake, have the potential to significantly improve the lifecycle of both commercial thermoplastics and composite reinforcing fibres.

B53. Vanillin-functionalized polymers battling bacterial growth in packaged meat and high-performance textiles for first responders

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Inhibiting bacterial growth on various surfaces is crucial for safeguarding public health and reducing the dependence on continuous disinfection. Polymer design transforms this necessity into a solution by creating intrinsically bactericidal materials that inhibit bacterial proliferation. This preventive measure not only mitigates the risk of infections but also reduces water consumption, making it imperative for diverse sectors. This study addresses this crucial challenge by developing scalable, cost-effective, and reusable vanillin-functionalized acrylic membranes and high-performance aramid textiles, demonstrating their efficiency in inhibiting bacterial growth in packaged meat and emergency responder textiles.

For food preservation, an organic and metal-free antimicrobial polymer is designed to extend the shelf life of packaged meat. The material, featuring covalently linked vanillin motifs, exhibits exceptional antibacterial activity against E. coli, S. aureus, and L. monocytogenes, with inhibition percentages of 99.95%, 99.96%, and 99.02%, respectively. Deployed as an absorbent food pad, the antimicrobial polymer film extends the shelf life by 50%, with covalently anchored vanillin groups ensuring persistent antimicrobial activity, allowing for at least ten wash-and-reuse cycles.

In emergency responder textiles, aromatic polyamides are introduced to achieve intrinsic bactericidal activity while preserving mechanical and thermal properties. Tensile tests revealed a 50% increase in Young's modulus, coupled with robust antibacterial efficacy (99.43% for S. aureus and 99.26% for K. pneumoniae), even after at least five washing cycles, catering to the practical constraints of emergency responders. Skin-friendly tests confirm the non-irritating nature of these materials.

This study underscores the transformative potential of vanillin-functionalized polymers in simultaneously addressing food safety concerns in packaged meat and providing antimicrobial durability in textiles crucial for emergency responders. This research highlights these polymers' promise in revolutionizing both food preservation practices and protective gear for those on the front lines of emergency response.

B54. Water quality management: smart polymers for pesticide extraction and detection in aqueous environments

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In the critical context of water quality management, the extraction and detection of pesticides from aqueous environments stand as imperative tasks. Pesticides, prevalent in water sources due to their use in various applications, pose ecological and health risks. Addressing this challenge, our study unveils a comprehensive approach utilizing smart polymers for both efficient pesticide extraction and sensitive colorimetric detection.

The first phase of our investigation introduces reusable polyacrylic membranes, synthesized from readily available monomers, as a promising solution for pesticide extraction. The membranes exhibit exceptional efficacy in removing water-soluble herbicides, particularly mecoprop (RE ≈ 99%) and bentazon (RE ≈ 95%), known for their contamination risks. Beyond their high removal rates, these membranes boast remarkable manageability, resistance, and environmental friendliness. Characterization techniques, including NMR, TGA, DSC, mechanical testing, N2 adsorption, and FTIR analysis, unravel the underlying mechanisms. This study sheds light on the pivotal role of charged aminoethyl groups in sorbent–sorbate interactions, and molecular dynamics simulations elucidate the hydrophobic nature of the extraction mechanism.

Complementing this extraction capability, our second aim focuses on polymeric films tailored for the colorimetric detection of pesticides and phenol derivatives in water. Phenols, originating from pesticides and fungicides, pose additional environmental hazards. The designed colorless films, embedded with diazonium groups, serve as sensory matrices. Immersed in aqueous media, these films undergo selective reactions with phenols, inducing a visually detectable color change. For quantitative analysis, UV–vis spectrophotometry (LOD: 0.12 ppm for 2-phenylphenol) and smartphone-based RGB analysis (LOD: 30 ppb for 2-phenylphenol) provide versatile and precise measurement options.

This cohesive dual-functional approach, combining effective pesticide extraction with sensitive colorimetric detection, represents a significant stride in advancing water quality management. Our findings underscore the potential of smart polymers as versatile tools in addressing the multifaceted challenges posed by pesticide contamination in aquatic environments.

B55. Bio-based elastomeric polyesters as a potentially degradable alternative to synthetic rubber matrices in tire compounds

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Rubber compounds are of practical interest only after crosslinking. They become thermoset polymeric materials and acquire great dynamic-mechanical properties and a fascinating entropic elasticity; however, this occurs at the expense of recyclability. Moreover, typical rubbers for tire compounds are not biodegradable or compostable. Tire debris are, together with textiles, a primary source of microplastics in the environment where they remain for a long time. The average amount of microplastics in the environment was estimated to be about 3.3 million tons, with 1.5 million tons ending into the ocean (1).

A way to make thermoset rubbers circular materials is to use polymers which could undergo remolding and depolymerization, by triggering their degradation reactions. The polymer chains should be prepared via step growth polymerization (2) and should be based on repeating units linked together by reversible bonds: the ester bond is a suitable one. Bio-based monomers such as diacids and (poly)alcohols could be used for the synthesis of polyesters. They were already suggested as building blocks of choice in the report from the US Department of Energy (3), and are available on the market. In this work, completely amorphous polyesters, suitable for the preparation of elastomeric materials, were synthesized using step-growth condensation polymerization of diacids and dialcohols (4). The reactivity of the bio-based polyesters with the vulcanization system was achieved by the introduction of innovative co-monomers along macromolecules and/or as chain ends. Thermal transitions and molecular mass were also determined.

Composites with carbon black and a polar filler such as silica were prepared and characterized by means of dynamic-mechanical and tensile measurements.

B56. Mechanical recycling of carbon fibers: from waste to multifunctional materials

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The continuous growth in the use of carbon fiber-reinforced polymer products has led the industry to face an important challenge in the management of both manufacturing-associated waste and end-of-life product disposal. In this way, different processes are proposing as alternatives to manage these waste types, as thermal or chemical processes, but the mechanical recycling appears as an economical and environmentally efficient method to obtain a homogeneous and valuable recycled product.

First, this study presents the effect of different variables of the mechanical recycling process by using a cutting mill, as sieve type, number cycles or rpm of the rotor, to obtain a recycled product from different carbon fiber sources, including prepregs scrap form the manufacturing of composites and the composites themselves after their end-of-life. Subsequently, the work focuses on the use of the previously obtained recycled carbon fibers as reinforcement of thermosetting polymers to develop multifunctional bulks and coatings. Specifically, the mechanical properties, the electrical conductivity, Joule effect heating capacity, and self-healing capability of the synthesized materials were analyzed. In this way, different contents of recycled carbon fiber and thermoplastic reinforcements (Polycaprolactone) were studied with the aim of optimizing these variables and achieving a composite that exhibits the best performance by combining these functionalities.

As conclusions, the developed material can be relevant for different applications, due to the obtained interesting functionalities, such as chemical protection, high wear resistance, high electrical conductivity (up to 16.5 S/m), and Joule heating (i.e. more than 200 oC by applying only 20 V). In fact, these smart composites are developed using a thermal stimulated self-healing polymeric matrix, whose repairing mechanism can be activated by Joule effect at very low electrical voltages (90% of self-healing efficiency applying 20V during less than 2 minutes), obtained electroactive smart recycled coatings with fast heating and low energy consumption.

B57. Peptide/Graphene Nanocomposites: An in Silico Investigation

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In the current work, the self-assembly of dipeptides on a graphene layer, in aqueous solution, is investigated, through all-atom Molecular Dynamics simulations [1]. The effect of graphene surface on the self-assembly propensity of dipeptides, as well as on the formed structures, as they have been observed in the corresponding bulk systems (i.e., dipeptides solutions in water) [2], is examined. Two graphene materials have been used, pristine graphene and graphene oxide (GO) with two different dipeptides, diphenylalanine (FF) and Cyclo-diphenylalanine (Cyclo-FF) at room temperature. Atomistic details about the conformational preferences, the orientation of dipeptides with respect to the surface and the hydrogen bond network are investigated. Length and time scales of the formed structures are quantified providing important insight into the adsorption mechanism of dipeptides onto the graphene surface. A hierarchical formation of dipeptide structures is observed involving two sequential processes: a stabilized interfacial layer of dipeptides onto the graphene surface, followed by the development of a structure of self-aggregated dipeptides on top of this layer. Strong $\pi - \pi^*$ interactions between the dipeptides and the graphene lead to a parallel to the graphene layer orientation of the phenyl rings, especially in the case of pristine graphene. Reduction in the number of hydrogen bonds between dipeptides is observed because of the graphene layer, since it disturbs their self-assembly propensity. The differences between pristine graphene and GO nanostructures with both FF and Cyclo-FF are highlighted.

B58. Polyelectrolyte ensembles as hierarchically self-assembled constructs for bioapplications

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We report on well-defined polyelectrolyte complexes (PECs) that harness Coulombic attraction as the driving force to enable the formation of nano-sized nanoconstructs. Starting from commercially available monomer synthons [i.e., 2-dimethylaminoethyl methacrylate (DMAEMA), and methacrylic acid (MAA)], we employed reversible addition fragmentation chain transfer (RAFT) polymerization with the use of poly(ethylene glycol) macro-chain transfer agents to produce the corresponding polycations/polyanions. The latter were further combined with, in-house synthesized, polymerizable drug containing monomers bearing either gemcitabine or camptothecin, both frontline oncology drug molecules, to produce model polymer-drug conjugates (PDCs). By simple mixing of the polyelectrolytes with the PDCs it was possible to generate colloidally stable nanoformulations with low critical micelles concentration and hydrodynamic radii of less than 70 nm. Also, it was possible to use naturally derived polyanions such as sodium alginate as a readily available polysaccharide component for PEC formation. Drug liberation could be fully controlled via suitable linker chemistries (i.e. ester or disulfide linkers) anchoring the drug molecules from the polymer backbone, which fully prevented burst release events. The PECs were found to be highly toxic against pancreatic cancer cells (PANC1); interestingly they were found to exert augmented cytotoxicity when combined with ultrasound irradiation in a dose dependent manner. These findings constitute a promising approach to develop multiple leads of nanomedicinal formulations for rapid testing and screening for precision oncology applications that can be derived either from solely synthetic polymers or natural biopolymers.

B59. An Innovative Zwitterionic Co-Polymer for Recovering Nonsteroidal Anti-inflammatory Drugs from Aqueous Solutions

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The utility of zwitterionic polymers for sample preparation before advanced analytical techniques remains constrained. Herein, we present the synthesis of a novel zwitterionic co-polymer derived from 2-(Methacryloyloxy) ethyl trimethylammonium chloride, 2-Hydroxyethyl Methacrylate, and Ethylene glycol dimethylacrylate, developed with the objective to engineer an innovative sorbent tailored for the extraction of NSAIDs (Nonsteroidal anti-inflammatory drugs) from aqueous matrices. Comprehensive characterization of the zwitterionic co-polymer involved scanning electron microscopy, Fourier Transform Infrared spectroscopy, and nitrogen adsorption experiments. Analyses confirmed the effective incorporation of the zwitterionic moiety within the co-polymer chain, and a non-porous nature of the material. To assess the efficacy of the co-polymer in NSAID extraction, three distinct pharmaceuticals (Diclofenac, Ibuprofen, and Naproxen) were employed for assessment. A dispersion of 30 mg of zwitterionic co-polymer in aqueous solution, enriched with analytes at 100 µg L-1 concentration, was subjected to evaluation at varying pH levels. Analysis was performed using an Orbitrap Q Exactive™ Focus mass spectrometer, following separation of target analytes on a Thermo Hypersil GOLD aQ column. Results indicated satisfactory NSAID recovery rates ranging from 72% to 89%, with a relative standard deviation ≤ 5% in intra-day replicates. Notably, pH exerted a significant influence, with optimal recovery achieved at neutral pH for all analytes. These findings underscore the potential of the newly developed zwitterionic co-polymer as an effective sorbent in analytical chemistry, particularly for the quantification of NSAIDs in aqueous matrices.

B60. Development of plasmonic nanodot-array-enhanced fluorescence substate fabricated by UV-nanoimprinting and physical vapor deposition

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A metal-enhanced fluorescence (MEF) substrate has been actively investigated to improve the sensitivity and reliability of fluorescence microarrays. In this study, a plasmonic nanodot array (PNA), which was fabricated by the physical vapor deposition of an Ag layer on a nanoimprinted polymer nanodot substrate, was developed as a low-cost and highly sensitive MEF substrate. A silicon master pattern with a nanodot array pattern with a diameter of 200 nm, a pitch of 400 nm, and a height of 100 nm was fabricated by KrF scanning lithography and a reactive ion etching process. A polydimethylsiloxane (PDMS) mold was replicated from the master pattern, and UV nanoimprinting was carried out on a slide glass substrate. Finally, a thin silver (Ag) layer was deposited onto the imprinted nanodot array to form a plasmonic nanodot array. The best enhancement factor was obtained when the gap between the Ag layer on top of the nanodots and the bottom of the substrate was minimized. We also applied the PNNAs MEF substrate for the quantification of proteins using a fluorescence signal. Thymus and activation-regulated chemokine (TARC) and thymic stromal lymphopoietin (TSLP), which are biomarkers related to atopic dermatitis, were selected as target proteins. Antibodies and antigens were procured from commercially available enzyme-linked immunosorbent assay (ELISA) kits. Seven drops of each antibody were deposited into each well of the PNNAs substrate. Following incubation, blocking, and washing, TARC and TSLP antigens of varying concentrations were introduced into each well of the PNNAs substrate to generate their calibration curves simultaneously. Similar experiments were conducted using commercial ELISA kits for TARC and TSLP individually. The coefficient of determination (R2) for the calibration curves obtained using the PNNAs EF microarrays closely mirrored those obtained with commercial ELISA kits. Moreover, the quantification accuracy of the PNNAs microarray was comparable to that of the ELISA kits. It clearly shows that the proposed PNNAs EF microarray can be applied to multiplex protein quantification and that it is compatible with commercial ELISA kits.

B61. Bio-based thermosetting resins from waste cooking oil

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In recent years, research on sustainable and bio-based polymers and their applications has gained considerable attention due to socio-economic factors and environmental concerns. Vegetable oils are renewable, abundant and low-cost resources used to obtain sustainable polymers with different structures, properties and applications, as they offer an opportunity to tap into a pool of complex molecules in terms of carbon skeletons, double bonds and the availability of different functionalities.

Our group has recently developed a strategy where acrylated–epoxidized monomers obtained from vegetable oils have been used with bio-based comonomers such as terpenes to produce thermosetting resins with comparable properties with respect to the ones obtained from comonomers of fossil origins (i.e., styrene). In the context of renewable bio-based materials, waste cooking oil (WCO) is a promising alternative to virgin vegetable oils since it is far cheaper and has a greater impact on waste valorization and sustainability principles.

In this work, WCO was used as a starting material for the preparation of acrylated monomers and their combination with terpenes (limonene and β-myrcene) as comonomers for the preparation of various thermosetting resins. The acrylated resins were obtained following a three-step process: (1) the epoxidation of the double bonds of WCO, (2) the acrylation of the epoxidized WCO and (3) curing in the presence of comonomers and a radical initiator.

Moreover, experiments on the use of epoxidized WCO to obtain non-acrylic thermosetting resins in combination with different dicarboxylic acids such as fumaric, tartaric, succinic, adipic and azelaic acids and monocarboxylic acids such as oleic and sorbic were carried out.

The thermal and mechanical characterization of bio-based thermosetting resins proved that the proper choice of the starting modified oil and comonomers allows for resins with tuneable properties to be obtained.

This study was conducted within the MICS (Made in Italy—Circular and Sustainable) Extended Partnership and received funding from the European Union Next-Generation EU.

B62. Stimulus-responsive bicompartmental microcarriers for dual drug delivery

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This work aimed to engineer microcarriers with two distinct pockets by employing electrohydrodynamic-co-jetting techniques for combination therapy to treat cancer. Herein we developed bicompartmental particles that carry the hydrophobic anticancer drug (paclitaxel) in one compartment along with a hydrophilic antitumor drug (doxorubicin hydrochloride) dual drug delivery. The second compartment is designed to have a pH-sensitive matrix that tunes the releases of hydrophobic drugs when the cell pH 7 (pH of tumor cells -5.6-6.8). Preferably, the idea of combination therapy was to reduce the side effects of chemotherapy, such as drug resistance. Occur with the usage of a single drug, over a long time. Hence, for the proof-of-concept of the idea, we employed an FDA-approved lactide-based polymer to fabricate distinct compartments in microcarriers to localize payloads individually without undergoing any interaction. The swelling study of particles was studied at pH 7.4 and pH 5 to see the stimulus-responsive behavior of the designed system. The morphological analysis of the carrier was characterized through an Optical microscope, SEM, and CLSM. Moreover, in vitro release study of model compounds, Paclitaxel and Doxorubicin hydrochloride exhibited the co-encapsulation and controlled release of hydrophobic and hydrophilic therapeutics in a single carrier. Furthermore, we are optimizing the nanoparticles 200nm to carry the cargo for combinational therapy.

B63. Sustainable Composites from Waste Polypropylene and Recovered Carbon Fiber

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Composite plastic waste is a serious concern in most countries due to the related environmental and health risks. Efforts are required to give this composite waste a second life, thus reducing its quantity and limiting the consumption of new resources.

This research study aims to manufacture thermoplastic composites utilizing waste polypropylene (wPP) and two different types of fillers: carbon fiber reinforced plastic powder waste (pCFRP) and reclaimed carbon fibers (rCF). A micromixer was used to mix wPP with either wCFRP or rCF, added in different weight ratios. The tensile properties of the blends were evaluated using samples cut from films of constant thickness produced by hot compression. The addition of more than 10 wt% of pCFRP, or more than 5 wt% of rCF to wPP causes about a 100% increase in the Young's modulus without a significant negative effect on the fracture stress or elongation at break of the composites. As expected, the stiffness of the composites increases with the amount of filler, and composites with rCF have a higher stiffness than those made with the same amount of wCFRP. SEM measurements were carried out to investigate the composite morphology, and rheological studies were conducted to assess the processability of these materials by injection moulding.

B64. Bilayer barrier-resistant pH-responsive films as freshness indicators for food packaging application

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The bilayer film is prepared by depositing the anthocyanin extract and polyvinyl alcohol (PVA) nanofibrous mat on the O2 plasma-treated polyethylene/clay nanocomposites film (PE/clay). Electrospinning achieves the inclusion of anthocyanin (pH-responsive) into PVA nanofibers. The 25 µm PE film was produced from a blown film extruder with a blown-up ratio (BUR) of 2.34. The aforementioned nanocomposite film of PE was plasma-treated, and its chemical and compositional changes were measured through X-ray photoelectron spectroscopy (XPS) and energy-dispersive X-ray analysis. Plasma-treated PE bolsters the PVA electrospun mat with a lowering water vapor transmission rate (WVTR) and oxygen transmission rate (OTR). LLDPE base matrix shows the WVTR and OTR of 15.8 g/m2/day and 1493.02 cc/m2/day. The various RCE concentration electrospun mats were produced, and the ammonia vapor sensing was monitored for different time intervals. The 40 % anthocyanin extract-PVA mats show an absorbance of 0.8 a.u. at 650 nm after 2 minutes measured by UV spectroscopy. The pseudo-second-order kinetic model has been used to calculate the rate constant of NH3 vapor absorbance. Also, the thermal characteristics of PVA-anthocyanins were measured by differential scanning calorimetric (DSC) and thermogravimetric analysis (TGA). The PE transmittance was observed with mechanical attributes like tensile strength and ductility ratio. The visual inspection of real-time indicators has been monitored for spoilage of prawns by measuring the Euclidian distance (dE) with the spectrophotometer.

B65. Production of HPP natural hydrogels using non-conventional starch sources

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Starch-based hydrogels are complex networks known for their ability to absorb and retain a significant amount of water. They have been a great matter of interest in recent years because of their great potential in achievable applications. These biomaterials have been produced using conventional starch sources including cereal crops, pulses, and tubers. This work aimed to produce starch-based HPP hydrogels using non-conventional starches isolated from unripe apples and banana peels. The recovered starches (20% w/w) suspended in distilled water were treated by HPP at processing conditions, namely 600 MPa for 15 min at room temperature, to enable starch gelatinization. Gel formation was assessed by analyzing the gelatinization extent, structuring level, and swelling power of the samples. The results showed that at the processing conditions utilized, stable hydrogels were obtained, which differed in physical appearance due to the various properties of the recovered starches. Moreover, the rheological properties and physical stability of these structured materials during their shelf life should be assessed.

B66. Advancements in Organic–Inorganic Composite Synthesis: Lignin and Nanosilica Integration

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Recent developments in the synthesis of organic–inorganic composites mark a significant step in material sciences, offering enhanced properties over those of singular components and broadening the scope for innovative applications. This study focuses on an especially promising approach: integrating lignin—the second most abundant biopolymer after cellulose—with nanosilica. We explore the complex interactions between lignin (lignosulphonate DP-1962, Sarpsborg, Norway) and amorphous, non-porous, highly dispersed silica (nanosilica, SBET=300 m2/g, Kalush, Ukraine). The challenge lies in distributing lignin's complex, three-dimensional, aromatic polymer network over the nanosilica's surface.

Our approach utilizes the gas-phase solvate-stimulated mechanosorption modification (GSSMSM) method, developed at the Chuiko Institute of Surface Chemistry of NASU. This method aligns with the principles of green chemistry, highlighting its eco-friendly and technologically progressive nature. Through this innovative process, we successfully synthesized a series of lignin/nanosilica composites varying in biopolymer content.

The characterization of these composites was conducted through infrared spectroscopy, thermogravimetry, nitrogen adsorption, and scanning electron microscopy. A key aspect of our analysis was the interaction between lignin and the nanosilica's surface. We quantified the degree of surface coverage by evaluating the perturbation of the nanosilica's silanol groups, which are its primary active sites. This was achieved by analyzing the hydrogen bonding between silanol groups and the polar functional groups of the lignin molecules. Our findings indicate that approximately 65% of the nanosilica surface was covered with lignin, as inferred from the IR spectra. This partial coverage is attributed to the intricate three-dimensional structure of lignin.

In conclusion, our research demonstrates the efficacy of the GSSMSM method in immobilizing lignin onto nanosilica surfaces. This work not only contributes to the field of material science but also opens new avenues for the application of lignin in organic–inorganic composites. Our findings have profound implications for the development of environmentally friendly and technologically advanced materials.

B67. A study on the manufacture of dash insulation with high sound absorption fibers applied to the surface and the improvement of sound absorption performance

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As the world joins environmental regulations, there is an increasing demand for the production of eco-friendly cars. As a result, the driving method of the vehicle was changed from the engine to the electric motor, and the main noise source was changed. In case of existing internal combustion engines (ICE), the low-frequency sound range, which is the engine's main noise, is the main source of sound. As it is converted into an eco-friendly car, the noise that was hidden by the engine combustion sound and the high-frequency noise of the motor are being highlightened. In case of fibers, noise is reduced as sound wave momentum is converted into thermal energy due to the friction between the fiber surfaces and sound waves. In this study, the sound absorption performance was improved by applying a low-denier(LD) PET fiber layer to the Dash Insulation, which reduces noise generated from automotive. The structure of Dash Insulation consists mainly of PET felt/TPO sheet/PU Foam. The LDPET fiber layer was applied to the surface layer above the PET felt to improve sound absorption performance more than 60%. When the weight of the LDPET fiber layer was increased, the sound absorption performance was increased more than 5%. In case of sound insulation performance, it was confirmed that it was equivalent or reduced compared to the conventional Dash Insulation structure depending on the weight. When LDPET fiber layer was applied to Dash Insulation, sound absorption performance was improved. Accordingly, with the application of the LDPET fiber layer, the sound absorption performance was improved even though the weight of the PET felt was reduced, resulting in a lightweightening effect. In conclusion, the application of the LDPET fiber layer improves sound absorption performance and reduces trim part weight was also expected to improve fuel efficiency.

B68. A Study on the Improvement of High-frequency Noise in Electric Vehicles by Optimizing Nonwoven Fabric Composites with Melt-Blown and Low-Density Polyurethane Foam

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Recently, due to the expansion of the market for eco-friendly electric vehicles, it is important to improve fuel efficiency to increase the mileage. In order to reduce the weight of automobiles, low-density polyurethane foam material is generally used as an engine room sound-absorbing material. Low-density polyurethane foam has excellent sound absorption performance in the frequency range of 1,000 to 2,000 Hz due to the structural characteristics of the material, but the sound absorption performance of more than 2,000 Hz is insufficient. In the case of electric vehicles, it is important to improve the high-frequency noise generated from the motor, so it is necessary to improve the sound absorption material of the engine room with polyurethane foam. In this study, in order to improve the insufficient sound absorption performance of more than 2,000 Hz, a nonwoven fabric with a double composite structure manufactured by the melt-blown method and the heat treatment method was developed. Since it is essential to increase the air permeability in order to improve the sound absorption performance in the high-frequency region, the air flow resistance was reduced by minimizing the binder content and patterning it when manufacturing the nonwoven fabric. The sound absorption performance can be optimized in the frequency range of 1,000 to 5,000 Hz by adjusting the density of polyurethane foam, fiber thickness, and weight of each layer of nonwoven fabric composite. In other words, the development of a lightweight engine room sound absorption material that selectively improves sound absorption performance for various noises generated depending on the motor of the electric vehicle can be expected.

B69. Poly(3,4-ethylenedioxythiophene)-Loaded Antimicrobial Coatings to Protect Biomedical Devices Against Bacterial Growth

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Preventing the development of biofilm on biomedical devices and implants is a critical concern that can be addressed with advanced solutions. In this research, we have developed polymer-based antimicrobial coatings to inhibit bacterial growth on biomedical device surfaces. We added poly(3,4-ethylenedioxythiophene) (PEDOT) to entrap an antibiotic (Ceftazidime), a quaternary ammonium salt (dodecyl trimethylammonium bromide), or a surfactant (sodium dodecyl sulfate) to its matrix through electro-polymerization. The analysis using scanning electron microscopy, Fourier-transform infrared spectroscopy, and energy-dispersive X-ray spectroscopy to prove the chemical composition of PEDOT-based coatings. By examining cyclic voltammograms and impedance spectra, the electrochemical behavior of the coatings was determined. The findings showed a strong ability of the coatings to transfer electric charge and carry drugs, as well as effectively inhibit the growth of Shewanella onediensis and Pseudomonas aeruginosa. The PEDOT-based coatings demonstrated strong electroactive properties, displaying antibacterial activity that responds to bacteria, making them a suitable choice for antimicrobial coatings on biomedical devices.

B70. On the effect of lignin self-assembly and its impact on antioxidant activity

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The release and accumulation of greenhouse gases in the atmosphere and non-degradable materials in ecosystems has created two of the most infamous environmental issues faced to date, i.e., global warming and pollution. Common to both is that they originate from petroleum resources. In order to remediate this, alternative sources for energy and fuels, alongside industrially relevant building blocks for materials, need to be generated from renewable resources in an efficient manner. One way to achieve this is to exploit lignocellulosic biomass.

In the present work, lignin, as one of the three major ingredients in biomass, was extracted from beechwood sawdust through organosolv processing. Being the most abundant and renewable polyaromatic compound available, it also carries natural antioxidant activity that can be exploited in a plethora of applications. Yet, the specific antioxidant performance for polymers such as lignin is complex and does not correlate easily with structural features. Herein, we show how varying the initial organosolv conditions influences the structural characteristics of lignin as measured using state-of-the-art analytics (gel permeation chromatography, 1H NMR,13C NMR, 31P NMR, HSQC). Subsequently, we show how this also sets prerequisites for its behavior in solution in the presence of inorganic salts that affect π-π stacking interactions, which influences the specific antioxidant activity (DPPH radical scavenging). Additional resolution of the polydisperse lignins was achieved by solvent-based (acetone-water) fractionation to create subsets of the initial lignin isolates. The results show that coil expansion enhances the antioxidant activity for lignins with certain chemical characteristics; other lignins described as more condensed remain unchanged in terms of antioxidant activity. These findings not only contribute to a QSAR-type explanation of structure-dependent antioxidant behavior but also give insight into how lignin polymers behave in general, easing their implementation into other areas of application when they are used as a replacement for petroleum-based equivalents.

B71. Deep eutectic solvents based on choline chloride as plasticizers and active agents in chitosan films

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The presented research focuses on the synthesis of novel chitosan-based films containing deep eutectic solvents (DESs). Choline chloride and various hydrogen bond donors were used as a plasticizer and the active properties of the DESs embedded in the chitosan (Ch) matrix were investigated. The structures and properties of the obtained Ch and Ch/DES films were examined by means of FT-IR spectroscopy, SEM, swelling tests, WVTR, TGA, mechanical testing and active property analysis. We have confirmed the plasticization of Ch prepared by the casting solution method using nontoxic DESs based on choline chloride. The Ch-based films with chlorine chloride/malonic acid can prevent mold spotting for up to 29 days longer in comparison to bread wrapped in polyethylene (PE) films. The obtained Ch/DES films exhibited mechanical properties comparable to conventional PE (e.g., tensile strength of up to 26 MPa and an elongation at break of up to 210%). The described synthesis route is a way toward the replacement of conventional packaging materials with environmentally friendly ones, created with green chemistry principals.

B72. Recycling of PVB interlayer via the Remelting/Restabilization Technique

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Laminated glass is obtained by bonding two glass layers using a polymeric interlayer (PVB), and it is used mainly in car windshields, construction, photovoltaics, coatings and adhesives. Its use is constantly growing with the total amount of PVB sheets produced for automotive and architectural applications estimated to be around 120 million kg per year. Currently, laminated glass wastes are being landfilled; thus, their waste management is a major issue. Meanwhile, PVB has a high value, with an average price of EUR 5,24/kg; therefore the revalorization of PVB comprises a lucrative approach in the frame of the circular economy. A proper recycling process must result in PVB material that is acceptable on the basis of its mechanical properties and also for uses requiring transparency. However, first-life use and high-temperature reprocessing favor degradation (largely in the form of chain scission) and yellowness. In this work, the objective is to limit posterior degradation (due to reprocessing and its forthcoming service life) by restabilizing PVB via incorporating proper additives, such as antioxidants (AOs, primary and secondary). Accordingly, several PVB-AO formulations were developed at a loading of 0,2-0,4 wt% by melt blending in an internal mixer apparatus. Different residence times were studied and the molecular weight was monitored both via melt flow rate determination (MFR) and gas permeation chromatography. Moreover, PVB-AO films were prepared by compression molding, and their yellowness index was determined according to the ASTM E313 standard. The best-performing AO formulations in terms of MFR retention and minimized yellowness will be subsequently adopted for reprocessing post-consumed PVB films on an industrial scale.

B73. Sustainability assessment of miscanthus fragmentation through acid hydrolysis and alkaline pre-treatment

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Given the increasing environmental concerns tied to fossil fuel usage, there is a growing emphasis on transitioning to renewable feedstocks. Lignocellulosic materials, owing to their abundance in cellulose, hemicellulose, and lignin, are emerging as promising partial solutions to be used in plastic production value chains. One commonly utilised lignocellulosic material is miscanthus, recognised for its resilience in impoverished soils, presenting high yields with minimal needs for herbicides, nitrogen, and water. It has an elevated cellulose content and a high energy content, making it ideal for producing chemical products and biofuels.

This study aims to evaluate the environmental impacts of pre-treating miscanthus through acid treatment and alkali pre-treatment to extract different valuable fractions. The Life Cycle Assessment (LCA) was modelled after a cradle-to-gate approach with a functional unit of 1 kg of miscanthus, evaluating 16 impact categories. The data gathered were collected from laboratory experiments. The process begins with acid treatment, producing a hemicellulose-rich liquid fraction and a solid fraction containing lignin and cellulose. The solid fraction undergoes alkali pre-treatment, yielding a lignin-rich liquid and a cellulose-rich solid. The lignin is then precipitated to obtain dry lignin. The cellulose fraction is divided into two streams: one kept as dry cellulose and the other used for glucose production through enzymatic hydrolysis. Overall, the LCA results identified the lignin precipitation and pulping steps as the main environmental hotspots of the process, representing 20% and 18% of the total impact, respectively. The generation of wastewater during lignin precipitation and the consumption of electricity during pulping are the main contributors to these hotspots. The enzymatic hydrolysis step is also a significant hotspot, contributing to 14% of the total impact. The scale-up of the fractionation process is likely to enhance the overall efficiency and yield favourable environmental outcomes.

B74. Chitin and Chitosan in Adhesives for Wood-Based Panel Production

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The growing concern over environmental pollution and its consequences on health has encouraged the wood industry to develop environmentally friendly wood adhesives. Even though the market share of bio-based wood adhesives is still small, it has been shown that they can compete with petroleum-based adhesives and be consideredan interesting alternative to traditional petroleum-based products. Bio-based adhesives have several advantages over adhesives derived from fossil resources, including biodegradability, lower toxicity, lower carbon footprint, positive impact on climate change, and sustainable design [1]. One of the highest abundant biopolymers on earth after cellulose, which has received wide attention for several commercial applications, is chitin [2,3].
The CHIMAR research team in the EU project Valuable (VALorisarion of fUngAl Biomass using noveL Enzymatic technology) framework developed adhesives modified with chitosan, which had been derived from crustaceans and Aspergillus niger biomass waste. The resin properties were determined using standard lab analysis techniques, and their bonding ability was tested in particleboard and plywood-type panel production at the lab scale, following a simulation of the industrial practice. The produced panels were evaluated according to the prevailing European standards. Moreover, since chitosan, due to its free amine (NH2) groups, has the potential to adsorb free and hydrolyzed formaldehyde from wood-based panels, its application as an environmentally friendly formaldehyde scavenger in wood-based panels was assessed as well.

B75. Alginate and arabic gum as sustainable biopolymers for seed coating

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Agricultural production is currently facing daunting and complex challenges. The core question is whether the agriculture can meet unprecedented demand for food without causing pressure on natural resources. Agricultural innovations, such as the implementation of new technologies and improved seeds, are crucial to ensure sustainability and increasing production. Seed coating is considered as an important tool in modern and precise agriculture. By using a variety of active ingredients, it is possible to protect seeds and enhance their handling, quality, and performance [1-3].

To replace synthetic polymers currently used in seed coating and reduce their negative impact on soil and human health, sustainable alternatives are required. Biopolymers represent attractive and biocompatible materials with additional antibacterial and antifungal properties, which can be used as biofungicides for plants, improving their quality and agricultural efficacy.

In this study, we describe the application of two biopolymers in the coating processes of cabbage seeds. The formulations composed of sodium alginate or sodium arabic gum with a forest residue biochar or coffee residue were prepared with 25, 50, and 75% (w/w) of bulk materials and used to coat cabbage seeds. After the coating process, covered seeds were dried at 30 °C for 24 h and evaluated for seed diameter, germination, germination speed index, average germination time, seedling length, seedling fresh and dry mass. The obtained results on the germination rates of coated seeds are promising showing, in particular, some advantages when using a mixture of alginate with a forest residue biochar.

B76. Effects of adsorption-active media on the physical-structural properties of polyhydroxyalkanoate blends

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Polyhydroxyalkanoates (PHAs) are versatile bioresorbable polymers that have FDA approval for various biomedical applications. While it is widely used in several in vivo implants and regenerative devices, the challenge of suboptimal mechanical properties prompts the focus toward blending PHAs with various biopolymer systems. Despite the extensive studies of PHA-based blend systems, unlocking the full potential and optimizing their performance requires the establishment of comprehensive relationships among composition, structure, and properties. Hence, it is crucial to understand the environmental crazing mechanism of neat and modified blends of PHAs in different adsorption-active media.

This research employed melt blending techniques to modify neat PHA by mixing it with biocompatible polyesters of poly(caprolactone) and poly(butylene succinate). Scanning Electron Microscopy (SEM) analysis was used to investigate the internal structure of blends which revealed a relatively coherent surface indicative of good interaction and partial miscibility of minor phases within the matrix. The state of miscibility was further examined by dynamic mechanical analysis and solid-state NMR spectroscopy. The influences of different soaking solvents on the structural and physico-mechanical characteristics of blends were investigated using X-ray diffraction, thermal, and mechanical analysis. Furthermore, the structure of the samples deformed to strains in the vicinity of particular deformation process instabilities was investigated by employing in-situ tensile testing and SEM microscopy.

The study is crucial as it aids in comprehending the interplay between resultant microstructures and their end-use properties by establishing the relationship between the structure of the starting material, the effect of adsorption-active media, and the deformation behavior of modified blends. Additionally, by comprehending the induced micro and nanoscale processes within the structure, our goal is to effectively modify, transform, and redesign these blends into advanced and reliable biomedical materials. Furthermore, we believe this study contributes another step towards fulfilling Regulation (EU) 2017/745 of the European Parliament on the legal frameworks for medical devices and requirements regarding design and manufacture.

B77. Bioprocess optimization for succinic acid production from lignocellulosic biomass

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The biotechnological production of succinic acid is a crucial step towards the transition to a bio-based economy. In this work, biotechnological methods using sustainable, cheap, and readily available raw materials bring bio-economy and industrial microbiology together via microbial production of one of the most important platform chemical - succinic acid (SA). SA was produced from a non-expensive side stream of pulp and paper industry (fibre sludge) proposing a sustainable way to valorize it towards economically important monomer for bioplastics formation. This work showed a promising new route for their microbial production which can pave the way for new market expectations within the circular economy principles. Fibre sludge was enzymatically hydrolysed for 72 h to generate a glucose rich hydrolysate (100 g·L−1 glucose content) to serve as fermentation medium for Bacillus coagulans A 541, A162 strains and Actinobacillus succinogenis B1, as well as Basfia succiniciproducens B2. All microorganisms were investigated in batch fermentations, showing the ability to produce either lactic or succinic acid, respectively. The highest yield and productivities for lactic production were 0.99 g·g−1 and 3.75 g·L−1·h−1 whereas the succinic acid production stabilized at 0.77 g·g−1 and 1.16 g·L−1·h−1. Moreover SA production was scaled up to pilot scale (50L). Additionally, SA was purified via downstream processing to meet industrial standards and high product quality.

B78. Effect of non-halogenated flame retardants on post-consumer low density polyethylene

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Polymers serve as commonly utilized insulating materials due to their lack of free electrons or ions. Exposure to fire or heat sources containing oxygen gas (O2) can lead to the breakdown of hydrocarbon bonds into smaller units, resulting in intense heat release, flames, non-flammable gases, such as H2O and CO2, and smoke or toxic gases such as CO, posing risks to both humans and the environment. To mitigate these dangers, flame retardants are incorporated into polymers. Halogenated types are often used, such as polybrominated diphenyl ethers (PBDEs) and short-chain chlorinated paraffins (SCCPs). However, they cause health and environmental problems by releasing toxic gases during the combustion of the material. This study aims to incorporate non-halogenated flame retardants (HFFR) into post-consumer low-density polyethylene (PCR-LDPE) - instead of the traditionally used PVC - to produce composites that meet international flammability standards. The selected flame retardants consist of non-halogenated inorganic compounds (in the form of phosphates, sulphates, or oxides) functionalized with maleic anhydride (MAH) and prepared using a co-rotating twin screw extruder. Flammability tests were performed according to the UL-94 flammability standard. In addition, the composites were compared with a commercially available flame retardant additive. The non-halogenated inorganic compounds were selected to promote intumescence and/or the combined flame-retardant effects and formulation outcomes revealed significant differences in flammability behavior compared to the commercial product.

B79. Decoding the Bio-Based Blueprint: Key Players and Evolutionary Trends in Materials Innovation

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In the rapidly evolving bio-based materials innovation landscape, our research pioneers the identification of key players and explores the evolutionary perspective of the innovation ecosystem. Despite the crucial role of these materials in promoting sustainable production and consumption models, systematic studies on the current innovation terrain are lacking, leaving gaps in understanding key players, emerging technologies, and trends.

To address this void, our study focuses on examining patents related to biobased monomers and polymers, aiming to illuminate the innovation strategies and business dynamics of leading assignees. Embedded within the BIOMAC project, a Horizon 2020 initiative, our research leverages this unique framework dedicated to advancing innovation ecosystems, specifically emphasizing the market readiness of nano and bio-based materials. The BIOMAC project serves as an optimal test case for our investigations.

In our comprehensive patent data collection, we implemented a meticulous multi-stage strategy, prioritizing validated keyword queries to ensure the superior quality and reliability of the collected data. Additionally, to understand primary contributors within these ecosystems, we conducted in-depth analyses of innovation strategies employed by leading companies in bio-based innovation. Preliminary findings from the ORBIT platform highlight a significant surge in patent publications between 2011 and 2022, with China emerging as a formidable player challenging historical dominance. This shift has crucial implications for global knowledge production in bio-based innovation.

In conclusion, our study offers unprecedented insights into the dynamic forces shaping the contemporary bio-based materials in the innovation arena. We discuss the potential transition in the leadership of bio-based innovation ecosystems and the emergence of novel knowledge domains. Implications for both theory and practical applications are succinctly outlined, providing valuable insights for researchers and industry practitioners alike.

B80. Application of carbon nanotube composites for the removal of 2-methylisoborneol, geosmin and N-nitrosamines in drinking water

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Nowadays, there is an increasing concern over water safety in view of several reports of the presence of emerging contaminants in surface waters, wastewater, and drinking water. These emerging contaminants are molecules not regulated or under-regulated that can be harmful to the environment, aquatic life, and human health.

The cyanobacteria metabolites 2-methylisoborneol and geosmin are emerging contaminants known for their characteristic earthy taste and smell in drinking water at concentrations in the part-per-trillion (ppt) range, which severely affects the quality of tap water. N-nitrosamines are another class of emerging contaminants that arise in water mainly as disinfection by-products during drinking water treatment, presenting carcinogenic potential in concentrations above 100 ppt.

These two classes of emerging contaminants are resistant to activated carbon adsorption performed in drinking water treatment plants; therefore, the development and application of novel materials such as polymers and composites as adsorbents for emerging contaminants is an alternative to better remove these compounds and provide safe drinking water.

For this purpose, analytical methods were developed for the quantification of 2-methylisoborneol and geosmin in a GC-MS/MS system utilizing Solid Phase MicroExtraction (SPME) as a pre-concentration technique and N-nitrosamines in an LC-MS/MS system utilizing Solid Phase Extraction (SPE) as a pre-concentration technique to determine the concentration of these contaminants in drinking water treatment samples. A sugarcane biochar composite coated with carbon nanotubes had its removal efficiency evaluated for these emerging contaminants utilizing adsorption isotherms studies.

B81. Development of a plant-based membrane that performs better than animal leather - manufacturing in a single extrusion step

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Animal leather and related products are among the most widely traded products in the world. International trade exceeds $80 billion per year, and should continue to grow along with the population and urbanization figures of emerging countries. Leather production is linked to serious sustainability and environmental issues, especially as a by-product of the meat industry. Animal leather properties are by nature extremely variable since they depend on the animal itself, its origin, breed, diet and even the location on the animal's body. This dependence makes it very difficult to produce large quantities of animal leather with uniform properties. This lack of uniformity also characterizes vegetable-based leathers, hence the difficulties of using them on a large scale. Currently, several eco-responsible innovations are beginning to emerge within the industrial subsidiary of leather-related applications. Despite the progress made, there is no product that can replace animal leather.

As part of the Federal Strategy for Sustainable Development, CTT Group have developed an innovative composition to manufacture a new product generation of 100% bio-sourced protective material (eco-leather) based on castor seed oil, natural rubber (non-vulcanized) and Soybean Oil (SBO). Using un-vulcanized rubber is somewhat unusual especially in combination with a bio-thermoplastic. Nevertheless, this strategy made it possible to reproduce leather’s performance.The formulation was adapted for extrusion, a common process, which allows the production of a uniform membrane (laminated on textiles) in a single step. This original, natural and uniform product is capable of addressing industry’s demanding performance requirements (flexibility, breathability, protection). A performance equivalent and even superior to those measured on animal leather and alternative products was obtained for the product developed. Among the advantages of this technological breakthrough is the ease of developing several products (different colors, different flexibilities, etc.) in a single step while complying with consumer’s expectation.

B82. Investigating the Optical properties of the prepared PVC films doped with content of Cr1.4Ca0.6O3

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We have prepared pure and doped PVC polymer film with different content (1, 2, and 3 wt%) of Cr1.4Ca0.6O3 by solution casting method. The prepared films were characterized by x-ray diffraction (XRD), Fourier transform infra-red spectroscopy (FTIR) and UV-Vis spectroscopy. The XRD measurement illustrates the semicrystalline structures of all PVC films. The crystal size of Cr1.4Ca0.6O3 was calculated by Scherer to be 29.15 nm. The absorption band was blue shifted upon increasing the content of Cr1.4Ca0.6O3. The blue shift upon the inclusion of 3 wt% Cr1.4Ca0.6O3 was nearly 10 nm. The Edir values of pure PVC film is 5.26 eV and decreased upon the increment of Cr1.4Ca0.6O3 content reaching 4 eV. The PVC/Cr1.4Ca0.6O3 films has a potential to be suitable for optoelectronic applications.

B83. In Situ Studies of Cross-Metathesis Breakdown of Rubbery Polymers

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Cross-metathesis chemistry offers the potential of a simple room-temperature process to break down cross-linked rubbers, yielding oligomeric products. Our initial research showed that this process worked remarkably well, even in the absence of the diester that was assumed to be necessary to introduce chain ends (https://doi.org/10.1039/C5GC03075G).

We have recently addressed several of the shortcomings that we discussed in the original work and have considerably improvedthe initial process. Firstly, we demonstrate that the catalysts can enable significant breakdown at orders of magnitude lower concentrations than initially used. Secondly, by switching to a Grubbs–Hoveyda catalyst, the process is now tolerant to oxygen and can work well in air. Thirdly, we find that the process works equally well using a more benign solvent than the chlorinated solvent used in the original work. Small-angle neutron scattering enabled the rate of the breakdown process to be studied in situ and suggested that the catalysts are predominantly active near the polymer chain ends rather than via a random scission process. We present the new results using the SANS methodology, which could readily be applied to a wider range of materials' breakdown processes.

B84. From wood waste to biobased composite materials for long-term applications

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Wood-to-Wood (W2W) is a Horizon Europe project which aims to develop a comprehensive framework for the multi-dimensional valorisation of wood waste. The project consists of four main pillars: Advanced Separation and Sorting Technologies; Upcycling Processes and Technologies; Digital Tools for Improving Circular Flows of Secondary Materials; and Supportive Framework in Policy, Market, and Skills. W2W demonstrates efficient and sustainable routes to produce wood without pollutants, biocomposite building materials, biopolymers, polyols, and chemical detergents, reducing the demand for virgin materials and the amount of waste that ends up in landfills or incineration facilities. New value-added products from waste materials will be created, supporting the transition towards a circular economy by promoting closed-loop systems. For the successful implementation of the proposed workflow, the consortium combines high-level scientific knowledge with industrial experience to deliver a holistic approach for wood waste management. The NTUA group combines poly(lactic acid) (PLA), as a biodegradable polymeric matrix, and lignocellulose-based materials recovered from wood waste, as reinforcement fillers, to deliver composite compounds that will serve as low-cost, sustainable, recycled materials for long-term applications. Different grades of PLA will be examined with different ratios of the filler content to meet the targeted specifications in terms of thermal and mechanical performance. Compounding will be performed in a twin-screw extruder, and crucial conditions, such as temperature profile and shear rate, will be studied and optimized to achieve good compatibility. Then, on selected compounds, various anti-hydrolysis additives (e.g. carbodiimides) will be tested to prepare hydrolytically stabilized PLA composites for long-term applications, such as construction. Samples with varying additive concentrations will be prepared and subjected to accelerated ageing. Crucial properties, such as molecular weight and mechanical properties, will be monitored and correlated to the corresponding properties of the unstabilized samples.

B85. Renewable with enhanced barrier properties and compostability poly(trimethylene 2,5-furanoate) copolymers with aliphatic diacids

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In our work we design of poly(trimethylene 2,5-furanoate) PTF based copolymers via-structure-property-biodegradability relationship analysis. The barrier properties and compostability were tailored by changing the length (molecular mass) of the aliphatic chain in dicarboxylic acid used as comonomer. Polymer films from the obtained copolymers were subjected to structural and thermal characterization. The mechanical response, barrier properties were studied. At some compositions copolymers showed outstanding gas barrier properties to O2 and CO2, better than those of PTF, PET and most polymers widely employed for flexible packaging. It was found, that the tuning of aliphatic co-unit content is an effective tool to modulate the chain mobility and, in turn, the kind and amount of ordered phases developed in the materials. In addition to the usual amorphous and 3D crystalline phase, a further phase, characterized by a lower degree of order than the crystalline one, is present, whose amount is strictly related to copolymer composition. The relative content of all these phases is responsible for the different mechanical and barrier performances and biodegradation kinetics.

B86. Toughening Polylactic Acid using Ultrafine Fully Vulcanized Powder Rubber from Graft Copolymerization of Deproteinized Natural Rubber with Methyl Methacrylate Monomer

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Polylactic acid (PLA) is a biodegradable polymer derived from lactic acid. Due to the inherent brittleness of PLA posing significant challenges, incorporating PLA with bio-based filler is an alternative pathway to overcome this disadvantage. Bio-based filler was prepared by grafting methyl methacrylate monomer onto deproteinized natural rubber (DPNR-g-PMMA), with 10 and 20 phr of MMA monomer. The DPNR-g-PMMA was successfully prepared, as confirmed by a Fourier transform infrared spectrometer, and the highest monomer conversion (52%) and highest grafting efficiency (82%) values were achieved witha 10 phr MMA monomer. The grafted DPNRs underwent vulcanization through electron beam irradiation and were transformed into ultrafine fully vulcanized powdered natural rubbers (UFPNRs) through a spray-drying process. The resulting UFPNRs were integrated into PLA at 15 wt% to produce a composite material. The flexural properties of the PLA composites filled with 10 phr-UFPNR exhibited the highest strain at break and flexural toughness of 12.6% and 9000 kJ/m3, respectively, representing 307% and 360% improvements compared to neat PLA. These results suggest that UFPNR has potential as a toughening filler for PLA.

B87. Boron-Enhanced Aluminum Solar Cables: A Key Path to Accelerating Green Transformation

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The demand for renewable energy sources is increasing day by day, and the need for clean and sustainable sources, especially solar energy, is rising to meet this demand. The growing need for harnessing solar energy necessitates the wider adoption and development of solar energy technologies. Solar energy systems (SES), which are crucial for meeting global energy needs and combating climate change, stand out as environmentally friendly and clean energy sources compared to fossil fuel-based energy production. However, the efficiency and durability of SES are limited by traditional cable materials. Therefore, alternative material studies are important to overcome the limitations of traditional cable materials. Thus, the development of innovative technologies with features such as high conductivity, low resistance, durability, and long life can facilitate the wider use of SES and accelerate the transition to clean energy. Turkey is one of the countries with the largest boron reserves in the world. These abundant boron reserves constitute an important resource to meet a large part of the world's boron demand. Boron has a wide range of applications in many industries such as agriculture, glass, ceramics, detergents, metallurgy, health, etc., and is widely used in the production of various products. Boron compounds have properties such as high temperature resistance, chemical resistance, high voltage resistance, and low thermal expansion coefficient. The abundance of boron in nature and its suitability for recycling provide a more environmentally sustainable solution. Additionally, it helps reduce the carbon footprint of SES.

This study examines the use of boron-modified aluminum solar cables as an innovative alternative to copper-conductive solar cables commonly used in electricity transmission in solar energy systems (SES) today. Currently, in aluminum solar cable sheaths, non-recyclable materials with high chemical content such as XLPE (cross-linked polyethylene) and XLHFFR (cross-linked halogen-free flame retardant) are utilized. By adding boron additives to recycled polyolefins, it is possible to develop environmentally friendly solar cable sheath insulation materials with superior properties. This innovative approach aims to pioneer the development of national technologies using domestic raw materials, contribute to the literature with innovative material studies, support the use of environmentally friendly and sustainable energy sources, promote green transformation, and encourage the widespread adoption of SES globally.

B88. Analgesic polymer hydrogels based on sodium alginate.

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Burns are a common occurrence during military operations for both military personnel and civilians. The search for promising dressing materials that are easy to use and capable of anesthetizing and accelerating the process of skin regeneration after burns is currently very relevant.

Natural polymer materials are widely used in medicine, both for the controlled release of active pharmaceutical ingredients (APIs) and for the effective healing of damaged skin. Polymeric hydrogels are widely used for the local release of APIs and provide a water balance in the case of burn injuries. Lidocaine is a local anesthetic with a low molecular weight and high lipophilicity. Due to its high efficiency, rapid controlled release and analgesic effect, lidocaine is most often used for local anesthesia.

The purpose of this work is to obtain polymer hydrogels based on sodium alginate and polyvinyl alcohol and to study the kinetics of lidocaine hydrochloride release from these drugs.

Hydrogels were prepared via the casting method from a mixture of sodium alginate and PVA solutions in a ratio of 50/50, followed by freezing and crosslinking with Ca2+ ions. The kinetics of lidocaine hydrochloride release from the hydrogels was studied using a VK 7000 device (VanKel, USA). Lidocaine hydrochloride release took place in acetate (pH 4.5) and phosphate (pH 6.8) buffers at a temperature of 32ºC. The content of lidocaine hydrochloride in the hydrogel was determined via a spectrophotometric method on an OPTIZEN POP UV VIS device (Mecasys, South Korea) at a wavelength of 262 nm.

From the data obtained in kinetic studies, it was established that more than 50% of lidocaine hydrochloride is released in 30 minutes, and within 90 minutes, the concentration exceeded 80%. This makes it possible to use polymer hydrogels as the main prolonged-release therapeutic agent for anesthetizing in the case of skin burns.

B89. Acrylic-Acid-Modified Cellulose and Styrene--Butadiene Rubber: An Efficient Polymer Blend for Silicon--Graphite Anodes in Lithium-Ion Batteries

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This study evaluates the performance and potential of novel binders, composed of acrylic-acid-modified cellulose and styrene--butadiene rubber (SBR), for use in silicon--graphite anodes of lithium-ion batteries (LIBs). Silicon (Si) is recognized for its higher theoretical capacity compared to graphite, making it a promising candidate for LIB anode materials. However, its application is hindered by substantial volume expansion during charge and discharge cycles, resulting in decreased capacity reversibility and the structural breakdown of the electrode. Traditional binders, such as polyvinylidene fluoride (PVDF), demonstrate limited effectiveness due to weak interaction with Si particles, failing to maintain essential particle cohesion and electrical conductivity within the anode. This research investigates the application of a blend of acrylic-acid-modified cellulose and SBR as an innovative binder for Si-based anodes. Unlike conventional linear binders, this blend engages in multi-point interactions with the Si surface, enhancing particle adhesion. Experimental results demonstrate a high initial coulombic efficiency of 82% at a current density of 0.2C. Remarkably, after 100 cycles, the anodes exhibit excellent capacity retention, maintaining a level of 2170 mAh/g of Si. These findings underscore the potential of using a cost-effective aqueous blend of SBR and acrylic-acid-modified cellulose as an environmentally friendly and efficient alternative to toxic solvents like N-methyl-2-pyrrolidone and expensive PVDF in the manufacturing of LIB anode materials. This research contributes to the development of more sustainable and high-performing lithium-ion batteries.

B90. Monitoring of PFAs levels in water using a Solid Phase Extraction coupled with LC/MS-MS analytical method

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Per- and polyfluoroalkyl compounds (PFAs) are a huge class of nearly 10,000 anthropogenic contaminants that are persistent, bioaccumulative and toxic. Due to their attractive physicochemical properties, thermal and chemical stability, they are used in numerous industrial and consumer products in everyday life.1,2,3 Their ubiquitous presence and resistance to degradation have led to their detection in the aquatic environment, rainwater, drinking water and consequently animals and humans4.

Their abundance led to their inclusion in the new European Drinking Water Directive (DWD) with a parametric value of 100 ng/L per compound and a maximum method detection of 30 ng/L. Thus, an analytical method for the determination of the 20 PFAs included in the DWD was developed based on ISO 21675:2019, for drinking and surface water samples. The method was validated according to ISO 17025:2017. Method Detection Limits vary between 0.49-10.37 ng/L. Reproducibility varies between 4.06-21.57%, recovery between 75-134% and uncertainty between 10-52% for both matrices.

Monthly monitoring of PFAs levels was carried out since September 2021 for drinking water samples from the city of Thessaloniki and for the resources the city has, e.g., ground water from Aravissos springs and surface water from Aliakmonas river. In approximately PFAs levels were below 10ng/L in drinking water samples and in river water, PFAs were detected in levels below 20ng/L.

B91. Evaluation of Active Packaging in Combination with Modified Atmosphere Packaging to Increase Shelf Life of Ready-to-Eat Cake

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Active packaging and modified atmosphere packaging (MAP) were combined to prolong the shelf life and quality of ready-to-eat cake. Carvacrol, eugenol, oleuropein, hydroxytyrosol and combinations were used as bioactive substances systems. The following concentrations of gases were chosen: 100%/N2 (MAP1), 40% CO2/60% N2 (MAP2), and aerobic conditions (Air). Microbiological and physicochemical analyses were conducted. Ready-to-eat cakes were stored for 20 days (analysis in 0, 5, 10, 15 and 20 days). The results showed a decrease in moisture content and lightness of crumb and an increase in hardness. Bioactive molecules significantly (p 0.05) slowed down the growth of microorganisms regardless of the type of gas mixture. However, the best bacteriostatic effect was in MAP2. The sensory quality (taste and aroma) and appearance did not change throughout the storage time. The results revealed a significant color changes in control samples (packaged under air without active packaging) compared to the active/MAP packaging ready-to-eat cake. Generally, the best results were obtained with the combination of MAP and active packaging—40% of CO2 and 60% of N2—where bioactive molecules were used.

B92. Exfoliation of graphite flake as reinforcement for polymer matrix to develop conductive nanocomposite materials

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Graphite flake, which is naturally abundant, has been widely used as conductive filler for polymeric materials to produce conducting polymer composites. Traditionally, polymers are reinforced with a micro-size filler to modify and improve their electrical, thermal and mechanical properties. However, high loadings are required for reasonable improvements and that can negatively affect their mechanical properties and processing. Therefore, similar to other nanomaterials, nanocomposites prepared from a nano-size filler have excellent properties for high performance applications. In this study, graphite flake was successfully exfoliated into graphite nanoplatlets (GNPs); its layers were separated down to a nanometer-scale thickness. Subsequently, these two reinforcements (graphite and GNPs) were incorporated individually with a polymer matrix with the melt compounding technique using an extruder, followed by compression molding to obtain both micro- and nanocomposites. The electrical, mechanical and thermal properties of these two composites were characterized as a function of graphite size and contents using a wide range of analytical techniques. The results showed the advantage of using conductive nanoscale graphite over its microscale size. For instance, the composites containing GNPs had a lower percolation threshold with much higher conductivity relative to equivalent graphite-based composites, and this resulted in improved mechanical properties at much lower GNP loading.

B93. Biopolymers research in the RISE Bioeconomy arena: from LAB to the DEMO scale

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The RISE Bioeconomy Arena brings together scientific excellence and state-of-the-art research infrastructure to speed up the transition to a bioeconomy. Cutting-edge facilities support industry and society to accelerate the development of new products and solutions based on sustainable origins for a sustainable, competitive, and resilient future. Enzymes and microorganisms revolutionise the transformation of low-value waste streams, such as fibre sludge and sawdust, into valuable and sustainable monomers for the production of biopolymers. In the new food-grade infrastructure, bioreactors from 1 L up to 10,000 L, as well as PILOT-scale downstream processing and a high-throughput strain development facilities, are used to develop, study, and produce bacterial nanocellulose (BNC), polyhydroxyalkanoates (PHA), and polylactic acid (PLA), covering strain development, process development, process optimisation, and scale-up within the framework of R&D projects or industrial contracts.

During the EU project BIOMAC, BNC production with Komagataeibacter xylinus from pulp and paper side streams has been optimised (strain and process), upscaled, and tested with different forms of fibre ejects in packaging applications (foams) using CASSMATERIALS, showing excellent properties. PLA and PHA (PHB) production from various waste and side streams from forestry, algae, and pulp and paper industries is studied in various projects from the lab to the pilot scale.

B94. Bioplastics produced chitosan extracted from insects (black soldier flies).

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The aim of this work was to extract chitin from black soldier fly (BSF) larvae exuviae and to convert it into chitosan, to be used to develop a bioplastic. Bioplastics are among the most sustainable materials that will contribute to the resolution of new and pressing environmental challenges. In this work, we will show the chitin extraction process, as well as deacetylation to synthesize chitosan-based bioplastics from black soldier fly (Hermetia illucens) exuviae, to achieve an environmentally sustainable product with low production costs. The use of mechanochemistry and the ability to control the size of the biomass produce different products during this study. The characterization of chitin and chitosan obtained from this natural source will be performed by X-ray Photoelectron Spectroscopy.

Poster Session B – Thursday 30 May

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