

**NORDIC
POLYMER
DAYS 2026**

NPD 2026 ABSTRACT BOOK

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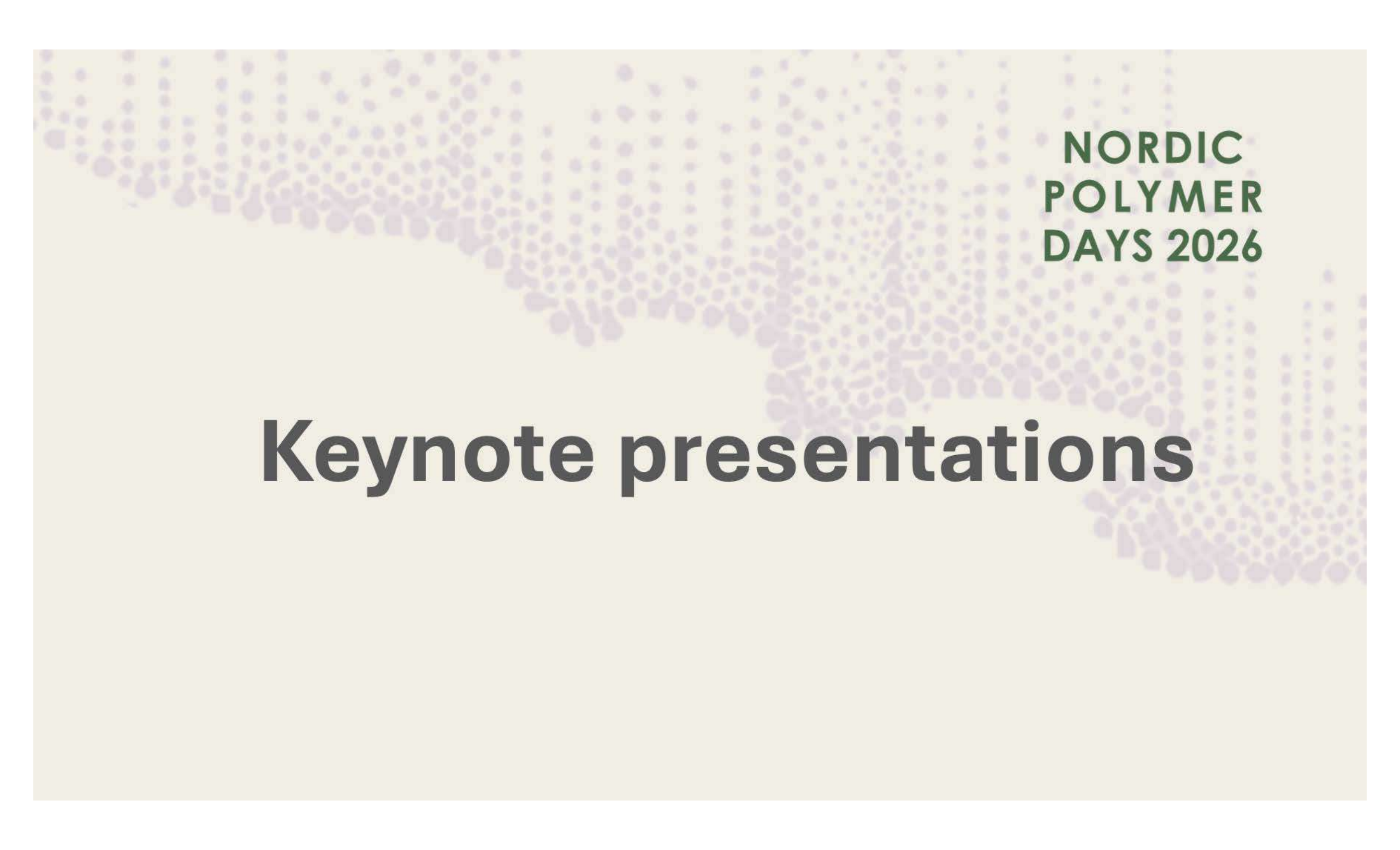
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Keynote presentations

K1 – Design of Biocomposites from Reinforced with Cellulose, Hemicellulose, and Lignin

Sergejs Gaidukovs

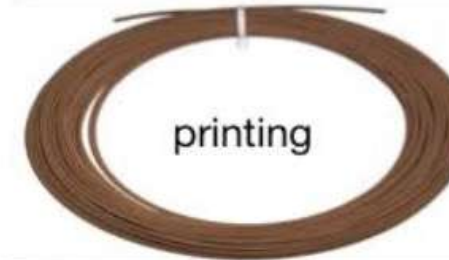
This presentation summarizes recent advances in the development of thermoplastic and thermoset biocomposites based on renewable polymers and lignocellulosic components. Several case studies will be discussed, including vegetable oil acrylate–nanocellulose composites, polybutylene succinate (PBS)–wood fiber composites, and plastics incorporating cellulose, hemicellulose, and lignin. The work highlights material design strategies, processing approaches, and structure–property relationships in these sustainable composite systems.

The presentation concludes with key findings from ongoing research, demonstrating the potential of lignocellulosic components to enhance the mechanical performance, functionality, and sustainability of next-generation bio-based plastics and composite materials.

extrusion



printing



injection



WOOD MIMICK



S. Nechausov and A. Miriyev, "CNT-filled UV-curable resins," Chem. Eng. J., vol. 496, p. 153759, 2024.

M. Jurinovs et al., "Sustainable 4D Printable Biobased Shape Memory Polymers with Linear Tunability and Multistimuli

S. Briede et al., "Acrylated vegetable oils," Mol. Syst. Des. Eng., vol. 7, pp. 1434-1445, 2022.

K2 – Controlled Radical Polymerization for Advanced Optoelectronics

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Effective emission tuning of photoluminescent materials is of great interest for both fundamental study and practical applications. In combination with thermally-activated delayed fluorescence (TADF), light-emitting polymers have emerged as promising materials in optoelectronics, especially organic light-emitting diodes (OLEDs), owing to their greatly enhanced performance, synthetic flexibility and solution processability. The development of structurally simple, multicolor emissive polymers that do not require sophisticated synthetic methodologies is highly appealing, yet remains challenging.^[1] Thanks to a serendipitous discovery, we developed a versatile approach for the design of well-defined light-emitting polymers with color-tunable solid state emission via controlled radical polymerization (Figure 1).^[2,3] Using a single-acceptor fluorophore as the initiator for atom transfer radical polymerization (ATRP), a series of electron-donor groups containing simple aromatic moieties were introduced by facile polymerization or post-functionalization. The resulted charge transfer-based polymer library showed continuously tunable emission color. This was

achieved by fine-manipulation of donor-acceptor interplay via simple controlled polymer synthesis. Theoretical investigations including molecular dynamics and time-dependent DFT calculations confirmed the structurally dependent charge transfer-induced emission redshifts. During this process, we discovered that the fundamental polymer chemistry has a significant impact on the photoluminescence properties of the resulting polymers. Most recently, we further investigated these effects in electroluminescent polymers for advanced optoelectronics.^[5] This study represents a key step for the development of next-generation light-emitting materials for high-resolution displays and flexible electronics.

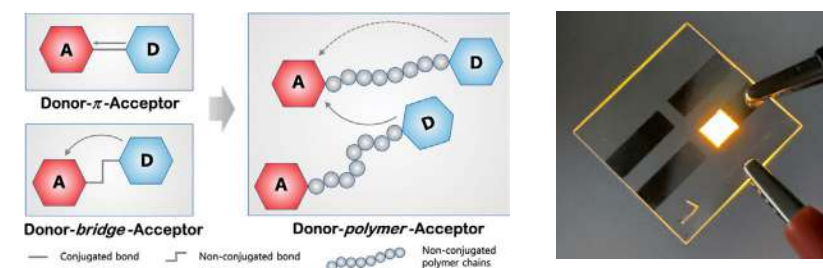


Figure 1. Illustration of charge transfer polymers and photograph of OLED based on TADF polymers synthesized by ATRP

[1] Ye, S.; Bao, Y. *Chem. Mater.* **2024**, 36, 5878–5896. [2] Ye, S.; Tian, T.; Christofferson, A. J.; Erikson, S.; Jagielski, J.; Luo, Z.; Kumar, S.; Shih, C. J.; Leroux, J. C.; Bao, Y. *Sci. Adv.* **2021**, 7, eabd1794. [3] Ye, S.; Meftahi, N.; Lyskov, I.; Tian, T.; Kumar, S.; Christofferson, A. J.; Winkler, D. A.; Shih, C.-J.; Russo, S.; Leroux, J.-C.; Bao, Y. *Chem* **2023**, 9, 924-947. [4] Bao, Y. *Langmuir* **2024**, 40, 3275–3282. [5] Bao, Y.; Lo, S.-W.; Shih, C.-J. EP25223816.7

K3 – ULTRASOUND-DRIVEN NANOPARTICLE TRANSPORT IN POLYMER NETWORKS

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The transport of nanoparticles (NPs) through polymer networks is a central problem in soft matter physics and biomedical applications, from drug delivery in tumors to filtration and sensing. In extracellular-matrix-like hydrogels, NP diffusion is often strongly hindered by a combination of steric constraints and transient adhesive interactions with the network. Low-intensity ultrasound has been reported to enhance NP diffusion in such systems, yet experimental observations remain contradictory [1,2] and the underlying mechanisms are still debated.

In this work we study ultrasound-driven NP transport in hydrogels using coarse-grained Langevin dynamics simulations, by systematically investigating the diffusion in polymer networks with tunable steric and adhesive interactions [3]. We found that ultrasound does not enhance diffusion in purely steric networks. In contrast, enhancement emerges when nanoparticles interact attractively with the network, where ultrasound reduces particle-polymer contact times via a stick-and-release mechanism.

This framework explains why acoustic enhancement is observed only under specific interaction strengths and ultrasound conditions, reconciling conflicting experimental observations.

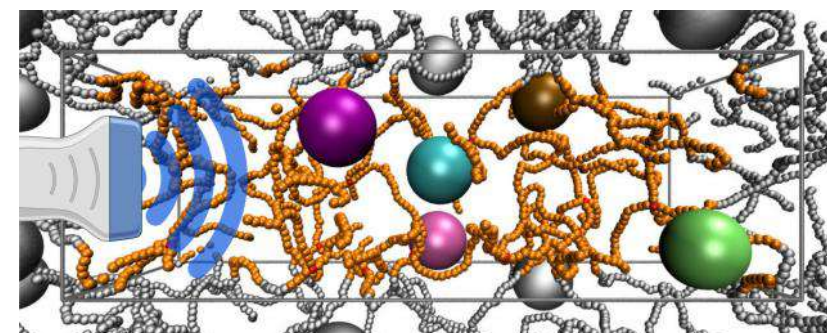


Figure 1: Simulation snapshot of nanoparticles diffusing in a hydrogel under ultrasound, shown for a purely steric network.

[1] C. Einen et al. Gels 9 (2023), 9, 771.

[2] D. Ma, J. S. Marshall and J. Wu, J. Acoust. Soc. Am. 144(6) (2018) 3496–3502.

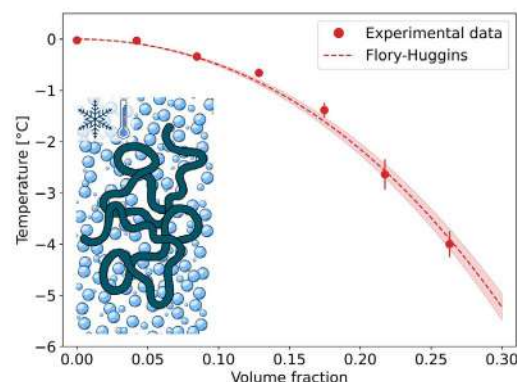
[3] P. M. Blanco, H. H. Rønneberg, and R. S. Dias, JCIS 704(2) (2026) 2139402.

K4 – Freezing Point Depression Beyond Colligative Effects: Specific Co-Ion and Counterion Effects in Polymer and Polyelectrolyte Solutions

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Freezing point depression is often presented as a colligative property, yet polymer solutions can depart from simple colligative behavior because polymer connectivity, polymer–water interactions, and ion-specific hydration shape the relevant free energy. Here we use freezing point measurements to quantify (i) co-ion effects in neutral polymer solutions with added salt and (ii) counterion effects in cationic polyelectrolyte solutions.

In ternary PEG–salt–water mixtures, sodium salts with anions spanning the Hofmeister series produce strong anion specificity. Strongly hydrated anions yield freezing point depressions that are clearly non-additive relative to separate PEG and salt contributions, whereas weakly hydrated, more polarizable anions give a more nearly additive response. A simple Flory–Huggins-based description captures the PEG nonlinearity and supports an interpretation in terms of ion-dependent “water withdrawal” from polymer hydration and possible preferential ion–polymer interactions.¹

In poly(METAC-co-HEMA) solutions, freezing point depression is essentially insensitive to chain length and only weakly dependent on charge density, but it depends strongly on counterion identity. Strongly hydrated counterions produce markedly larger freezing point depressions than weakly hydrated ones, consistent with a shift from relatively dissociated ions toward increased ion pairing and reduced effective osmotic activity.²

Overall, freezing point depression in polymeric aqueous solutions is governed by ion-specific hydration and association phenomena rather than simple colligative counting, providing a compact macroscopic probe of specific co-ion and counterion effects.

1. I. E. Sørensen and E. Thormann (2026). Quantifying Hofmeister Effects on Polymer-Water Interactions through Freezing Point Depression. *Langmuir*, DOI: 10.1021/acs.langmuir.5c05841.
2. Ingrid Eklundh Sørensen and Esben Thormann (2026). Freezing Point Depression of Aqueous Polyelectrolyte Solutions: Effects of Chain Length, Charge Density, and Counterion Type. Submitted.

K5 – Beyond PEO, Beyond Cation and Beyond Segmental Motions – Deepening Our Understanding of Ion Transport in Polymers

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Ion transport in polymer matrices is a topic of interest not least for the potential use of such ion-conducting *polymer electrolytes* in solid-state batteries. A solid body of research has been built up since the first discoveries in the 1970s, primarily from studies on poly(ethylene oxide) (PEO) as the prototypical host material for solvent-free polymer electrolytes. While this has been vital to form the basis of our understanding of how ions move in polymeric systems – such as the coupling between polymer segmental motions and ion movement – a notable flaw has been a lack of perspectives beyond this basic polyether. PEO may be an excellent polymer host material, but perhaps not fully representative of polymer electrolyte materials in general.

By raising our gaze to a broader palette of materials, we can also discover additional facets of how ions interact with polymer hosts and how these ion–polymer interactions add another layer of complexity that complements the role of segmental motions. By introducing a more diverse set of polymer architectures, we can target our synthetic efforts on structures that do not unintentionally hinder ion movement. And by not forgetting about the counterions to the Li^+ , Na^+ , Mg^{2+} and

other cations that we are typically optimizing ion transport for, we can get a more complete picture of the overall process of how to get ions from anode to cathode in the most efficient way possible.

Adding to the legacy of PEO, we have used a combination of synthetic, computational and experimental efforts to get a more comprehensive view of ion transport in cation-coordinating polymers. And while this has undoubtedly uncovered important new facets of these processes, it has also uncovered new unknowns and questions to be answered – making us in a way know both more and less at the same time...!

K6 – Controlled wood cell wall reconstruction for multifunctional lignocellulosic structures

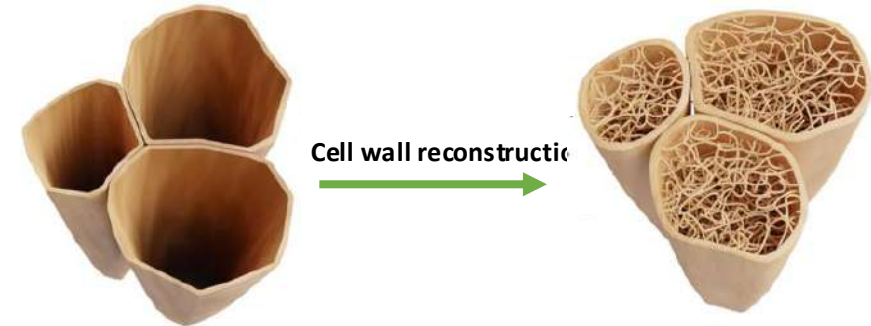
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Developments in materials engineering enriched the modern materials systems and enabled advanced applications. Biomaterials are getting increasing attention with the pursue of sustainable development. Wood is of particular interest due to its advanced hierarchical structure, biodegradability, and large-scale processability. Multifunctional structure design from wood is mainly through a bottom-up approach, disintegrating wood into nano building blocks followed by structure reassembling.

In this talk, top-down approach through controlled cell wall reconstruction will be introduced. The step of nano building blocks extraction is eliminated which is beneficial for scalable fabrication. The wood hierarchical structure is largely preserved and in-situ modified. Wood aerogel structure, a hierarchical nano porous structure with cellulosic nanofibril network filling the empty lumen space, will be explained as an example, including the sustainable fabrication, structure understanding, as well as the potential applications.



Xu, X., Sehati, A., Celada, L. M., Olsén, P., Berglund, L., & Li, Y. (2026). Green and efficient cell wall nano-reconstruction under ambient temperature towards strong cellulosic aerogels. *Green Chemistry*, 28(1), 242-254.

Garemark, J., Yang, X., Sheng, X., Cheung, O., Sun, L., Berglund, L. A., & Li, Y. (2020). Top-down approach making anisotropic cellulose aerogels as universal substrates for multifunctionalization. *ACS nano*, 14(6), 7111-7120.



**NORDIC
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Contributed presentations

WEDNESDAY

Q1.1 – Enabling Circular ABS Value Chains through Stakeholder Engagement: A Socio-Technical Framework for Recycled Acrylonitrile-Butadiene-Styrene

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Acrylonitrile-butadiene-styrene (ABS) is a widely used engineering thermoplastic in automotive and consumer applications, yet its circular deployment remains limited despite advances in mechanical recycling and material processing. Within the Horizon Europe project ABSolEU, a structured stakeholder engagement journey was designed and implemented to identify enabling key conditions for large-scale adoption of recycled ABS (rABS) across the value chain and to end consumers. The approach combined consumer acceptance studies, citizen laboratories, field observations of collection schemes, citizen and multi-actor value chain labs.

Results show that adoption of rABS is conditional on two interdependent dimensions: (i) trust in material performance and environmental integrity, and (ii) accessibility of participation systems. Stakeholders expect performance parity with virgin ABS in durability, safety, and lifetime, supported by transparent and harmonised life cycle assessment (LCA) methodologies and verifiable quality assurance data. Sensitivity to greenwashing underscores the need for standardised metrics and evidence-based communication.

Simultaneously, participation in recycling systems is primarily determined by infrastructure availability, simplicity, and territorial coverage rather than awareness alone. Complex sorting requirements and limited accessibility significantly reduce engagement, even among motivated users.

The findings demonstrate that successful circular implementation of ABS requires integration of materials engineering, quality verification pathways, transparent LCA standards, and system-level design of collection infrastructures. Given the complexity of challenges, this needs to be supported by a non-contradictory, well-designed enabling policy framework. While developed for a specific high-performance thermoplastic, the stakeholder-centred method is transferable to other polymer systems seeking scalable circular deployment.

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Acknowledgements: This work was carried out under the Horizon Europe project ABSolEU - "Paving the way for an ABS recycling revOLution in the EU" (HORIZON-CL4-2021-RESILIENCE-01-Project: 101058636).

Q1.2 – Understanding the temperature dependence of SAN Dissolution as a key factor in the physical recycling of ABS

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Acrylonitrile–butadiene–styrene (ABS) is a widely used engineering plastic whose complex composition limits efficient recycling. Selective dissolution represents a promising physical recycling strategy, enabling the recovery of the poly(styrene–co-acrylonitrile) (SAN) matrix while separating polybutadiene rubber (PBR) particles and additives. However, the thermodynamic and kinetic mechanisms governing SAN dissolution remain insufficiently understood.

In this presentation, the dissolution behaviour of SAN was investigated in solvents with different affinities using isothermal mixing calorimetry coupled with in-situ FTIR spectroscopy and dynamic mechanical analysis (DMA). High-boiling solvents were selected based on Hansen solubility parameters to explore dissolution both below and above the SAN glass transition temperature. The experiments provide complementary insight into the enthalpy of dissolution, induction time, and dissolution kinetics.

Calorimetric measurements reveal exothermic dissolution enthalpies that decrease with increasing temperature, indicating a transition from processes dominated by glassy-rubbery transition when operating below the T_g of SAN to polymer–solvent interaction-controlled behaviour at higher temperatures.

Complementary ATR-FTIR monitoring highlights strong solvent-quality effects on the induction time prior to chain solubilisation, evidencing the critical role of polymer segmental mobility. In good solvents, SAN dissolution occurs rapidly above moderate temperatures, while poorer solvents require temperatures near or above the glass transition to achieve complete dissolution.

In addition, DMA experiments (with the sample immersed in a thermo-regulated bath containing the solvent) were conducted to highlight the thermo-mechanical behavior during the course of SAN dissolution.

These results provide a comprehensive description of SAN dissolution by identifying the thermodynamic and kinetic factors governing the process. The combined calorimetric–spectroscopic-mechanic approach offers a powerful methodology to optimise solvent selection and operating conditions for selective dissolution processes aimed at ABS physical recycling.

Acknowledgements: This work was carried out under the Horizon Europe project ABSolEU - "Paving the way for an ABS recycling revOLution in the EU" (HORIZON-CL4-2021-RESILIENCE-01-Project: 101058636).

Q1.3 – Renewable Solvents for ABS Recycling: Bridging Molecular Screening, Process Optimisation and Mechanistic Insight

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With the global plastic production on rise, important engineering polymers such as acrylonitrile–butadiene–styrene (ABS) reached 14 Mt in 2022 and will exceed 20 Mt by 2027.¹ Despite its widespread use in automotive, electronics and durable goods, efficient recycling of ABS remains challenging due to its multiphase morphology and the structural complexity.

Within the ABSolEU project, the University of Aveiro team has developed a sustainable dissolution-based recycling framework for waste ABS using rationally selected biosolvents and renewable (deep) eutectic solvents (DES) through an extensive in silico COSMO-RS screening. Selected oxygenated solvents, adhering to safe-by-design principles, selectively dissolve the styrene–acrylonitrile (SAN) matrix while enabling separation of degraded poly(butadiene) rubber (PBR).

The robustness of the renewable solvent strategy was first tested using virgin ABS under controlled conditions and subsequently validated on post-consumer waste electrical and electronic equipment (WEEE) ABS.

Process performance was further refined via design-of-experiments optimisation (temperature and solid/liquid ratio) combined with kinetic modelling, while comprehensive characterisation (FTIR, NMR, DSC, TGA) verified consistency with virgin SAN while enabling quantification of PBR removal.

Computational spectroscopy combining DFT and vibrational analysis elucidated solvent–polymer interactions and shed light into the underlying dissolution mechanism, identifying energetically favourable interaction pathways. Solvent reuse was assessed over multiple cycles to evaluate process robustness and circularity potential.

Beyond advancing a sustainable solvent portfolio for ABS recycling, this work establishes a robust and transferable dissolution-based technological framework for selective polymer recycling.

¹ Statista Research Department, Production capacity of acrylonitrile butadiene styrene worldwide from 2022 to 2027, 2024.

Acknowledgements: This work was developed within the scope of the project CICECO Aveiro Institute of Materials, UID/50011/2025 (DOI 10.54499/UID/50011/2025) & LA/P/0006/2020 (DOI 10.54499/LA/P/0006/2020) & UID/PRR/50011/2025 (DOI 10.54499/UID/PRR/50011/2025), financed by national funds through the FCT/MCTES (PIDDAC). The FCT is acknowledged for the research contract to AMF, FHBS and AFS (CEECIND/00361/2022, CEECIND/07209/ 2022, and CEECINSTLA/00002/2022). The European Commission is acknowledged by VP for a doctorate grant, and CFA for a research contract, under Horizon Europe ABSolEU - "Paving the way for an ABS recycling revoLution in the EU" (HORIZON-CL4-2021-RESILIENCE-01-Project: 101058636).

Q1.4 – Solvent-based recycling of polymers from waste plastics: development of TNO's Möbius dissolution process for ABS recycling - a use-case study

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Dissolution-based recycling technology has the potential to recover purified polymers from waste plastics with improved quality compared to mechanical recycling and with lower energy costs and higher carbon efficiency than through chemical recycling. It enables e.g. removal of contaminants and additives that are responsible for odour and colour and enables replacement of deteriorated components in the recycle. At TNO, a dissolution process is under development for upcycling of polymers from hard-to-recycle waste plastics such as multilayer packaging films, polymer blends and engineering plastics from waste electronics or end-of-life vehicles.

The dissolution technology under development aims for the use of a single superheated solvent, to obtain hot polymer solutions with sufficiently high concentration for viable process economics and with sufficiently low viscosity to allow for effective use of conventional purification techniques like microfiltration and sorption. Predicting the interactions between solvent, polymer and contaminants and using them to our benefit is key in the development strategy.

In the ABSolEU project, TNO's Möbius process was developed and used for SAN recovery from waste ABS from end-of-life vehicles.

Acknowledgements: This work was carried out under the Horizon Europe project ABSolEU - "Paving the way for an ABS recycling revOLution in the EU" (HORIZON-CL4-2021-RESILIENCE-01-Project: 101058636).

The final setup was operated at a loading of approximately 500 – 1000 g waste per run, producing approximately 400-600 g of product (TRL5).

In this presentation, the process development methodology will be explained, illustrated with examples from TNO's experience and with references from ongoing developments at other institutes and industry. Specifically, steps involved (a) screening for suitable solvents to establish a solvent-polymer interaction model, (b) experiments on purification methods to remove additives and degraded polybutadiene rubber from the polymer solutions, (c) testing of SAN recovery from the solution – either by evaporation of the solvent or by precipitation – followed by polymer devolatilization and (d) recovery of the solvent for recycling in the process.

The current developments show the potential of a dissolution-based recycling process for our use-case of ABS recycling from End-of-Life vehicle waste to produce recycled ABS grades that could meet brand owners' requirements, as shown by some product examples.

Q1.5 – Willingness to pay for recycled plastics products: lessons from ABSolEU project in Southern France

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d’azur*

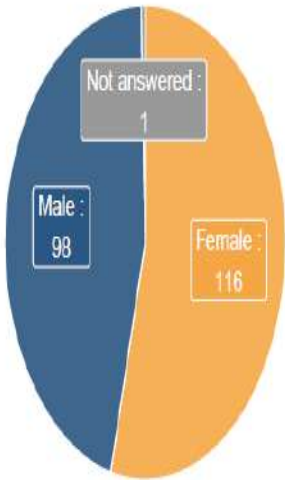


Figure: Gender distribution

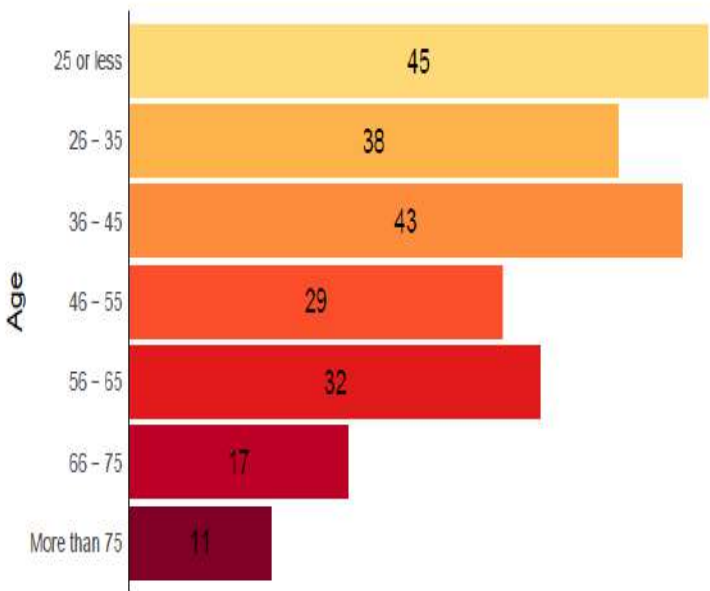


Figure: Age distribution

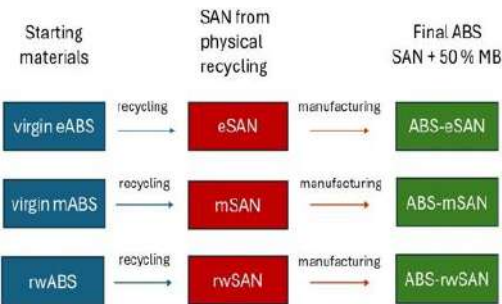


Q1.6 – Effect of physical recycling on properties of final ABS materials

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Materials included in the study

ABS is a terpolymer consisting of acrylonitrile, butadiene and styrene monomers. The morphological structure of ABS is formed of a continuous phase of copolymers of styrene and acrylonitrile (SAN) and a dispersed phase containing mostly polybutadiene rubber (PBR). The final ABS product normally contains also various additives. Currently, only a small proportion is recycled through mechanical recycling. The reasons are that the recycled ABS has often lower performance compared with virgin material and the presence of possible contaminants and unwanted substances.

These drawbacks can be avoided by using a physical recycling processes based on dissolving the polymer waste in a suitable solvent, filtering out any insoluble contaminants, additives and other unwanted substances, and recovering the pure SAN polymer through re-precipitation and drying. In this study, three different ABS materials underwent a physical recycling process viz. emulsion polymerized, mass polymerized and mechanically recycled ABS resulting in pure SAN polymers. The SANs obtained were further mixed with one master batch and extruded to produce final ABS materials (see fig.) containing the same amount of PBR and additives. This approach provided an opportunity to compare the effect of SAN recycled from different sources on properties

of the final material. The comparison included evaluation of mechanical and rheological properties, morphology and content of certain substances of concern. As expected, mechanical properties such as E-modulus, tensile strength and impact strength are independent of the material from which SAN is recycled. The same applies to rheological properties evaluated by measuring melt flow rate (MFR). Of course, all ABS materials have the same morphology because SAN is mixed with the same master batch. However, some differences have been measured regarding how effectively the process removes unwanted substances (see table below).

Substance (mg/kg)	eABS	eSAN	mABS	mSAN	rwABS	rwSAN
Styrene	200	< 0,5	170	<0,5	120	90
Bisphenol A	<1	<1	<1	<1	320	130
Oligomers	9500	79	30000	170	37000	4800
Triphenyl phosphate	<1	<1	<1	<1	2	0,7
DEHP	<5	<5	<5	<5	70	40
Solvents unknowns	500	2600	270	450	310	1800
Bromine	<20	<20	<20	<20	270	40
Irganox 1076	1400	approx. 8	2300	<10	3100	470

D. Deshmukh, H. Kulkarni, D. Sai Srivats, S. Bhanushali, A. P. More, Recycling of acrylonitrile butadiene styrene (ABS): a review, Polymer Bulletin (2024) 81:11361– 11398

Anderson, L., Yu, E., Chen, W.T., 2022. Chemical recycling of mixed plastics in electronic waste using solvent-based processing. Processes (2022), 10, 66.

Q1.7 – Traceability to facilitate and increase circular use of ABS plastics

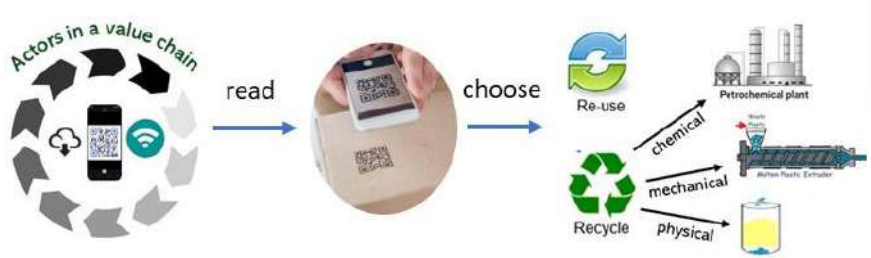
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The circular economy goes beyond the simple concept of material recycling as it must integrate economic, environmental and social sustainability. Because of the more extensive regulation, severe security threats to the goods and the demand for fast and secure exchange of information, traceability has become the responsibility of all organizations in the value chain. The definition of traceability is “The ability to trace the history, application, or location of an item, data, or sample using recorded documentation”. Circular use of ABS materials implies that products and materials are maintained at their highest value for the longest time possible and are designed for the reduction of waste from the outset avoiding and eliminating hazardous and toxic substances. Soon, traceability and information exchange between all actors of a value chain of the plastics industry will be crucial to establishing more effective recycling systems. A suitable traceability system should combine a physical marking with data-sharing platforms that provide access to information for all actors in a value chain. For data sharing, there are various digital technologies that enable information that is attached to a product to identify and store, share, and analyse data throughout its life cycle e.g. Digital Product Passport, blockchain technology, standards etc.



Plastics must be easily identified and separated at the end of life by their material type, chemical structure and quality to maximize their value for the next use. Marking is the most desired option for all actors who want to track information about a product. It is important that the readability of the tracer during a product’s entire service life is robust even when the material becomes waste. There are several different labeling techniques available such as photoluminescence, digital watermarks, laser marking, printing, in-mould marking, stickers, etc. Which technology is the best option depends on the product’s size, appearance, manufacturing method, area of use, price sensitivity and more. Ultimately the decisive step in the introduction of the traceability system will be the acceptance and involvement of all actors in the ABS plastic industry and society in general.

I. Jakubowicz, N. Yarahmadi, Review and Assessment of Existing and Future Techniques for Traceability with Particular Focus on Applicability to ABS Plastics, Polymers 2024, 16,1343

L. Probst, L. Frideres, B. Pedersen, Traceability across the Value Chain—Advance Tracking Systems; European Commission: Brussels, Belgium, 2015.

Q1.8 – Data-driven design of biobased polymers and quality assessment of recycled plastic

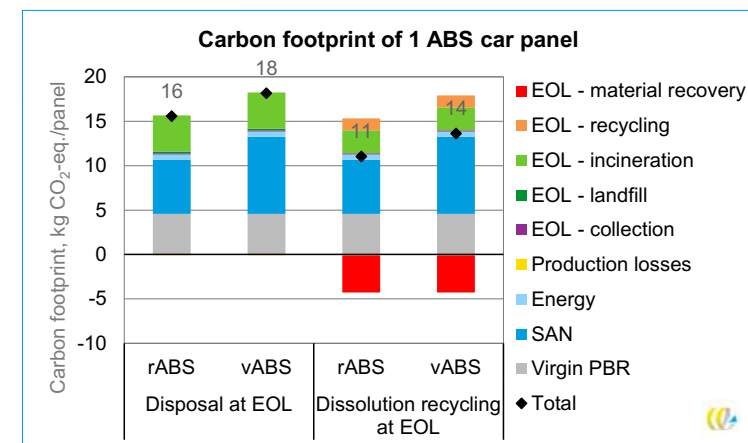
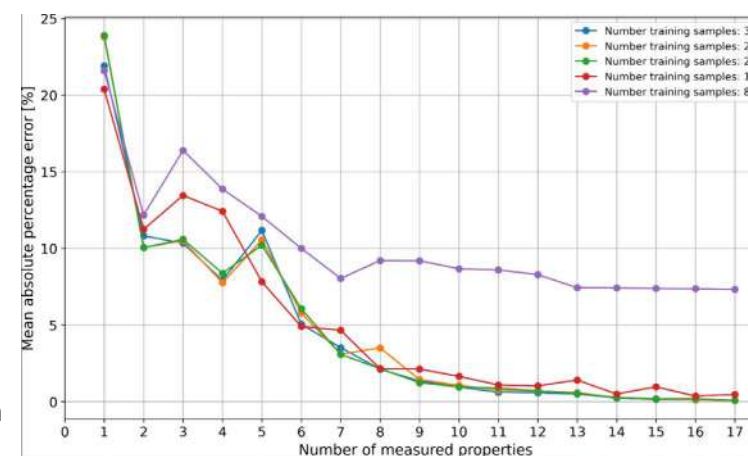
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Achieving a sustainable polymer economy requires rapid, reliable methods to quantify material composition, degradation pathways, and recyclability. In this work, we present a novel integrated framework for quality assessment of recycled plastics and demonstrate its relevance for advanced routes such as dissolution-based ABS recycling, which can deliver high-quality recyclate with lower environmental impacts. RecyQmeter employs a compressed-sensing-based analytical workflow to extract chemical, structural, and morphological features from polymer waste streams with minimal data acquisition requirements. This enables accurate identification of material classes, filler content, and degradation-induced chemical changes while reducing measurement time and energy consumption. The methodology is validated on ABS recyclate, demonstrating strong performance even for highly heterogeneous samples. A prospective LCA of ABS dissolution recycling shows production of rSAN with ~65% lower carbon footprint than vSAN and larger reductions across most impact categories. Using rABS in automotive panels yields a 19% carbon footprint reduction versus vABS under the Circular Footprint Formula. Thus, dissolution recycling can substantially reduce environmental impacts while maintaining near-virgin quality, supporting broader applications for recycled ABS and complementing mechanical recycling for difficult waste streams.



- Poort, J.; Golkaram, M.; Janssen, P.; Urbanus, J.H. Prediction of Acrylonitrile–Butadiene–Styrene Mechanical Properties through Compressed-Sensing Techniques. *J. Chem. Inf. Model.* **2024**, 64, 7257–7272, doi:10.1021/acs.jcim.4c00622.
- Golkaram, M.; Demets, R.; Vogels, J.T.W.E.; Urbanus, J.H.; Christoula, A.; Elbing, R.; Meester, S. De; Ragaert, K. RecyQMeter: Application-Specific Quality of Recycled Plastics. *Waste Manag.* **2025**, 202, 114846, doi:https://doi.org/10.1016/j.wasman.2025.114846.

Q1.9 – Circular Traceability of ABS Plastics

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Tatiana Nevzorova¹,
Shafi K. Mohammed²,
Pål Huse²

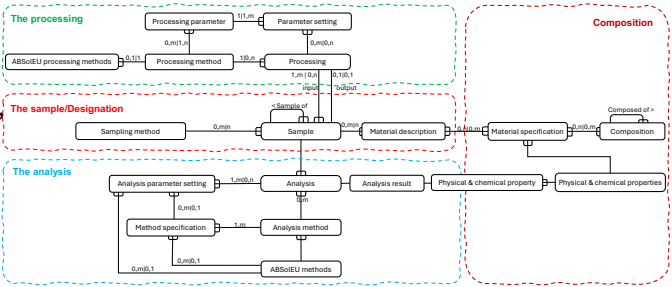
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A pioneering solution for achieving circular traceability of **ABS** plastics has been developed within the EU project **ABSolEU**. The work has been made with the EU regulation **ESPR** in mind and has worked intimately together with ABS researchers on innovative chemical recycling of ABS plastics, ABS plastics property specifications, aging, public acceptance, challenges and needs as well as its innovation potentials. Much consideration has been given to stakeholder needs for material property specifications, including OEM, dismantlers and recyclers. This intimacy across entire circular life cycles of ABS was essential to acquire the practical requirements of a circular traceability system. Starting at OEMs property designation, including mechanical, thermal, chemical, surface texture, colour stability, odour, toxicity and other requirements. Then following the material designation through recipe design and property tests, the quality assurance from designation to delivery specification can be near perfectly traced by matching document, test and sample IDs. The system is designed for the ID to follow from material batch to component moulding, through product lifetimes, by for example a QR code as ID-mark.

Based on in-depth studies of circular ABS life cycles, the project developed a formally structured data model grounded in relational database (**SQL**) design principles. This structure was validated for material designation data, ABS recipe specification, material processing, and test data documentation, including specific laboratory standards and parameter settings. Combined with fully back-traceable sample ID handling, the system enables tracing an ID-marked ABS item from any point in its product life cycle back to its original material designation. The same information can support subsequent material analyses, such as chemical degradation or contamination assessment prior to blending with other ABS fractions for recycling. The data model has been translated into an ISO-standardized format (**ISO 10303**) and is currently considered as a **DPP** use case.



ABSolEU: Paving the way for an ABS recycling revOLution in the EU

ESPR: The Ecodesign for Sustainable Products Regulation (ESPR) (EU 2024/1781);

DPP - Digital Product Passport: Described in detail in ESPR (above) and is currently developed in the joint standardization committee CEN-CENELEC/JTC 24 Digital Product Passport

SQL - Structured Query Language: SQL Reference Volume 1; IBM; SC27-5509-00

ISO 10303 (STEP - Standard for the Exchange of Product model data) Application Protocols AP235 (material information) AP242 (models)

Q31.1 – Chitosan-Deoxycholic Acid Conjugates as Molecular Blocks for Concerted pH-Responsive on Cancer Cell Disruption

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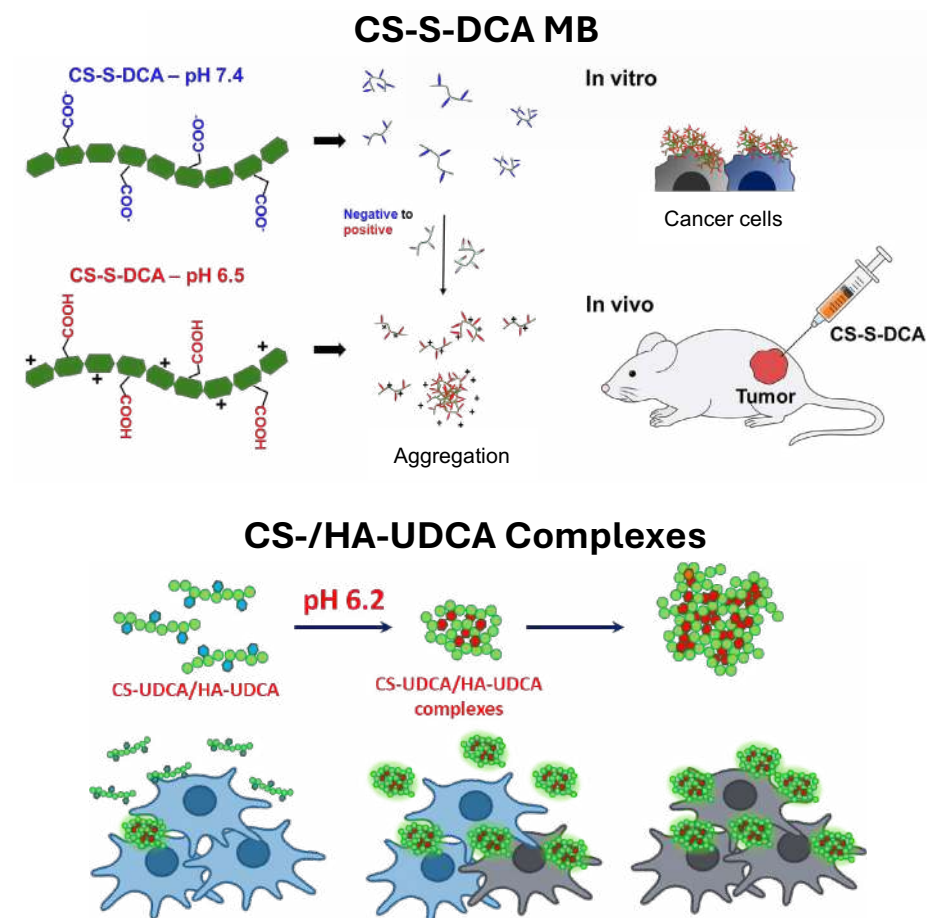
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pharmacotherapies based on the behavior of polymeric nanoparticles that remain dispersed in blood circulation but aggregate in the acidic tumor microenvironment (pH 6.3-6.5), leading to cancer cell membrane disruption. In this study, a chitosan-based MB system is developed through the conjugation of deoxycholic acid (DCA) onto chitosan succinate (CS-S). The pH-responsive CS and DCA enable their concerted performances: DCA aggregation promotes cancer cell membrane disruption, while cationic charge of CS interacts with negatively charged cancer cell surfaces through ionic interactions. The pH-triggered aggregation of the MB system results in selective cytotoxicity toward cancer cells, including MiaPaCa-2, A-549, and HT-29, while maintaining compatibility with normal cells such as NHDF. These findings highlight the potential of bile acid-modified CS-based systems for the development of pH-responsive molecular blocks for drug-free cancer therapy. The presentation will extend to a system involving complexation between chitosan and hyaluronic acid modified with ursodeoxycholic acid (CS-UDCA/HA-UDCA) to clarify how polymer complex formation enhances MB performance.



Thanongsak, W., Kawahara, M., Nakamoto, M., Homma, K., Sereemaspun, A., Tachaboonyakiat, W., Ruktanonchai, U., Yoshimoto, K., Katayama, R., Matsusaki, M., Chirachanchai, S. (2026). Concerted pH-Responsive Performance of Chitosan-Deoxycholic Acid as a Polymeric Molecular Block for Cancer Cell Disruption. ChemMedChem, 21, e202500587.

Q31.2 – Probing the Moisture-Induced Drug Recrystallization in Cellulose Derivative-based Amorphous Solid Dispersions

Arvinth Seshadri Suresh¹, Famke Van Brempt¹, Susanna Abrahmsen-Alami², Anette Larsson^{1, *}

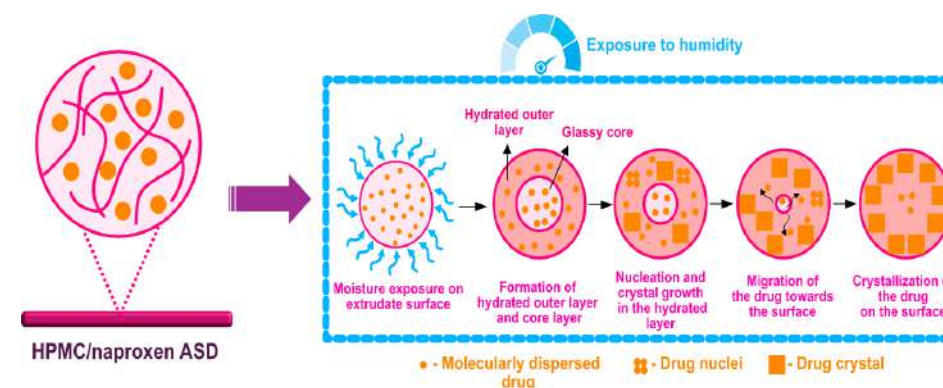
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Hydroxypropyl methylcellulose (HPMC), a widely used cellulose derivative, plays a central role in stabilizing drug-containing amorphous solid dispersions (ASDs), by inhibiting the drug recrystallization.¹ However, the moisture sorption behavior of HPMC can compromise the physical stability of ASDs under humid conditions. This study examines how humidity, drug loading, storage time, and spatial location within the ASD together influence the recrystallization behavior of a model drug (naproxen) in HPMC-based ASDs prepared via hot melt extrusion. We hypothesized that moisture induced drug recrystallization is governed primarily by the water sorption characteristics of HPMC. To investigate moisture induced drug recrystallization, extrudates were stored for 14 days at 75% and 98% RH. All formulations remained fully amorphous (>99.5%) at 75% RH, whereas significant recrystallization occurred at 98% RH. Notably, recrystallization initiated at the extrudate surface, reflecting moisture driven structural gradients within the polymer matrix.

These results establish a structure–property relationship linking HPMC hydration and increased chain mobility to drug recrystallization, providing a mechanistic insight relevant for designing robust moisture-resistant cellulose derivatives-based drug delivery systems.



Schematic of moisture-induced drug recrystallization mechanism

1. Vlad, R. A., Pinte, A., Pinte, C., Rédei, E. M., Antonoaea, P., Bîrsan, M., & Ciurba, A. (2025). Hydroxypropyl Methylcellulose—A Key Excipient in Pharmaceutical Drug Delivery Systems. *Pharmaceutics*, 17(6), 784. <https://doi.org/10.3390/pharmaceutics17060784>

Q31.3 – HA-Disulfide Hydrogels with Drug-Loaded Nanoparticle Exhibiting Self-Healing, Redox Sensitivity, and Light-Triggered Fluorescence Release

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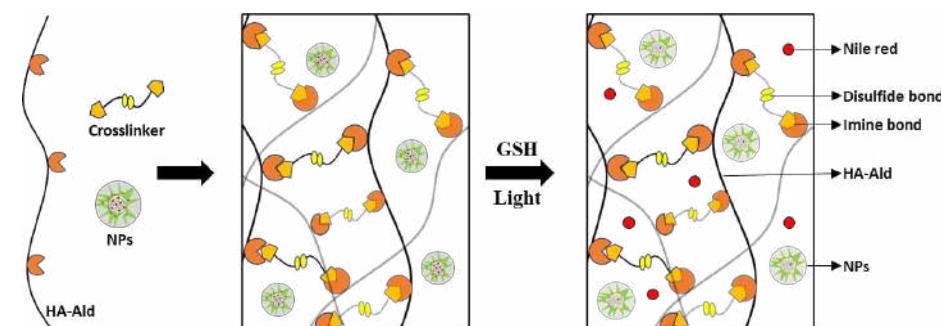
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Stimuli-responsive hydrogel was developed using hyaluronic acid-based dynamically crosslinked networks incorporating disulfide bonds and Nile red-loaded nanoparticles. The nano-particles (NPs) were prepared with disulfide bonds and light-sensitive groups. Fluorescence studies showed that Nile Red release was governed by nanoparticle degradation and the hydrophobic core environment in the hydrogel. In a water solution, light irradiation cleaves the photosensitive groups while glutathione (GSH) reduces disulfide bonds, leading to nanoparticle disassembly and release of Nile Red from the hydrophobic core of NPs into the aqueous phase, resulting in decreased fluorescence intensity. However, when nanoparticles are embedded within the hydrogel, a different behavior is observed. The 50% aldehyde modification of hyaluronic acid and crosslinking with DTPH creates hydrophobic domains within the network. Upon GSH or light exposure, nanoparticles degrade faster due to their high surface area, releasing Nile Red that partitions into the hydrophobic regions of the hydrogel, causing an initial increase in fluorescence. As the hydrogel gradually degrades under reducing conditions, Nile Red diffuses into water, leading to a decrease in fluorescence intensity.

Rheological studies confirmed dynamic viscoelastic behavior and structural changes in reducing environments, while gel-cutting experiments demonstrated self-healing with methylene blue diffusion across the healed interface after 24 hours.



1. Taha Behroozi Kohlan, Yanru Wen, Carina Mini, Anna Finne-Wistrand (2024) Schiff base crosslinked hyaluronic acid hydrogels with tunable and cell instructive time-dependent mechanical properties Carbohydrate Polymers 338, 122173
2. Nancy Ferrentino, Taha Behroozi Kohlan, Shokoufeh Mehrdashfar, Anna Finne-Wistrand, Daniela Pappalardo (2024) Dual-Responsive Nanoparticles for Smart Drug Delivery: A NIR Light-Sensitive and Redox-Reactive PEG-PCL-Based System Biomacromolecules 25, 7660–7673

Q31.4 – Sustainable Biobased Composites: Bioactive Glass Scaffolds via UV-Curing

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The demand for patient-specific scaffolds is rising as the population ages¹⁻⁵. Simultaneously, the industry for circular economy products, and biobased polymeric materials by extension, is experiencing rapid growth¹⁻⁵.

In this context, UV-curable biobased scaffolds reinforced with multifunctional bioactive glasses were developed for advanced tissue engineering. These composites have bioactive glass as the common filler and biobased monomers as the matrix, with applications from soft to hard tissue regeneration.

The progression began with chitosan hydrogels incorporating Te-doped, silanized bioactive glass (BG-Te-Sil) for soft tissue engineering¹ (Figure 1), advancing to highly porous polyHIPE² (High Internal Phase Emulsion Polymers) foams (Figure 2) and rigid 3D-printed constructs using acrylated epoxidised soybean oil (AESO) matrices for hard tissue engineering³ (Figure 3). Cu/Te-doped bioactive glasses were integrated to enhance osteoconductivity, antimicrobial activity, and mechanical strength through silanization, optimising polymer-filler interfaces⁴.

The final innovation integrated covalent adaptable network (CAN) chemistry into AESO-BG scaffolds, enabling reprocessability through transesterification reactions⁵.

All scaffolds underwent comprehensive thermomechanical characterization, along with in vitro biological testing to evaluate cytocompatibility, antibacterial performance, and osteoinductive potential.



Figure 1. Hydrogel scaffolds

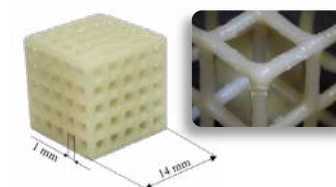


Figure 3. AESO-based scaffolds

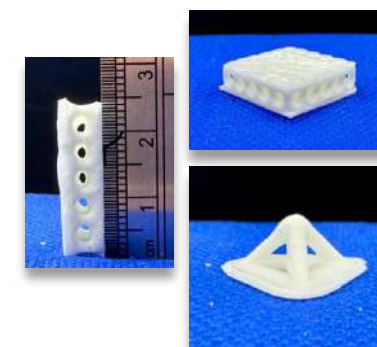


Figure 2. PolyHIPE scaffolds

1. Bergoglio, M.; et al. Tellurium-Doped Silanised Bioactive Glass–Chitosan Hydrogels: A Dual Action for Antimicrobial and Osteoconductive Platforms. *Polymers* 2025, 17, 1651.

2. Matteo Bergoglio, Marta Miola, Enrica Vernè, Marco Sangermano, and Neil R. Cameron. *Biomacromolecules* 2025 26 (12), 8548-8559

3. Bergoglio, M. et.al UV-Cured Bio-Based Acrylated Soybean Oil Scaffold Reinforced with Bioactive Glasses. *Polymers* 2023, 15, 4089

4. Matteo Bergoglio, et al, Silanized and Cu-doped bioactive glass as filler for biobased photocurable 3D printed scaffolds, *Materials Today Chemistry*, Volume 44, 2025, 102559, ISSN 2468-5194

5. Bergoglio, M.; et al. 3D-Printed Acrylated Soybean Oil Scaffolds with Vitrimeric Properties Reinforced by Tellurium-Doped Bioactive Glass. *Polymers* 2024, 16, 3614.

Q31.5 – SOLVENT-FREE PROCESSING OF BIOPOLYMER–FULLERENE COMPOSITE FILMS FOR LIGHT-ACTIVATED ANTIMICROBIAL SURFACES

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Biofilms on clinical surfaces drive contamination and healthcare-associated infections [1]. Many antimicrobial coatings lose activity over time or rely on leaching, limiting their durability. Melt-processable antimicrobial materials remain underexplored. Here we investigate solvent-free biopolymer–fullerene (C₆₀) films as light-activated antimicrobial surfaces [2].

C₆₀ (0.5 wt%) was incorporated into poly(lactic acid) (PLA), poly(3-hydroxybutyrate-co-valerate) (PHBV), and plasticized chitosan using thermo-physical processing. Raman confirmed retention of the C₆₀ Ag(2) mode (~1467 cm⁻¹) and matrix-dependent distribution. XRD and DSC revealed distinct structural responses across matrices. PLA films showed strongly reduced crystallinity and pronounced cold crystallization, consistent with a largely amorphous structure. PHBV retained semicrystalline order with increased melting transitions and crystallite size (~7.6 → ~9.2 nm), consistent with nucleation by C₆₀. Chitosan films displayed reduced structural order and modified dehydration-related transitions.

Thermophysical processing governs C₆₀ domain formation and matrix-dependent crystallinity, guiding design of compliant versus structurally robust photoactive coatings. Ongoing work evaluates light-triggered antimicrobial activity under aPDT-relevant conditions.

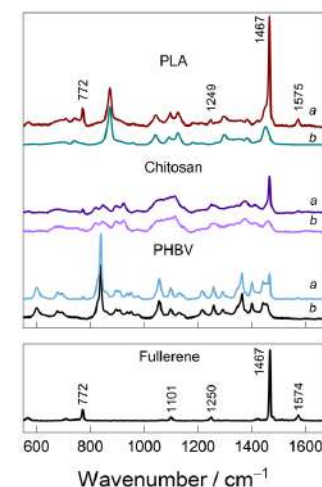


Figure 1. Raman spectra of PLA, chitosan, PHBV, and fullerene samples.

1. Weber DJ et al., American Journal of Infection Control, 2023, 51, A114–A119.
2. Songca SP et al., International Journal of Molecular Sciences, 2022, 23, 3209.

Q31.6 – CHEMICALLY CROSSLINKED BIO-BASED HYDROGELS FOR TISSUE REGENERATION

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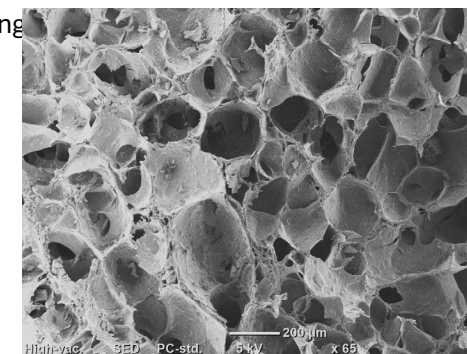
Biohydrogels are uniquely suited for bioapplications due to their high water content, soft tissue-like mechanical properties, and intrinsic biocompatibility, which together create a physiologically relevant microenvironment for cells and biomolecules. Their tunable network structure allows precise control over swelling, degradation, and mechanical strength. In particular, click crosslinking chemistries such as thiol-ene, and Diels-Alder reactions enable rapid, selective, and cytocompatible gel formation under mild conditions, making them highly attractive for injectable systems, cell encapsulation, and in situ forming scaffolds. Despite their versatility, biohydrogels still face several important limitations that restrict broader clinical translation. One major challenge is their relatively poor mechanical strength and structural stability, particularly under load-bearing conditions, which limits their use in applications such as cartilage or bone regeneration. Many biohydrogels also exhibit uncontrolled or rapid degradation, leading to premature loss of mechanical integrity. Moreover, multicomponent hydrogel systems offer synergistic properties, integrating bioactivity with mechanical robustness and dynamic responsiveness. This modular design approach allows the development of advanced platforms for tissue engineering, drug delivery, wound healing, and self-healing biomaterials.

Choi, H., Kim, M., Yang, G. H., & Kim, G. (2024). A review of advanced hydrogel applications for tissue engineering and drug delivery systems as biomaterials. *Gels*, 10(11), 693.

Liu, B., & Chen, K. (2024). Advances in hydrogel-based drug delivery systems. *Gels*, 10(4), 262.

This study is part of a project that has received funding from the European Union's Horizon Europe research and innovation program under the Marie Skłodowska-Curie grant agreement No [101105270].

In this study, a series of bio-based hydrogels are designed to be chemically crosslinked via photo-curing and click reactions for cartilage tissue regeneration. Gelatin, alginate, K-carrageenan and chitosan were modified with methacrylate, thiol, furan and maleimide moieties in order to introduce the necessary reactive units for the aforementioned crosslinking reactions. The fabricated hydrogel systems were characterized in terms of mechanical, rheological and morphological properties. They showed uniform porosity, Young's moduli suitable for cartilage regeneration, good stability and low cytotoxicity. As a result, these chemically crosslinked multi-component hydrogels are promising biomaterials for tissue eng



SEM image of a gelatin/alginate/carrageenan hydrogel

Q31.7 – BIOMINERALIZATION STUDIES ON CNC MODEL FILMS

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Nanocomposites made of nanocellulose and hydroxyapatite are promising materials for bone healing as the chemical structure of hydroxyapatite is close to the structure of inorganic component of bone and nanocellulose can form a porous three-dimensional network mimicking the collagen fibril network of bone. The aim of this study is to examine how the different surface modifications of nanocellulose affect its capacity to induce hydroxyapatite and calcium phosphate formation in simulated body fluid (SBF).

SiO₂ sensors coated with an ultrathin film of sulphated, phosphorylated and carboxylated cellulose nanocrystals (CNCs) were mineralized in 1.5 × SBF for 96 h in 37 °C. Calcium phosphate growth was monitored in situ by quartz crystal microbalance with dissipation monitoring (QCM-D) and ex situ by atomic force microscopy.

For carboxylated CNCs, the frequency drop in QCM-D during the incubation time was the largest, indicating significant calcium phosphate deposition. Phosphorylated CNC surfaces also showed a significant decrease in frequency indicating precipitation on the sensor surface, while on sulphated CNCs much less precipitation was observed. Changes in dissipation were high for all the samples meaning that the absorbed layer is not rigid, which indicates that the precipitation is amorphous calcium phosphate rather than hydroxyapatite.

Of these three types of CNCs, the carboxylated one showing most capacity to induce calcium phosphate growth, is most probably the best material for bone healing. The next step is to develop mineralized nanocomposites out of cross-linked, carboxylated CNCs and hydroxyapatite.

Domingues, R.M.A., M.E. Gomes, and R.L. Reis, *The Potential of Cellulose Nanocrystals in Tissue Engineering Strategies*. Biomacromolecules, 2014. **15**(7): p. 2327–2346

Tanahashi, M. and T. Matsuda, *Surface functional group dependence on apatite formation on self-assembled monolayers in a simulated body fluid*. J Biomed Mater Res, 1997. **34**(3): p. 305–15.

Q31.8 – Highly Selective O – Phenylene Bisurea Catalysts for Ring Opening Polymerization of Lactones and Carbonates for Biomedical Applications

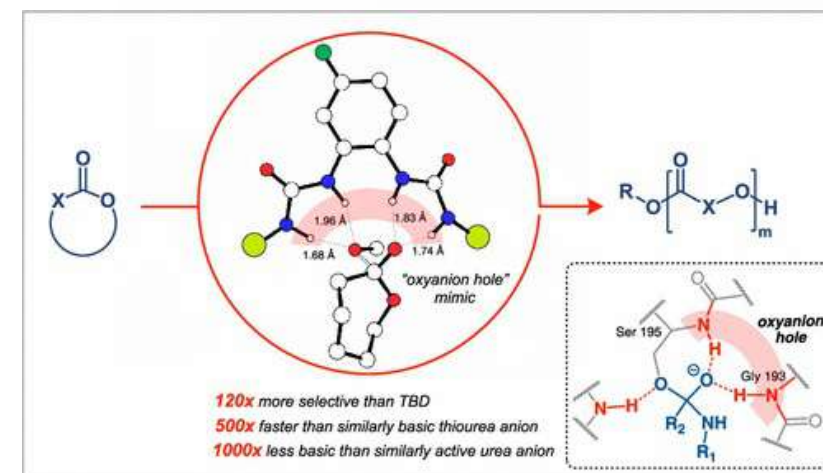
Authors:

Jia Zhang, Kai Hin Lui, Rachele Zunino, Yuan Jia, Romain Morodo, **Niklas Warlin**, James L. Hedrick, Giovanni Talarico, Robert M. Waymouth*

Organocatalyzed ring-opening polymerization (ROP) of lactones enables the synthesis of biodegradable polyesters but often involves a trade-off between catalytic activity and selectivity. Recently we discovered that *o*-phenylene bisureas (OPBU) catalyze ROP of lactones and cyclic carbonates with exceptional control and speed at room temperature.

The ortho-phenylene linker positions two urea groups in close proximity, creating a semiflexible hydrogen-bonding pocket that stabilizes the transition state during polymerization. The resulting mono- and dianionic catalysts catalyze living ROP of cyclic esters and carbonates, producing polymers with predictable molecular weights and extremely narrow dispersities ($\mathcal{D} \approx 1.01$).

These catalysts provide an efficient platform for the controlled synthesis of well-defined biodegradable polymers suitable for biomedical applications such as the delivery of mRNA into cells.



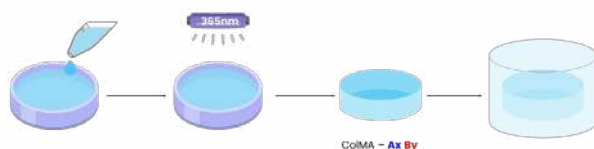
Q31.9 – Photocurable Collagen-Based Hydrogel for Wound Healing Application

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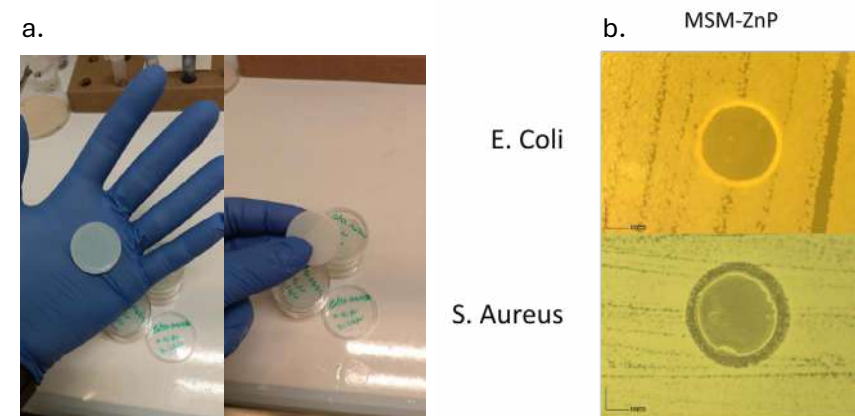
Schematic Illustration of Photocurable ColMA Hydrogel fabrication

Collagen-based hydrogels represent a promising class of biomaterials due to their intrinsic biocompatibility, tunable structure, and potential applicability in biomedical systems. In this work, photocurable formulations based on collagen methacrylate (ColMA) were developed and optimized in order to produce mechanically stable hydrogels via photopolymerization. The focus was placed in understanding how formulation composition affects the final hydrogel morphology and swelling properties.

ColMA hydrogel were manufactured using a water-based system containing ColMA, acrylic acid, and N,N'-methylenebisacrylamide as crosslinker, in presence of Irgacure 2959 as photoinitiator. Photorheological tests proved fast curing kinetics. Additionally, Free-Swelling Capacities (FSC) were evaluated in different conditions (MilliQ, pH=5 and PBS) proving the adaptability of ColMA hydrogels to different exudate environments. Swelling data were then systematically analyzed and fitted through a Full Factorial Design (FFD) matrix, from which was possible to structure the relative sorption models.

Eventually, the formulation showing the best sorption capabilities was selected to be compounded with mesoporous Si fillers, known as potent coagulants. These formulations were subsequently tested in diffusion tests against Gram (+) and Gram (-) bacteria.

Overall, this research project set the basis for the development of novel ColMA hydrogel pads potentially applicable in wound dressing sector.



Picture of the photocured hydrogel (a) and the relative antibacterial properties towards *E. Coli* and *S. Aureus* (b)

Guo, B., Dong, R., Liang, Y., & Li, M. (2021). Haemostatic materials for wound healing applications. *Nature Reviews Chemistry*, 5(11), 773–791.

Ge, L., Xu, Y., Li, X., Yuan, L., Tan, H., Li, D., & Mu, C. (2018). Fabrication of Antibacterial Collagen-Based Composite Wound Dressing. *ACS Sustainable Chemistry & Engineering*, 6(7), 9153–9166.

Q33.1 – Is it possible to completely dry cellulose?

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Ximena Ruiz-Caldas², Varvara
Apostolopoulou-Kalkavoura^{* 2,3},
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Technology (ITN), Linköping
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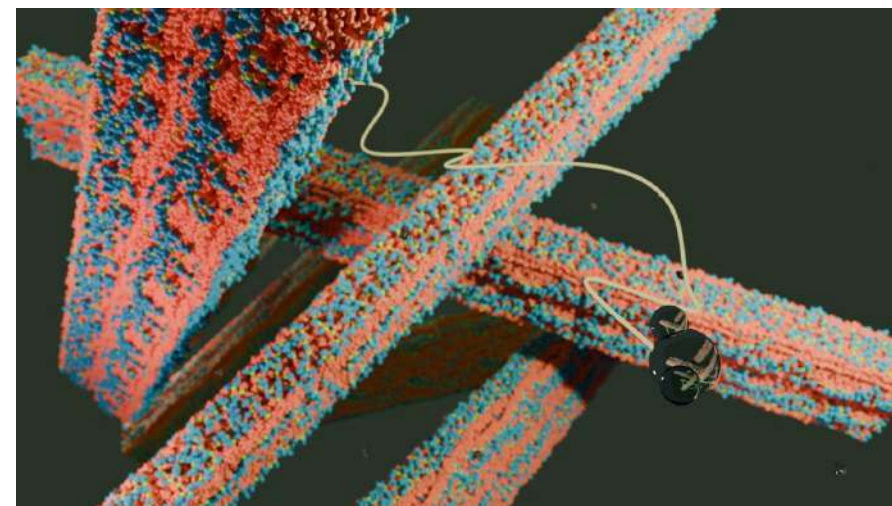
² Department of Materials and
Environmental Chemistry,
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Cellulose nanocrystals (CNCs) are widely used in industrial applications due to their high strength, sustainability, and tunable surface chemistry. However, the presence of bound water in CNCs, particularly in chemically modified forms, remains a challenge for processing and application. In this study, we investigate the drying behavior and water retention of native and TEMPO-modified CNCs using a combination of hybrid Grand Canonical Monte Carlo (GCMC)/Molecular Dynamics (MD) simulations and experimental validation. Our simulations reveal that while native CNCs can be fully dehydrated under low-pressure, high-temperature conditions ($\leq 0.04\%$ water content at 1 mbar, 110°C), TEMPO-modified CNCs retain significantly more water (1–7 wt%, depending on pressure). The presence of charged carboxylate groups and their associated counterions enhances water retention through strong electrostatic interactions, making complete dehydration nearly impossible under typical drying conditions.

Experimental drying studies of TEMPO-modified CNC foams confirm these findings, with excellent agreement between simulated and measured water content. These results highlight the necessity of considering residual bound water in modified CNCs for moisture-sensitive applications and suggest that similar behavior can be expected in other chemically charged cellulose materials.



Q33.2 – Nanoscale wetting of cellulose substrates

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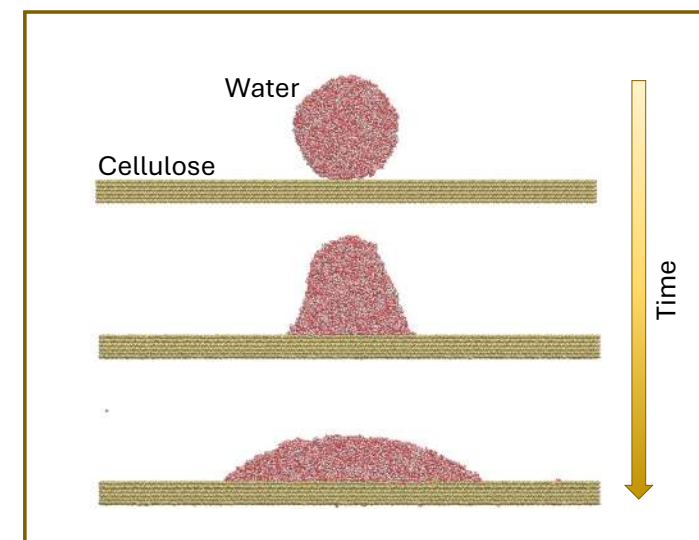
The interaction between cellulose and water is of huge importance both from a fundamental point of view, such as the function and properties in the hydrated plant cell wall, as well as in most practical applications involving cellulose-based materials. Cellulose's chemical structure leads to its surfaces having a high density of available hydroxy groups, ideal for making favorable interaction with water molecules.

One way to characterize solid-liquid interactions is through the concept of contact angles computed from simulation. In contrast to experimentally determined contact angles, they do not suffer from uncertainties due to poorly characterized substrates but are on the other hand sensitive to choice of simulation protocol and models.¹

We use molecular dynamics (MD) to study nanoscale wetting of cellulose by simulating how nanodroplets spread on cellulose substrates (Figure 1) that differ in structure (hydrophilic and hydrophobic crystal planes) and chemical composition

(native and surface modified). Both equilibrium contact angles and the wetting dynamics are characterized. Important methodological considerations are discussed.

Figure 1. A nanosized ($r = 5$ nm) water droplet spreading on the hydrophobic plane of native cellulose



1. A. Sridhar, L. A. Berglund, and J. Wohlert (2023) Wetting of native and acetylated cellulose by water and organic liquids from atomistic simulations. *Cellulose*, 30:8089-8106

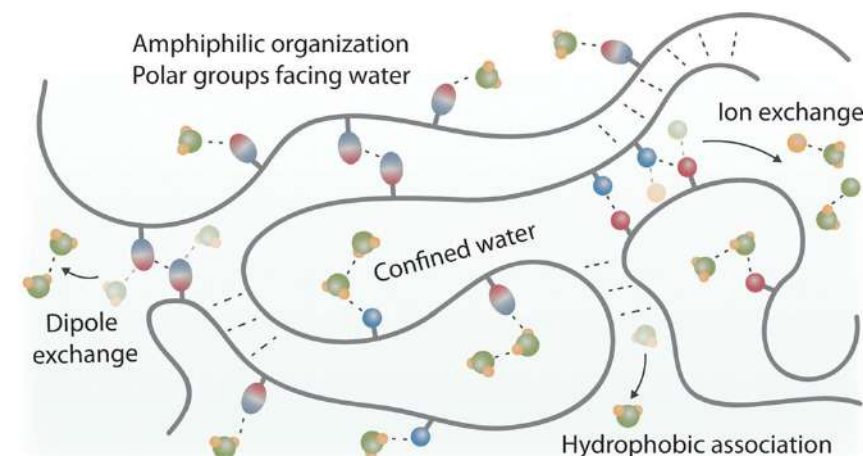
Q33.3 – Entropy-driven polymer association explained by charge-exchange and amphiphilic assembly

Tobias Benselfelt*, Jakob Wohler, Mahiar Hamedi, Lars Wågberg

The Department of Fibre and Polymer Technology, KTH Royal Institute of Technology, Stockholm, Sweden

Hydrogen bonding has been used to explain the associative behavior of synthetic and natural polymers in water. Although hydrogen bonds may contribute to adhesion in condensed materials where water has been driven out, they are not the cause of initial association in more dilute systems. Instead, entropy-driven association mediated by the reorganization of water is becoming an established mechanism. However, classical mean-field theories and experiments lack the molecular resolution to describe this mechanism, and new models are needed to understand and exploit it. Molecular dynamics simulations have emerged as an essential tool to provide such details. This contribution describes the scientific journey of exploring polymer association in water and our contribution, from our early investigation of xyloglucan adsorption onto cellulose [1][2] to a more recent general mechanistic model that provides molecular details [3]. The mechanistic model consists of two simple driving forces: charge exchange and amphiphilic assembly. It seems to be able to explain most polymer systems in water and likely other solvents.

The general principle is to stop looking at the chemistry of the polymers and the electrostatic or electrodynamic bonds they may form and instead focus on what water is doing, because water can form the same bonds. The figure below outlines some behaviours of water and how they dictate polymer association.



[1] Benselfelt, T., Cranston, E. D., Ondaral, S., Johansson, E., Brumer, H., Rutland, M. W., & Wågberg, L. (2016). Adsorption of xyloglucan onto cellulose surfaces of different morphologies: an entropy-driven process. *Biomacromolecules*, 17(9), 2801-2811.

[2] Kishani, S., Benselfelt, T., Wågberg, L., & Wohler, J. (2021). Entropy drives the adsorption of xyloglucan to cellulose surfaces—a molecular dynamics study. *Journal of colloid and interface science*, 588, 485-493.

[3] Benselfelt, T., Cinar Ciftci, G., Wågberg, L., Wohler, J., & Hamedi, M. M. (2024). Entropy drives interpolymer association in water: Insights into molecular mechanisms. *Langmuir*, 40(13), 6718-6729

Q33.4 – Modelling the properties of water in cellulose nanoconfinement

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Bound, hard-to-remove water is a persistent feature across the entire cellulose value chain, from plant cell walls through pulp to paper and advanced cellulosic products. The presence of this water population on the internal surfaces of the cellulose fibril aggregate has been shown to contribute to the stability of the aggregate.[1]

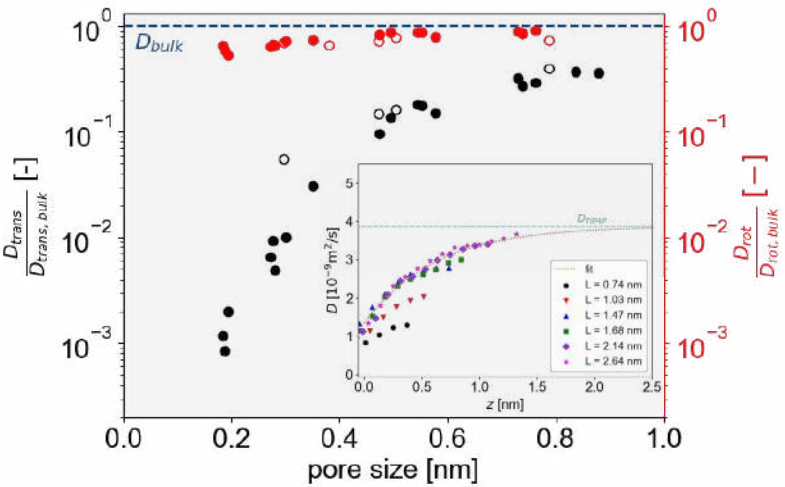
Atomistic simulations offer spatial and temporal resolution beyond what is available experimentally. In this study, the confined water in cellulose fibril aggregates is studied by molecular dynamics simulations, to understand in what ways, and to what extent its properties are different from that of bulk water. Simulations of the fibre pullout in the fibril aggregate help connect these microscale observations to macroscale properties.

Our results highlight that the translational dynamics of water confined in cellulose are highly dependent on the pore size.[2]

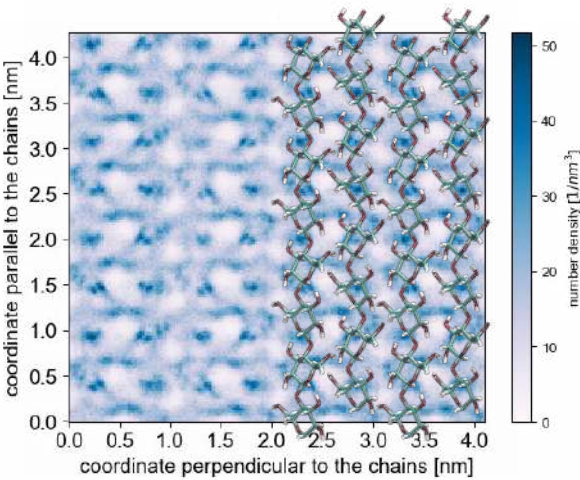
Rotational motions, on the other hand, are significantly less hindered, and in both cases it is shown that the slowing down is more prominent near the confining walls. Investigating the structure of the water we also find that in confinement, it attains a nanoscale periodic structure, which corresponds to the regularity of the confining surfaces. Characteristic fluctuations of the shearing force between two parallel fibrils are related to this structuring.

[1] Chen, P.; et al. J. Phys. Chem. Lett. 2022, 13 (24), 5424–5430.

[2] Lelik, A.; et al. J. Phys. Chem. B 2025, 129 (47), 12348–1235



Diffusion coefficients of water in cellulose as a function of pore size and distance from the surface z (inset)



Local water density variation across the cellulose surface

Q33.5 – MOLECULAR INSIGHTS INTO CELLULOSE NANOCRYSTALS INTERACTIONS AND SWELLING WITH CATIONIC AND ANIONIC FUNCTIONALIZATION

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¹KTH Royal Institute of Technology, Department of Fiber and Polymer Technology, School of Engineering Sciences in Chemistry, Biotechnology and Health, Teknikringen 56, SE-100 44 Stockholm, Sweden

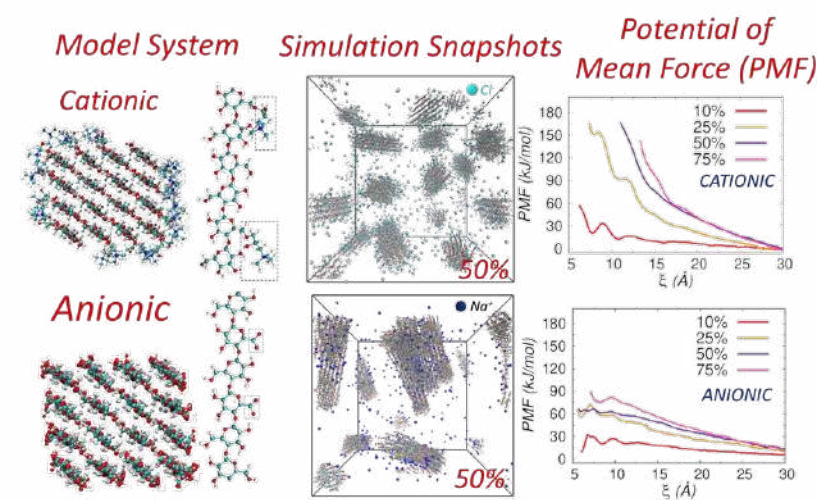
²Department of Chemical Engineering, Birla Institute of Technology and Science (BITS), Pilani Campus, Vidya Vihar, Pilani, Rajasthan 333031, India

³Linköping University, Campus Norrköping, Department of Science and Technology (ITN), Laboratory of Organic Electronics (LOE), Bredgatan 33, SE-60174 Norrköping, Sweden

Cellulose-based materials are widely explored for applications such as in hydrogels, biomedical scaffolds, and superabsorbent materials, where the degree of swelling strongly influences the transport properties, mechanical stability, and therefore the overall functionality. Surface functionalization alters the interactions between the Cellulose nanocrystals (CNCs) and therefore provides a route to control swelling. Experimental studies have consistently reported that cationically modified CNCs swells more than their anionic counterparts at comparable charge densities. The molecular mechanisms responsible for their asymmetric behavior remains insufficiently understood.

In the current work, Molecular dynamics (MD) simulations are used to study how varying the degree of functionalization influence the CNC swelling behaviour in aqueous environments. CNCs were functionalized with cationic trimethylammonium and anionic carboxylate groups to study how inter CNC interactions are affected.

The simulation results show larger interparticle separation and complete dissociation of the CNCs for cationically functionalized systems at higher surface charge density as compared to the anionic system. Potential of mean force (PMF) reveal repulsive interactions for both cationic and anionic CNCs due to the structured bound water layers between them. Further, anionic system show a more compact arrangement due to the counterion association near the CNC which is less pronounced in cationic counterpart as result of the bulky cationic side groups.



Garg, M., Linares, M., & Zozoulenko, I. (2020). Theoretical rationalization of self-assembly of cellulose nanocrystals: Effect of surface modifications and counterions. *Biomacromolecules*, 21, 3069–3080.

Sjöstedt, A., Wohler, J., Larsson, P., & Wågberg, L. (2015). Structural changes during swelling of highly charged cellulose fibres. *Cellulose*, 22.

Q33.6 – Efficient production of tough cellulose nanopapers via filtration from ethanolic suspensions

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³Institute of Environmental Biotechnology, University of Natural Resources and Life Sciences, Vienna, Austria

⁴Institute of Materials Chemistry and Research, University of Vienna, Austria

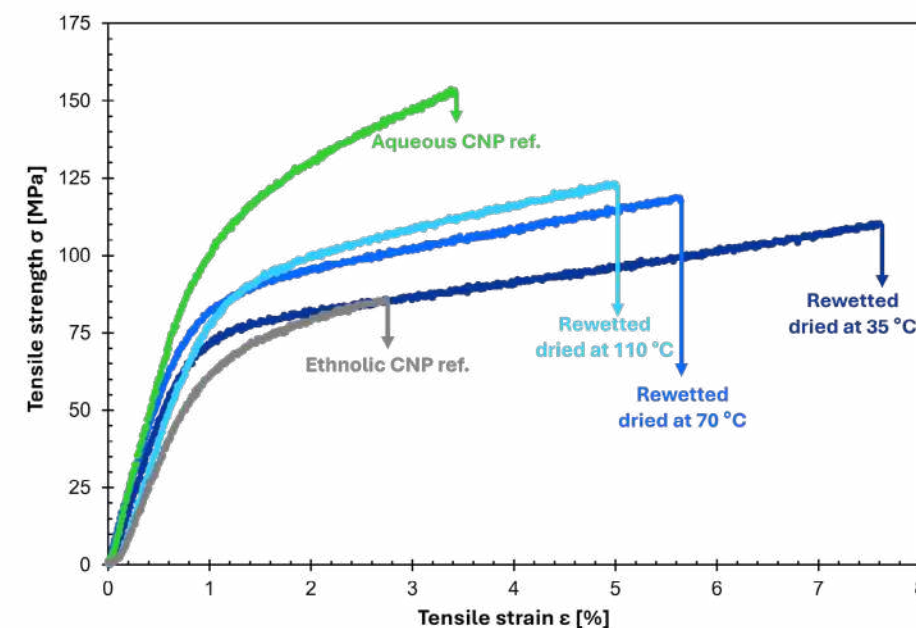
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One key set of materials in the quest for green and renewable engineering materials with outstanding mechanical and optical properties can be found in the form of freestanding films of cellulose nanofibres (CNF), often termed cellulose nanopapers (CNP).

Unfortunately, due to their hygroscopic nature, and nanoscale dimensions, the filtration of CNF during CNP production is slow and energy intensive. Substituting water for an ethanolic suspension medium during filtration resulted in a drastic reduction (73 %) of the filtration times. The lower surface tension of an ethanolic suspension medium however, yields CNPs with increased porosity¹ and thus, reduced transparency and mechanical properties.

A simple a simple post processing procedure consisting of rewetting and drying the CNPs at different temperatures was developed to combat the negative aspects of using non-aqueous suspension media, resulting in an up to 167 % (2.8 % to 7.5 %) increase in the strain to failure of the rewetted nanopapers, outperforming CNPs directly prepared from aqueous suspensions (3.3 %), while sacrificing less than 20 % of their tensile strength.

Additionally, the rewetting and drying post-processing, resulted in nanopapers with high haze, and higher total luminous transmittance than CNPs prepared directly from aqueous suspensions.



1. Ferguson, A., Khan, U., Walsh, M., Lee, K. Y., Bismarck, A., Shaffer, M. S., Coleman, J. N., & Bergin, S. D. (2016). Understanding the Dispersion and Assembly of Bacterial Cellulose in Organic Solvents. *Biomacromolecules*, 17(5), 1845-1853.

Q33.7 – Cellulose-based nanocomposite films reinforced with nano clay for enhanced packaging performance

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Polymer Synthesis Technology,
Department of Chemical and
Metallurgical Engineering, Aalto
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The development of biobased alternatives to conventional plastic packaging is crucial in addressing growing environmental concerns about plastic pollution. Herein, we report a novel approach to enhance the performance of cellulose-based packaging films by chemically modifying microcrystalline cellulose (MCC) with octadecanoic acid (MCCC18) and reinforcing it with surface-modified nanoclay. The homogeneous grafting of octadecanoic acid onto MCC achieved a high degree of substitution (2.2), imparting intrinsic hydrophobicity to the cellulose matrix. Transparent composite films were fabricated via solvent casting by incorporating varying amounts (1, 3, or 5 wt%) of nanoclay.

Remarkably, the composite with 3 wt% nanoclay exhibited an optimized balance of properties, including a 26 % reduction in oxygen transmission rate (OTR), a 48 % decrease in water vapor transmission rate (WVTR), significant improvement in tensile strength and modulus, and a contact angle exceeding 100°, all while retaining high optical transparency (~85 %). These results demonstrate, for the first time, that the synergistic combination of long-chain fatty acid grafting and nanoclay reinforcement can simultaneously enhance barrier, mechanical, and hydrophobic properties of cellulose-based films.

The MCCC18/nanoclay composites represent a promising biobased alternative for sustainable packaging applications, potentially replacing petroleum-derived plastics.



1. Ashish Chahal, Hossein Baniasadi, Jukka Niskanen, Cellulose-based nanocomposite films reinforced with nano clay for enhanced packaging performance, Industrial Crops and Products, Volume 237, 2025, 122248, ISSN 0926-6690, <https://doi.org/10.1016/j.indcrop.2025.122248>

Q33.8 – Fractionation of Hemp Shives to Lignin containing- microfibrillated Cellulose Films for Active Packaging

Avinash K. Pai¹, Joseph S. M
Samec, Aji Mathew

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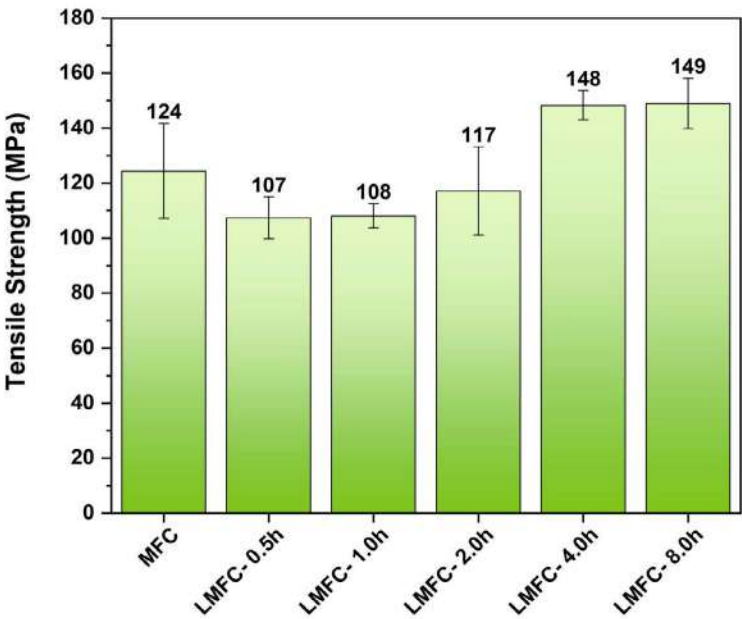
¹Department of Chemistry,
Stockholm University, 106 91
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Hemp, a herbaceous plant widely cultivated for fiber production across EU is well know for its environmental and sustainability benefits. However after fiber extraction process, hemp shives which constitutes 70% of the crop is still under utilized for low value or burnt for energy. Valorization of hemp hurds to high value products viz. biocomposites, specialty papers for packaging will create a huge impact on its mass cultivation and open up new markets.

Herein, we performed a organosolv pulping of hemp shives with a biomass sourced acid at varying reaction times from 0.5h to 8.0h. The pulp containing residual lignin was passed through a high pressure microfluidizer for a total of 8 passes. The resultant gels were vacuum filtered and hot pressed at 100°C to form flexible L-MFC films.

Retaining lignin on cellulose fiber has been explored mainly to improve the mechanical properties, thermal stability & hydrophobicity¹. Nonetheless, foldability of these L-MFC films is a challenge that needs to be addressed. In this work, we could achieve a highest tensile strength of 149 MPa at a film thickness of 40-50µm and good fold retainability. The maximum young's modulus and elongation @ break of LMFC films was found to be 4,43 GPa and 9,25%.

It is noteworthy at certain residual lignin content, L-MFC films exhibited higher tensile strength than pristine MFC films (2 times bleached). From LCA point of view, the exclusion of bleaching step will have a positive impact on multiple impact categories.



Foldability of L-MFC film and translucency at varying lignin content.



1. Li, H., Kulachenko, A., Mathew, A. P., Stoltz, R. B., & Sevastyanova, O. (2023). Enhancing the strength and flexibility of microfibrillated cellulose films from lignin-rich kraft pulp. ACS Sustainable Chemistry & Engineering, 11(47), 16793-16805.

Q33.9 – MAPPING WHEAT STRAW DELIGNIFICATION AND FIBERS LIBERATION USING OPTOTRACING IN A ONE-STEP PERACETIC ACID PROCESS

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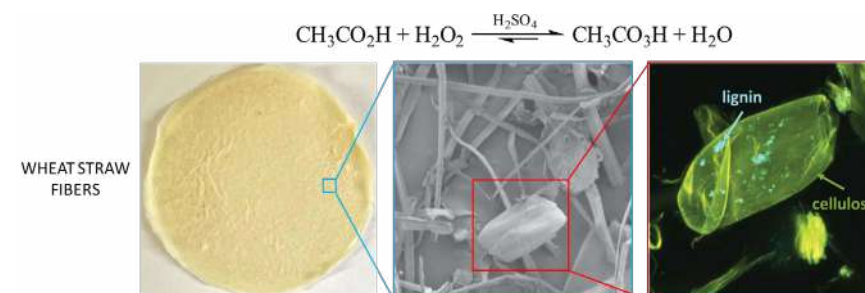
Diversification of lignocellulosic fiber sources is essential to produce more bio-based materials and reduce the current pressure on forest-origin lignocellulose. Wheat is the second most produced grain in the world and the residual straw represents a highly available feedstock of fibers that must be considered.

In this study, a one-step peracetic acid (PAA) treatment was investigated for partial delignification of wheat straw fibers while preserving most hemicelluloses. Sulfuric acid was used as a catalyst to improve the process and fiber liberation was achieved at sulfuric acid concentrations as low as 50 mM. The liberation is controlled by the primary removal of acid-soluble lignin and arabinose, as shown by UV-visible spectroscopy and anion exchange chromatography.

Advanced imaging approaches, including scanning electron microscopy, confocal fluorescence microscopy, and optotracing, were used to map and visualize the delignification process at sub-cellular resolution. The images highlighted the heterogeneity of the process due to the straw structure and revealed that residual lignin can persist in the epidermal and parenchyma cell layers, limiting the

These observation demonstrate the need for an adapted process for each biomass and encourage for a better understanding of the cell structure of the biomass to find the most suitable process.

The recovered holocellulose fibers display sufficient structural integrity to form self-standing paper-like sheets with a water contact angle of 52° and are ready to use for further studies and applications for material production.



Rivière G. N., Hammar H., & Edlund U., (2026) Efficient Delignification Pathways in a One-Step Peracetic Acid Process, 242, 112907 <https://doi.org/10.1016/j.indcrop.2026.112907>.

Q33.10 – Citrus fiber-based edible films for sustainable food packaging applications

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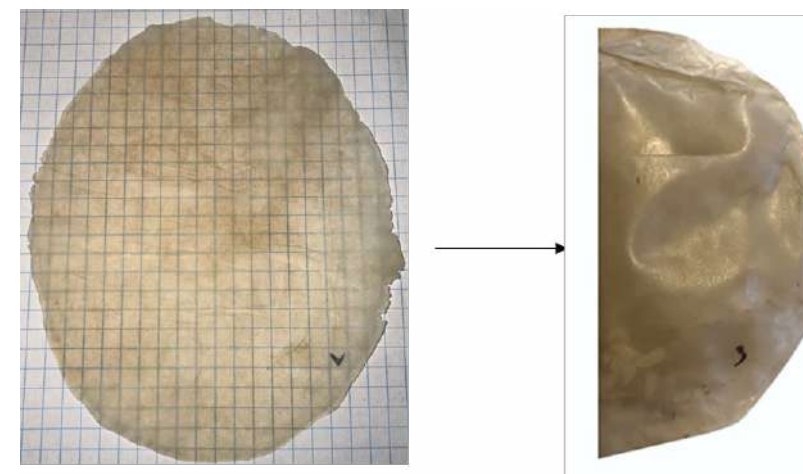
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The modern food packaging industry faces the challenges of meeting growing consumer demands for convenience, safety, and long shelf life while simultaneously minimizing environmental impact. The widespread use of plastic packaging materials has raised serious concerns regarding their end-of-life management, including persistent waste, limited recycling rates, and long-term environmental pollution. As regulations are becoming stricter and consumer awareness increases, the search for sustainable, functional, and cost-effective alternatives in food packaging has become a priority. Biopolymer-based materials have attracted significant attention as sustainable substitutes for conventional plastics. In particular, edible packaging represents an innovative approach to food packaging, as it can serve as protective barrier while also being safely consumed together with the product, thereby eliminating packaging waste.

The present research focuses on the development of edible films from citrus fibers and biopolymers for food packaging applications.

Thin films with thickness less than 100 μm can be produced providing sufficient mechanical strength and exhibiting oxygen and moisture barrier properties comparable to conventional fossil-based plastics, while maintaining shelf-life performance suitable for food packaging applications. At the same time, these films are produced from food-grade materials and are fully consumable, offering a truly sustainable alternative to conventional plastic packaging.



Q34.1 – Solvent-Tuned Charge Transport in PEDOT:Tos: Experiments and Machine Learning

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³Univ. Lille, CNRS, Lille, France

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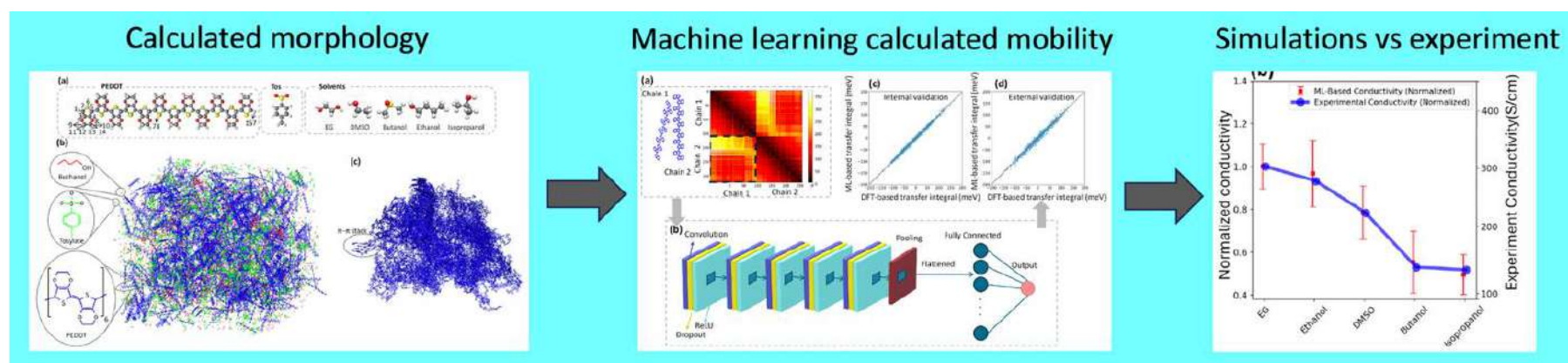
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We investigate how solvent post-treatment affects the morphology and charge transport of PEDOT:Tos thin films using a combined experimental and computational approach. Electrical measurements, GIWAXS, and XPS show that conductivity variations arise primarily from solvent-induced mobility changes rather than differences in oxidation level.

To quantitatively link morphology to transport, we integrate molecular dynamics, density functional theory, and multiscale

modeling with a machine learning framework that predicts transfer integrals directly from structural descriptors. The ML-assisted approach dramatically accelerates mobility calculations while accurately reproducing experimental trends.

This work demonstrates how combining experiments with machine learning-enabled modeling provides predictive insight into structure–property relationships in conducting polymers.



Zahabi, N.; Petsagkourakis, I.; Rolland, N.; Beikmohammadi, A.; Liu, X.; Fahlman, M.; Pavlopoulou, E.; Zozoulenko, I. Deciphering Conductivity in PEDOT Guided by Machine Learning: From Solvent Baths to Charge Paths. *Phys. Rev. Mater.* **2025**, 9 (10), 105402. <https://doi.org/10.1103/5h7d-yvvd>.

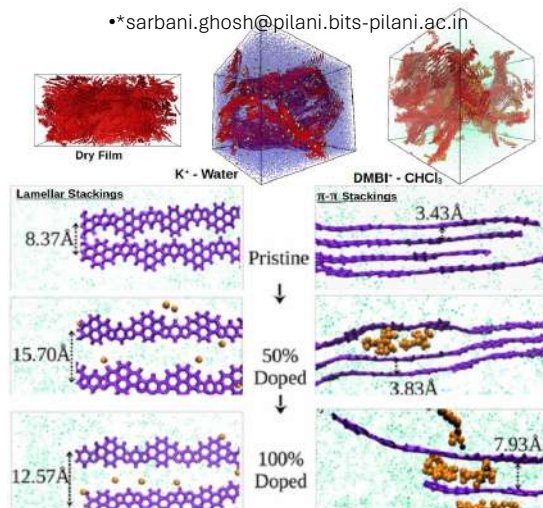
Q34.2 – Microscopic Insights of Swelling of an n-Type Organic Mixed Ionic-Electronic Conductor, BBL

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Mohit Garg¹, Igor Zozoulenko²

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Structural phase transition of BBL during electrochemical switching

•The ladder-type benzimidazobenzophenanthroline (BBL) polymer is one of the most important and most studied n-type conducting polymers and also an organic mixed ion-electron conductor (OMIEC), which can undergo electrochemical switching in electrolyte solutions by accommodating opposite ions. Electrochemical switching of OMIECs involves complex coupling between ionic uptake, solvent uptake, and polymer structural rearrangements that critically influence charge transport. However, molecular-level insights into the dynamic structural changes during electrochemical switching remain limited experimentally, despite their critical role in governing charge transport through morphology-dependent π - π stacking networks and ionic pathways.

•Theoretically, using molecular dynamics simulations, we systematically examine the effects of reduction level, counterion species (K^+ and $DMBI^+$)¹, and electrolyte molarity on polymer morphology, ion–water interactions, and film swelling.

•The simulations reveal that reduction-induced charge compensation drives counterion and water uptake, leading to significant conformational changes in the polymer chains and restructuring of the film morphology. The extent of swelling is strongly modulated by electrolyte molarity through changes in charge-screening length and counterion hydration, which alter chain conformations and pore formation within the film. Furthermore, the nature of the counterion influences π - π stacking interactions and crystallinity, thereby affecting electronic transport pathways.

•Our results provide microscopic insight into how electrolyte composition, salt concentration, and reduction state collectively govern swelling and structural organization in n-type conducting polymers, offering design guidelines for optimizing OMIEC device performance.

- ¹Sunny et al., *Macromolecules*, 2024, 57, 11, 5155–5165

Q34.3 – Purification matters: unlocking the intrinsic electrochemical properties of polymeric electrode materials

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Organic mixed ionic electronic conductors (OMIECs) can be carefully tailored to achieve desired electrochemical properties, yet they contain residual transition metals and organic impurities from their synthesis. These impurities can significantly influence their photophysical and electrochemical properties and provide electrocatalytic activity to an OMIEC despite the lack of binding sites, as has been demonstrated for presence of residual Pd in facilitating the 4e⁻ pathway in oxygen reduction reaction (ORR).[1]

Despite extensive synthetic purification efforts, these impurities often persist, complicating the determination of the polymers' fundamental characteristics and understanding of the design rules which underpin their function. Additionally, batch-to-batch variation in the molecular weight distribution further limits drawing comparisons of polymer performance to investigate the role of microstructure on charge transport properties across this class of conjugated polymers.

In this presentation, I will highlight the effectiveness of high-performance liquid chromatography (HPLC) in purifying a set of conjugated polymers designed for electrochemical applications (bioelectronics, electrosynthesis and electrocatalysis). By lowering metal traces and removing other side products remaining from synthesis, the intrinsic properties of polymers can be investigated. We fractionate polymeric OMIECs based on hydrodynamic volume and find that higher molecular weight polymers exhibit enhanced electrochemical stability during continuous operation in combination with improved charge transport properties.

This work underscores the necessity of improving purification methods for OMIECs to better understand the chemical design rules that dictate their performance, as standardization of these materials paves the way for more thorough investigation of their intrinsic properties. We thank ERC project 10111607 for supporting this study.

[1] De La Fuente Durán, A, *et. al*, Energy Environ. Sci., 2023,16, 5409-5422

Q34.4 – Improving OECT Performance and Reproducibility via Aggregation-Assisted Purification of Conjugated Polymers

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Compared with inorganic semiconductors, the development and commercialization of organic semiconducting polymers (OSCs) as materials for next-generation bioelectronic devices are limited by batch-to-batch variations and performance differences arising from molecular weight effects. Despite OSCs presenting important advantages, such as mechanical flexibility, synthetic tunability, and solution processability^{1,2}, one of the critical challenges is their purity. Impurities left over from synthesis, such as heavy metal ions or low-molecular-weight chains, negatively impact electronic charge transport and long-term stability. When employed in bioelectronic devices, leakage of heavy metal ions left in the polymer can harm biological systems and cells. Traditional purification techniques, such as Soxhlet extraction³ and metal scavenging,⁴ are often ineffective in removing chemical side products left over from synthesis, making it difficult to study the intrinsic properties of the materials. Therefore, developing complementary purification techniques to remove these side products is crucial in achieving reproducible and safe bioelectronic devices.

In my talk, I will describe how high-performance liquid chromatography (HPLC) improves the purity of polymeric n-type OSCs. HPLC fractionation allows separation based on hydrodynamic volume, making it possible to narrow the molecular-weight distribution and to selectively remove low-molecular-weight chains as well as metal residues. OSCs based on naphthalene-1,4,5,8-tetracarboxylic-diimide-bithiophene (NDI-T2) achieve improved electronic charge transport properties in organic electrochemical transistors (OECTs) and fewer batch-to-batch variations in device performance and stability.

We thank the ERC project number 10111607 for financial support for this study.

1. Paulsen, B.D., Tybrandt, K., Stavrinidou, E. *et al.* (2020). Organic mixed ionic–electronic conductors. *Nat. Mater.* **19**, 13–26.
2. Yu, S., Kousseff, C. J., Nielsen C. B. (2023). n-Type semiconductors for organic electrochemical transistor applications. *Synthetic Metals*, **293**, 117295.
3. Liu, J., Loewe, R. S., McCullough, R. D. (1999). *Macromolecules*, Employing MALDI-MS on Poly(alkylthiophenes): Analysis of Molecular Weights, Molecular Weight Distributions, End-Group Structures, and End-Group Modifications **32**, 18, 5777–5785.
4. Kuwabara, J., Yasuda T., Takase N., Kanbara T. (2016) Effects of the Terminal Structure, Purity, and Molecular Weight of an Amorphous Conjugated Polymer on Its Photovoltaic Characteristics. *ACS Appl. Mater. Interfaces*, **8**, 3, 1752–1758

Q34.5 – Biobased antifatigue organohydrogel with superior ionic conductivity enabled by lignin nanostructures

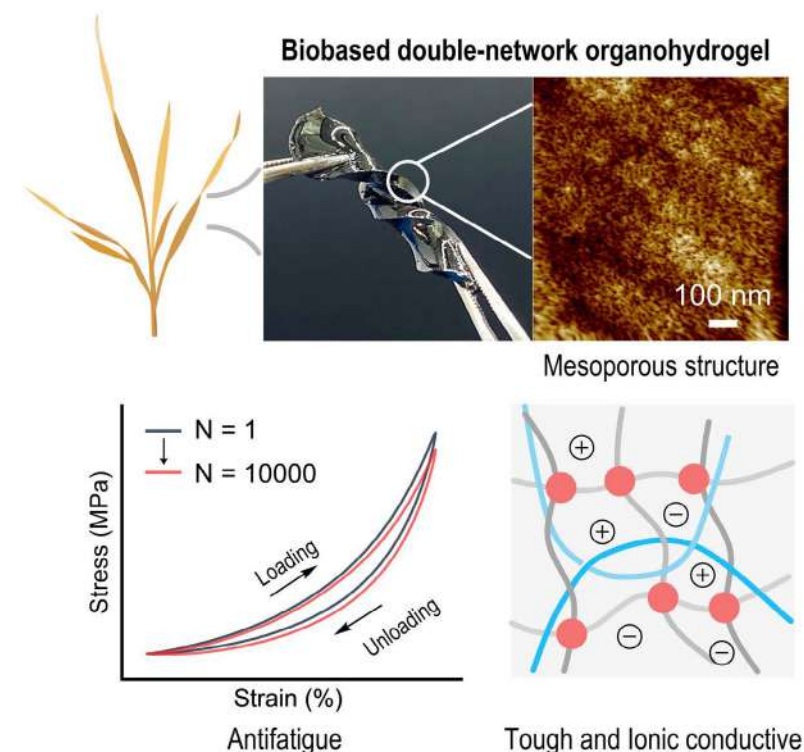
Vu Thanh Truong¹, Matilda Andersson^{1,2}, Alexandros E. Alexakis¹, Mika H. Sipponen^{1,2*}

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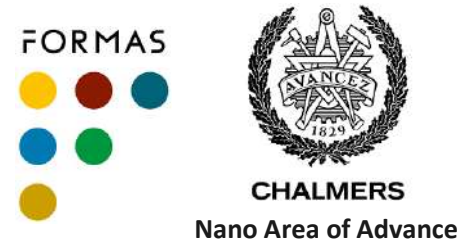
Organogels that exhibit efficient mechanical energy dissipation, high mechanical robustness, long-term durability, and outstanding ionic conductivity are promising for flexible electronic devices, yet integrating these attributes into a single material remains an outstanding challenge. Here, we present a biobased double-network organohydrogel synthesized via mild, catalyst-free crosslinking of lignin acetoacetate (LA) in Cyrene-water solvent mixture. The crosslinked LA network serves as the primary reinforcing component, generating a mesoporous structure that simultaneously enables efficient deformation, energy dissipation, and ionic conductivity. This architecture endows the organohydrogel with exceptional mechanical strength, antifatigue under repeated loading, and stable damping capacity at broad temperature and frequency range. As a resistive compression-type sensor, the organohydrogel responds to varying strain levels with consistent and reliable sensitivity. Overall, this family of biobased organohydrogels surpasses fossil-based counterparts and offer strong potential for next-generation flexible electronics.



Q34.6 – Advanced Bio-Based Materials Enabled by Graphene and Conjugated Polymers for building material and Energy Storage

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This project is financed by



The transition toward sustainable materials is essential for reducing the environmental impact of both the construction sector¹ and energy storage technologies².

Natural fibers such as cellulose and other lignocellulosic fibers are promising for lightweight and sustainable building cement composites. However, their compression strength performance and durability often limit broader structural applications¹. In this study, thin graphene coated biofiber cement showed improved compression strength compared to without the coating. Graphene also provide additional functionalities such as barrier performance and electrical conductivity, supporting the development of advanced multifunctional smart building materials.

Sample	Strength to break [MPa] (7days)	Strength to break [MPa] (28days)
Ref. cement	48	61
Cellulose 9% in cement	23	25
Graphene coated Cellulose 9% in cement	26	33

In parallel, lignin was investigated as a sustainable redox-active component for aqueous zinc battery electrodes. To overcome the intrinsically low conductivity of lignin, it is physically incorporated with the n-type conducting polymer. In addition, different bio-based dopants are evaluated for tune its doping level to facilitate zinc ion transfer for energy storage. This strategy enables a more sustainable approach to zinc battery electrode design by combining biomass-derived redox chemistry with conductive polymer engineering.

By integrating bio-derived materials with graphene and conductive polymer, this work demonstrates a promising route toward multifunctional, low-carbon materials for future building technologies and energy storage systems.

1. Singh, A., Yadav, B.P. Sustainable innovations and future prospects in construction material: a review on natural fiber-reinforced cement composites. *Environ Sci Pollut Res* **31**, 62549–62587 (2024)
2. Yi Huang, Wei Liu, Chenxiao Lin, Qingxi Hou, Shuangxi Nie, Advances in application of sustainable lignocellulosic materials for high-performance aqueous zinc-ion batteries, *Nano Energy*, Volume 123, 2024, 109416,

Q34.7 – Fibre contaminants classification in electric vehicle battery pack systems

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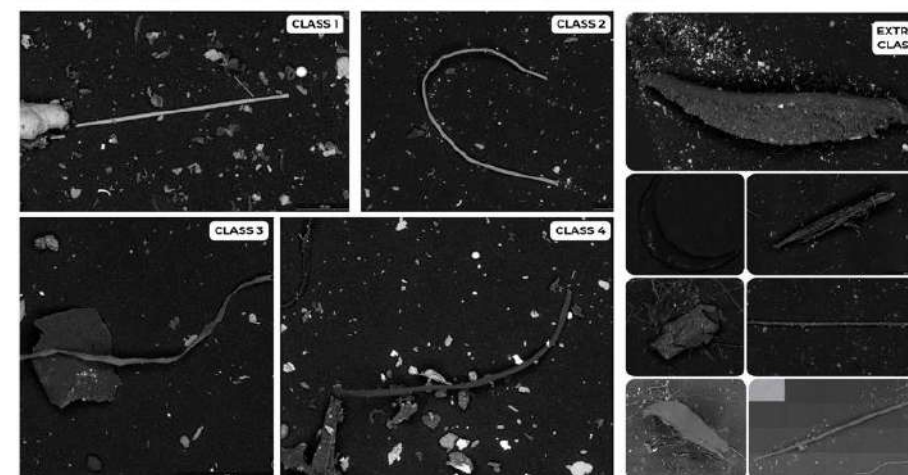
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Technical cleanliness is critical for various systems, e.g. fuel systems in engines, battery modules and packs, etc. Fibres (including hair contamination) and particles (metallic/non-metallic) can bridge gaps, alter local conductivity, and trigger internal short circuits, especially under humidity and temperature variation. Standards such as ISO 16232 and the VDA 19 framework guide cleanliness assessments. Fibrous/hair contamination is very difficult to control during production/assembly, and strict specifications from OEMs may require entire production/assembly to be conducted in controlled areas or even cleanrooms, thus increasing overall product costs. Understanding fibre-/hair-related damage mechanisms is crucial to creating balanced cleanliness specifications. Our initial study (SEM/EDS, optical) on materials and particle-trap samples indicates recurring fibre classes (e.g., SiC-like stiff fibres, PVC-like flat fibres, polymeric twisted fibres) and co-contaminants (Al, Si, P, Zn).

In this contribution, we present the protocols and strategies we have developed to characterise the detected contaminants, including guidelines for sample preparation, data collection, and processing to classify the pollutant fibres.

The five classes of fibre/contaminant we found



Q34.8 – Functional Polymers for Interphase Engineering of Zinc Anode for Stable Aqueous Zinc Ion Batteries

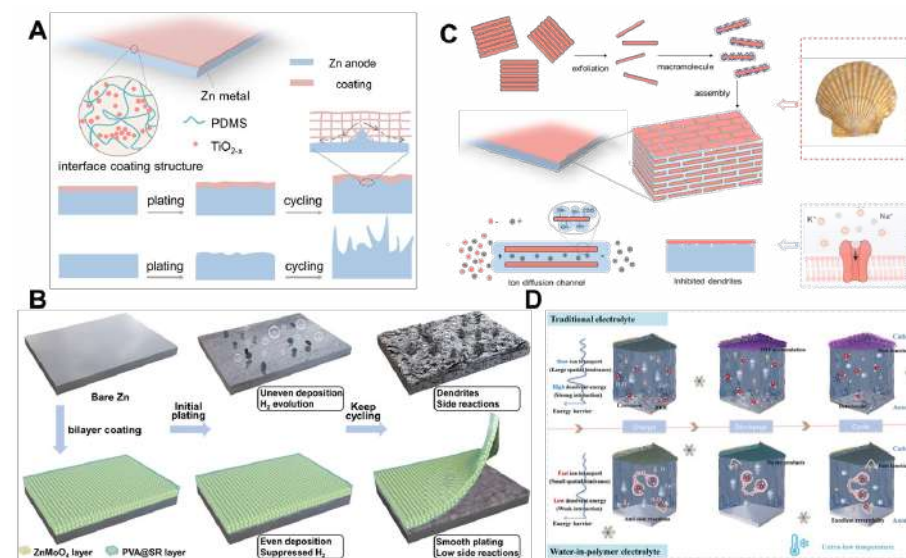
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Aqueous zinc ion batteries (AZIBs) have emerged as promising energy-storage systems owing to their intrinsic safety, low cost and the abundance of zinc resources. However, the practical application of AZIBs remains limited by dendrite growth, corrosion, and parasitic side reactions at the zinc anode. Here, we employ functional polymers to regulate the interfacial electrochemical behavior of zinc anodes including dynamic and self-adapting interphase¹, double-layer design², bioinspired architecture³, and *in situ* gelation⁴ (Figure 1). These polymer-based approaches effectively modulate Zn plating/stripping, suppress corrosion and side reactions, and improve the cycling stability of zinc anodes, enabling long-life AZIBs.

Figure 1. Polymers strategies. (A) Dynamic and self-adapting¹. (B) Double-layer design². (C) Bioinspired architecture³. (D) *In situ* gelation⁴.



1. Y Zhang*, et al. (2022). A dynamic and self-adapting interface coating for stable zn-metal anodes. *Advanced Materials*, 34(2): 2105133.
2. Y Zhang*, et al. (2023). Multifunctional SEI-like structure coating stabilizing Zn anodes at a large current and capacity. *Energy & Environmental Science*, 16(1): 275-284.
3. Y Zhang*, et al. (2025). Ultrastrong bioinspired “brick-and-mortar” artificial SEI for dendrite-free Zn anode. *Matter*, 8(11): 102269.
4. Y Zhang*, et al. (2025). Lean-water gel electrolyte enables zinc ion battery at $-70\text{ }^{\circ}\text{C}$. *Angew. Chem. Int. Ed.*, 64(47): e202511520.

Q34.9 – Single-step electrografting of copolymer electrolytes with enhanced mechanical integrity for separator-less structural sodium batteries

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Electrografting sodium-based solid polymer electrolytes presents a promising strategy for electrochemically enhanced separator-less structural and solid-state batteries. Previous work has shown electrografting to be a scalable, single-step method for forming homopolymer electrolyte coatings.¹ While the resulting chemisorbed ultrathin layers offer electrochemical advantages, sufficient mechanical strength is required to maintain both physical and electrical separation between electrodes.

Here, we investigate electrografted copolymer SPEs formed from monofunctional (M) and bifunctional (B) PEG-acrylates coated onto carbon fibres. Three copolymer compositions are examined and compared with homopolymer-coated and pristine fibres. The copolymer coatings exhibit improved mechanical robustness while remaining ultrathin, flexible, and ionically conductive, enabling fibre handling while introducing minimal system resistance and maintaining electrode separation in half-cell configurations against sodium metal.

An electrochemical threshold is observed at a monomer ratio of 1B:2.3M, where the added SPE resistance significantly suppresses electrochemical performance. In contrast, lower B contents of 1B:3.6M and 1B:7.7M maintain electrochemical performance comparable to pristine fibres, indicating negligible additional resistance from the copolymer SPE. Post-cycling analysis shows that the coatings remain intact within the 0.01-2 V vs Na/Na⁺ potential window. Further, the C-C bond between the fibre surface and the SPE is stable within a voltage window of 0.01-4 V vs Na/Na⁺.

These results demonstrate that electrografted PEG-acrylate copolymers provide ultrathin SPE coatings with improved mechanical robustness without compromising electrochemical performance, offering a scalable strategy for separator-less structural and solid-state battery architectures.

1. Lind, E., Nieboer, V., Cattaruzza, M., Johansson, M., Odelius, K., Zenkert, D. and Lindbergh, G., (2026). Electrografting solid polymer electrolytes for separator-less structural sodium batteries. *EES Batteries*.

Q34.28 – Nanocellulose Surface Chemistry Controls ZIF-8 Nucleation and Interfacial Mechanics in Hybrid Networks.

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Hybrid materials combining metal-organic frameworks (MOFs) with nanocellulose have attracted growing interest due to their potential in sustainable membranes, separations, and energy applications.¹ However, the mechanisms governing MOF-nanocellulose interaction remain poorly understood, particularly regarding the role of surface chemistry and interfacial interactions. In this work, we investigate the assembly of zeolitic imidazolate framework-8 (ZIF-8) in the presence of cellulose nanofibers with different surface chemistries, namely native cellulose nanofibers (CNF) and phosphorylated cellulose nanofibers (PCNF). The formation of CNF–ZIF-8 hybrids was studied using high-resolution scanning electron microscopy (HRSEM), X-ray photoelectron spectroscopy (XPS), and atomic force microscopy (AFM) through colloidal probe and nanomechanics supported with other characterization.

Distinct morphologies and bonding were identified depending on the nanocellulose surface chemistry, leading to variations in ZIF-8 particle size and anchoring mechanisms. Nanomechanical analysis reveals that PCNF possesses a higher intrinsic stiffness (10.8 GPa) than CNF, whereas the CNFZIF8 hybrid exhibits stronger mechanical reinforcement (5.3 GPa) compared with PCNFZIF8 (3.1 GPa). AFM force spectroscopy further shows a time-dependent increase in adhesion in the CNF system, driven by displacement of interfacial water that facilitates interaction via hydrogen bonding and the hydrophobic effect. In contrast, the high charge density of PCNF creates a robust hydration shell that acts as a repulsive barrier, limiting accessibility and interfacial stress transfer. These findings reveal that hybrid reinforcement is not dictated by intrinsic fiber stiffness but rather by intermolecular interfacial forces governing stress transfer at the nanoscale.

¹Abdelhamid, H. N.; Mathew, A. P. Cellulose–Metal Organic Frameworks (CelloMOFs) Hybrid Materials and Their Multifaceted Applications: A Review. *Coord. Chem. Rev.* **2022**, 451, 214263. <https://doi.org/10.1016/i.ccr.2021.214263>.

Q36.1 – Development of PHBV materials by combining experiments, modelling, and sustainability assessment

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This presentation describes the work done at **VTT Technical Research Centre of Finland** in development of **PHBV polymer materials with high 3-hydroxyvalerate content**. The work combines experimental work (spectroscopy, thermal degradation), molecular modelling, and environmental sustainability assessment.

To move towards a more sustainable world, one of the key aspects is to reduce the society's dependence on fossil-based plastics by moving to bioplastics. One of the most promising types of biopolymers are polyhydroxyalkanoates (PHAs). PHAs can be biosynthesized and they are often biodegradable.¹

One of the most important classes of PHAs are copolymers of 3-hydroxyvalerate and 3-hydroxybutyrate (PHBV).¹ PHBV is commercially available and has promising properties. However, the polymer tends to lose its mechanical properties over time, and its degradation temperature is close to its melting temperature.^{2,3} These features along with associated costs hinder the adaptability of PHBV and thus more development work is required.

The focus of the presentation is on experimental work on studying the effect of additives on the properties of PHBV as well as the thermal degradation of the polymers. The main tool has been nuclear magnetic resonance (**NMR**) spectroscopy, including diffusion ordered spectroscopy (**DOSY**). By combining spectroscopy and chromatography, the mechanism of degradation has been studied for different PHBV grades as well as related PHAs. The degradation proceeds through cis-elimination and unzipping. Polymers with lower crystallinity are more susceptible to thermal degradation. The modelling part has been utilizing molecular dynamics (**MD**) simulations, both for polymer-additive interactions and for thermal properties of the materials. The sustainability assessment employs life cycle analysis (**LCA**) and **circularity assessment**. The work follows the Safe and Sustainable by Design framework (**SSbD**).

Funding from EU Horizon project *Viable, safe and sustainable PHBV value chain for food packaging applications (ViSS)* is gratefully acknowledged.

1. Zhou, W.; Bergsma, S.; Colpa, D. I.; Euverink, G.-J. W.; Krooneman, J. Polyhydroxyalkanoates (PHAs) synthesis and degradation by microbes and applications towards a circular economy. *Journal of Environmental Management* **2023**, 341, 118033. DOI: 10.1016/j.jenvman.2023.118033. 2. Torabi, H.; Zarrin, H.; Behzadfar, E. Multiscale thermal degradation of PHAs: kinetic and rheological analysis across processing and decomposition regimes. *Rheol. Acta* **2025**. DOI: 10.1007/s00397-025-01538-3 3. Srubar, W. V.; Wright, Z. C.; Tsui, A.; Michel, A. T.; Billington, S. L.; Frank, C. W. Characterizing the effects of ambient aging on the mechanical and physical properties of two commercially available bacterial thermoplastics. *Polym. Degrad. Stab.* **2012**, 97 (10), 1922-1929. DOI: 10.1016/j.polymdegradstab.2012.04.011.

Q36.2 – CONTROLLING MICROSTRUCTURE AND MECHANICAL PROPERTIES OF POLYHYDROXYALKANOATES THROUGH INJECTION MOLDING PARAMETERS

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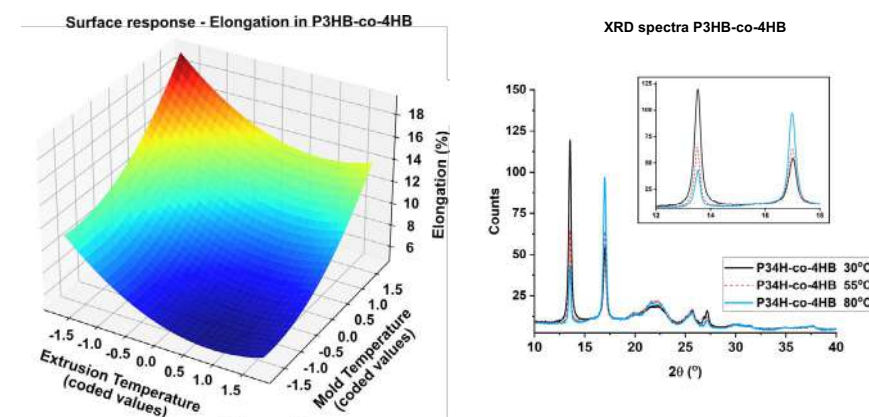
³Swedish Centre for Resource Recovery, Faculty of Textiles, Engineering and Business, University of Borås, Sweden

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Polyhydroxyalkanoates (PHAs) are a versatile family of biodegradable polyesters with strong potential to substitute conventional plastics in agricultural applications such as food packaging, films, and foams. However, melt processing of these polymers into final products remains challenging due to their generally low nucleation density and limited thermal stability¹.

This work investigates processing–structure–property relationships in two PHA polymers: poly(3-hydroxybutyrate) (PHB) and poly(3-hydroxybutyrate-co-4-hydroxybutyrate) (P3HB-co-4HB). The study is divided into two parts. First, a design-of-experiments (DoE) approach based on a rotational central composite design (RCCD) was implemented to model the effects of extrusion temperature, mold temperature, and cooling time in the mold on the tensile properties and crystallinity of the polymers. Response surfaces were generated using stepwise regression, revealing that mold temperature was the most influential parameter governing the mechanical behavior of the materials.

In the second part of the study, the isolated effect of mold temperature on microstructure development was investigated using X-ray diffraction (XRD), solid-state nuclear magnetic resonance (NMR), and differential scanning calorimetry (DSC). Correlation with mechanical properties revealed a strong influence of mold temperature on polymer ductility. Higher mold temperatures resulted in up to threefold higher elongation at break in P3HB-co-4HB, which was attributed to reduced molecular orientation and increased chain relaxation during slower cooling, leading to a more homogeneous microstructure.



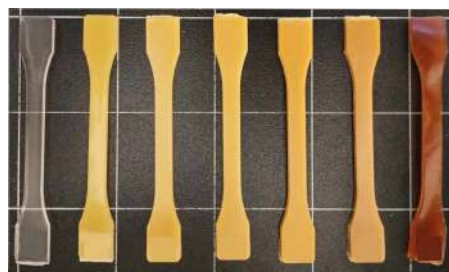
1. Wang, Q., Xu, Y., Xu, P., Yang, W., Chen, M., Dong, W., & Ma, P. (2022). Crystallization of microbial polyhydroxyalkanoates: A review. *International Journal of Biological Macromolecules*, 209, 330–343.

Q36.3 – Development and Characterization of PLA-Zein Plasticized Blends for Injection Molding : Innovation in Processing and Analysis of Mechanical and Morphological Properties

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This study presents the development of polylactic acid (PLA) blends incorporating plasticized zein, a corn-derived protein, processed through twin-screw extrusion followed by injection molding, enabling the production of biopolymer systems through scalable industrial techniques. The incorporation of dipropylene glycol (DPG) as a plasticizer facilitates the processing of zein [1].

Mechanical characterization revealed that increasing the plasticized zein content significantly improves the ductility of the blends. The elongation at break increased from 6.3% for neat PLA to 56.3% for the 50/50 PLA-zein blend. However, this increase in flexibility was accompanied by a progressive decrease in tensile strength and elastic modulus, indicating a reduction in stiffness of the material. Impact resistance also decreased with increasing zein content, suggesting that the presence of dispersed protein-rich domains limits effective energy dissipation during fracture [2].

Morphological analysis by FESEM confirmed the presence of heterogeneous phase structures within the blends. As the

plasticized zein concentration increased, the fracture surfaces became progressively rougher and more porous, showing clear evidence of phase separation [3].

Overall, the results demonstrate that the incorporation of plasticized zein effectively enhances the ductility of PLA, although the resulting heterogeneous morphology significantly influences the mechanical performance of the blends.

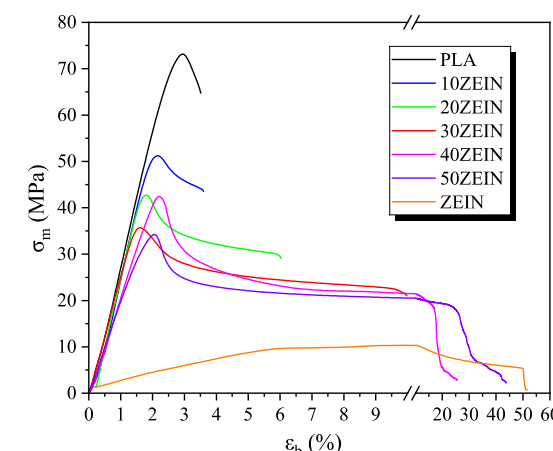


Figure 1: Tensile test curves for the PLA-zein blends

[1] Plasencia, L., et al., *Innovative development and characterization of thermoplastic zein-based biopolymers for food packaging via injection molding*. Food Hydrocolloids, 2025. **163**: p. 111134.

[2] Zhang, J.-F. and X. Sun, *Mechanical properties of poly (lactic acid)/starch composites compatibilized by maleic anhydride*. Biomacromolecules, 2004. **5**(4): p. 1446-1451.

[3] Fang, K., et al., *Properties and morphology of poly (lactic acid)/soy protein isolate blends*. Journal of applied polymer science, 2009. **114**(2): p. 754-759.

Q36.4 – Evaluation of methods for estimating polymer glass transition temperature from molecular simulations

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Molecular simulations are in high demand to speed up the design phase of novel bio-based plastics materials. As such, reliable simulation models and property estimation methods are needed. One key property for polymer applicability is the glass transition temperature (T_g). In this study, we investigate different T_g estimation methods based on molecular dynamics (MD) dilatometry data using poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV) as a model system.

We first conclude that dilatometric T_g estimation methods should primarily use volume-temperature data, instead of density-temperature data often reported in MD studies, due to the latter leading to a systematic underestimation of the T_g . We then investigate the impact of parameter choices on the T_g values obtained by three different methods. We note that due to the kinetic nature of the transition, T_g values obtained from MD simulations should result in higher values compared to experiments due to the significantly higher cooling rates. However, this is often not taken into consideration in the literature.

To relate the predictions of the MD simulations (very fast cooling rates) to experimental conditions, we use an extrapolation scheme based on the WLF equation¹ and discuss its sensitivity to parameter choices, as well as the physical sensibility of the extrapolated results.

We finally compare the extrapolated T_g predictions against experimental values obtained with the flash DSC method, which is able to reach cooling rates of up to thousands of Kelvins per second. This allows us to narrow the gap between experimental results and simulated predictions.

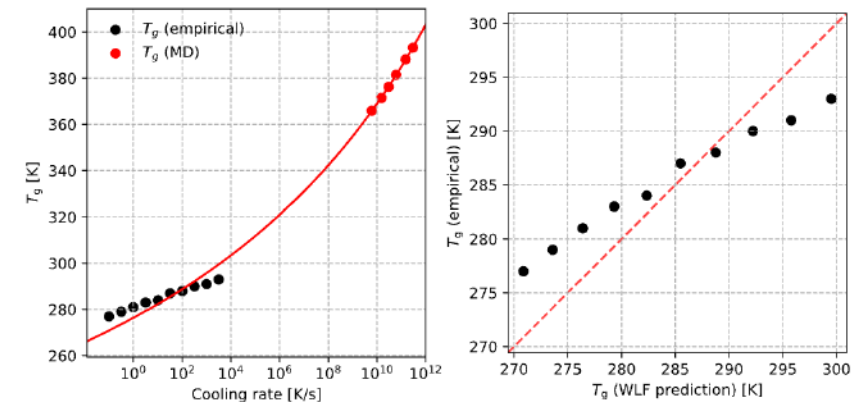


Figure: Left: WLF equation fitted to T_g values obtained from MD dilatometry. Right: extrapolated T_g predictions compared to experimental values.

1. Soldera, A., and Metatla, N., Glass transition of polymers: Atomistic simulation versus experiments. *Phys. Rev. E* 74:061803 (2006). <https://doi.org/10.1103/PhysRevE.74.061803>

Q36.5 – Plastics, bio-based polymers, and chemical recycling

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Sustainable and high-performance polymers can be produced by combining and utilizing both bio-based and recycled materials. By carefully choosing the monomers (bio-based or from recycled plastics and textile fibres), the properties of these polyesters and polyamides can be tuned for applications ranging from textile fibres to packaging applications, thereby reducing our dependence on fossil-based polymers.

Plastics are an integral part of modern life. The annual polymer production in the world reached 430 Mt in 2024 and is expected to increase to 1230 Mt by 2060.^{1,2} Polyolefins make for roughly 58% of the annual production, whereas poly(ethylene terephthalate) (polyester, PET) is roughly 6% and polyamides, polyurethanes, and polystyrene account together for the rest: 26%. It should be noted that polyesters makes for 57% of the annual textile fiber production.³ Substituting existing fossil-based polymers and plastics with biobased alternatives is both attractive and necessary for future sustainability. However, incompatibilities of biobased polymers and materials with existing recycling streams are of concern.

Mechanical recycling is currently the main recycling method of plastics. However, the materials degrade as they are processed into new products. In chemical recycling, e.g. polyesters are depolymerized into monomers or oligomers by hydrolytic reactions. The obtained monomers and oligomers can then be repolymerized.

2,5-furandicarboxylic acid (FDCA) is a versatile bio-based monomer. The bio-based polyester poly(ethylene furanoate) (PEF) is compatible with PET⁴ and they can be processed and copolymerized together. PET and PEF may also be chemically recycled together, yielding materials with similar properties to virgin materials.⁵ Soft and 3D-printable copolyesters from PEF can be obtained by copolymerization with long-chain aliphatic diols.⁶ Similarly, copolyamides can be obtained from FDCA by copolymerization of diamines with varied long-chain diamines.⁷ Poly(tetramethylene ether)glycol can be obtained from chemically recycled elastane yarn and utilized as a soft and elastic segment of polyesters in which bio-based monomers and recycled materials are combined.⁸

1. Plastics the Fast Facts 2025 • Plastics Europe, <https://plasticseurope.org/knowledge-hub/plastics-the-fast-facts-2025/>. 2. OECD, Global Plastics Outlook, https://www.oecd.org/en/publications/global-plastics-outlook_aa1edf33-en.html. 3. Global textile fiber market share by type 2023, <https://www.statista.com/statistics/1250812/global-fiber-production-share-type/>. 4. N. van Strien, J. Niskanen, A. Berghuis, H. Pöhler and S. Rautiainen, *ChemSusChem*, 2023, 17, e202300732. 5. L. Välinen, H. Baniasadi and J. Niskanen, *Green Chemistry*, 2026, submitted. 6. A. Ponkratenkova, L. Välinen, H. Baniasadi, A. Tropa, O. Starkova, S. Gaidukovs and J. Niskanen, *Polymer*, 2026, **349**, 129723. 7. Z. Paganelli, L. Välinen, O. Hanafi, S.-P. Hirvonen, H. Baniasadi and J. Niskanen, *RSC Adv.*, 2026, **16**, 7581–7589. 8. V. Räihä, Master's thesis, Aalto university, 2026.

Q36.6 – Design Principles and Chemical Control for Circular and Functional Polymeric Materials

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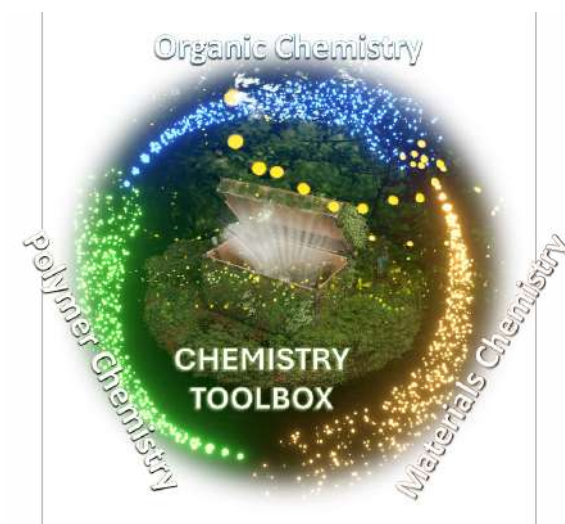
Wood Science Center, Linköping
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The transition to circular materials demands more than replacing fossil feedstocks with biobased alternatives. True circularity requires deliberate polymer design, where molecular structure, macromolecular architecture, and interfacial chemistry are engineered to enable functionality, reversibility, and controlled chemical recycling.

Our work addresses this challenge at the interface of polymer, organic, and materials chemistry by developing chemical tools that translate intrinsic molecular reactivity into controlled macromolecular and material behavior. Starting from the inherent synthetic features of renewable platform molecules, we design new polymerization concepts and equilibrium-controlled systems that combine high performance in use with programmed depolymerization or reconfiguration at end of life.

Polymer thermodynamics and kinetics, such as ceiling-temperature and reversible covalent bonding are treated as active design parameters.[1] Reversible chemistries operating in aqueous environments, including oxime ligation,[2] enable covalent modification and reconfiguration in water-rich systems. Recycling thus becomes a programmable material function governed by architecture and chemical environment.

These principles extend to hierarchical biobased substrates, where interfacial control is decisive. Chemistry-guided interphase design enables highly charged fiber systems via radical transfer strategies[3] and mechanically robust, optically transparent materials through controlled structural collapse of wood. Across length scales, functionality emerges from molecular-level control, allowing plastic-like performance with retained chemical disassembly and reuse.



[1] Nieboer, V.; Odelius, K.; Olsén, P. *Angew. Chem. Int. Ed.* **2025**, 64, e202502436. Improving Circularity via Chemical Recycling to All Rings.

[2] Subbotina, E.; Ram, F.; Dvinskikh, S. V.; Berglund, L. A.; Olsén, P. *Nat. Commun.* **2022**, 13, 6924. Aqueous Synthesis of Highly Functional, Hydrophobic, and Chemically Recyclable Cellulose Nanomaterials through Oxime Ligation.

[3] Atoufi, Z.; Celada, L. M.; Ruiz, M. C.; Billon, J.; Wågberg, L.; Olsén, P. *Matter*, **2026**, *accepted*. Radical Transfer Grafting Enables Supercharged Cellulose Fibers with Preserved Nanostructure.

Q36.7 – Synthesis and characterisation of bio-derived furan-based polyamides copolymers from dimethyl furan-2,5-dicarboxylate

Zoe Paganelli¹, Lauri Välinen¹, Onsi Hanafi¹, Sami-Pekka Hirvonen², Hossein Baniasadi¹, Jukka Niskanen^{1*}

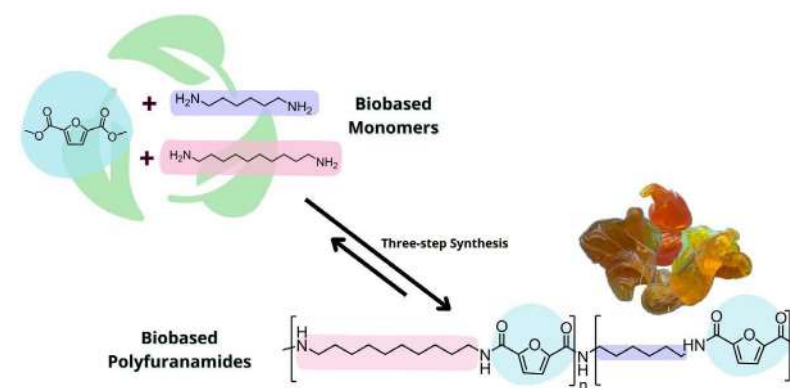
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Polymers and plastics play integral roles in everyday life due to their versatility and durability. Among them, polyamides are particularly valued for their excellent properties and broad range of applications. The study explores the synthesis and characterisation of bio-derived polymers copolymers. Specifically, polyamides and copolyamides have been successfully synthesised from dimethyl furan-2,5-dicarboxylate and two diamines, hexamethylene diamine and 1,10-decanediamine, by employing a new three-step method. Key findings include the successful polymerisation of polyamides and copolyamides with a molecular weight up to 26,900 g/mol while demonstrating robust thermal stability, withstanding up to 403.7 °C. In addition, the mechanical properties, such as elastic modulus, of these amorphous polyamides and copolyamides were found to be comparable to commercial polyamides. Notably, the variation of molar ratios of diamines greatly influences the final properties of the polyamides and copolyamides, offering insight into customising mechanical, thermal, and physical qualities of the polymer.

This research contributes significantly to the advancement of sustainable polymer solutions, positioning bio-derived polyamides as viable substitutes to mitigate reliance on fossil fuels while enhancing environmental sustainability.



Q36.8 – Translating the inherent chemical features of Vanillin for new polyether concepts

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Creating valuable products from wood biomass is an essential component of a sustainable, bio-based economy. In this bio-based economy, biorefineries play a key role in converting lignocellulosic feedstocks into high-value products, such as vanillin. Vanillin can be seen as a platform molecule for bio-based polymer development, making it a valuable target chemical for biorefineries. Derivation of vanillin can yield from 5.3 up to 8wt% from lignin [1,2]. Lignin-derived vanillin can offer a lower carbon footprint, compared to synthetic vanillin, however the lignin depolymerization method has a significant influence on the carbon footprint [2,3]. Currently, Borregaard operates the only commercial-scale process for lignin-derived vanillin, providing a low carbon footprint around 1.34kg CO₂ eq/kg vanillin [2]. Vanillin is known to have pKa of 7.4 at 25°C [4] which increases to around 10-11 when vanillin is reduced to vanillyl alcohol. Taking the dimer of vanillin, Divanillin to reduced Divanillin this same trend continues, however our measurements indicate that the phenol could be still ‘participate’ in polymerization.

Here, a polyether concept derived from reduced Divanillin (r-Diva) is proposed. We show that the pKa of r-Diva is still comparable to that of vanillyl alcohol with an ‘active’ phenol. The two C_α carbonyl positions in r-Diva are of particular mechanistic interest, as their reactivity under different conditions could enable the formation of a p-quinone methide intermediate during polymerization.

Investigating this reactivity provides insight into transformations comparable to those in lignin biosynthesis. Preliminary observations further indicate that the formed ether bonds may undergo dynamic exchange, suggesting a potential route for depolymerization back to the monomer. This work highlights r-Diva as a promising precursor for exploring new bio-based polyether materials.

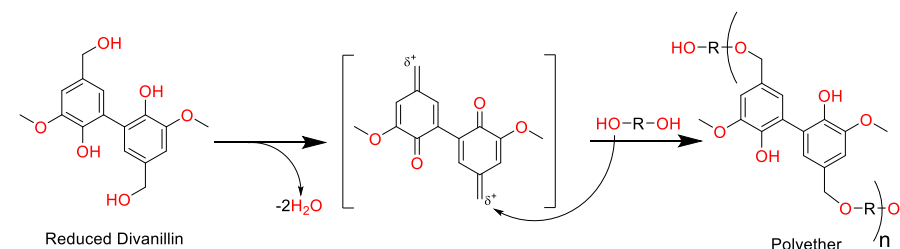


Figure 1: Reduced Divanillin under acidic conditions (*p*-TSA) undergoes a polycondensation reaction to form a polyether. The proposed *p*-quinone-methide intermediate state is highly reactive, so a self-condensation product is also possible.

- [1] S. Liu *et al.*, “Statistical design of experiments for production and purification of vanillin and aminophenols from commercial lignin,” *Green Chem.*, vol. 22, no. 12, pp. 3917–3926, 2020, doi: 10.1039/D0GC01234C.
 [2] Á. Cabeza Sánchez *et al.*, “Innovative vanillin yielding from lignin: process modelling and assessment,” *Open Res. Eur.*, vol. 4, no. 5, 2024, doi: 10.12688/openreseurope.16734.2.
 [3] N. Wongtanyawat *et al.*, “Comparison of different kraft lignin-based vanillin production processes,” *Comput. Chem. Eng.*, vol. 117, pp. 159–170, 2018, doi: 10.1016/j.compchemeng.2018.05.020.
 [4] E. P. Serjeant and B. Dempsey, *Ionisation Constants of Organic Acids in Aqueous Solution*. Oxford, U.K.: Pergamon Press, 1979.

Q36.9 – EFFECT OF EXTREME HEATING/COOLING RATES ON POLYMERS: CRYSTALLIZATION, REORGANIZATION, AND NANOPARTICLE BEHAVIOR

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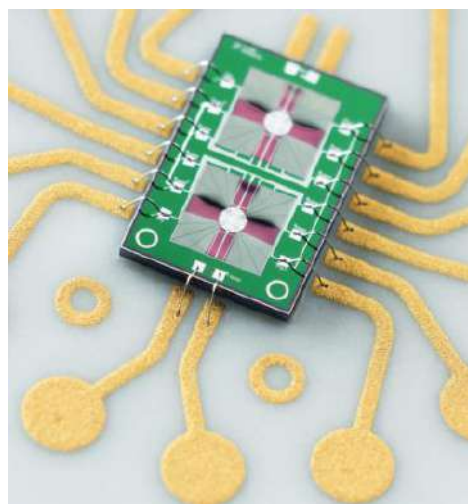


Figure 1: MEMS-based sensor with sample position circles of 0.5 mm diameter for Ref and Sample

An often overlooked factor when studying the thermal behavior of polymers is the relatively extreme conditions that the materials undergo in many of the most standard manufacturing processes (ex. Injection molding, extrusion, etc.). Most thermal analysis equipment is not designed to replicate these production conditions, nor are the standard testing methods (ex. 10 or 20 K/min heating/cooling rates for DSC) in line with reality.

By placing samples directly on the sensor and heating element, the Flash DSC (Mettler Toledo AB) allows for heating and cooling rates vastly beyond that of a standard DSC (up to 2,400,000 K/min for both heating and cooling). This allows the formation and stabilization of metastable phases (such as amorphous isotactic polypropylene, iPP) in order to better study the control of their transformations (IE. crystallization). In the case of polyamide 11 (PA 11), extreme cooling rates help elucidate on how the inclusion of nanofillers affect the final crystallite size and mechanical properties of the material in production.

Full publication list can be accessed at:

<https://www.mt.com/ch/en/home/library/know-how/lab-analytical-instruments/flash-dsc-technology.html>

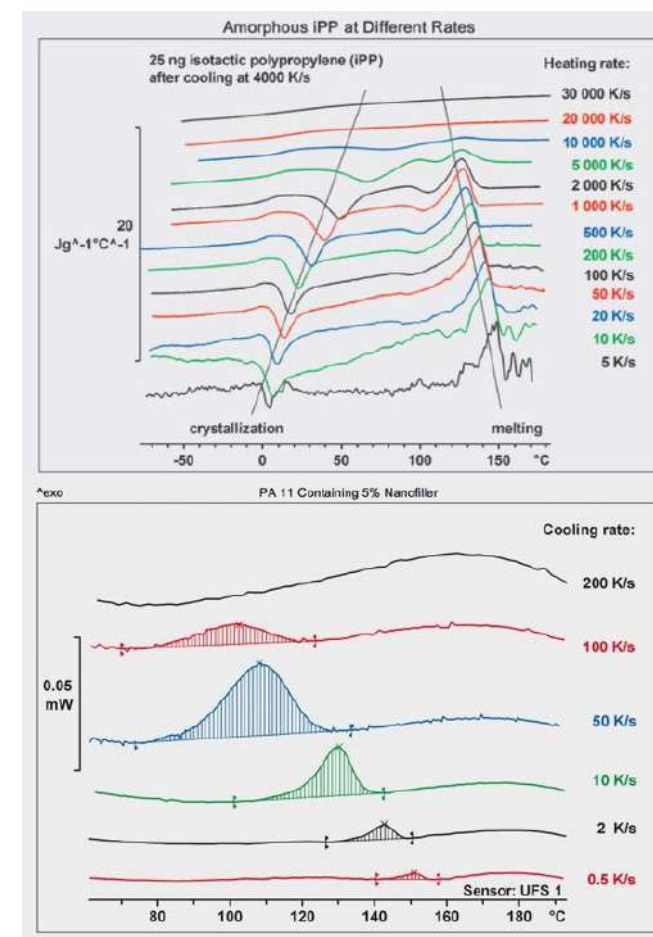


Figure 2: High heating rate's affect on amorphous iPP crystallization (Top) and shift in crystallization temperature and enthalpy upon cooling of PA 11 (Bottom)



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Q1.10 – Light-induced 3D-Printing of biobased filled formulations

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In this work we investigated light-induced 3D-printing technology of filled biobased photocurable formulations. The CNTs were added up to 1 wt% in a acrylated polyglycerolate resin, reaching highly conductive 3D-printed structures [1]. When Conductive fillers, such as silver, copper, nickel powders, and mechanically recycled carbon fibers (RCF) were dispersed into the same photocurable formulation a significant Joule effect was achieved, resulting in a highly homogeneous heating of the 3D-printed samples [2]. bioactive glasses were dispersed in acrylates soybean oil and bone scaffold were design that combines mechanical strength with bioactivity using sustainable and biobased materials [3]. Finally, we investigate the use of epoxy linseed oil (ELO) and epoxy soybean oil (ESO) as matrix for 3D-printing bio-composite. We employed bio-derived fillers such as walnut shell (WS), tagua (T), and hemp (H) and exploited Hot-lithography for 3D-printing technique [4].

1. M. Porcarello, S. Bonardd, G. Kortaberria, Y. Miyaji, K. Matsukawa, M. Sangermano, “3D-printing of electrically conductive objects with bio-based polyglycerol acrylic monomers”, ACS Applied Polymer Materials, 6, 2868–2876, 2024
2. A. Cellai, L. Pezzana, K. Matsukawa, A. Jimenez-Suarez, M. Sangermano, A. Cortés, “Digital Light Processing of Bio-Derived Conductive Composites for Smart Devices with Joule Heating Capabilities”, Progress in Additive Manufacturing
3. M. Bergoglio, Z. Najmi, A. Cochis, M. Miola, E. Vernè, M. Sangermano, “innovative biobased 3D-printed scaffolds: photo-curable resin reinforced with silanized and Cu-doped bioactive glass”, Materials Today Chemistry, 44, 102559 (1 of 16), 2025.
4. L. Pezzana, R Wolff, J. Stampfl, R. Liska, M. Sangermano, “Hot-lithography 3D-printing of fully bio-based composites: green vegetable oil epoxy matrix and bio-derived filler powder”, Additive Manufacturing, 79, 103929 (1 of 16), 2024

Q1.11 – Thiol containing inks for inkjet 3D printing with tunable refractive index

Elizaveta Sovdagarova¹, Arnav Joshi¹, Niyagama Gamage Wudith¹, Markku Pekkarinen², Hossein Baniasadi¹, Jukka Niskanen^{1*}

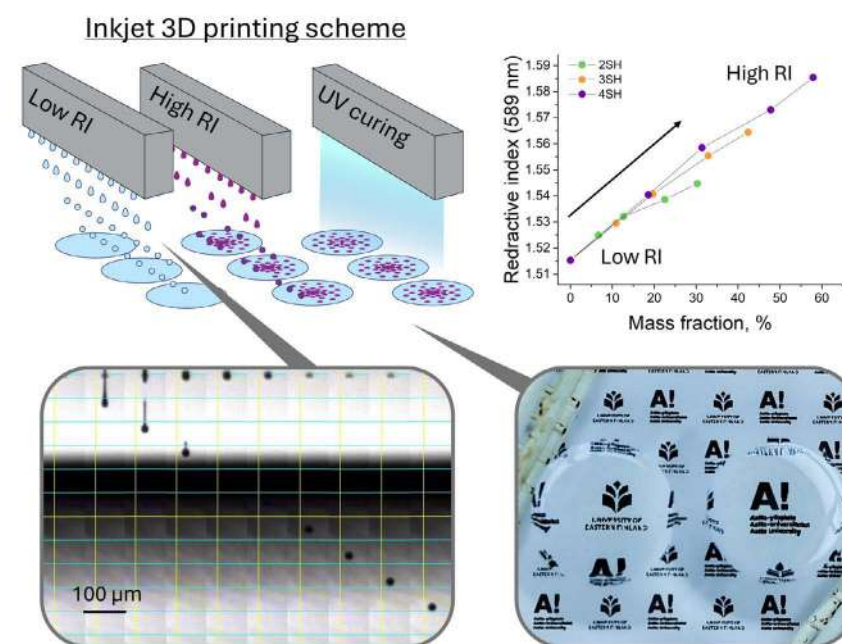
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Inkjet 3D printing enables dot-by-dot control of printed objects internal composition, which enables unique solution for fabrication of optical elements with gradient refractive index (GRIN). GRIN optical elements has several advantages when compared to the conventional lenses, such as correction of chromatic aberration and higher optical power. However, production of GRIN objects by traditional manufacturing methods is challenging, and progress in 3D-printed GRIN devices has been constrained by the limited availability of inks with tunable refractive indices (RI).

We evaluated three aliphatic thiols with varying molar mass and functionality as high RI additives to a UV-curable inkjet resin, producing a series of formulations with controlled RI. Structure–property relationships were established, linking additive structure and loading to curing behavior, optical performance, and jetting characteristics of developed resins. Resins containing up to 57 wt% additive cured effectively under UV. Cured self-standing films showed total transmittance >89% across the visible spectrum above 435 nm. The maximum RI increase (relative to the unmodified resin) was $\Delta RI = 0.07$, while dispersion remained within acceptable limits. Printability was validated on a Fujifilm Dimatix system:

for each additive, the highest-RI formulation produced stable, satellite-free droplets. These results provide a practical framework for designing UV-curable inkjet resins with tunable RI for 3D printing of GRIN optical components.



Q1.12 – PHOTOCURABLE, HIGH REFRACTIVE INDEX RESINS CONTAINING URETHANE METHACRYLATES FOR INKJET 3D PRINTABLE OPTICS

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DAYS 2026
Stockholm • May 20-22

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¹ Polymer Synthesis Technology, Department of Chemical and Metallurgical engineering, Aalto University, Espoo, Finland

² Materials to Products, Department of Mechanical Engineering, Aalto University, Espoo, Finland

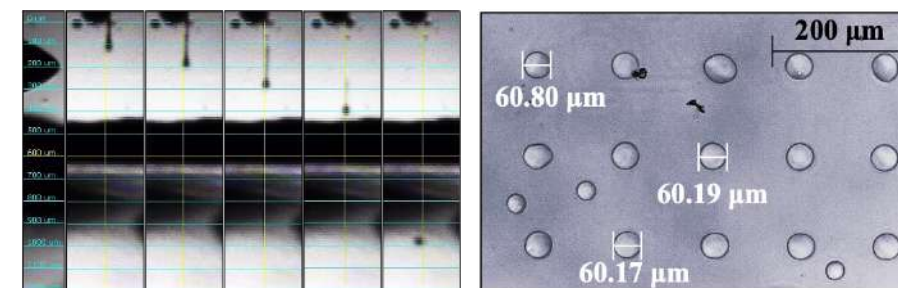
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Photocurable, high-refractive index (HRI) resins with robust thermo-mechanical properties addressing the advancements in polymeric optical materials for inkjet 3D printable optics. While acrylate-based systems contribute significantly to commercial polymer-based photocurable and inkjetable resins, their low refractive indices ($n_D \approx 1.45$ to 1.50) limit their application in high-performance optical devices. In this research, a long-chain, fluorene-based cardo-type diurethane dimethacrylate (DUDMA) monomer was synthesized via conventional urethane chemistry between 9,9-bis[4-(2-hydroxyethoxy) phenyl] fluorene (BHEPF) and 2-isocyanatoethyl methacrylate (IEM).

The synthesized monomer was integrated as a reactive functional system into a commercial acrylate-based resin (MR) at varying concentrations. The results demonstrate that increasing DUDMA content showed an improvement in the refractive indices ($n_D \approx 1.514$ to 1.549 at 589 nm) while maintaining optical transparency ($> 90\%$) in the visible spectrum region. The modified resins exhibited excellent mechanical performance, with tensile strength, modulus,

elongation increasing up to $\sim 62\%$, $\sim 34\%$, and $\sim 55\%$, respectively, alongside higher Shore-D hardness from 77 to 82. Thus, cured resins will have higher structural stability, stiffness, toughness, impact resistance, abrasion and scratch resistance along with higher thermal stability ($T_d > 400$ °C). Although the resins showed higher room-temperature viscosities, they reached optimal inkjet printing ranges at 40 – 50 °C. A successful drop-on-demand printing of microdroplet arrays confirmed the state-of-the art for resin printability. With a decrease in polymerization shrinkage with higher DUDMA content, the modified resin systems offer an ideal balance for the precise fabrication of complex geometries with high optical clarity and dimensional stability, thus making it a viable candidate for precision micro- to macro-optics.

Jetting behaviour of modified resin with optical microscopy images for microdroplet array



Buchheit, H., Bruchmann, B., Stoll, K., & Mülhaupt, R. (2021). Functionalized acrylic polyhydroxy urethanes as molecular tool box for photocurable thermosets and 3D printing. *Journal of Polymer Science*, 59, 882–892.

Magazine, R., van Bochove, B., Borandeh, S., & Seppälä, J. (2022). 3D inkjet-printing of photo-crosslinkable resins for microlens fabrication. *Additive Manufacturing*, 50, 102534.

Q1.13 – RAFT-MEDIATED POLYMERIZATION: TOWARDS RECYCLABLE 3D PRINTED OBJECTS

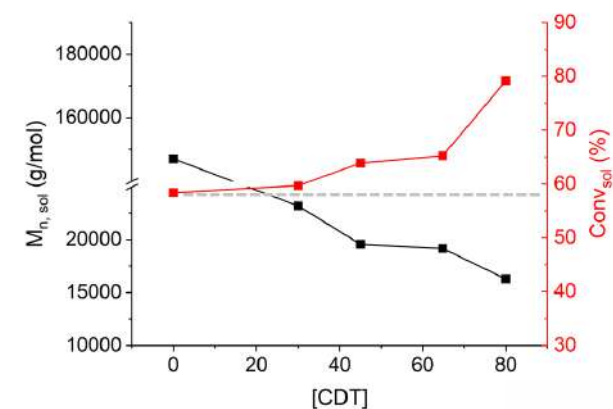
Céline Croutxé-Barghorn*, Emile Golbach, Lucile Halbardier, Xavier Allonas

University of Haute Alsace,
Laboratory of Macromolecular
Photochemistry and Engineering,
Mulhouse France

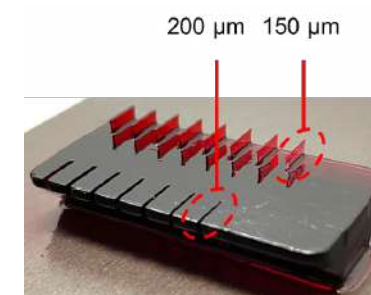
*celine.croutxe-barghorn@uha.fr

3D DLP printing of acrylate-based thermosets was investigated through the incorporation of RAFT agents. These agents promote the formation of more homogeneous 3D polymer networks. As a result, significant improvements in mechanical performance were observed. Samples with similar conversion exhibited higher elongation at break, and toughness increased by approximately 20–25%. Based on these results the potential of RAFT-agents was investigated for 3D DLP printing of thermoplastics. The conversion and the molar mass at the point of solidification were determined using photorheology and SEC experiments. These results were compared to those obtained through the photopolymerization occurring in the vat, i.e. for solidification of the material immersed in the formulation. In the presence of RAFT agents, solidification occurs at higher conversion and with lower polydispersity, resulting in a more distinct liquid–solid transition. This clearer phase separation limits thermoplastic dissolution and improves the repeatability of the printed material. Finally, a RAFT-mediated thermoplastic was successfully printed via DLP, achieving a resolution of 150 μm .

Evolution of the molar mass and conversion as a function of the concentration in the RAFT agent (CDT)



3D DLP printing of a resolution piece based on a thermoplastic formulation containing 30 mM of CDT



Goldbach E., Allonas X., Croutxé-Barghorn C., Ley C., Halbardier L., L'Hostis G., (2023). Influence of thiocarbonylthio- RAFT agents on the homogeneity of polymer network and mechanical properties of 3D printed polymers. Eur. Polym. J. 188, 111947-111954

Goldbach E., Allonas X., Ley C., Halbardier L., Croutxé-Barghorn C. (2023). RAFT-mediated thermoplastic material by photopolymerization: Controlling liquid–solid transition for vat photopolymerization in 3D DLP printing. Eur. Polym. J. 197, 112335-112341

Q1.14 – Light-based 3D printing of reversible networks across length-scales

Pia S. Klee¹, Samantha O. Catt¹,
Lea Sielaff¹, Eva Blasco^{1*}

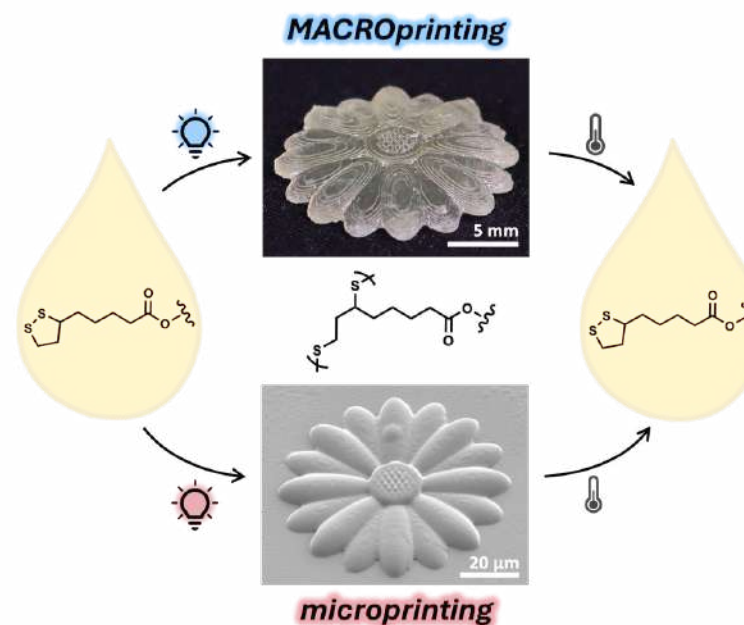
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3D printing shows large potential as a sustainable manufacturing method, through aspects such as low waste generation.^[1] Light-based 3D printing in particular gives access to high resolution structures down to the micro-scale. However, currently most inks for light-based 3D printing are based on (meth)acrylates resulting in densely crosslinked networks that are hard to depolymerise. In the search for alternative photo-crosslinking moieties, dithiolanes in the form of naturally sourced lipoic acid have presented themselves as suitable candidates for a new class of crosslinking units for light-based 3D printing.^[2]

Here we present a single component ink that can be printed by digital light processing (DLP) and two photon laser printing (2PLP) covering a length scale of cm to μm without the need for a photoinitiator. The printability and mechanical properties on both the macro- and microscale are characterised as well as the depolymerisation behaviour of the printed material. The conditions at which depolymerisation takes place can be further modified through incorporation of a latent base. Upon thermal activation, the

base is released, leading to depolymerisation of the material from within. After establishing the principle on the macroscale structures, it is adapted to 2PLP printed samples.^[3]



1. E. Sanchez-Rexach, T. G. Johnston, C. Jehanno, H. Sardon, A. Nelson, *Chem. Mater.* 2020, **32**, 7105–7119.
2. T. O Machado, C. J. Stubbs, V. Chiaradia, M. A. Alraddadi, A. Brandolese, J. C. Worch, A. P. Dove, *Nature*, 2024, **629**, 1069–1074.
3. P. S. Klee, S. O. Catt, L. Sielaff, E. Blasco, *Polym. Chem.*, 2025, **16**, 4571–4579.

Q1.15 – Bio-based epoxy resins for VAT 3D printing: from sustainable photocuring to dynamic polymer networks

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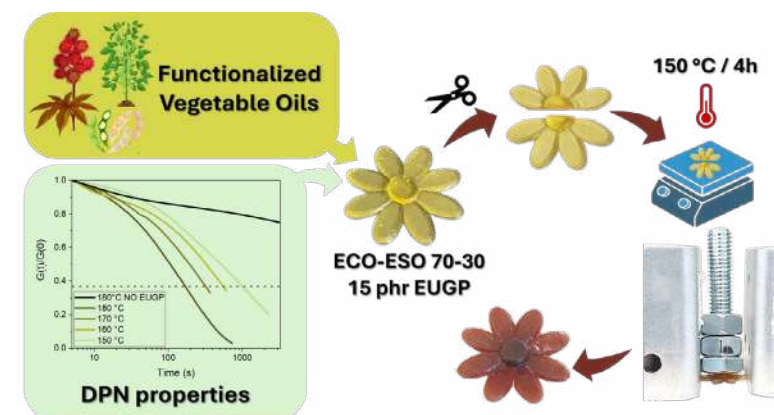
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This contribution presents a comprehensive study on fully renewable, acrylic-free epoxy resins tailored for sustainable VAT photopolymerization, from initial formulation design to the development of advanced dynamic polymer networks (DPNs). In the first part, we report— for the first time—bio-based epoxy systems specifically engineered for conventional VAT 3D printing under low light intensity, at room temperature, and in the complete absence of acrylic monomers.¹ Epoxy monomers were synthesized from macaw palm, grapeseed, and castor oils through a rapid and green epoxidation route. Epoxidized macaw palm oil was employed as a low-viscosity reactive diluent, while cationic photopolymerization was initiated via charge-transfer complexes based on isopropyl-9H-thioxanthen-9-one or curcumin combined with an iodonium borate salt. The systems achieved epoxy conversions up to 78% within 120 s and enabled the successful printing of complex geometries, while exhibiting high renewability metrics (>97% bio-based content).

Building on these results, dynamic epoxy networks were developed using epoxidized castor oil, inherently capable of transesterification

due to residual hydroxyl groups. To reach a suitable viscosity for 3D printing process it was blended with lower-viscosity epoxidized soybean oil, improving printability while retaining network dynamics. In the presence of a bio-based transesterification catalyst, selected formulations exhibited effective stress relaxation, successful 3D printability, and thermal reprocessability. Overall, this work demonstrates a viable pathway toward high-performance, circular, plant-oil-based resins for additive manufacturing.



1. Turra Alarcon, R., Porcarello, M., Cellai, A., Schmitt, C., & Sangermano, M., (2025). Advancing green additive manufacturing: Epoxidized vegetable oils for room-temperature photopolymerization 3D printing. *Polymer*, 336
2. Porcarello, M., Greco, E., Cellai, A., Turra Alarcon, R., Rossegger, E., Sangermano, M., (2026). 3D printing of biobased epoxidized formulations based on vegetable oils with dynamic polymer network properties, *Polymer Chemistry*, accepted manuscript.

Q1.16 – Photocurable double dynamic polyester resins with circular end-of-life

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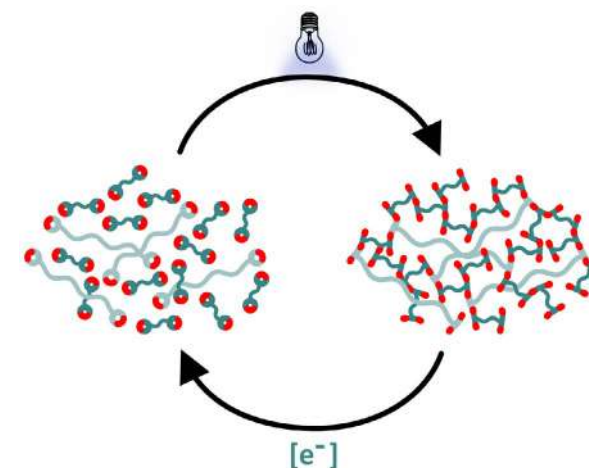
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Today's material economy is reliant on a linear take-make-waste approach which causes significant waste accumulation after products' end-of-life. To facilitate a more circular use of plastics, smarter material designs are needed where recycling becomes an inherent material property. [1] In this project, a *designed to recycle* strategy was implemented by combining esters and disulfides into a double dynamic system. Aliphatic polyesters were end-functionalised with a photoreactive disulphide group and mixed with a shorter crosslinker. Resin mixtures were then irradiated under UV to make crosslinked networks. By combining components in different ratios, a total of eight films were made and evaluated for their properties and recyclability.

By exploiting the dynamic bonds present in crosslinked networks, films could be efficiently recycled under mild conditions. Mechanical recycling was performed by shredding films and then reprocessing under elevated temperature. Tensile testing before and after reprocessing showed a good retention of mechanical properties over two cycles.

Networks could also be chemically recycled under mild conditions. By dissolving films in lowly reductive conditions, disulphide crosslinks could be selectively cleaved, leaving the polyester backbone structure intact. As this process led to retrieval of the original photoreactive components, films could then be reformed again under UV, showing very similar mechanical properties to original films.



[1] Aarsen, C. V.; Liguori, A., Mattsson, R.; Sipponen, M. H.; Hakkarainen, M.; Designed to Degrade: Tailoring Polyesters for Circularity. Chem. Rev. 2024, 124 (13), 8473-8515. DOI: 10.1021/acs.chemrev.4c00032

Q1.17 – Cationic Photopolymerization of Biobased Oxetane Monomers

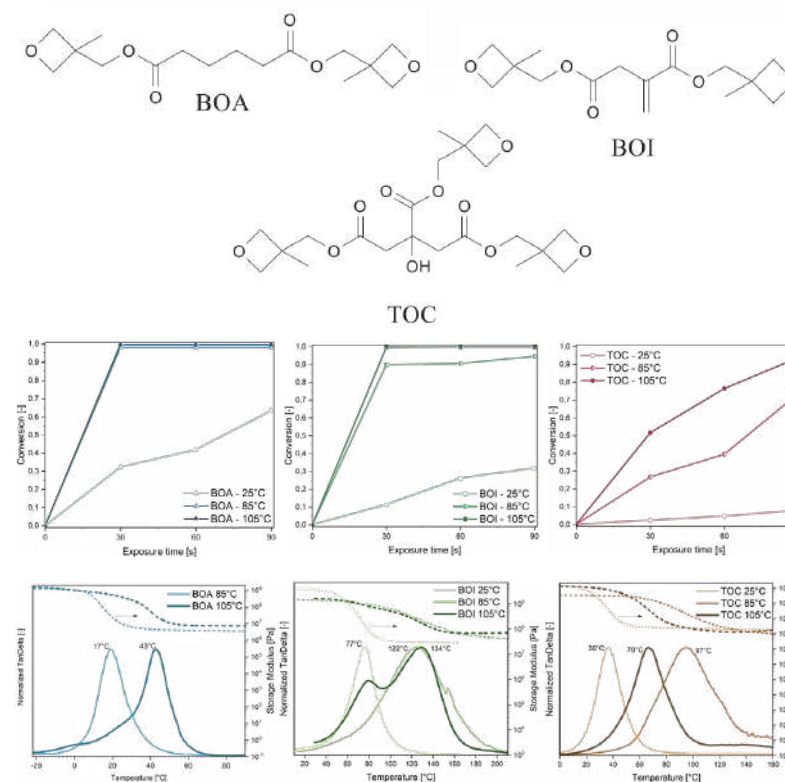
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Cationic photopolymerization offers significant advantages over radical polymerization, primarily due to its resistance to oxygen inhibition and superior dimensional stability during the crosslinking process. This study advances the development of renewable materials by synthesizing oxetane-functionalized derivatives of adipic, itaconic, and citric acids. Three bio-based monomers were synthesized and characterized: bis((3-methyloxetan-3-yl)methyl) adipate (BOA), bis((3-methyloxetan-3-yl)methyl) itaconate (BOI), and tris((3-methyloxetan-3-yl)methyl) citrate (TOC). The molecular structures were verified via Nuclear Magnetic Resonance (NMR) spectroscopy. Reaction kinetics and the degree of oxetane ring-opening conversion were monitored using Fourier Transform Infrared (FTIR) spectroscopy and photo-Differential Scanning Calorimetry (photo-DSC). All monomers exhibited high reactivity, reaching nearly complete conversion within 90 seconds of UV exposure. Thermomechanical assessment via Dynamic Mechanical Thermal Analysis (DMTA) and gel content measurements indicated that BOI-based films possessed superior glass transition temperatures (T_g) and higher crosslinking densities compared to BOA and TOC counterparts. These results highlight the potential of bio-based oxetanes as sustainable, high-performance alternatives to petroleum-derived precursors in the production of UV-curable materials.



D. Moraru, L. Papadopoulos, M. Hakkarainen, and M. Sangermano, “Cationic Photopolymerization of Biobased Oxetane Monomers Obtained from Adipic, Itaconic, and Citric Acid Functionalization.” *Macromolecular Chemistry and Physics* 226, no. 21 (2025): e00233. <https://doi.org/10.1002/macp.202500233>

Q1.18 – TOWARDS FULLY BIO-SOURCED ARTIFICIAL POLYMER MUSCLES FOR LIGHT-CONTROLLABLE MOTION

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The heliotropic movement of sunflowers is driven by a differential stem growth, which leads to the bending of the flower head. This striking strategy allows the plant to optimize the sunlight capture.[1] Inspired by this, we developed a method to generate spatially selective motion, guided by light, in helically twisted polymeric fibers. Typically, the twist introduced in monofilament polyamide coiled yarns (artificial muscles) can generate contraction and expansion due to an asymmetric expansion of the material upon stimuli like heat.[2] However, the type of motion is limited to linear actuation. By adding a photothermal component, allowing the conversion of light into thermal energy, we achieved partial untwisting of the helical structure through the application of a localized stimulus. The interplay between localized heating and thermal diffusion allows polymeric fibers to perform dynamic and multidirectional bending at the irradiation site. Importantly, the performance of this actuator is not dictated by a predetermined deformation, allowing it to bend toward the light deliberately.[3] In this presentation, we also present our recent results for fully bio-sourced photothermal polymers that enable motion to be driven by focused sunlight.

Together, these discoveries form a promising leap in the realms of artificial muscles and biomimetic technologies. We showcase how these artificial muscles can be seamlessly integrated into textiles – providing a way for imparting light-driven macroscopic motions. These prototypes depict a world where textiles are not just passive entities, but active accomplices responding to environmental stimuli, paving the way for adaptive, shape-changing systems.



[1] J. P. Vandenbrink, E. A. Brown, S. L. Harmer, B. K. Blackman, *Plant Science* (2014), 224, 20.

[2] C. Haines, M. Lima, G. Spinks, J. Foroughi, J. Madden, S. Kim, S. Fang, M. Jung de Andrade, F. Göktepe, Ö. Göktepe, S. Mirvakili, S. Naficy, X. Lepró, J. Oh, M. Kozlov, S. Kim, X. Xu, B. Swedlove, G. Wallace, R. Baughman. *Science* (2014) 343.

[3] Z. Madani, P. E. S. Silva, H. Baniasadi, M. Vaara, S. Das, J. C. Arias, J. Seppälä, Z. Sun, J. Vapaavuori, Light-Driven Multidirectional Bending in Artificial Muscles. *Advanced Materials* (2024), 36, 2405917

Q1.19 – Fabrication strategies enabling coiling motion in twist-coiled polymer actuators

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Soft robotics and artificial muscles present an alternative to rigid robots and actuators, drawing inspiration from living organisms to provide more flexible and adaptable motions¹. However, achieving complex and controllable motions that combine multiple modes of motion within one single-component system remains a challenge. Twist-coiled polymer actuators (TCPAs) may help address this, as torsional, rectilinear and bending motions have already been demonstrated for these artificial muscles^{2,3}.

Herein, TCPAs capable of coiling motion are developed based on a tilted helical structure. Regular TCPAs are made from commercially available polyamide fishing lines and through a second thermosetting step the regular helix is modified into a tilted helix, generating tilted TCPAs. Two methods are used to create the tilted TCPAs. The first method uses a coil-tilting stage that mechanically compresses a TCPA, creating a tilt angle in the helix. The second method uses pre-stretching to create tension within the TCPA, which during the second thermosetting results in a tilted structure formation of the polymer fiber. Both methods create tilted TCPAs

that form a superhelix, where the coils of the TCPA further create an additional helix structure. The tilted helical structure enables the TCPA to both bend and twist when actuated, thus generating a three-dimensional coiling motion. The coiling motion achieved here for a monomaterial polymer actuator provides an additional mode of motion to TCPAs and can, for example, be used as latching grippers (Fig. 1).

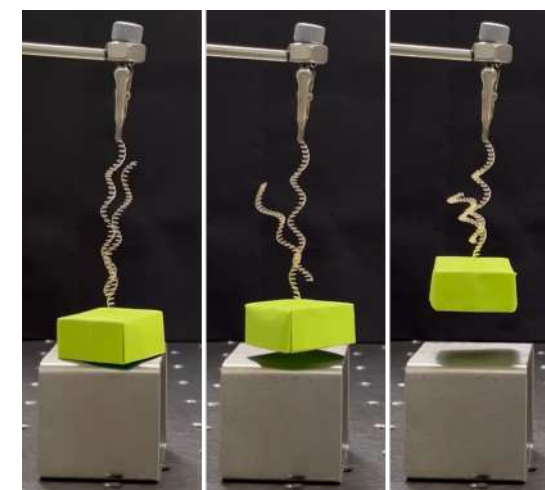


Fig 1. Snapshots of tilted TCPAs as latching grippers.

- [1] C. Greco, P. Kotak, L. Pagnotta, and C. Lamuta, “The evolution of mechanical actuation: from conventional actuators to artificial muscles,” *International materials reviews*, vol. 67, no. 6, pp. 575–619, Aug. 2022, doi: 10.1080/09506608.2021.1971428.
- [2] C. S. Haines et al., “Artificial Muscles from Fishing Line and Sewing Thread,” *Science (American Association for the Advancement of Science)*, vol. 343, no. 6173, pp. 868–872, Feb. 2014, doi: 10.1126/science.1246906.
- [3] Z. Madani et al., “Light-Driven Multidirectional Bending in Artificial Muscles,” *Advanced materials (Weinheim)*, vol. 36, no. 38, pp. e2405917–n/a, Sept. 2024, doi: 10.1002/adma.202405917.

Q1.20 – ENHANCING ANISOTROPIC RESPONSE IN NANOCOMPOSITE HYDROGELS BY COVALENT ANCHORING

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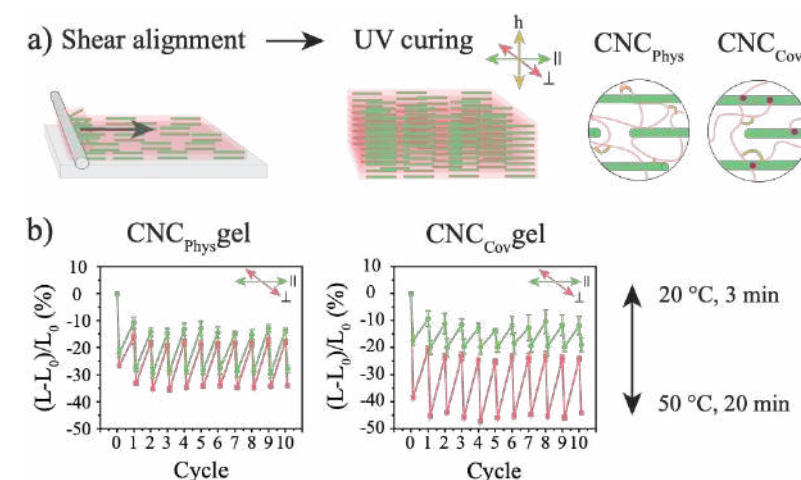
Stimuli-responsive hydrogels that exhibit anisotropic deformation are promising materials for applications that require more complex, directional modes of actuation.¹ While gels that bend in response to an applied stimulus are well-studied, there are scarce examples of gels that predominantly contract along one axis, enabling pushing and pulling motions that are reminiscent of biological muscles.¹

Here we combine a thermoresponsive poly(*N*-isopropylacrylamide) (PNIPAM) hydrogel matrix, which shrinks upon heating, with aligned rod-like cellulose nanocrystals (CNCs). Covalent anchoring of the polymer network to the CNC surface (CNC_{Cov}) is hypothesized to amplify anisotropic deformation compared to gels comprising aligned, physically dispersed CNCs (CNC_{Phys}) (Fig. 1.a).^{2,3}

When heated above 48 °C, both CNC_{Cov} and CNC_{Phys} undergo anisotropic actuation—i.e., the side perpendicular ($\perp$) to the direction in which the CNCs are aligned shrinks to a larger extent than the side parallel ($\parallel$) to such alignment. The anisotropy ratio increases from 1.3 for CNC_{Phys} to 2.3 for CNC_{Cov} gels and remains stable during repeated actuation cycles (Fig. 1.b).

Covalent anchoring also enhances mechanical anisotropy and load transfer between the polymer network and CNCs.

Thus, the CNC_{Cov} design concept enables the preparation of tough hydrogel actuators that predominantly contract along a single axis under uniform stimulation, opening a path towards artificial muscles and tendons, as well as biomimetic tissue models.



1. Z. Chen, H. Wang, Y. Cao, Y. Chen, O. Akkus, H. Liu, C. Cao, “Bio-inspired anisotropic hydrogels and their applications in soft actuators and robots” *Matter*, vol. 6, no. 11, pp. 3803-3837
2. A. Ianiro, J. A. Berrocal, R. Tuinier, M. Mayer, and C. Weder, “Computational design of anisotropic nanocomposite actuators” *J. Chem. Phys.*, vol. 158, no. 1, pp. 014901
3. M. Folkesson, J. P. Wesseler, C. Pierucci, C. Rader, C. Weder, A. Ianiro, J. A. Berrocal, “Thermoresponsive Gels Based on Cross-Linked Polymer-Grafted Cellulose Nanocrystals” *Biomacromolecules*, DOI: 10.1021/acs.biomac.5c02262

Q1.21 – THERMO-RESPONSIVE POLY(N-ACRYLOYL GLYCINAMIDE): SYNTHESIS AND FUNCTIONAL OPPORTUNITIES

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Stimuli-responsive materials with reversible supramolecular networks controlled by temperature are of significant interest in biomedicine¹, analytical chemistry², and the field of sensors and actuators³. Among these systems, temperature-responsive polymers capable of undergoing reversible solubility transitions offer attractive opportunities for the development of adaptive materials. While lower critical solution temperature (LCST) polymers have been widely studied, significantly fewer polymeric systems exhibiting an upper critical solution temperature (UCST) in aqueous media are known. Poly(*N*-acryloyl glycineamide) (pNAGA) is a non-ionic polymer that displays a sharp UCST phase transition in water driven by reversible hydrogen bonding interactions.

For these materials to become more impactful, the development of greener and more accessible synthetic approaches is required, including the use of sustainable solvents, reduced energy consumption, and minimal catalyst loadings.

In this work, we investigated the polymerization of *N*-acryloyl glycineamide via copper(0)-mediated reversible-deactivation radical polymerization using a copper wire as the catalyst. The polymerization proceeds efficiently in aqueous media under mild, non-inert conditions, reaching high monomer conversions within minutes while maintaining controlled polymer growth.

Importantly, the resulting pNAGA polymers retain a sharp and reversible UCST phase transition. The operational simplicity of this approach eliminates energy-intensive deoxygenation steps, enables catalyst recycling, and allows polymerization in simple reaction vessels that facilitate a potential scale-up. This strategy provides an accessible platform for preparing UCST-responsive polymers and suggests opportunities for integrating such systems into more complex functional materials⁴.

1. Vu, T. T., Jo, S. H., Kim, S. H., Kim, B. K., Park, S. H., & Lim, K. T. (2024). Injectable and Multifunctional Hydrogels Based on Poly(*N*-acryloyl glycineamide) and Alginate Derivatives for Antitumor Drug Delivery. *Acs Applied Materials & Interfaces*, 16(12), 15322-15335. <https://doi.org/10.1021/acsami.4c00298>
2. Wu, G. G., Li, Y. P., Han, M., & Liu, X. X. (2006). Novel thermo-sensitive membranes prepared by rapid bulk photo-grafting polymerization of *N,N*-diethylacrylamide onto the microfiltration membranes Nylon. *Journal of Membrane Science*, 283(1-2), 13-20. <https://doi.org/10.1016/j.memsci.2006.05.017>
3. Chung, T., Choi, J., Kim, H., Ki, K., Enomoto, T., Lee, D., Shin, S., Lee, A., Sakai, T., Kim, Y. K., Yoshida, R., & Kim, Y. S. (2026). Self-Oscillating Helix Showing Amplified Winding and Unwinding Motions. *Advanced Materials*. <https://doi.org/10.1002/adma.202521736>
4. Křivánková, N., Kaya, K., van der Wijngaart, W., & Edlund, U. (2023). Copper-mediated synthesis of temperature-responsive poly(*N*-acryloyl glycineamide) polymers: a step towards greener and simple polymerisation. *Rsc Advances*, 13(42), 29099-29108. <https://doi.org/10.1039/d3ra04993k>

Q1.22 – Fundamental aspects of lignin solubility - insights from experiments and Molecular Dynamics simulations

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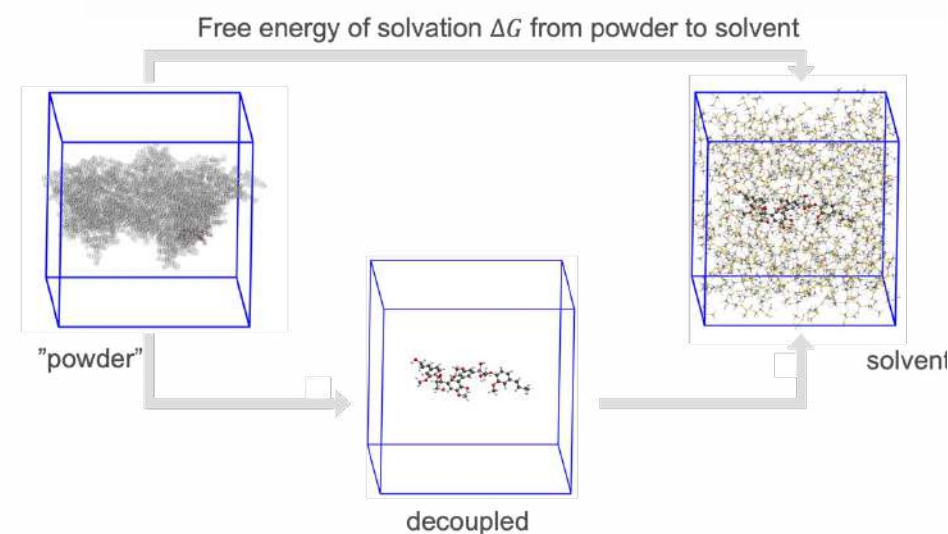
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Lignin solubility is critical for extraction, tailoring processing and downstream applications. Understanding the factors governing its solubility helps understanding the behavior of this chemically heterogeneous aromatic biopolymer. This study [1] explores the molecular weight dependence of lignin solubility across different solvents.

Molecular dynamics simulations are connected to experimental solubility measurements by ranking solvents, enabling an integrated approach that combines atomistic insights with experimental validation while quantifying solvation free energy, its enthalpic and entropic contributions, and specific interactions such as hydrogen bonding and π - π stacking [2]. The results show that differences in lignin solubilization efficiency between organic solvents and water are primarily enthalpy driven with a smaller entropic contribution. The results and simulation approach is compared to empirical solubility parameter approaches.



[1] Hackenstrass et al. "Thermodynamic and atomistic insights into lignin solubility from experimentally validated molecular dynamics simulations", submitted to *Biomacromolecules* (2026).

[2] Hackenstrass et al. *Faraday Discuss.*, (2026), 263, 52-64

Q1.23 – Complexation and reduction of metal ions in lignin nanoparticle dispersions: structural and chemical analysis

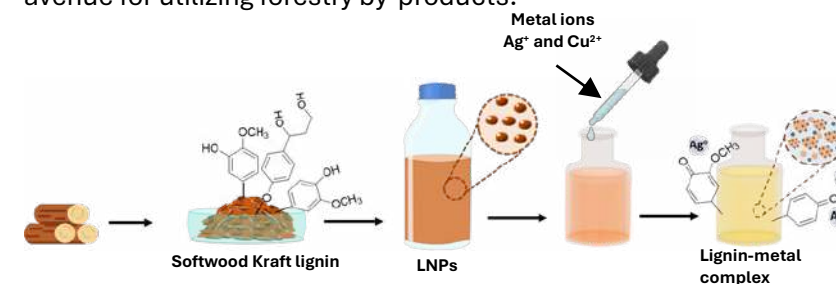
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Lignin, a primary component of plant biomass, is an important natural resource with many promising applications in biomedical, antibacterial, and antioxidant research. The phenolic and hydroxyl groups of lignin facilitate electron transfer. Using this redox activity, metallic nanoparticles can be synthesized, such as from Ag⁺ ions, without requiring hazardous chemical reduction agents like sodium borohydride. The goal of this study is to optimize the properties of lignin nanoparticles by examining their interaction with metal ions. Using synchrotron small-angle X-ray scattering (SAXS), we investigated how metal ions affect the structure and size of lignin. Lignin's diverse hydroxyl groups offer numerous binding sites for metal ions, leading to colloidal interactions and structural changes. In particular, the phenolic hydroxyl groups are expected to be responsible for reducing metal ions such as Ag⁺ and Cu²⁺, which are examined across different molar ratios, pH levels, and temperatures. Using softwood kraft lignin as a start, the lignin is dissolved in acetone-water and allowed to self-assemble into lignin nanoparticles (LNPs). To assess particle size and stability, SAXS (CoSAXS and FORMAX beamlines, MAX IV, Lund) and dynamic light scattering (DLS) measurements are used to examine the formation of metallic silver in the presence of LNPs.

Spectroscopic technique such as UV-Vis spectroscopy data, revealed the formation of metallic silver. Additionally, TEM, XRD, SEM, and FTIR are used to study the structure, metal binding sites, and functional groups of LNPs. Lignin-metal hybrid materials are potentially applicable in biomedical imaging and pharmaceutical applications due to their antimicrobial properties. By examining lignin's interactions with metal ions, this study highlights a new avenue for utilizing forestry by-products.



Schematic illustrations of the synthesis of lignin-metal hybrid materials

References:

- [1] Morsali, M., Moreno, A., Loukovitou, A., Sipponen, M., Stabilized Lignin Nanoparticles for Versatile Hybrid and Functional Nanomaterials. *Biomacromolecules* 2022, 23, 4597–4606.
- [2] Liu, J., Sipponen, Mika, Ag-lignin hybrid nanoparticles for high-performance solar absorption in photothermal antibacterial chitosan films. *iScience* 26, 108058, October 20, 2023.

Q1.24 – Engineering colloidal lignin particles: Interlaboratory insights and structure-property relationships

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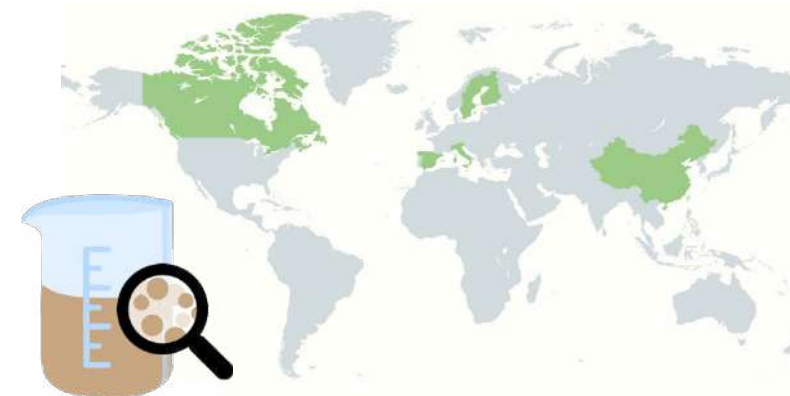
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Lignin is an abundant and structurally complex biomacromolecule with untapped potential as a sustainable building block for advanced materials applications. Among the most promising valorisation routes is the preparation of colloidal lignin particles (CLPs). These particles address some of the limitations in the widespread use of lignin, such as its heterogeneity. Several protocols for the preparation of CLPs have been developed in the past years; the most widely used and green among them is the solvent shift precipitation method. Nevertheless, the reproducibility of this protocol has been questioned and remains insufficiently understood. In this contribution, results from an ongoing international interlaboratory study are presented, aiming to systematically evaluate the robustness of solvent shift precipitation for CLP formation. The study examines the influence of lignin structural features, the order of solvent–antisolvent mixing, and different organic solvent removal strategies on particle size, morphology, and surface charge. By comparing datasets generated across multiple laboratories, critical parameters influencing reproducibility and variability are identified.

In parallel, the impact of lignin heterogeneity on CLP formation is further explored through solvent fractionated kraft lignin. The obtained fractions, differing in molecular weight and functionality, are chemically modified prior to particle assembly. Structure–property relationships between lignin fraction characteristics and resulting CLP properties are evaluated. The potential of these tailored CLPs in different applications is preliminarily assessed, highlighting both opportunities and current limitations.

Altogether, this work contributes to a deeper understanding of CLP assembly and provides insights toward more reproducible and tunable lignin-based colloidal systems for advanced material applications.



Q31.10 – Tailorable iodine-containing polymers

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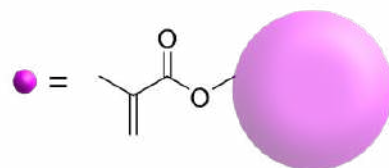
³FibRe – Centre for
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Technology, School of Engineering
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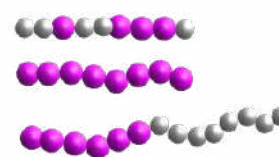
Iodinated polymers, in which iodine is covalently incorporated into the polymer backbone or side chains, exhibit high X-ray attenuation and high refractive indices. These properties make them attractive for applications in imaging, optics, and sensing.¹ To date, most iodinated polymers have been prepared through step-growth polymerizations, such as polyesters and polyurethanes.² In contrast, vinyl-based iodinated monomers remain relatively unexplored, despite the potential of chain-growth polymerization to generate more complex macromolecular architectures, including block copolymers and star polymers.

In this project, we design and synthesize methacrylate-based monomers with high iodine content (>60 wt%) and tunable linker structures. These monomers enable the preparation of polymers with both high iodine loading and tailorable physicochemical properties. We investigate how monomer structure influences polymerization behavior as well as resulting material properties, including glass transition temperature, surface free energy, and refractive index. Ultimately, this work aims to establish design principles for iodinated vinyl polymers and to expand the range of functional materials accessible through iodine-containing monomers.

Iodine-containing monomers



Tailorable iodine-containing monomers



iodine 0-60 w%
architecture
physicochemical properties

[1] Zeng, J.-J., et al. (2025). "Iodine-containing materials for biomedical applications." Journal of Materials Chemistry B 13(29): 8583-8597.

[2] Garavatti, J. and H. L. Ornaghi Jr (2024). "A Short Review on Radiopaque Polyurethanes in Medicine: Physical Principles, Effect of Nanoparticles, Processing, Properties, and Applications." Journal of Composites Science 8(10): 409.

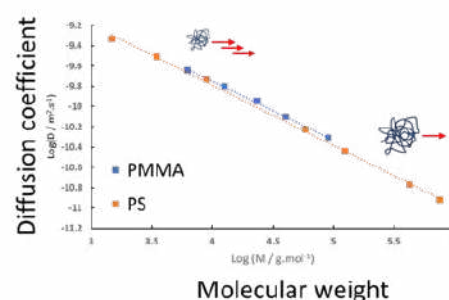
Q31.11 – Pulsed Field Gradient/DOSY NMR for Polymer Molecular Weight and Functionalization Analysis with benchtop NMR

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Plot of log(D) vs log(M) for PMMA
(blue) and PS (orange)



The strength of Pulsed Field Gradient Nuclear Magnetic Resonance (PFG-NMR) lies in its ability to separate molecules by hydrodynamic radius while simultaneously resolving chemical structures. The latest generation of benchtop NMR systems offers these capabilities in a compact, user-friendly, and cost-effective manner, making the technique a viable alternative to established methods like size exclusion chromatography.

In this study, benchtop PFG-NMR was employed for molecular weight (MW) determination using Diffusion-Ordered Spectroscopy (DOSY) at 80 MHz. Self-diffusion coefficients (D) of polystyrene and polymethyl methacrylate standards in deuterated chloroform were measured and correlated with MW, achieving measurement times below 10 minutes—significantly improving throughput compared to Size-Exclusion Chromatography (SEC).

To assess accuracy, DOSY-derived MW values ¹ were validated against end-group analysis for polyphenylsulfone, demonstrating strong concordance.

A similar validation for polysiloxanes further confirmed DOSY's robustness for MW determination. Additionally, DOSY analysis of lignin revealed a well-defined D-MW correlation, highlighting its applicability to both synthetic and natural polymers. Investigations on chitosan further support its relevance for biopolymer analysis.

Beyond MW determination, PFG-NMR was used to monitor end-group functionalization of poly(ϵ -caprolactone) (PCL) via the Pulsed Field Gradient-Stimulated Echo (PGSTE) method. This approach effectively resolved reactants and functionalized polymer species, even in cases of spectral overlap, eliminating the need for extensive purification.

Benchtop PFG-NMR provides a compact, cryogen-free platform for rapid, solvent-flexible polymer characterization, offering a viable alternative to high-field NMR for both synthetic and natural macromolecules.

1. Tooley, O., Pointer, W., Radmall, R., Hall, M., Beyer, V., Stakem, K., Swift, T., Town, J., Junkers, T., Wilson, P., Lester, D., Haddleton, D., MaDDOSY (Mass Determination Diffusion Ordered Spectroscopy) using an 80 MHz Bench Top NMR for the Rapid Determination of Polymer and Macromolecular Molecular Weight. *Macromol. Rapid Commun.* 2024, 45, 2300692.

Q31.12 – Scalable Production of Chitin Nanocrystals: Insight into Deacetylation induced Surface Defects from High Resolution Atomic Force Microscopy

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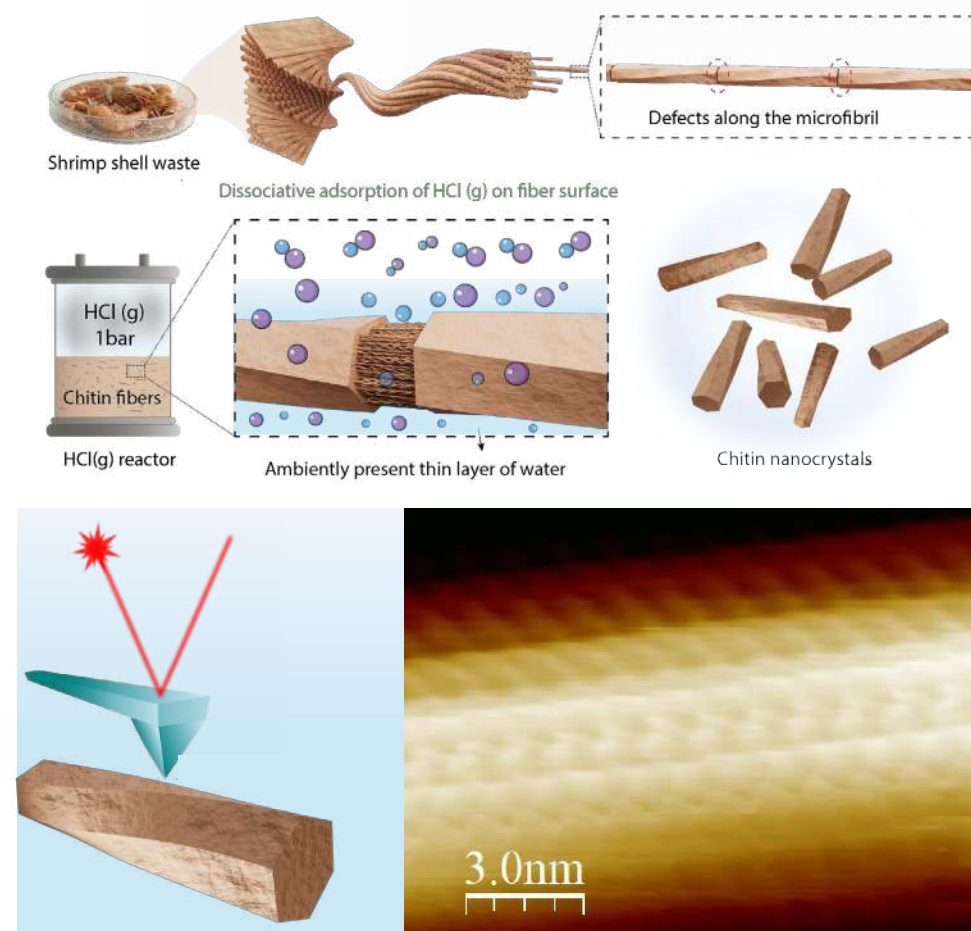
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Polysaccharide nanocrystals derived from cellulose and chitin serve as versatile building blocks for functional materials, with applications ranging from chiral optics and catalysis to structural adhesives. In these contexts, surface chemistry and topography typically govern material efficacy. However, a systematic investigation into the surface topography of these crystals, particularly following surface modification, is conspicuously lacking in the literature. This understanding is essential for developing synthesis protocols that yield nanomaterials with optimal performance.

In this contribution, we report an efficient and scalable isolation method for chitin nanocrystals (ChNCs) using pressurized hydrogen chloride gas ($\text{HCl}_{(g)}$) catalyzed hydrolysis. This approach offers near-quantitative yields at room temperature with significantly reduced water consumption, as the reaction proceeds under nearly dry conditions. Furthermore, we established surface-confined deacetylation as a post-hydrolysis treatment to reliably tune surface chemistry. High-resolution atomic force microscopy (HR-AFM) performed in the liquid state provided insights into deacetylation-induced surface defects driven by stochastic surface chain dissolution.



1. Habibi, Y., Lucia, L. A., & Rojas, O. J. (2010). Cellulose nanocrystals: chemistry, self-assembly, and applications. *Chemical Reviews*, 110(6), 3479-3500.
2. Frka-Petesic, B., Parton, T. G., Honorato-Rios, C., Narkevicius, A., Ballu, K., Shen, Q., ... & Vignolini, S. (2023). Structural color from cellulose nanocrystals or chitin nanocrystals: self-assembly, optics, and applications. *Chemical Reviews*, 123(23), 12595-12756.

Q31.13 – ELECTROSPRAYED BIO-INSPIRED POLYDOPAMINE FILMS: A SUSTAINABLE ROUTE TO FUNCTIONAL COATINGS

Majid Al-waeel^{1,2}, Ronja Bodesheimer³, Cordelia Zimmerer³, Jukka Lukkari¹, and **Mikko Salomäki^{1*}**

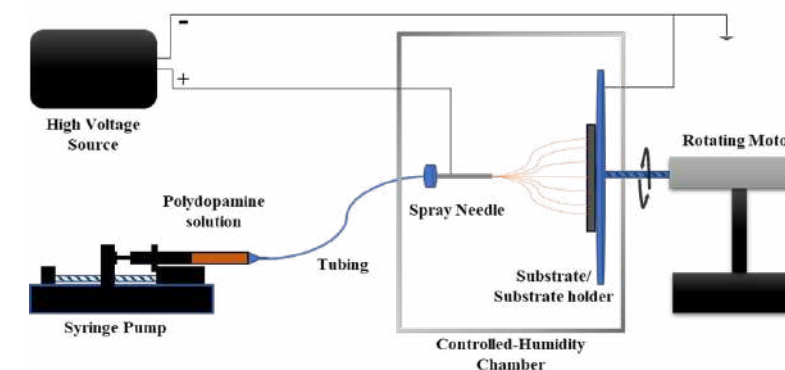
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Polydopamine (PDA) is a versatile bio-inspired polymer that forms strongly adhesive coatings on virtually any substrate. Due to its stability, biocompatibility, and redox activity, PDA films have attracted significant interest for applications in surface engineering, biomedical technologies, energy storage, water purification, and sensing. However, the preparation of thin PDA coatings using conventional methods remains inefficient and poorly controlled. In particular, dopamine polymerization is typically initiated using alkaline buffers or chemical oxidants, which offer limited control over the oxidation process and often lead to unnecessary material consumption. In this work, we demonstrate electrospray deposition (ESD) as a highly material-efficient, tunable, and scalable strategy for PDA film fabrication. The ESD process is combined with a copper-assisted PDA synthesis route¹ that produces stable aqueous PDA stock solutions. This approach enables precise control over film formation and morphology while dramatically improving deposition efficiency compared to conventional dip-coating.

We observed linear relationship between deposited PDA mass and film thickness, confirming controllable film growth.² The chemical composition of the coatings remained consistent with the established PDA structure. The resulting coatings exhibited excellent adhesion and chemical stability on both conductive and insulating substrates. Overall, electrospray deposition provides a sustainable and scalable route for producing uniform PDA thin films with minimal material waste, offering strong potential for future bio-based and nanostructured polymer coating technologies.



1. Al-waeel, M.; Lukkari, J.; Kivelä, H.; Salomäki, M. Heterogenous Copper(0)-Assisted Dopamine Oxidation: A New Pathway to Controllable and Scalable Polydopamine Synthesis. *Langmuir* 2024, 40, 38, 20133–20148

2. Al-waeel, M.; Bodeheimer, R.; Zimmerer, C.; Lukkari, J.; Salomäki, M. Electrosprayed Polydopamine Coatings: Uniformity and Adhesion at Low Material Cost. *Submitted* 2026

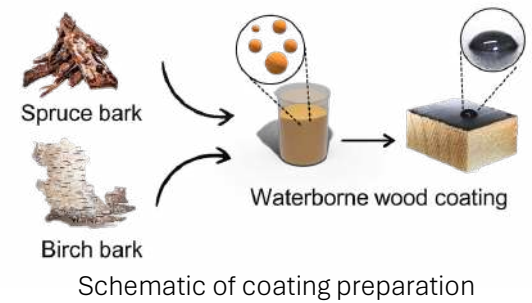
Q31.14 – Fully bio-based water-resistant wood coatings derived from tree bark

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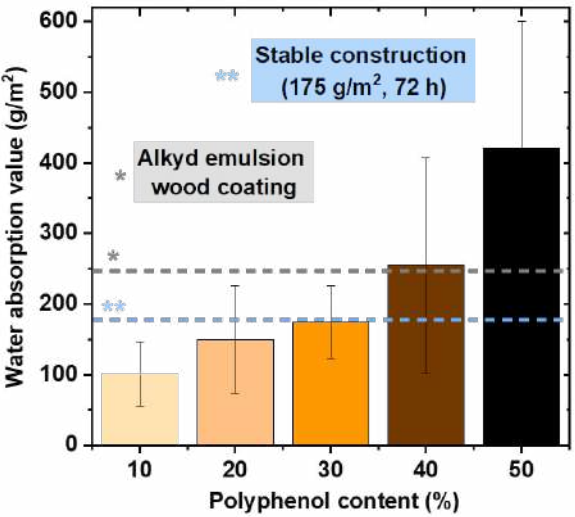
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Surface protection is essential when using wood as a construction material. However, the industry lacks sustainable alternatives to replace the presently dominant fossil-based synthetic water-resistant coatings. Here, we show a fully bio-based wood surface protection system using components sourced from birch bark and spruce bark, inspired by the natural barrier function of bark in trees. The coating formulation contains suberinic acids and spruce bark polyphenols, resulting in a waterborne suspension that is safe and easy to apply to wood. The polyphenols play a dual role in the formulation as they stabilize the water-insoluble suberinic acids and serve as nanofillers in the thermally cured coating, enabling the adjustment of the mechanical properties of the resulting coating.

When applied to spruce wood, the coating formulation with 10% polyphenol and 90% suberinic acids achieved a water absorption value of 100 g m⁻² after 72 hours of water exposure, demonstrating superior performance compared to an alkyd emulsion coating. We conclude that instead of combusting tree bark, it can serve as a valuable resource for wood protection, closing the circle in the wood processing industry.



Wang, F., Morsali, M., Rižikovs, J., Pylypchuk, I., Mathew, A. P., & Sipponen, M. H. (2024). Fully bio-based water-resistant wood coatings derived from tree bark. *Materials Horizons*, 11(24), 6504-6515.

Q31.15 – LIGNIN-ENHANCED BIOBASED COATINGS FOR ROBUST CORROSION PROTECTION

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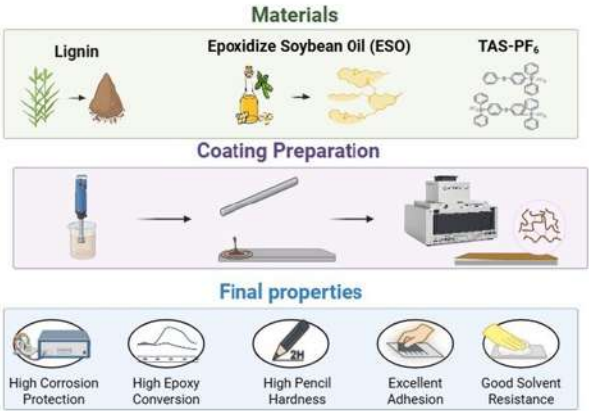
Saba Moradi Boldaji, Leonardo Iannucci, Sabrina Grassini, Luca Carlomaria Pariani, Letizia Anna Maria Rossato, Paola D'Arrigo, Camilla Noè, Massimo Messori, (2026) Progress in Organic Coatings 214, 110024

Corrosion of metallic materials poses significant industrial, economic, and environmental challenges, with organic coatings serving as a primary protective strategy. Growing concerns for sustainability, however, necessitate a shift towards bio-based alternatives. Epoxidized soybean oil (ESO), a highly available and cost-effective bio-based building block, shows promise for anticorrosion coatings due to its inherent flexibility and moisture resistance. Yet, ESO typically requires reinforcement to enhance its mechanical and thermal properties.

This study addresses this need by presenting a novel, fully bio-based, and UV-cured anticorrosion coating, developed through the incorporation of lignin into ESO. Comprehensive characterization of lignin and subsequent photocurable formulations revealed stable rheological properties, high UV reactivity, and high epoxy group conversion (over 75% with lignin). The coatings exhibited robust thermal stability and improved surface properties, including increased hardness, enhanced adhesion to steel substrates, and greater hydrophobicity.

Crucially, lignin incorporation demonstrably translated into superior barrier performance. Electrochemical impedance spectroscopy confirmed that lignin drastically boosts corrosion protection in a harsh 3.5 wt% NaCl environment, a stark contrast to unmodified ESO films offering low protection. Field Emission Scanning Electron Microscopy further validated the excellent corrosion resistance of coatings with 3 wt% lignin, maintaining protection for up to two weeks.

These findings validate a sustainable route to high-performance, eco-friendly corrosion protection, showcasing the feasibility of developing effective UV-curable organic coatings from unmodified renewable sources. This represents a significant step towards a new generation of protective coatings, offering a promising alternative to petrochemical systems and advancing a sustainable industrial future.



Q31.16 – Development and Characterization of Sustainable Cellulose Nanocrystal-Reinforced Polyvinyl Acetate Latex for Advanced Coatings and Composites

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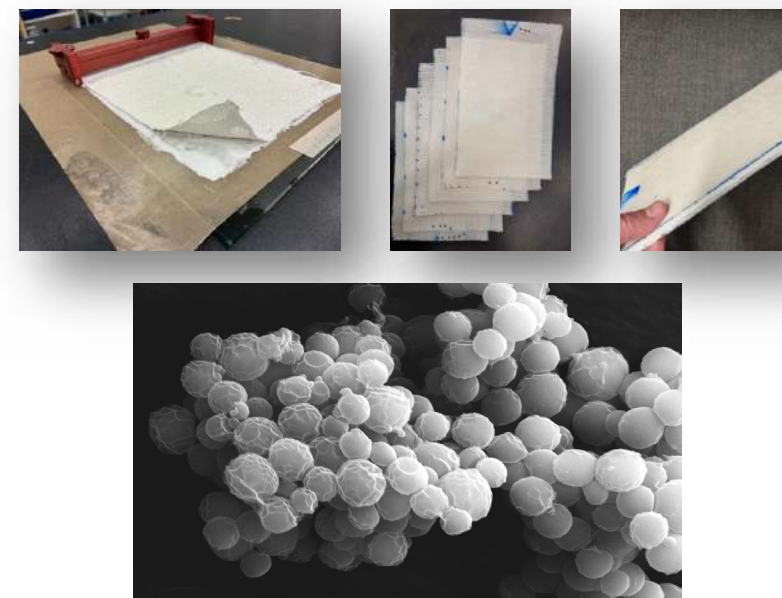
This research presents a scalable and sustainable approach to the development of cellulose nanocrystal (**CNC**)-reinforced polyvinyl acetate (PVAc) nanocomposites for industrial applications.

Utilizing a semi-batch water-based emulsion polymerization technique, stable latexes were synthesized targeting a high total solid content (TSC) ensuring relevance to industrial storage and transportation requirements.

The process successfully incorporated CNC concentrations up to 3.22 wt. % relative to the vinyl acetate monomer, employing various stabilization systems. Characterization through **FTIR**, **SEM**, and **polarized microscopy** revealed that CNC incorporation influences hydrogen bonding, polymer particle size and surface structure.

When applied as **paper coatings**, these nanocomposites demonstrated barrier properties compared to uncoated substrates or pristine PVAc. Mechanical analysis (**DMA**) showed that **annealing** and CNC enhanced dimensional stability, reaching to 93% **reduction in creep**.

The nanocomposite was utilized as a matrix for **viscose fabric composites** produced via prepreg and compression molding method. The results showed that **13.7%** increase in ultimate tensile strength, **36.2%** improvement in **impact resistance**, and a **56%** enhancement in flexural strength compared to the reference.



Q31.17 – $\text{Cs}_{0.33}\text{WO}_3\text{-TiO}_2$ INTEGRATED FLEXIBLE AND THERMORESPONSIVE pNIPAM/GELATIN METHACRYLATE HYDROGEL FILM FOR SMART WINDOWS

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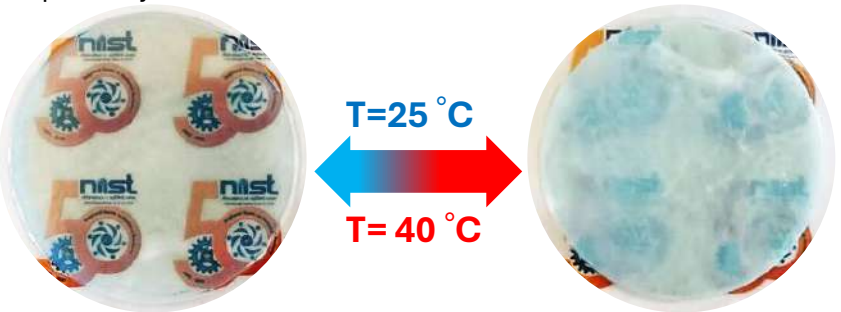
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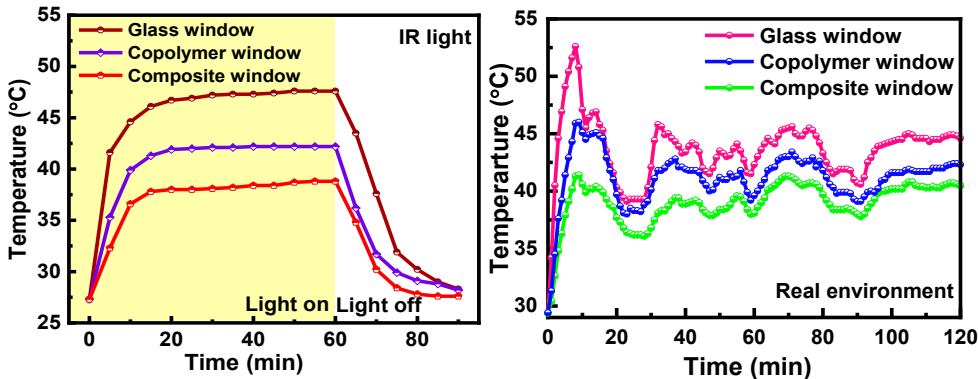
Thermoresponsive smart windows with near-infrared (NIR) shielding potential have attracted increasing attention due to their solar-regulation capability for energy conservation in buildings. A stable and flexible composite hydrogel film was developed by integrating the NIR shielding $\text{Cs}_{0.33}\text{WO}_3\text{-TiO}_2$ heterostructures into the copolymer of poly(N-Isopropylacrylamide) (pNIPAM), gelatin methacrylate (GelMA), and castor oil-derived acrylated epoxidized methyl ester (CAME) developed through free radical polymerization reaction. The copolymeric hydrogel film exhibits tunable lower critical solution temperature (LCST) of 23-27 °C and relatively reduced pNIPAM content making it greener and sustainable.

The composite hydrogel film with 0.7 wt% of $\text{Cs}_{0.33}\text{WO}_3\text{-TiO}_2$ exhibits a significant reduction in NIR transmittance (14% to 4%), while maintaining the daylighting capability, with visible light transmittance changing from 71% below LCST to 18% above LCST. The smart window with composite hydrogel film demonstrated excellent optical modulation ability with luminous transmittance (T_{lum} , 25°C) of 65% and justifiable solar modulation ability (ΔT_{sol}) of 42%.

The composite hydrogel smart window displayed a maximum indoor temperature difference of 8.8 °C and 11.3 °C compared to the glass window on exposure of IR light and in the real environment respectively.



Indoor temperature variation curve with different windows



1. Sudhakaran, N., Abraham, M., Parvathy, P. A., Das, S., & Sahoo, S. K. (2024). Flexible and thermoresponsive AEMR-pNIPAM/ $\text{Cs}_{0.33}\text{WO}_3$ composite hydrogel film with NIR shielding potential for smart windows and smart curtains. *Chemical Engineering Journal*, 490, 151603

Q31.18 – Recyclable Thermosets: Covalent Adaptable Networks Based on Methacrylated Lignin

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Daniel Fischbach¹, Jens Weber^{1*}

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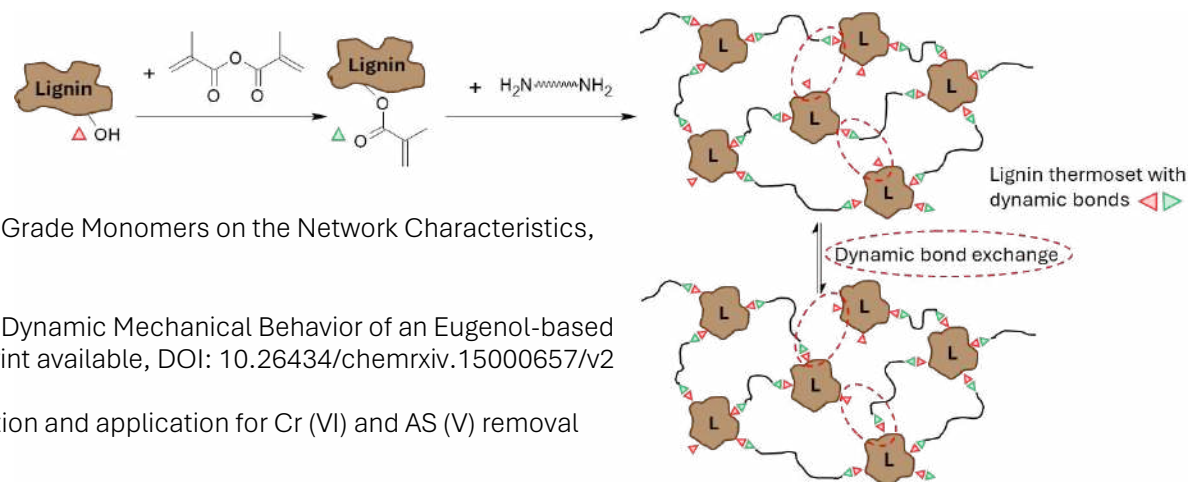
The depletion of fossil resources and the increasing level of environmental pollution intensify the demand for sustainable polymer materials. This challenge is particularly pronounced for thermosets, as desirable end-of-life solutions such as recycling are hindered by their permanently crosslinked network structure.

A promising approach to overcome this limitation is the concept of covalent adaptable networks (CAN), in which dynamic covalent bonds are incorporated into the polymer network, enabling recycling and reprocessing of otherwise permanently cured materials.

In this work, this concept is applied to the synthesis of lignin-based CANs. As lignin is one of the most abundant natural polymers, this strategy offers significant potential for the large-scale production of bio-based recyclable thermosets.

In our approach, lignin is functionalized with methacrylic anhydride to obtain lignin methacrylate. The synthesis is investigated with respect to the influence of different lignin sources, with particular focus on kraft and soda lignin, and is further optimized with regard to potential scale-up.

Network formation is achieved by reacting the methacrylated lignins with amines, yielding dynamic β -amino esters. Key parameters such as lignin source, degree of functionalization, and the incorporation of different comonomers are systematically varied to evaluate their influence on the dynamic mechanical properties and the reprocessability of the CANs



Tannert, R. et al., (2023) Biobased Epoxy Eugenol Vitrimers: Influence of Impurities of Technical Grade Monomers on the Network Characteristics, *Macromolecular Materials and Engineering*, 309, 2300236

Tannert, R. et al., (2026) Consequences of Monomer Impurities on Network Characteristics and Dynamic Mechanical Behavior of an Eugenol-based Covalent Adaptable Network, *Macromolecular Materials and Engineering* (submitted), PrePrint available, DOI: 10.26434/chemrxiv.15000657/v2

Salfate, G. et al., (2024) Lignin and functional polymer-based materials: Synthesis, characterization and application for Cr (VI) and AS (V) removal from aqueous media, *International Journal of Biological Macromolecules*, 278, 134697

Q31.19 – FURAN-DERIVED NANOCRYSTALLINE CELLULOSE AS FILLER FOR REPROCESSABLE DIELS-ALDER COMPOSITES

Andrea Riccioni^{1*}, Andrea Ravicini², Matthieu Fumagalli^{3,4}, Vincenzina Barbera², Roberta Bongiovanni¹, Alessandra Vitale¹

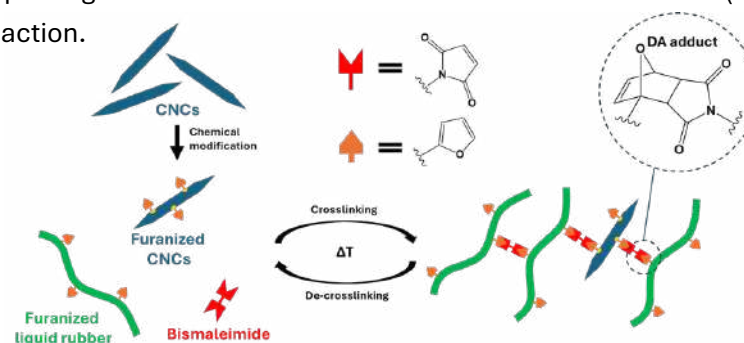
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In the last few decades nanocellulosic materials have received increasing interest due to their great strength, high surface area and good renewability. Among them, cellulose nanocrystals (CNCs) are particularly promising as reinforcing agents in sustainable composites and their surface can be chemically functionalized to tune properties, enabling tailored interfacial interactions and enhanced compatibility with polymer matrices. In addition to replacing conventional fillers, the recyclability of the polymer matrix represents a crucial aspect for composite and elastomer sustainability. In this context, dynamic covalent polymer networks combine thermoset durability with thermoplastic reprocessability, exploiting reversible transformations such as the Diels–Alder (DA) reaction.



The present work describes the preparation of a reprocessable rubber composite based on DA crosslinking and containing furan-functionalized cellulose nanocrystals (F-CNCs). CNCs were extracted from delignified hemp pulp through acid hydrolysis and subsequently functionalized following two different synthetic strategies to introduce furan moieties. Successful functionalization was confirmed by FT-IR and SS-NMR spectroscopy. Different composite formulations containing either pristine CNCs or F-CNCs were prepared through thermal crosslinking of furanized polybutadiene rubber mixed with a bismaleimide crosslinker. The mechanical and chemical properties of the obtained materials were evaluated by DMA, tensile testing, DSC and FT-IR spectroscopy. Composites containing F-CNCs exhibited higher elastic modulus and stress at break compared to both the unfilled matrix and the composites with pristine CNCs, highlighting the beneficial role of covalent interfacial interactions. The reprocessability of the DA-based system was eventually performed through thermomechanical treatment, confirming the potential of this system for sustainable and recyclable rubber composites.

H. Kazemi, F. Mighri, and D. Rodrigue, “A Review of Rubber Biocomposites Reinforced with Lignocellulosic Fillers,” *Journal of Composites Science*, vol. 6, no. 7. MDPI, Jul. 01, 2022. doi: 10.3390/jcs6070183

Zheng N, Xu Y, Zhao Q, Xie T. Dynamic Covalent Polymer Networks: A Molecular Platform for Designing Functions beyond Chemical Recycling and Self-Healing. *Chem Rev*. 2021 Feb 10;121(3):1716-1745. doi: 10.1021/acs.chemrev.0c00938. Epub 2021 Jan 4.

Q31.20 – Combining Oleic and Linoleic Acids for Vitrimeric Materials: A Model Case for Utilizing Rubber Seed Oil

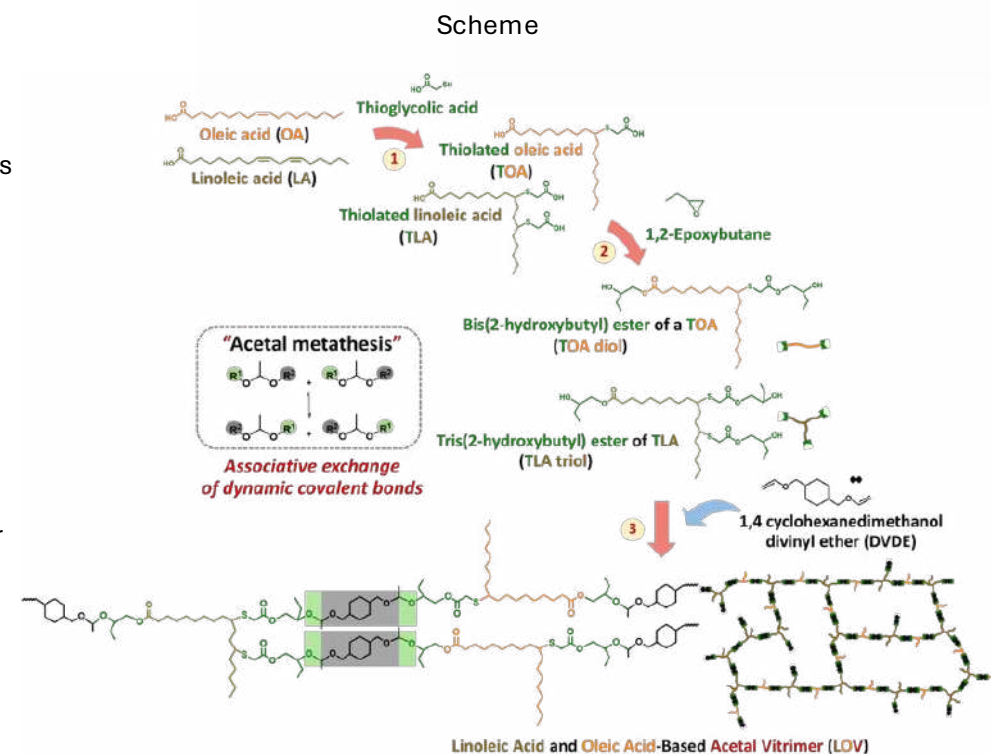
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Although rubber seeds are generally treated as agricultural waste, rubber seed oil (RSO) contains abundant saturated and unsaturated fatty acids, including palmitic, stearic, oleic (OA), linoleic (LA), and linolenic acids, making it a promising sustainable feedstock for bio-based materials. Vitrimers are polymeric materials within covalent adaptable networks (CANs) that contain dynamic covalent (DC) bonds.¹ Their thermoplastic-like reprocessability combined with thermoset-like crosslinked structures makes them promising environmentally friendly materials. Among various DC chemistries, catalyst-free acetal metathesis is particularly attractive, as it forms through reactions between hydroxyl and vinyl ether groups and undergoes acetal exchange at elevated temperatures without external catalysts.² From our perspective, combining fatty acid with DC networks offers a practical strategy for developing materials with tailorable structures, desirable mechanical properties, and reprocessability. In this work, OA and LA are utilized to construct vitrimeric materials (Scheme). OA and LA are first reacted with thioglycolic acid (Step 1), followed by reaction with 1,2-epoxybutane (Step 2) to yield diol and triol monomers. Subsequent reaction with divinyl ether (Step 3) forms acetal-crosslinked OA- and LA-based vitrimers. The presentation will also cover the material performance in relation to the DC networks.



1. Damien M., Capelot M., Tournilhac F., Leibler L. (2011). Silica-like malleable materials from permanent organic networks. Science, 334, 965-968.

2. Yue L., Su Y. L., Li M., Yu L., Montgomery S. M., Sun X., Finn M. G., Gutekunst W. R., Ramprasad R., Qi H. J. (2023). One-pot synthesis of depolymerizable δ -lactone based vitrimers. Advanced Materials, 35, 2300954.

Q31.21 – Design of Bio-based Elastomers via Dynamic and Permanent Network Architectures for Tunable Mechanics and Circularity

Ratthapit Wuttisarn¹, Sorapat Niyomsin¹, Autchara Pangon², Apirat Laobuthee³, Chatchai Veranitisagul⁴, Seema Agarwal^{5,*} and Suwabun Chirachanchai^{1,*}

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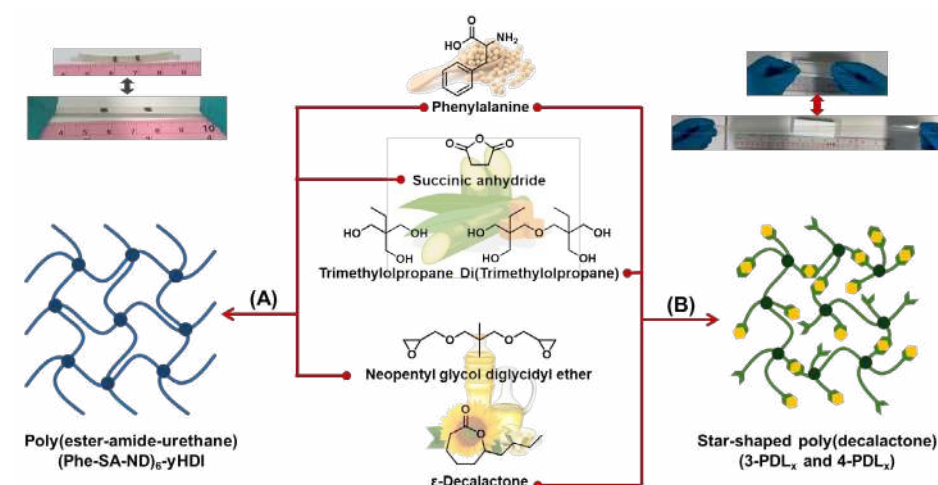
The development of sustainable elastomers with tunable mechanical properties and controlled end-of-life behavior is essential for advancing circular polymer materials. This work explores two distinct network design strategies, i.e., permanently crosslinked networks and dynamic covalent networks to construct bio-based elastomers using amino acid-derived building blocks in combination with potentially bio-based chemicals, including glycidyl ether, succinic anhydride, and ϵ -decalactone.

For the permanent crosslinked network approach, a poly(ester-amide-urethane), namely Phe-SA-ND)₆-yHDI based on phenylalanine, succinic anhydride, and neopentyl glycol diglycidyl ether is proposed (Scheme Route A). The material exhibits glass transition temperatures (T_g) from -15 to -12 °C, a tensile strength up to 1.5 MPa, and an elongation at break up to 300%. It demonstrates excellent aqueous stability with minimal swelling and undergoes efficient methanolysis-based degradation at ambient temperature.¹

For the dynamic crosslinked network approach, star-shaped poly(ϵ -decalactone) networks, i.e., 3-PDL_x and 4-PDL_x, incorporating vinylogous urethane bonds as dynamic crosslinks using diphenylalanine as a multifunctional crosslinker, are proposed, yielding vitrimeric elastomers (Scheme Route B). The materials consist of associative bond exchange, enabling thermal reprocessability while maintaining network integrity. They exhibit T_g

values from -49 to -39 °C and an elongation at break exceeding 2000%, retaining approximately 75% of their initial mechanical performance after multiple reprocessing cycles. The materials undergo industrial composting, depending on the crosslink density.

This study highlights the design of sustainable bio-based elastomers and provides molecular-level insights into balancing mechanical performance, recyclability, and degradability in next-generation soft materials.



1. Ratthapit Wuttisarn, S. Niyomsin, A. Pangon, C. Veranitisagul, A. Laobuthee, & S. Chirachanchai. (2026). α -amino acid-derived poly(ester-amide-urethane): A potential bio-based elastomers with tunable mechanics and methanolysis-driven degradability. Polymer Degradation and Stability, 244, 111786.

Q31.22 – FURFURAL-BASED RECYCLABLE EPOXY RESIN FOR HIGH-PERFORMANCE COMPOSITES

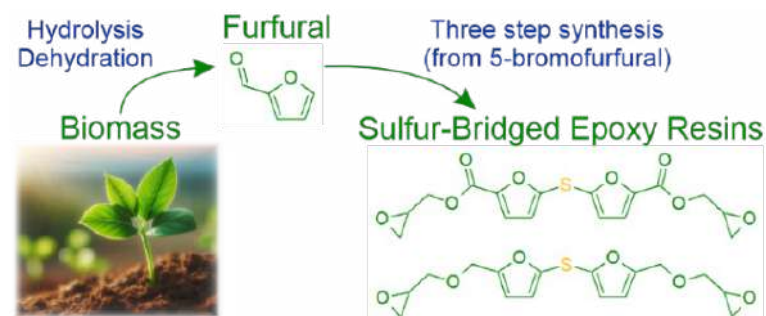
Reima A. Terho^a, Bianca Dal Pont^b,
Mikko Aleksi Salonen^a, Juho Antti
Sirviö^c, Tuomo P. Kainulainen^a,
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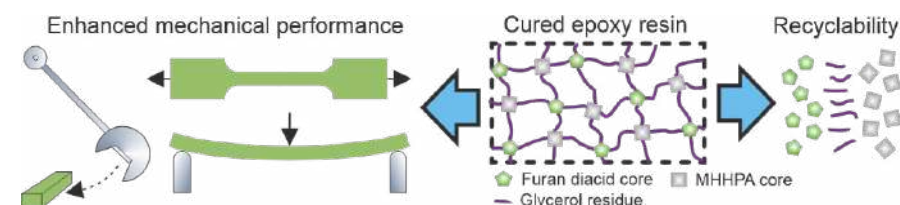
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Interest in reducing fossil-based resources has grown, boosting the search for renewable biobased alternatives. Lignocellulosic biomass offers aromatic platform chemicals, such as cellulose-derived HMF. In contrast, hemicellulose-based furfural has received less attention despite promising recent findings. This work introduces two new furfural-derived epoxy resins, evaluated against DGEBA. After curing, mechanical, thermal, and adhesion testing, the bioresins demonstrated strong potential as sustainable DGEBA replacements.¹

Epoxy thermosets based on DGEBA are widely used in high-performance composites. The novel renewable furfural-derived diol- and diacid-based diepoxies were studied as replacements for DGEBA in anhydride-cured systems reinforced with glass or flax fibers. The composites prepared using biobased resins show superior mechanical performance. Glass fiber composites with the diacid epoxy reach markedly higher Young's modulus, 24.0 GPa (tensile) and 28.5 GPa (flexural), and strengths, along with improved impact toughness compared to DGEBA-based composite. They also enable closed-loop recycling through mild K_2CO_3 -catalyzed methanolysis of furan ester bonds, yielding reusable monomer. This approach offers a promising route to sustainable, high-performance composites.²



1) Terho, R. A.; Kainulainen, T. P.; Salonen, M. A.; Sirviö, J. A.; Heiskanen, J. P. Renewable Furfural-Based Sulfur-Bridged Epoxy Resins with Excellent Adhesive Properties. *Macromolecules* 2024, 57, 10735. DOI: 10.1021/acs.macromol.4c01000. 2) Terho, R. A.; Dal Pont, B.; Kainulainen, T. P.; Aliotta, L.; Gigante, V.; Lazzeri, A.; Heiskanen, J. P. Circular composite materials: Biomass-based furan epoxies with high-performance and closed-loop recyclability. *Composites Part B* 2026, 311, 113256. DOI: 10.1016/j.compositesb.2025.113256.

Q31.23 – Biobased Epoxidized Castor Oil Covalent Adaptable Networks Adhesives Reinforced with Recycled Carbon Fibers

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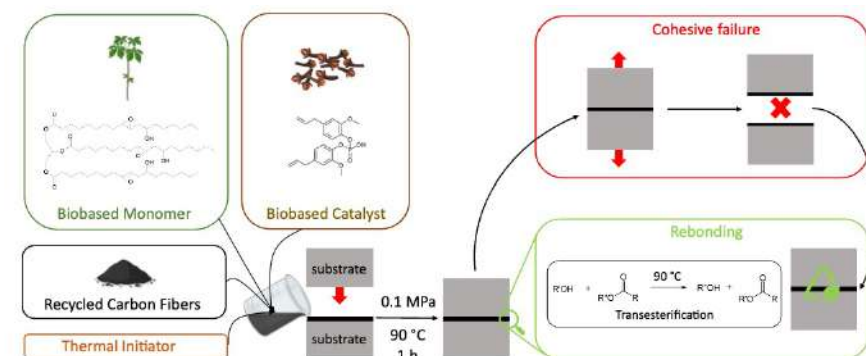
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Thermosetting adhesives face significant recycling challenges due to their permanent crosslinked structures [1]. This study presents a fully bio-based Covalent Adaptable Network (CAN) adhesive formulated from epoxidized castor oil (ECO) and a novel eugenol-based phosphate ester (EUGP) catalyst [2,3]. To enhance thermomechanical performance, recycled carbon fibers (RCF) were integrated as reinforcing fillers. The curing process, initiated by Ytterbium(III) triflate (YTT), enabled efficient crosslinking at both 90°C and room temperature (25°C, 24 h), providing a low-energy production route. FT-IR confirmed high epoxy conversion rates (up to 88%), while DMTA revealed a storage modulus enhancement from 1 MPa (pristine) to 40 MPa with 20 phr RCF. Rheological stress-relaxation tests (1000 s at 70°C) confirmed thermally activated transesterification and material reprocessability. Mechanical testing on ceramic matrix composite (CMC) and Al alloy joints showed that joint strength increased with fiber loading.

Notably, rebonded joints retained up to 91% of their initial strength after two repair cycles. This work demonstrates a sustainable, high-performance alternative to conventional functional adhesives for circular electronics and advanced composites.



1. Sangermano, M., et al. (2024). Biobased Vitrimeric Epoxy Networks. *Macromolecular Materials and Engineering*, 309, 2300371.
2. Alarcon, R.T., et al. (2020). Spectroscopic characterization and thermal behavior of vegetable oils and their epoxidized derivatives. *Industrial Crops and Products*, 154, 112585.
3. Sölle, B., et al. (2023). Synthesis and characterization of bio-based transesterification catalysts for green 3D-printable dynamic photopolymers. *Polymer Chemistry*, 14, 4994–5003.

Q33.11 – When nanocellulose meets its bio-friends

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At the intersection of nanotechnology and renewable resources, nanocellulose stand out for serving as a versatile foundation for sustainable materials across various applications. The scientific efforts over the past years have highlighted the importance of processability¹ and structural design of these materials to overcome limitations in mechanical, optical, and swelling properties.

Here, it is presented how mechanical, optical, and water binding properties are affected in hybrid nanocellulose films containing biobased extractives, nanoparticles, or polymers.

Our efforts have shown that these extractives and lignin nanoparticles can produce excellent, durable UV-shielding materials for optoelectronics. For instance, nanocellulose films dyed with red onion extractives can block 99.9% of radiation below 400nm, and, as a result, solar cells could last 5.7 times longer than when used with conventional UV filters².

Furthermore, when incorporating Tempo cellulose nanofibrils (T-CNF) within an agar film, the mechanical and water binding properties were affected. For instance, when the film contains the same amount of TCNF and agar, its tensile strength is almost double that of the agar film itself, achieving comparable strength to conventional plastics such as low density polyethylene.

Unfortunately, the presence of TCNF within the agar film increases swelling capacity, posing a major challenge for certain packaging applications.

The last example uses the complexation between TCNF with trimethyl chitosan (TMC) to produce coatings with antifouling and antibacterial properties. The positive charges of TMC electrostatically attract and disrupt the negatively charged bacterial membranes. The negative charges of TCNF help create a resistant coating, which acts as a protective barrier against biofilm formation.

Therefore, it is safe to conclude that hybrid nanocellulose materials present a promising platform for multifunctional systems that are relevant for versatile applications.

1. Kaschuk, J. J.; et al (2024). Processing Factors Affecting Roughness, Optical and Mechanical Properties of Nanocellulose Films for Optoelectronics. *Carbohydrate Polymers*, 332.
2. Nizamov, R.; et al. (2025) Sustainable Nanocellulose UV Filters for Photovoltaic Applications: Comparison of Red Onion (*Allium Cepa*) Extract, Iron Ions, and Colloidal Lignin. *ACS Applied Optical Materials*, 3 (3), 664–675.

Q33.12 – Production of Carboxylated Cellulose Nanocrystals from Brewer's Spent Grain

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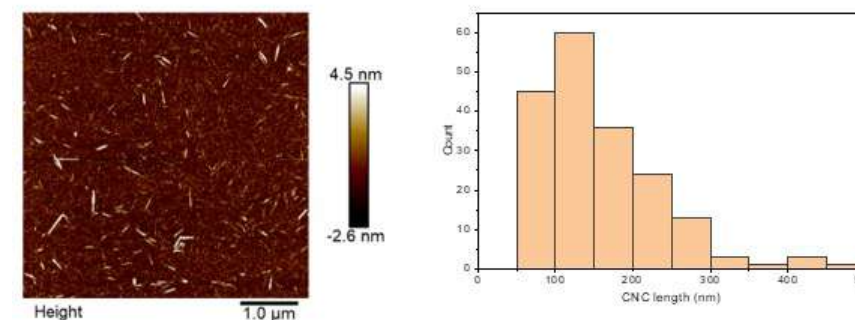
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Agricultural side streams are among the future raw materials for many of the products made of cellulose due to the limited resources of wood and environmental concerns. Brewer's spent grain (BSG), also called beer residuals, is the major by-product of the brewing industry with an average annual global production of 39 million tons.¹ Brewing process removes the soluble parts of the grain and leaves the insoluble materials (BSG), including 15-26 % of protein and 25-60 % of fibrous material.² The main application of BSG has been limited to animal feedstock due to the abundant amount of nutrients.

The production process of cellulose nanocrystals (CNCs) from BSG draws from our recently introduced nanocellulose isolation from potato residue.³ In that process, alkali extracted potato residue was hydrolyzed with gaseous HCl and NaClO₂ was used to block humin formation and act as bleaching agent. The process simultaneously yielded cellulose nanofibrils and cellulose nanocrystals. The latter product was carboxylated with TEMPO oxidation.

In the same vein, barley malt and whole oat grain malts were mashed in a laboratory scale device to produce BSG samples. Alkali extraction, HCl/NaClO₂ hydrolysis and TEMPO oxidation was applied to produce raw material for carboxylated CNCs. Fully dispersed CNCs were produced with a microfluidizer. Despite abundance of barley malt, whole grain oat would be a promising raw material for nanocellulosic products due to the higher yield. The results are compared with those gained earlier for potato residues.



AFM height image length analysis of the CNC suspension made of barley malt

1 Verni, M., Pontonio, E., Krona, A., Jacob, S., Pinto, D., Rinaldi, F., Verardo, V., Díaz-de-Cerio, E., Coda, R., Rizzello, C. G. (2020) Bioprocessing of Brewers' Spent Grain Enhances Its Antioxidant Activity: Characterization of Phenolic Compounds and Bioactive Peptides. *Frontiers in Microbiology*, 11, 1831

2 Shen, Y., Abeynayake, R., Sun, X., Ran, T., Li, J., Chen, L., Yang, W. (2019) Feed Nutritional Value of Brewers' Spent Grain Residue Resulting from Protease Aided Protein Removal. *Journal of Animal Science and Biotechnology*, 10 (1), 78.

3 Wang, Y., Pääkkönen, T., Solhi, L., Yousefi, N., Kontturi, E. (2025) Targeted Isolation of Cellulose Nanofibers of Specific Length Distributions from Potato Residue. *Carbohydrate Polymers*, 354, 123315.

Q33.13 – Sustainability-Validated Valorization of Secondary Lignocellulosic Biomass via Direct TEMPO Oxidation

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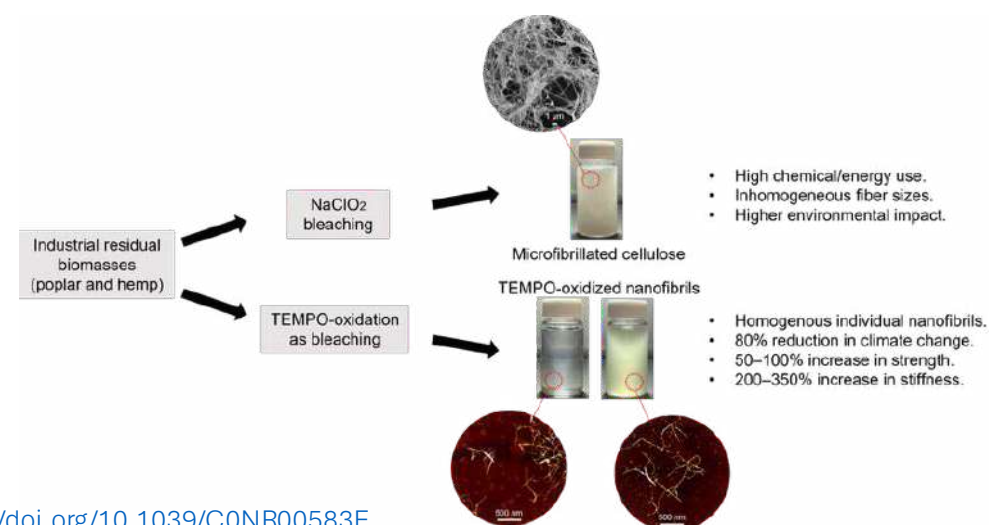
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A circular bioeconomy is a foundation of a sustainable society. Advancing circularity through sustainable use of resources and development of sustainable processes and products is crucial in this context. Therefore, this study focuses on the extraction and characterization of nanocellulose from two major industrial residual sources: poplar and hemp.

We propose a refining route that replaces traditional bleaching with 2,2,6,6-tetramethylpiperidine-1-oxyl (TEMPO) oxidation, which simultaneously facilitates lignin degradation and C6-carboxylation to produce high-quality nanofibrils.¹ Two degrees of TEMPO-oxidation were performed to yield TEMPO-oxidized cellulose nanofibrils (TO-CNFs) and TEMPO-oxidized lignin-containing cellulose nanofibrils (TO-LCNFs). These nanofibrils were compared against conventional microfibrillated cellulose (MFC) produced from NaClO₂ bleaching.

The results revealed this route effectively separates cellulose into individual nanofibrils with widths of 2.2-3.6 nm. Mechanical properties were evaluated in the form of nanopaper, showing a 50–100% increase in strength and a 200–350% increase in stiffness compared to their MFC counterparts. The environmental impact was quantified via Life Cycle Assessment (LCA) using the EF 3.1 method. The finding indicates that replacing conventional bleaching with TEMPO-oxidation offers a superior environmental profile, achieving an ~80% reduction in climate change compared to MFC production.



1. Isogai, A., Saito, T., & Fukuzumi, H. (2011). TEMPO-oxidized cellulose nanofibers. *Nano scale*, 3(1), 71–85. <https://doi.org/10.1039/C0NR00583F>

Q33.14 – Low-volatility plasticizers for improved melt processability and thermomechanical properties of dialcohol cellulose fibres

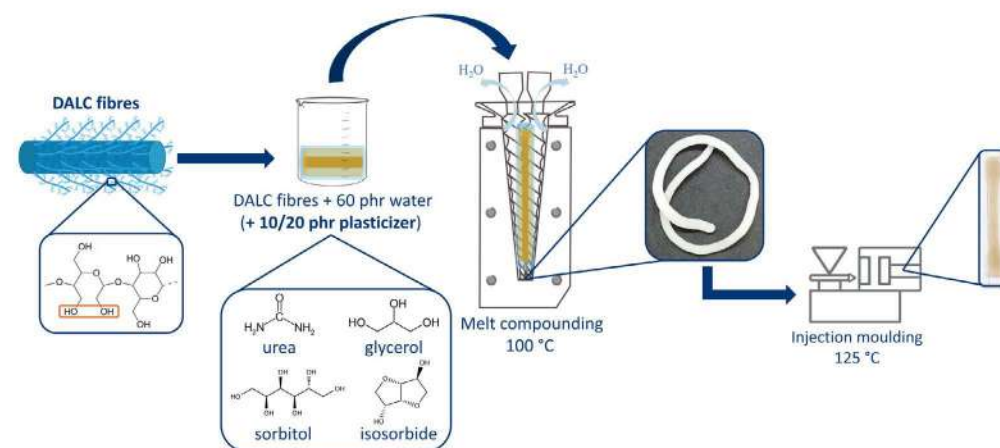
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Growing concerns about the environmental impact of fossil-based plastics have increased interest in renewable replacements. Cellulose-based polymers are promising alternatives. However, their strong intermolecular interactions raise the melting point above the degradation temperature, hindering their melt processing in conventional equipment. Chemical modification of cellulose pulp into dialcohol cellulose (DALC) fibres reduces crystallinity, creating a processing window between the reduced glass transition and degradation temperature. Previous studies showed that DALC fibres can be melt-processed with water as a processing aid^{1,2}, but water evaporation leads to rigid materials with moisture-sensitive properties. This study explores the use of less volatile plasticizers (urea, glycerol, sorbitol, and isosorbide) to tailor the thermomechanical and viscoelastic properties of DALC. All the resulting formulations were evaluated in terms of melt processability, morphology, thermal stability, mechanical performance, viscoelastic behaviour, and molecular mobility.

Improved processability was observed, associated with a reduced glass transition temperature and enhanced molecular mobility, while environmental sensitivity was also decreased. The results highlighted both progress and remaining challenges.



¹ Lo Re, G., Engel, E. R., Björn, L., Sicairos, M. G., Liebi, M., Wahlberg, J., ... & Larsson, P. A. (2023). Melt processable cellulose fibres engineered for replacing oil-based thermoplastics. *Chemical Engineering Journal*, 458, 141372.

² Pellegrino, E., Al-Rudainy, B., Larsson, P. A., Fina, A., & Lo Re, G. (2025). Impact of water plasticization on dialcohol cellulose fibres melt processing-structure-properties relationship. *Carbohydrate Polymer Technologies and Applications*, 9, 100642.

Q33.15 – Biodegradable earplugs- Greener approach

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Interest in biobased materials is rapidly increasing as society moves towards more sustainable and eco-friendly future. This study focuses on biobased sound-absorption materials, particularly earplugs. Commercial earplugs are typically made from polyurethane (PU) and polyvinyl chloride (PVC) foams derived from petroleum-based fossil fuels, whose production impacts the environment¹.

TEMPO-oxidized hardwood cellulose (TO) and chitosan are used to fabricate porous cryogels for earplug applications. Due to high carboxylic groups in TO that facilitates ionic crosslinking with other biopolymers². Chitosan acts as an elastomer and enhances the mechanical properties of the material. A chitosan solution (CH) in acetic acid (AA) is mixed with TO and then freeze casted and dried to obtain porous, anisotropic-structured cryogels.

The cryogels are optimized by varying the molecular weight of chitosan, the blending ratio of the two biopolymers, and the solvent concentration. The surface morphology of the resulting structures were characterized using scanning electron microscopy.

Acoustic properties are evaluated by measuring the sound absorption coefficient (SAC) and transmission loss (TL) for both the whole cryogels and the squeezed (to mimic earplugs) cryogels configurations. Figure 1 shows the SAC of the fabricated materials of different ratios in different solvent concentration, 1:1, 2:1 and 3:1 (TO:CH) in 3% AA exhibited near perfect sound absorption ranging from 0.95 to 1 in the frequency range of 1500–6000 Hz. The squeezed cryogels exhibited transmission loss up to 60 dB, that outperformed commercial products such as PU and melamine foams.

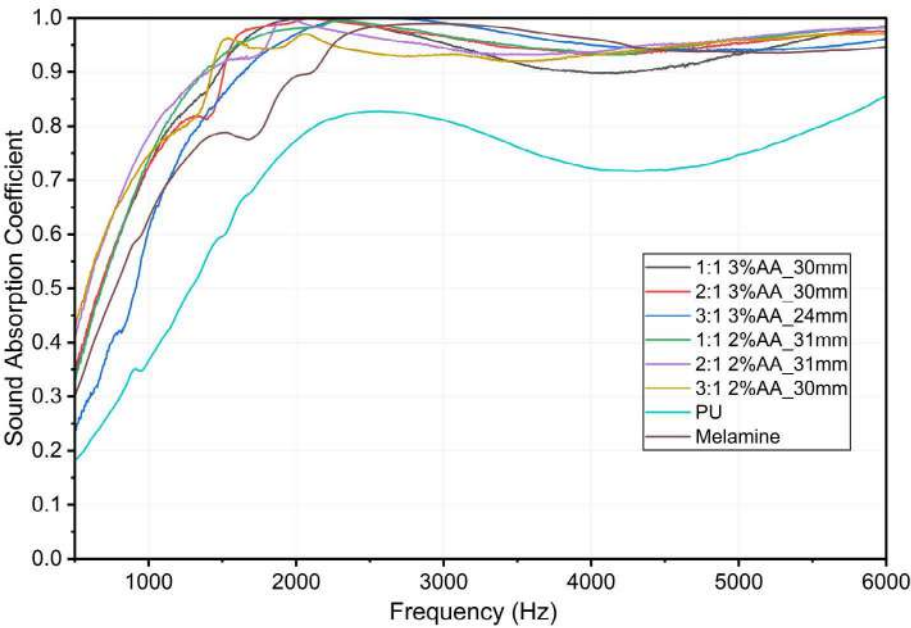


Figure 1 Sound absorption coefficient of cellulose cryogels

1. Pfohl, P. *et al.* Environmental degradation and fragmentation of microplastics: dependence on polymer type, humidity, UV dose and temperature. *Microplastics and Nanoplastics* 5, 7 (2025).

2. Lan, X. *et al.* TEMPO-Oxidized Cellulose Nanofiber-Alginate Hydrogel as a Bioink for Human Meniscus Tissue Engineering. *Front. Bioeng. Biotechnol.* 9, (2021).

Q33.16 – Green and Fire Safe Cellulose-Based Lightweight Materials

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Polyelectrolyte complexation is a versatile strategy for producing functional composites and coatings, thanks to the broad range of polyelectrolyte pairings and tunable assembly conditions. In this work, polyelectrolyte complexes (PECs) are exploited to produce 3D self-standing fiber networks. To this aim, cellulose fibers have been functionalized by a Layer-by-Layer (LbL) assembly encompassing chitosan and sodium polyphosphate. Self-standing 3D structures based only on chitosan/sodium hexametaphosphate coated cellulose fibers were achieved by means of freeze-drying. SEM observations pointed out the formation of a porous fiber network where the deposited LbL coating is acting as a glue conferring structural integrity. The cellulose fiber content ranged between 80-90 wt.% highlighting the potentialities of the proposed approach in delivering lightweight porous structure with extremely high fiber content. Flammability tests in horizontal configuration evidenced a self-extinguishing behavior for foams prepared from 1BL coated fibers. By cone calorimetry the prepared foams showed very low heat and smoke release values, well below a commercial polyurethane foam.

In a different system, sodium hexametaphosphate/gelatin/polyacrylic acid/gelatin assembly has been developed as LbL coating for rice husk particles. The so coated particles have been dispersed in a nanocellulose gel in order to prepare nanocellulose/coated rice husk composites characterized by high coated particle concentration (>80%wt). Thanks to the presence of the LbL coating and the favorable interaction with the nanocellulose matrix the prepared composites showed a compressive strength at 10% deformation up to 167 kPa at a density of 80 kg/m³. The same sample can easily self-extinguish a flame in vertical configuration.

The obtained results clearly demonstrate the versatility of PECs in delivering functional materials where mechanical properties, flame retardancy and sustainability are optimized.

[1] Marcioni, M.; Zhao, M.; Maddalena, L.; Pettersson, T.; Avolio, R.; Castaldo, R.; Wågberg, L.; Carosio F.; Layer-by-layer-coated cellulose fibers enable the production of porous, flame-retardant, and lightweight materials. ACS Appl. Mater. Interfaces 2023, 15, 36811D. DOI: 10.1021/acsami.3c06652

Q33.17 – HiProBio: High speed production of biodegradable caps in natural fiber materials from locally sourced agricultural waste

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¹Danish Polymer Center, DTU Chemical Engineering, Lyngby, Denmark

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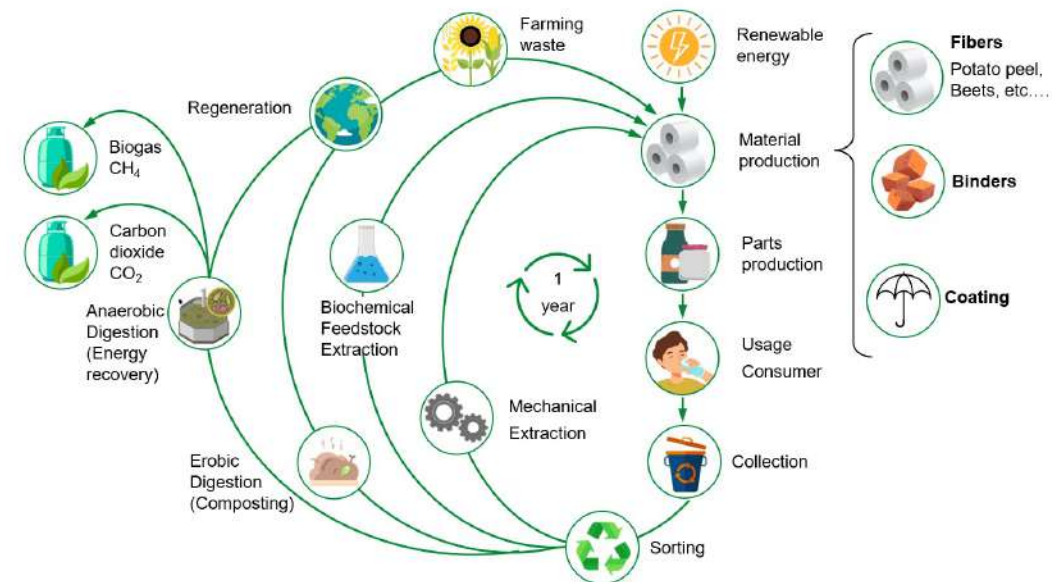
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The food and beverage industry rely heavily on low-cost, fossil-based packaging for their fast-paced production. Paper and cellulose-based alternatives are attractive as they are inexpensive and sustainable. However, cellulose displays unsatisfactory barrier properties for the packaging industry, and is often combined with an inner plastic coating.^{1,2} Today, paper-based solutions require at minimum a layer of plastic (polyolefins or PLA), which prevents recycling.

The renewable sources considered to produce paper materials is also of critical importance. Agricultural waste fibers are a sustainable and underutilized source of cellulose fibers. They present the advantage of being grown over the course of a year, making a regenerative process with 1 year circularity.

The aim of this project is to develop a binders solution to apply on an air-laid, non-woven cellulose mat, with the purpose of modifying the barrier properties.



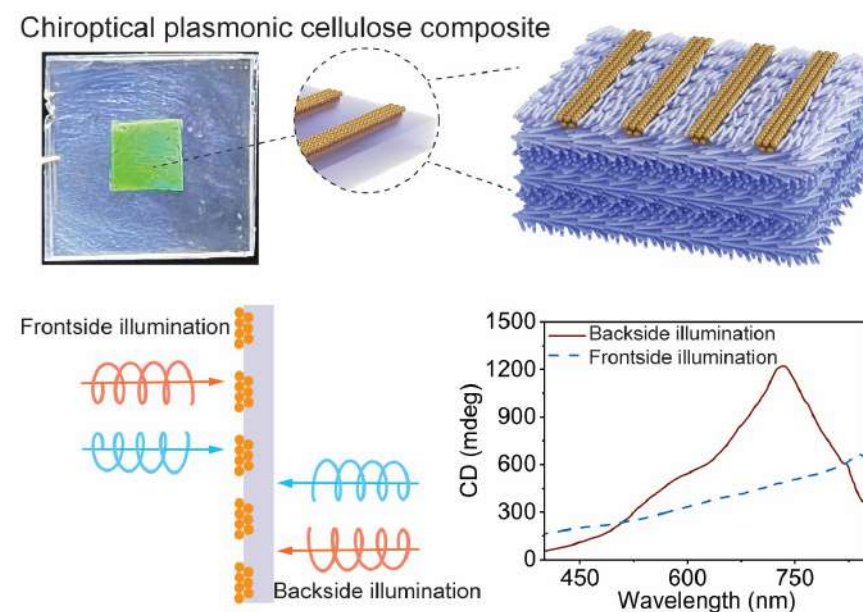
¹Quilez-Molina, A. I., Pasquale, L., Debellis, D., Tedeschi, G., Athanassiou, A., and Bayer, I. S. (2021). Responsive Bio-Composites from Magnesium Carbonate Filled Polycaprolactone and Curcumin-Functionalized Cellulose Fibers. *Advanced Sustainable Systems*, 5, 2100128.

²Chinga-Carrasco G., Syverud K. (2012). On the structure and oxygen transmission rate of biodegradable cellulose nanobarriers. *Nanoscale Res Lett.*, 7(1), 192.

Q33.18 – Engineering Chiroptical Interactions through Integrating Plasmonic Arrays with Cholesteric Nanocellulose

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Achieving scalable fabrication with precise control of chiroptical properties in chiral plasmonic materials remains challenging. We present a new family of engineered chiroptical composites comprising linearly assembled gold nanoparticle arrays integrated with cholesteric self-assembled cellulose nanocrystals (CNCs). Aqueous CNC suspensions are cast onto pre-assembled achiral plasmonic nanoparticle arrays via evaporation-induced transfer imprinting lithography, yielding centimeter-scale hybrid films with custom-tailored chiroptical responses. During drying, CNCs co-assemble with the gold nanoparticles at the interface, preserving the array's linear arrangement and keeping it isolated from the overlying cholesteric CNC layers. This configuration combines the linear dichroism of the plasmonic array with the linear birefringence of the CNC matrix, producing strong and tunable plasmonic circular dichroism at the surface lattice resonance, reaching 1217 ± 51 mdeg with a dissymmetry factor of -0.19 ± 0.02 . Our approach provides a sustainable platform for engineering multifunctional chiral plasmonic materials with potential applications in optical sensing, photonic devices, and chiral biointerfaces.



H. Tao, S. Jo, G. Chu, et al. “ Engineering Chiroptical Interactions through Integrating Plasmonic Arrays with Cholesteric Nanocellulose.” *Advanced Materials* (2026): e19964. <https://doi.org/10.1002/adma.202519964>

Q33.19 – Porosity engineering in biomass-derived polymer materials enables tuneable fluid absorption

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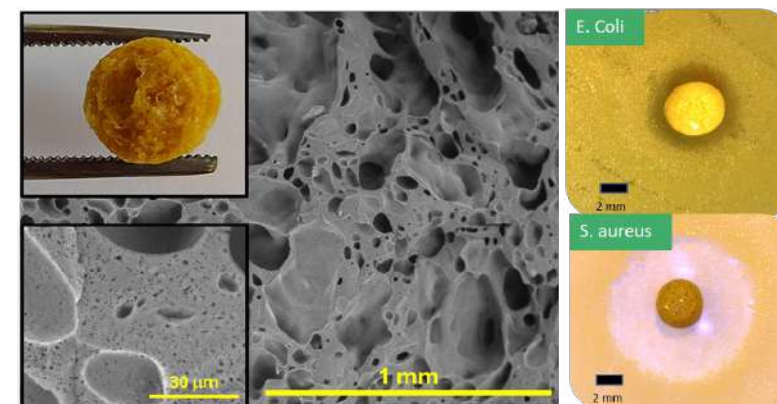
3. University of the Basque Country, Leioa, Spain

The ability to control pore architecture is central to the design of absorbent materials. (1) In bio-based polymer systems, however, achieving tuneable porosity through scalable processing remains a major challenge. In this work, we demonstrate how biomass-derived polymer blends can be engineered to generate controlled porous architectures that directly regulate fluid absorption performance. (2)

Biopolymer blends derived from industrial biomass residues, including proteins and lignocellulosic components, were processed through reactive extrusion using low-energy thermomechanical routes compatible with conventional polymer processing equipment. By tailoring formulation and processing parameters, stable pore networks with tuneable morphology were obtained. The resulting materials exhibit interconnected porous structures that govern liquid transport and retention behavior.

This structure-property relationship enables the modulation of absorption capacity by controlling pore architecture, highlighting the potential of these materials as sustainable absorbent systems.

As a proof of concept, the porous bio-based matrices were designed to encapsulate therapeutic active molecules for their evaluation in wound dressing applications, where efficient fluid uptake, retention, and adequate antibacterial properties are essential. Overall, this work demonstrates that porosity engineering in biomass-derived polymer blends provides a scalable pathway to design functional absorbent materials, offering a sustainable alternative to petroleum-based porous plastics for single-use applications.



(1) Federico et al. (2022) *Polymer Testing*, 116, 107753.

(2) Latras et al. (2025) *ACS Applied Polymer Materials*, 7 (19), 13099-13113.

Q33.20 – Topology Optimization of Variable-Density Bio-Based Foams for Circular and Material-Efficient Design

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•³ CNR -- Consiglio Nazionale delle Ricerche, Istituto di Chimica della Materia Condensata e di Tecnologie per l'Energia, Via R. Cozzi 53, 20125 Milano, Italy

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•Engineering structures are often optimized by combining different materials to adapt to local stress distributions and functional demands. Although this improves performance, it also creates major challenges for recycling, since multi-material components are difficult to separate and reprocess. Monomaterial, bulk structures are more attractive from a circularity perspective, but they offer limited options for adapting local material properties, often resulting in limited performance. Foams provide a promising remedy: while remaining single-material systems, they can be locally tailored through variations in density, enabling adaptation to local stresses while remaining as recyclable as corresponding bulk structures.

•In this work, we combine bio-based materials, and computational design for lightweight and circular material solutions. We study 3D-printed foams based on bio-based polymers such as cellulose acetate, manufactured with spatially varying density using additive foam manufacturing. Structural design is carried out using topology optimization in our open-source Python package TopOptLab1, which optimizes the material layout within a prescribed domain. We show that the ability to vary foam density introduces an additional and practically relevant design variable that can significantly improve structural efficiency. Through representative mechanical benchmark problems, we highlight how variable-density, bio-based monomaterial foams can enable designs that use material more efficiently while aligning with the principles of circular materials.

- 1 Hiemer, Stefan. "topoptlab: An Open and Modular Framework for Benchmarking and Research in Topology Optimization." Journal of Open Source Software 11.118 (2026): 9105.

Q33.21 – GREEN ENGINEERED LIGNIN AS A SUSTAINABLE SUPPORT FOR PRECIOUS METAL CATALYSTS FROM E-WASTE REPURPOSE

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Rapid technological advancements have resulted in a surge of Waste Electrical and Electronic Equipment (WEEE), which contains hazardous substances posing significant environmental and health threats. However, WEEE are also emerging as a rich source of valuable and critical materials including precious and semi-precious metals, such as silver, copper, gold, and platinum, whose recover is essential for meeting the sustainable demand for metal resources while promoting the circular economy.

In this context, biowastes are promising sustainable and low-cost materials, particularly as sorbents and catalyst supports. Among them, polyphenols show great potential as sorbents due to their huge content of both hydroxyl and carboxyl groups, which can chelate and reduce precious metal ions [1]. Lignin is a major renewable aromatic resource, though its reactivity is limited by methoxy groups.

Therefore, unlocking the phenolic hydroxyl functionality through O-demethylation (ODM) is a valuable approach that increases the number of active sites, thus enhancing metal adsorption performance and, consequently, the catalytic functionality of lignin.

In this study, demethylated lignin was obtained via Brønsted acid-mediated cleavage using concentrated lithium bromide under mild conditions, achieving a ~30% increase in phenolic hydroxyl groups as confirmed by ³¹P NMR. Additionally, the catalytic activity of the samples was investigated via the reduction of 4-nitrophenol to 4-aminophenol. The demethylated lignin showed markedly higher catalytic performances with respect to the pristine sample, confirming the key role of phenolic hydroxyl groups introduced by the ODM treatment.

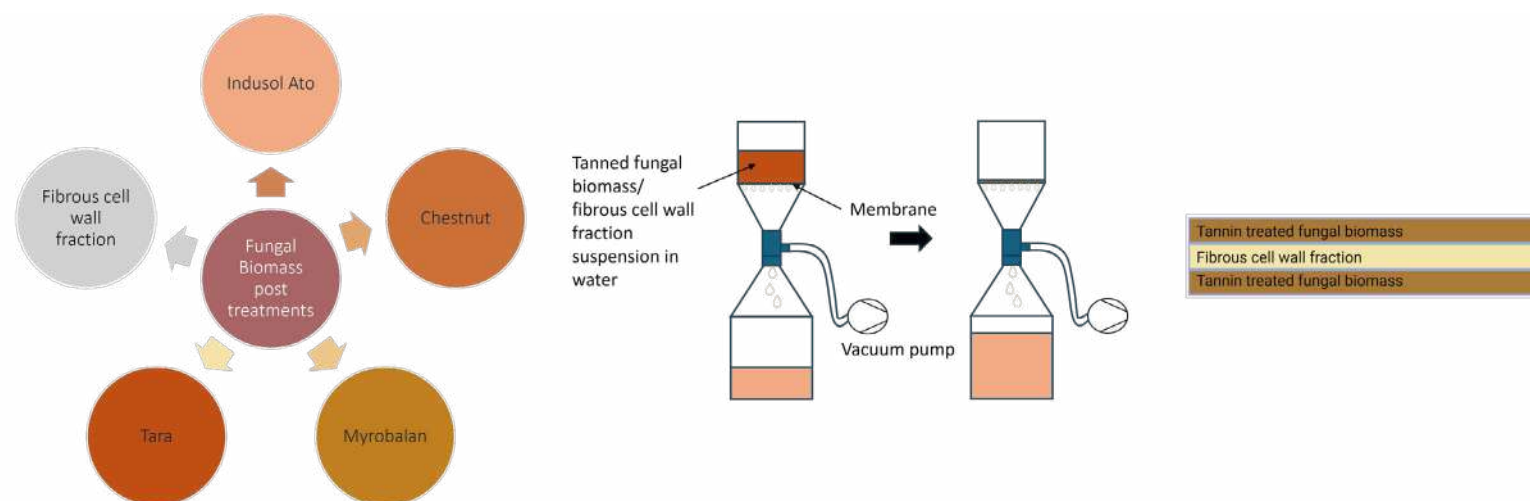
Overall, this work demonstrates lignin potential as a sustainable framework for catalysts based on metals recovered from WEEE.

[1] M.B.Q.L.F. Torrinha, Uptake and recovery of gold from simulated hydrometallurgical liquors by adsorption on pine bark tannin resin, Water (Switzerland) 12 (2020) 1–18

Q33.22 – Sandwich composite leather alternatives produced with fungal biomass from food waste.

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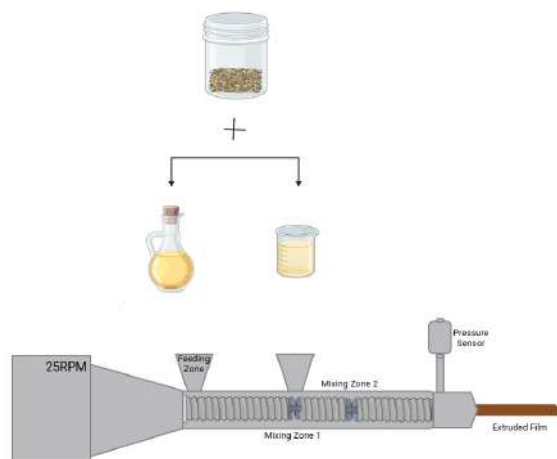
Leather is often considered a luxury material, yet it carries a significant environmental and ethical footprint. Therefore, sustainable vegan leather alternatives are increasingly in demand. Fungi are nature's recyclers, can efficiently convert organic waste into biomass, and the materials produced from fungal mycelium could be a promising alternative for natural leather. In the presented work, the fungal biomass grown on stale bread was used to produce fungal-based alternative leather materials. The fungal cultivation was done in a pilot scale 1300 L bubble column bioreactor. Harvested biomass underwent tannin and alkali pretreatments. Composite materials were prepared with tanned fungal biomass and fungal cell wall material produced by alkali treatment. The produced materials were analysed on mechanical properties and fastness properties and finally compared to natural leather via Ashby's plots. This work demonstrates the potential for producing alternative leather materials with diverse properties using fungal mycelium through sandwich-composite fabrication.

Wijayarathna, E.R.K.B., Svensson, S.E., Sar, T. *et al.* Multilayer biocomposite vegan leather materials derived from vegetable-tanned fungal biomass cultivated on food waste. *Sci Rep* **15**, 15366 (2025). <https://doi.org/10.1038/s41598-025-98361-w>

Q33.23 – Improving hydrophobicity and mechanical properties of biopolymer composites

Eleftheria Gitsouli ^{1*}, Anders Egede Daugaard ¹

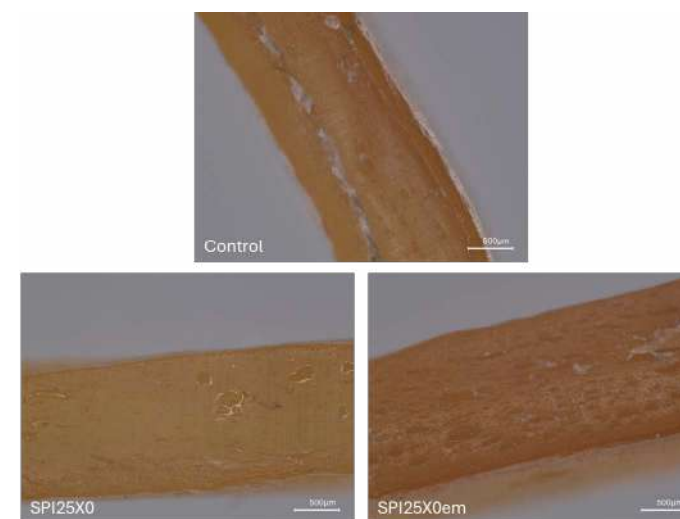
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Biopolymers have been extensively investigated for several applications such as food packaging, pharmaceuticals, and agriculture. Even though their properties are appealing to the industry, their use is limited due to their high water affinity and solubility. Various strategies have been explored to improve the hydrophobicity however, the majority of them typically require additional processing steps, and they do not produce a fully hydrophobic material.

In this project, a novel and scalable method for sunflower oil incorporation into Soy Protein Isolate (SPI) extrudates was developed and optimized. The samples were processed via extrusion, a thermoprocessing method that promotes chemical interactions between the components¹. A sunflower oil emulsion stabilized with a combination of a protein and a polysaccharide² was introduced into the premix. This facilitated the addition of high loading of oil and enhanced protein-oil interactions.

The produced films exhibited high hydrophobicity and superior mechanical properties, while remaining fully biobased and biodegradable. These findings expand the potential for tailoring biopolymer-based materials.



1. Rech A.; Siamos E.; Nicholas P.; Daugaard A. E. ACS Sustain. Chem. Eng. 2023, 11, 8939–8947.
2. L. Li, W. Wang, S. Ji, Q. Xia, Food Chem. 461 (2024) 140794.

Q33.24 – Influence of Lignin Origin and Concentration on the Bio-Fabrication of Living Mycelium Composites

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Engineered Living Materials offer a sustainable pathway for creating adaptive, biologically integrated structures that leverages living systems as active components. This study investigates the synergy between the white-rot fungus *Ganoderma lucidum* and kraft lignin nanoparticles (LNPs) derived from softwood and hardwood sources to engineer a new class of living hybrid materials. We focus on a comparative analysis of how lignin origin, concentration and particle size influence the bio-fabrication process and the resulting material properties. Our results demonstrate that LNPs exhibit a strong affinity for the fungal mycelia, which not only enhances growth kinetics but also facilitates the easy recovery of the hybrid material after growth. By optimizing the interaction between the fungal hyphae and the LNPs, we achieved a seamless integration that yields robust hybrid structures. Furthermore, the resulting materials are highly hygroscopic, offering possible applications in both the wet state for wastewater treatment and the dry state as a functional composite material.

Additionally, tuning the physical environment through lignin concentration and particle size dictates the final morphology and confers intrinsic antioxidant properties to the living matrix. These findings provide a scalable, low-energy pathway for valorizing industrial side-streams into high value, biobased materials, contributing to a circular bioeconomy.

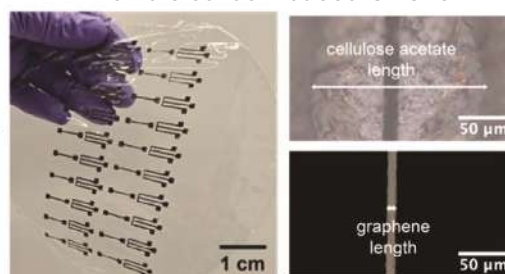
Q34.10 – Strategies toward fully biodegradable organic electrochemical transistors

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Flexible carbon-based OECTs



Organic electrochemical transistors (OECTs) are key bioelectronic devices, with applications ranging from biosensing and electrophysiological monitoring to flexible electronics. Their operation relies on organic mixed ionic/electronic conductors (OMIECs) and precise device architectures defined during fabrication.

While OMIECs have traditionally prioritized performance and long-term stability, not all devices need to be long-lasting. Future bioelectronics need to combine high device performance and operational stability with safe and controlled degradation into non-toxic products.

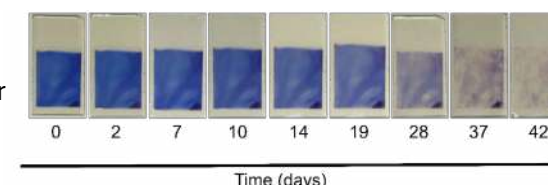
Here, I will present our recent efforts toward fully degradable OECTs, tackling key challenges in microfabrication of carbon-based devices and OMIEC degradation after service life.

On one hand, we developed an **additive-subtractive microfabrication strategy for carbon-based flexible OECTs**. This approach combines extrusion printing of a water-dispersed graphene ink for electrode contacts and spin-coating of a cellulose acetate ink for the substrate and encapsulation layers.¹

Femtosecond laser ablation enabled micrometer-scale patterning of freestanding devices with channel openings down to 1 μm and sheet resistance below 10 Ω/sq . This lithography-free approach enabled the microfabrication of horizontal, vertical, and planar-gated OECTs, providing a versatile route toward rapid prototyping of carbon-based organic bioelectronic devices.

In parallel, we investigated the **biodegradation of conjugated polymers** for OECTs.² The n-type donor-acceptor polymer f-BTI2g-TVTCN exhibits state-of-the-art performance ($\mu\text{C}^* = 41.3 \text{ F cm}^{-1} \text{ V}^{-1} \text{ s}^{-1}$). Our work shows that thin films of f-BTI2g-TVTCN undergo degradation via reactive oxygen species produced by myeloperoxidase, an enzyme released by immune cells. Using UV-Vis spectroscopy, NMR, and high-resolution mass spectrometry combined with machine learning analysis, we identified degradation mechanism and products, enabling assessment of their potential toxicity.

Degradation of a
conjugated polymer
thin film over days



¹ A. E. Avila Ramirez,[§] J. Jessika, [§] Y. Fu, G. Gyllensting, M. Batista, D. Hijman, J. Shakya, Y. Wang, W. Yue, R. Kroon, J. Li, M. M. Hamed, A. Herland, * E. Zeglio*, (2025) Carbon-based microfabricated organic electrochemical transistors enabled by printing and laser ablation, ACS Applied Materials and Interfaces, 17 (47), 64783.

² M. Batista, F. Menger, K. Solodka, F. Kui, X. Guo, A. Kruve, A. Herland, B. Das, E. Zeglio*, Enzymatic degradation of conjugated polymer semiconductors for organic electrochemical transistors, manuscript.

Q34.11 – Future sustainable materials with Cellulose and electronic nanomaterials

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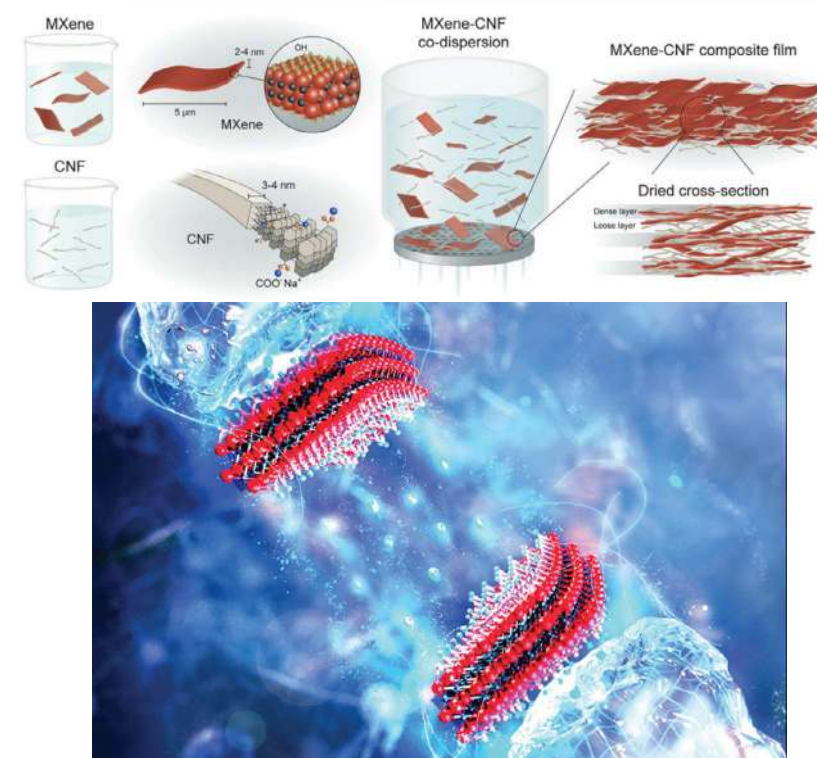
Alireza Hajian, Andreas B Fall, Karl Håkansson, Michaela Salajkova, Fredrik Lundell, Lars Wågberg, Lars A Berglund, Stefan B. Lindstrom, Torbjörn Pettersson, Weiqian Tian, Armin VahidMohammadi, Michael S. Reid, Zhen Wang, Liangqi Ouyang, Johan Erlandsson, Torbjörn Pettersson, Majid Beidaghi, Lengwan Li, Jowan Rostami, Bin Chen, Kyle Matthews, Farsa Ram, Tobias Benselfelt, Yury Gogotsi, Alberto Salleo.

Cellulose nanofibers (CNF) are the only truly one-dimensional 1D biomaterial which now exists at scale for research and industrial use. In addition to bionanomaterials like CNF, we have seen the emergence of a plethora of electronic low-dimensional synthetic materials. Notable among these is the mass production of 1D carbon nanotubes, and the discovery and water-based exfoliation of two-dimensional (2D) materials like transition metal dichalcogenides (e.g. MoS₂) and MXenes.

We have shown in seminal works that CNFs have an excellent ability to interact with these electronic 1D/2D materials to fabricate colloiddally stable dispersions, and to form a new generation of advanced electronic nanocomposites.

In these materials systems we explore the dynamic interaction of ions, electrons and water for a range of applications, such as a new generations of electronic soft muscles, structural energy storage materials and iontronic neuromorphic computers.

The convergence of electronic 1D/2D materials with CNFs is still at its infancy and many possibilities remain.



ACS Nano 8(3), 2014.

Advanced Materials, 1902977, 2019.

Advanced Materials, 202301163, 2023.

Advanced Materials 202303255, 2023.

Q34.12 – Flexible and High-Thermal-Conductivity Substrates Based on Cellulose Nanofiber/Hexagonal Boron Nitride for Next-Generation Electronics

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Flexibility of CNF/h-BN

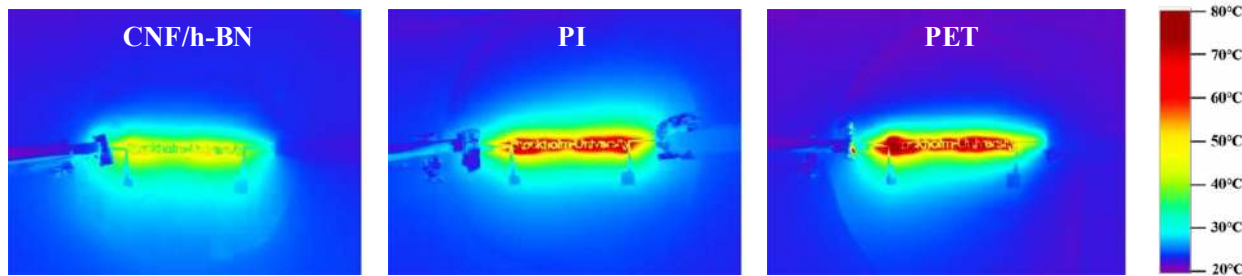


Sustainable substrates can reduce electronic waste, but achieving efficient thermal management remains a challenge¹. Here, we developed flexible, high-thermal-conductivity substrate with cellulose nanofiber (CNF) composites with hexagonal Boron Nitride (h-BN).

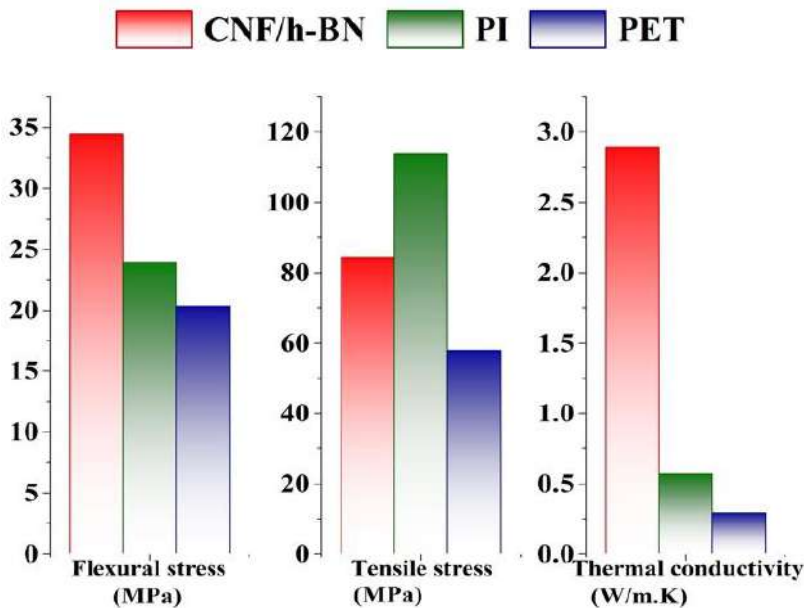
The CNF/h-BN composite exhibits excellent flexibility and high mechanical strength, with a flexural stress of 34 Mpa and a tensile stress of 84 Mpa, comparable to those of PI and PET, while achieving a thermal conductivity of $2.89 \text{ W} \cdot \text{m}^{-1} \cdot \text{K}^{-1}$, about 12 times higher than PET and 6 times higher than PI.

Additionally, electrical heating experiment confirm that the CNF/h-BN composite exhibits heat dissipation efficiency about five times higher than that of conventional substrates such as PI and PET.

Different Heat Dissipation of CNF/h-BN, PI and PET



Overall, the CNF/h-BN nanopaper combines high mechanical strength, flexibility, and thermal conductivity through the synergistic works of nano- and microscale h-BN. Its excellent heat dissipation capability and hydrolytic recyclability highlight its promise as a sustainable substrate for next-generation flexible electronics.



1. Hu, S., Shi, Z., Chen, K., Chen, X., Zhou, H., Yan, N., & Yang, G. (2025). Bacterial cellulose as green matrix material for environmental-friendly electronic devices. Carbohydrate Polymers, 368,

Q34.13 – SYNTHESIS OF AMORPHOUS CONJUGATED POLYMERS FOR THERMALLY STABLE POLYMER SOLAR CELLS

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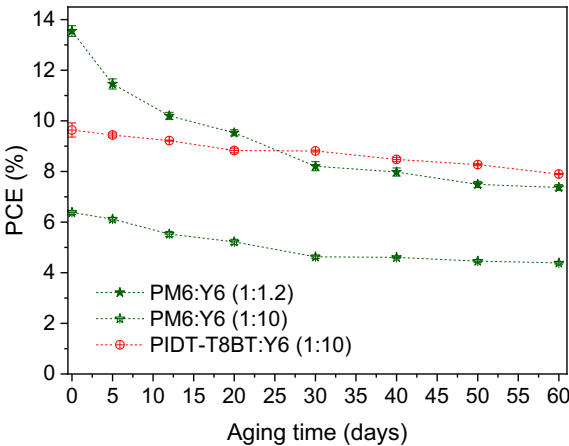
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Polymer solar cells have gained considerable interest over the last few decades as a low-cost, environmentally friendly, lightweight, and flexible alternative to traditional photovoltaics. In recent years, photovoltaic performance has increased rapidly, with high power conversion efficiency for lab-scale devices. This work focuses on the design and synthesis of new conjugated polymers, as well as the thermal stability of polymer solar cells. Thermally stable materials are important for stable solar cells, as solar cells are often exposed to elevated temperatures during fabrication and use. Our work includes device stability measurements and morphology stability studies using dynamic mechanical thermal analysis (DMA). The DMA technique is a highly sensitive method for determining the thermal transitions of the used materials. Most modern conjugated polymers turn out to have a non-classical morphology consisting mainly of aggregates and crystallites.

In this work, we have synthesised several completely amorphous indacenodithiophene-based polymers (PIDT) with varying side chains, which were used in solar cells combined with the Y6 acceptor molecules. Low donor:acceptor (D:A) ratios are generally

believed to yield lower efficiency than the more conventional 1:1.2 weight ratio. However, several of the solar cells exhibit a peak power conversion efficiency (PCE) of over 11% at a lower D:A ratio.¹ Unexpectedly, our recent experiments show that the thermal stability of the solar cells at 85 °C is significantly improved for PIDT-T8BT:Y6 (1:10), outperforming commercial high-performance polymer systems (PM6:Y6) in efficiency after 30 days of stability measurements.

Polymer solar cells aged and tested under N₂ at 85 °C



1. Andrew Dolan, Xun Pan, Matthew J. Griffith, Anirudh Sharma, Jessica M. de la Perrelle, Derya Baran, Gregory F. Metha, David M. Huang, Tak W. Kee, Mats R. Andersson. Enhanced Photocatalytic and Photovoltaic Performance Arising from Unconventionally Low Donor–Y6 Ratios, Adv. Mater. 2024, 36(15), 2309672.

Q34.14 – OPTIMIZING TRANSPARENT COMPOSITE PEDOT:PSS-CELLULOSE-SILVER NANOWIRE ELECTRODES FOR ORGANIC SOLAR CELLS

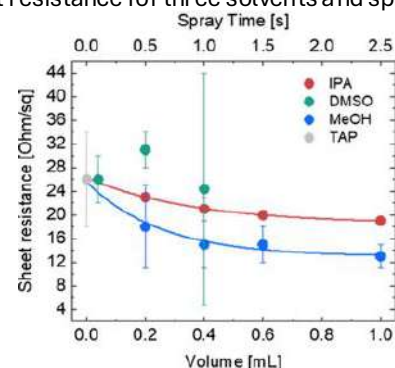
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Sheet resistance for three solvents and sprayed volume



Composite electrodes for organic solar cells combining hole-blocking polymer layers and conductive electrodes necessitate transparency and high conductivity at the same time¹. A post treatment for optimizing nanostructure, transparency, and conductivity is required. Here, we use a composite electrode of poly(3,4-Ethylenedioxythiophene) polystyrene sulfonate (PEDOT:PSS) and cellulose nanofibril: silver nanowires². Roll-to-roll Spray deposition is used for installing the composite electrode in a scalable, layer-by-layer approach. Subsequently, dimethylsulfoxide (DMSO), isopropanol (IPA), or methanol (MeOH) are spray-deposited for solvent-annealing of the PEDOT:PSS layer. We monitor the induced nanostructural changes using grazing incidence wide-angle X-ray scattering and correlate changes in PEDOT:PSS crystallinity and morphology with changes in conductivity and transparency.

We observe a decrease of the π - π stacking distance in PEDOT for all solvents and all sprayed volumes, leading to the observed decrease in sheet resistance (i.e. increase in conductivity), see Figure.

DMSO leads to local inhomogeneous conductivity changes in the PEDOT:PSS layer due to its high boiling point, while solvent annealing using MeOH leads to a homogenous, both transparent (> 40 %) and highly conductive electrode with (~12 Ohm/sq).

This approach combines a facile and effective combination of fabrication and quality enhancement of sprayed, conductive polymer films using scalable and integrated spray deposition. This approach makes the overall production process of organic electrodes faster and cheaper and therefore the usage of sustainable and bio-based materials and fabrication methods more attractive for the industry.

1. Betker, M., Erichlandwehr, T., Sochor, B., Erbes, E., Kurmanbay, A., Alon, Y., Li, Y., Fernandez-Cuesta, I., Müller-Buschbaum, P., Techert, S. A., Söderberg, L. D. & Roth, S. V. (2024). Micrometer-Thin Nanocellulose Foils for 3D Organic Electronics. *Advanced Functional Materials*, 34(40), 2403952.
2. Betker, M., Sochor, B., Erbes, E., Kurmanbay, A., Erichlandwehr, T., Li, Y., Müller-Buschbaum, P., Fernandez-Cuesta, I., Techert, S. A., Söderberg, L. D. & Roth, S. V. (2025). Spray Deposition for Solvent Annealing of Hybrid Poly(3,4-Ethylenedioxythiophene) Polystyrene Sulfonate Cellulose Silver Nanowire Composite Electrodes Using a Roll-to-Roll Coater. *Advanced Engineering Materials*, 27(12), 2402354.

Q34.15 – Ambient Direct Arylation Synthesis of Thienothiophene Based Copolymers with Mixed Alkoxy and Oligoether Side Chains

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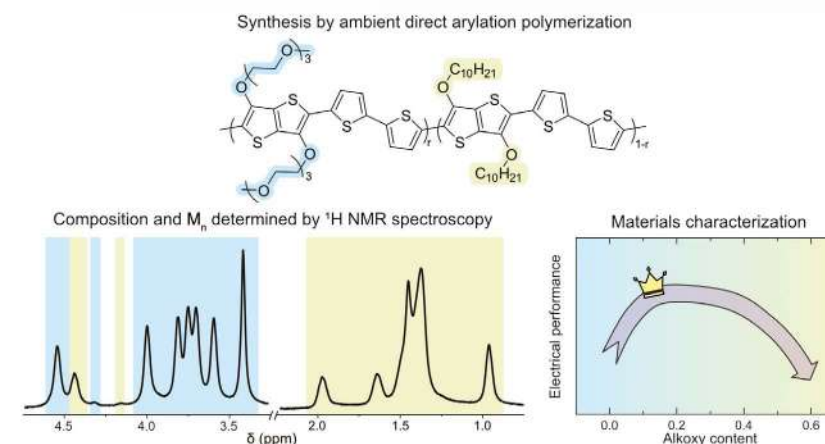
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Conjugated polymers with both oligoether and alkoxy side chains are an emerging type of organic mixed ionic-electronic conductor. Here, direct arylation polymerization is introduced as a viable synthetic route for such materials. The composition and molecular weight of the synthesized thienothiophene-based random copolymers are determined with high-temperature ¹H NMR spectroscopy. Chemical and electrochemical doping of the copolymers reveal that the introduction of a minor fraction of alkoxy side chains results in materials with a highly promising set of electrical and mechanical properties. A copolymer with an alkoxy side-chain fraction of 12 % features an electrical conductivity of 390 S cm⁻¹ and a charge-carrier mobility of more than 3 cm² V⁻¹ s⁻¹.

Organic electrochemical transistors with a NaCl aqueous electrolyte feature a high figure of merit of 1313 F cm⁻¹ V⁻¹ s⁻¹ thanks to a high volumetric capacitance of 417 F cm⁻³. Evidently, the introduction of a minor fraction of alkoxy side chains is a viable route for improving the electrical properties of organic mixed ionic-electronic conductors.



A. Giovannitti, I. P. Maria, D. Hanifi, M. J. Donahue, D. Bryant, K. J. Barth, B. E. Makdah, A. Savva, D. Moia, M. Zetek, P. R. F. Barnes, O. G. Reid, S. Inal, G. Rumbles, G. G. Malliaras, J. Nelson, J. Rivnay and I. McCulloch, *Chem. Mater.*, 2018, 30, 2945-2953.

N. Simons, D. Pearce, H. Yu, S. M. Tuladhar, G. S. LeCroy, R. Sheelamanthula, R. K. Hallani, A. Salleo, I. McCulloch, A. Giovannitti, J. M. Frost and J. Nelson, *Proc. Natl. Acad. Sci. U. S. A.*, 2023, **120**, e2306272120.

J. Kimpel, Y. Kim, H. Schomaker, D. R. Hinojosa, J. Asatryan, J. Martín, R. Kroon, M. Sommer and C. Müller, *Sci. Adv.*, 2025, **11**, eadv8168.

Q34.16 – Dynamic Nuclear Polarization (DNP-NMR) Using In-Situ Generated Oxidative Radicals in Conjugated Polymer–CNF Composites

Sami Zeliouche^{*1,2,3}, Jan Erik Jacobs^{1,2}, Christian Müller^{1,2}, Lårs Evenäs^{1,2,3}

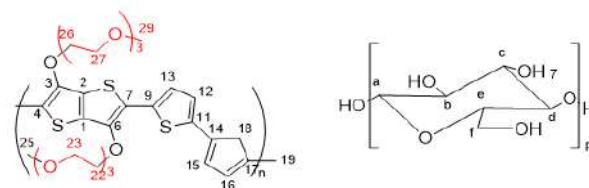
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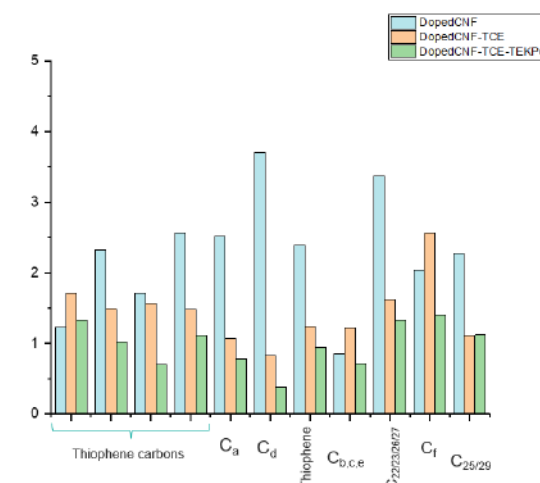
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Dynamic nuclear polarization (DNP) has become a key strategy to overcome the intrinsically low sensitivity of solid-state NMR, but its classical implementation relies on adding exogenous stable radicals such as nitroxides or trityls, which often introduce paramagnetic broadening, perturb relaxation times, or require cryogenic conditions. Recent advances in alternative DNP pathway such as light activated DNP, which generates transient electron spins and alleviates some of these limitations—highlight growing interest in radical-free or minimally invasive approaches to hyperpolarization.¹ Harnessing dynamic nuclear polarization (DNP) without external radicals is a promising strategy to enhance solid-state NMR sensitivity while preserving the native chemistry of functional materials.^{2,3} In this work, we demonstrate that controlled chemical oxidation of conjugated polymer–cellulose nanofiber (CNF) composites spontaneously generates stable organic radicals capable of efficient microwave-driven DNP. We compare the influence of solvent (TCE) and DNP radicals (TEKPol) on the enhancement values.



The radical-mediated sensitivity gain enables rapid acquisition of spectra, improved assignment of backbone and interfacial environments, and accelerated T_1 and saturation-recovery analyses without any sample preparation. These results suggest that MAS-DNP could evolve into a routine analytical tool for oxidized conjugated polymers—and, more broadly, for conductive polymer systems—by leveraging their intrinsic redox-generated radicals as endogenous polarizing agents

Enhancement of the different carbons and influence of the sample preparation



1. Jvaed, A. et al., Dynamic nuclear polarization: State of the art and future possibilities with light activation, *Chem. Phys. Rev.*, **2025**, 6, 021301.
2. Ong, T-C. et al., Solvent-Free Dynamic Nuclear Polarization of Amorphous and Crystalline ortho-Terphenyl, *J. Phys. Chem. B*, **2013**, 117, 3040–3046.
3. Horii, F. et al., Development of DNP-Enhanced High-Resolution Solid-State NMR System for the Characterization of the Surface Structure of Polymer Materials, *Journal Infrared Milli Terahz Waves*, **2012** 33:756–765

Q34.17 – Design and synthesis of Carboxylate-functionalized polar polythiophene with pH-tunable water processability for organic electronic applications.

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Shimolo, Renee Kroon

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Conjugated polymers are electroactive materials with alternating single and double bonds along their backbone, which create a continuous π -electron system that enables charge delocalization throughout the chain and results in optoelectronic properties.¹

Incorporating ionic side groups into conjugated polymer backbones produces **conjugated polyelectrolytes (CPEs)**, a class of materials that combine the optoelectronic properties of π -conjugated polymers with water solubility and the ability to transport ions efficiently.² Among anionic CPEs, sulfonate-functionalized systems have been extensively investigated due to their permanent negative charge, enabling efficient electrochemical doping and high-water solubility.³ However, the fully dissociated nature of sulfonate groups can induce excessive swelling or dissolution during device operation, morphological disorder, and limited tunability, which compromise device performance in mixed ionic-electronic systems.

To overcome these challenges, current molecular engineering approaches have shifted toward carboxylate-functionalized conjugated polyelectrolytes, in which the carboxylate moieties enable pH-responsive water processability, and more precise modulation of polymer-ion interactions compared to sulfonate counterparts.⁴ This adjustable ionic character affords improved control over swelling behavior and microstructural organization, while preserving effective mixed ionic-electronic transport.^{5, 6}

In this talk, I will present the synthesis and properties of a glycolated, carboxylate-functionalized polythiophene (P2CAT-K) featuring a low ionization energy (-4.4 eV).⁷ The incorporation of the carboxylate functional group results in formation of stable aqueous nano dispersions, benign chemical fixation and enables efficient electrochemical operation under neutral conditions. Exploiting P2CAT-K water processability, we co-processed with carboxy methylated cellulose nanofibrils (CNFs) to produce composite materials to alleviate limited ion ingress because of crosslinking. Devices fabricated from the resulting polymer/CNF composite ink exhibited improved cycling stability. Overall, this glycolated carboxylate framework provides water-processability with stable device operation in aqueous environments.

1. Coghi, P. & Coluccini, C. Literature Review on Conjugated Polymers as Light-Sensitive Materials for Photovoltaic and Light-Emitting Devices in Photonic Biomaterial Applications. (2024) doi:10.3390/polym16101407.
2. Zhang, C., Yao, L., Pu, M. & Zhou, C. RSC Applied Polymers REVIEW Recent material development and applications of conjugated polyelectrolytes by leveraging electronic and ionic transport properties. (2025) doi:10.1039/d5lp00012b.
3. Beaumont, C. *et al.* Water-Processable Self-Doped Conducting Polymers via Direct (Hetero)arylation Polymerization. *Macromolecules* **54**, 5464–5472 (2021) doi.org/10.1021/acs.macromol.1c00847.
4. Sun, Z. *et al.* Carboxyl-Alkyl Functionalized Conjugated Polyelectrolytes for High Performance Organic Electrochemical Transistors. *Chem. Mater* **35**, 9299–9312 (2023) doi.org/10.1021/acs.chemmater.3c02103 Chem.
5. Sun, Z. *et al.* pH Regulates Ion Dynamics in Carboxylated Mixed Conductors. (2026) doi:10.1021/acs.chemmater.5c03288.
6. Sun, Z. *et al.* Controlling Ion Uptake in Carboxylated Mixed Conductors. *Adv. Mater.* **37**, 1–10 (2025) doi: 10.1002/adma.202414963.
7. Bruschi, C. *et al.* Autonomous aqueous H₂O₂ production with a carboxylate-functionalized polythiophene. *J. Mater. Chem. A* **14**, 337–342 (2026) doi: [10.1039/D5TA07162C](https://doi.org/10.1039/D5TA07162C).

Q34.18 – Biochar as a multifunctional carbon filler: Linking structure, processing, performance, and sustainability in polymer composites

**NORDIC
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Hossein Baniasadi*¹, Jaana Vapaavuori¹, Erlantz Lizundia², Jukka Niskanen¹

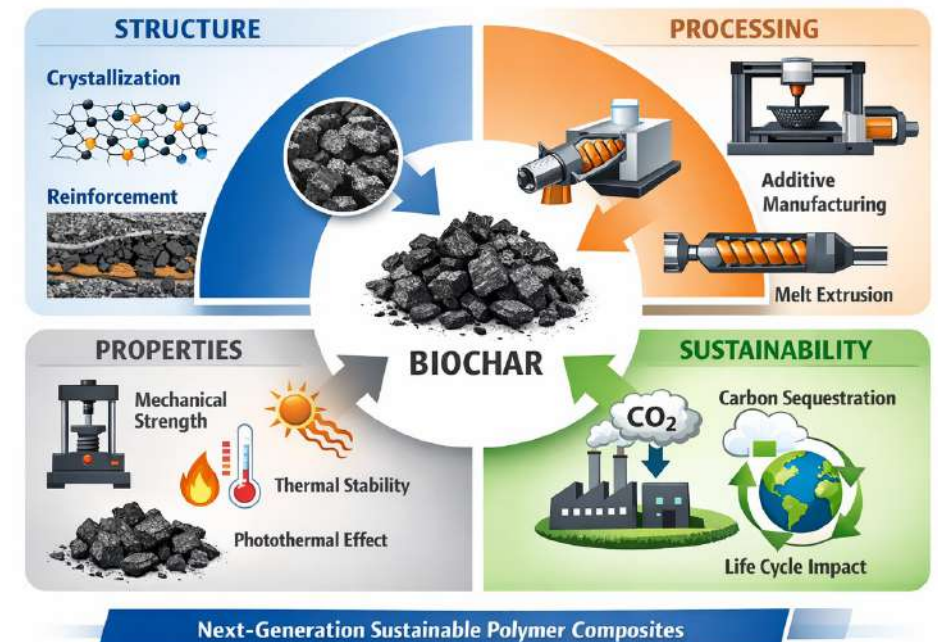
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Biochar derived from biomass pyrolysis is emerging as a promising sustainable filler for polymer composites, yet its multifunctional role across polymer processing routes remains insufficiently understood. This work presents a systematic investigation of biochar as a structural and functional carbon additive in polyamide-based systems prepared via in-situ polymerization and additive manufacturing, as well as in porous bio-based foams. Across multiple polymer matrices, biochar acts simultaneously as a reinforcing phase, crystallization nucleating agent, rheology modifier, and photothermal absorber. Homogeneous dispersion and strong interfacial compatibility enable substantial improvements in tensile modulus, strength, and thermal stability, while also enhancing melt elasticity and processing performance in extrusion and selective laser sintering. At high loadings, biochar enables structurally stable and functional composite architectures, including thermally responsive and energy-management materials. Life cycle assessment consistently demonstrates major reductions in climate impact due to biogenic carbon sequestration and partial replacement of fossil-based polymer content.

These results establish biochar not merely as a passive filler but as a multifunctional design element that links structure, processing, performance, and environmental impact. The findings provide generalizable design principles for next-generation sustainable polymer composites and multifunctional material systems.



1. H. Baniasadi et al. (2023). *Additive Manufacturing*. <https://doi.org/10.1016/j.addma.2023.103869>
2. H. Baniasadi et al. (2024). *Composites Part B: Engineering*. <https://doi.org/10.1016/j.compositesb.2024.111809>
3. H. Baniasadi et al. (2025). *Environmental Research*. <https://doi.org/10.1016/j.envres.2025.121446>
4. H. Baniasadi et al. (2025). *Chemical Engineering Journal*. <https://doi.org/10.1016/j.cej.2025.165502>
5. H. Baniasadi et al. (2025). *Carbohydrate Polymers*. <https://doi.org/10.1016/j.carbpol.2025.123999>
6. H. Baniasadi et al. (2026). *Carbon*. <https://doi.org/10.1016/j.carbon.2025.121027>

Q34.19 – Controlled humination of lignocellulosic fibers via HCl gas treatment

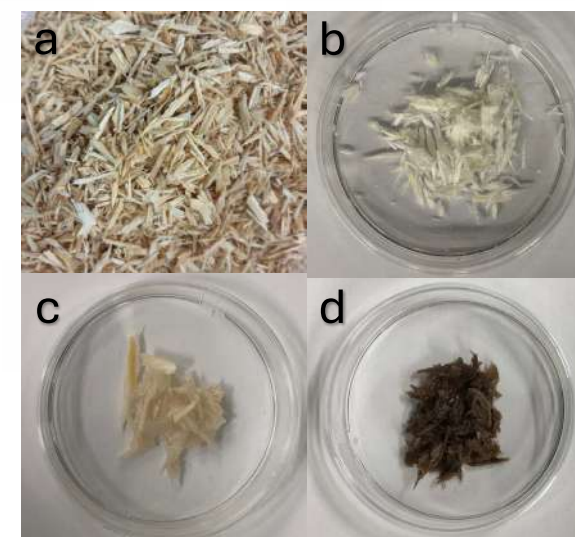
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Humins are insoluble, carbonaceous polymers that result from acid-catalyzed condensation of carbohydrate-derived intermediates in biorefinery processes. ¹ Although humins are often considered as undesired byproducts, there is ongoing interest to valorize them as precursors of functional materials. The major barrier is their tarry, heterogeneous nature, which results in poor mechanical integrity and limited processability. To address these challenges, we propose a controlled humination process for biomass using HCl gas as a catalyst. This approach aims to confine the humination on the fiber surface and keep the crystalline core of cellulosic fibrils intact. By maintaining this structural framework, the resulting material combines the mechanical integrity of natural fibrils with the chemical functionality of humin. By transforming an undesired byproduct into a stable, tailored material, this work outlines a simple, scalable pathway for humin valorization that minimizes the chemical consumption. ²

Progression of birch to holocellulose and HCl gas-catalyzed humination products



(a) 10mm milled birch wood chips (b) holocellulose after peracetic acid catalyzed delignification (c) HCl gas catalyzed hydrolysis of 5% moisture content fibers after 5h (d) HCl gas catalyzed hydrolysis of 5% moisture content fibers after 24h

1. Mija, A., van der Waal, J. C., Pin, J. M., Guigo, N., & de Jong, E. (2017). Humins as promising material for producing sustainable carbohydrate-derived building materials. *Construction and Building Materials*, 139, 594-601. <https://doi.org/10.1016/j.conbuildmat.2016.11.019>
2. Van Zandvoort, I., Wang, Y., Rasrendra, C. B., van Eck, E. R., Bruijninx, P. C., Heeres, H. J., & Weckhuysen, B. M. (2013). Formation, molecular structure, and morphology of humins in biomass conversion: influence of feedstock and processing conditions. *ChemSusChem*, 6(9), 1745-1758. <https://doi.org/10.1002/cssc.201300332>

Q34.20 – Spark plasma sintering for ultrafast carbonization of lignin

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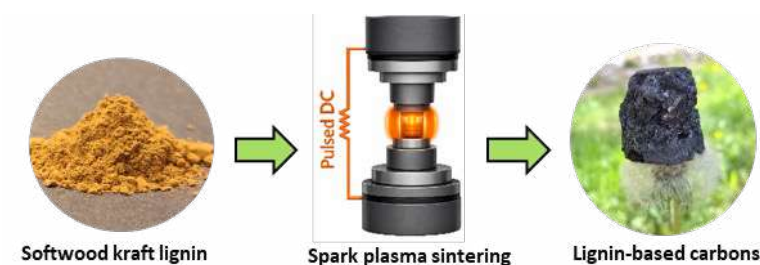
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Pyrolysis is commonly used for production of lignin-based carbons, but because of the long duration of the process it becomes energy consuming. This is caused by the slow rates applied during heating, as well as the long times at the final carbonization temperatures. Therefore, the interest for new advanced ultrafast methods is increasing. One of the methods gaining interest is spark plasma sintering (SPS) (field-assisted sintering technology/FAST) ¹. SPS is a low voltage technique, and depending on the experimental setup both pressureless sintering or hot-pressing can be used. The SPS instrument has an efficient joule heating of the tools connecting two electrodes inside the instrument vacuum chamber, which makes it possible to reach ultrafast heating rates and to high temperatures ².

This study investigated SPS as an ultrafast method for direct lignin carbonization. The synthesis was carried out at the National Spark Plasma Sintering facility at Stockholm University. Heating rates between 15 to 1000 °C min⁻¹ were tested in order to get an understanding of the impact using conventional pyrolysis rates compared to ultrafast heating rates. The obtained carbon material was characterized using various techniques, in order to gain insight in structure and the properties. In addition, the energy consumption (kWh) was investigated to see if SPS can be a potentially a more energy-efficient method for carbonizing lignin.

Because of the ultrafast heating, the fastest synthesis was as short as 4 min excluding the cooling down of the instrument. It was observed that the heating rate affected the energy consumption (kWh) of the process. The power input increased with increasing heating rate but because of the shortening of the process time the overall energy consumption was lowered. The lignin formed a macroporous lignin-based carbon material. From structural analysis, it was possible to conclude a disordered structure (d-spacing ~3.7 Å), typically observed for "hard carbons". The characterization also indicated a high carbon content in all samples, and an electrical conductivity in the range of 0.76 to 1.62 S cm⁻¹. Overall this study indicates that SPS as a promising technique for future direct carbonization of lignin.



1. Wang, A., Zhang, G., Li, M., Sun, Y., Tang, Y., Sun, K., Lee, J-M., Fu, G., Jiang, J. (2025). Lignin derived hard carbon for sodium ion batteries: Recent advances and future perspectives. Progress in Materials Science, 152, 101452.
2. Guillon, O., Gonzalez-Julian, J., Dargatz, B., Kessel, T., Schierner, G., Räthel, J., Herrman, M. (2014). Field-Assisted Sintering Technology/Spark Plasma Sintering: Mechanisms, Materials, and Technology Developments. Advanced Engineering Materials, 16, 830–849.

Q34.21 – Biomaterial-Enabled Electrode Design for Soft, Stretchable, and Sustainable Batteries

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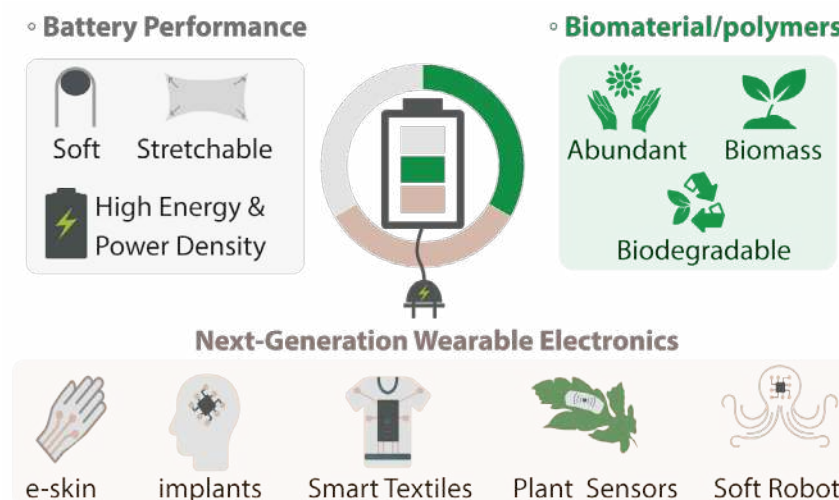
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Soft and stretchable batteries are essential for powering next-generation wearable electronics such as e-skin patches, smart textiles, plant sensors and soft robotics.¹ While soft electronic components have advanced rapidly, the development of mechanically compliant power sources remains a major bottleneck. Most current batteries rely on rigid & bulky, mechanically coupled electrode designs, where increasing energy storage inevitably increases stiffness, limiting their suitability for soft systems.² Here, I will present our work using biomaterials (lignin, cellulose, gelatin, bio-polyesters etc.) as a platform to explore an electrode design concept that decouple electrochemical function from mechanical stiffness, enabling intrinsically soft batteries. Our approach offers new pathways toward soft, high-performance, and environmentally responsible energy storage for wearable electronics.

I will briefly introduce our initial work on conventional (mechanically coupled) composite electrodes that use bio-elastomers as a binder in the active electrode. Despite improving material sustainability and achieving comparable battery performance with petrochemical-based binders, the electrodes remain mechanically coupled, leading to high bending forces and limited mechanical compliance.

This will be followed by a discussion on *mechanically-decoupled* soft, electrode-less battery concept that relies on diffusion of the redox-active species within a porous conductive scaffold based on cellulose fibres.³ Building on this principle, I will highlight our recent paper on a redox-active electrofluid batteries, where the battery electrode's physical state is engineered from *a conventional solid film to a fluid* with no fixed shape, and yield easily to external strain, making the electrode intrinsically deformable.⁴



¹ F. Wentz, R. Arvidsson, * Rahmanudin, * et al., Integrating Environmental Assessment into Early-stage Wearable Electronics Research. [J. Mater. Chem. C, 2025, 13, 19983-19999.](#)

² A. Rahmanudin, * K. Tybrandt., N. Kim* et al., Sustainable Stretchable Batteries for Next-generation Wearables. [J. Mater. Chem. A, 2023, 11, 22718-22736.](#)

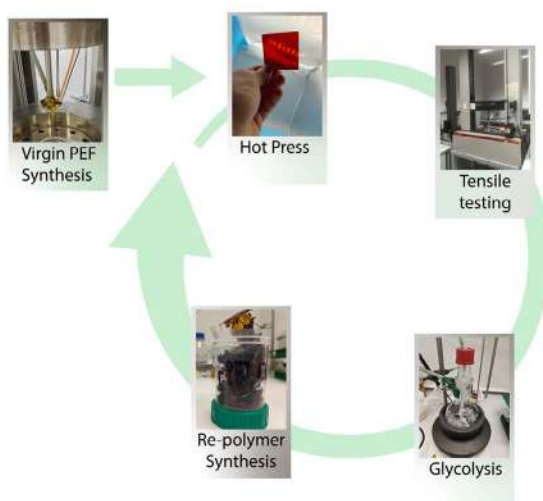
³ A. Rahmanudin, * K. Tybrandt * et al., Stretchable and Biodegradable Plant-based Redox-Diffusion Batteries. [Mater Horiz, 2024, 11, 4400-4412.](#)

⁴ M. Mohammadi, K. Tybrandt, * A. Rahmanudin* et al., Make It Flow from Solid to Liquid: Redox-Active Electrofluids for Intrinsically Stretchable Batteries. [Sci. Adv., 2025, 11, eadr9010.](#)

Q36.10 – Glycolysis and repolymerization of poly(ethylene terephthalate), poly(ethylene furanoate) and their copolyesters

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Plastics are essential packaging materials for multiple different reasons: plastics are strong and lightweight, having great barrier properties. Plastics prevent food from getting spoiled and gives that way major carbon dioxide emission decrease.¹ However, while plastics are durable, they also persist in nature for long time, accumulating in seas and in landfills. The accumulation should be decreased by two means: Recycling and alternative bio-based materials. Currently however, biobased materials available are not recyclable due to incompatibility in current recycling streams.²

Poly(ethylene terephthalate) (PET) is commonly used plastic material in food packaging applications. PET can undergo glycolysis to form oligomers that can be polymerized back into virgin quality plastic. This decreases CO₂ emissions³ but more importantly it creates possibility to reuse material without compromises. Poly(ethylene furanoate) (PEF) is a biobased alternative to PET. It has similar properties while not relying on fossil raw materials. Since it is a polyester, it can undergo glycolysis as well.

In our work, we Polymerized PEF and made it into plastic material with good properties. We then used glycolysis for PET and PEF to make oligomers from those two polyesters, that we then repolymerized into homo- and copolymers. Mechanical properties of these copolymers were comparable to virgin PET.

We have demonstrated the possibility to combine PEF with PET in a same recycling feed using glycolysis. This makes possible integrating PEF bottles into same existing recycling feed with PET, giving possibility to feasible recycle biobased alternatives.



1. Meng, F., M. Brandão, and J.M. Cullen, Environ. Sci. Tech., 2024, **58**, 2716-2727.
2. L. F. P. Mantia, L. Botta, M. Morreale, R. Scaffaro, Polym. Degrad. Stab., 2011, **97**, 21-24.
3. Uekert, T., et al., ACS Sustainable Chem. Eng., 2023, **11**, 965-978.

Q36.11 – VISCOSITY MODIFICATION OF RECYCLED LOW-DENSITY POLYETHYLENE THROUGH SILANE CHEMISTRY

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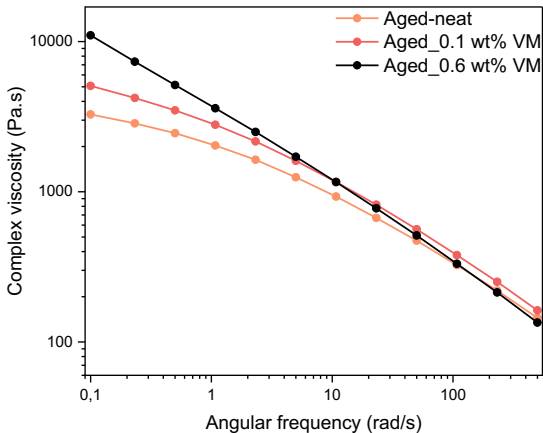
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The annual amount of plastic waste exceeds 300 million tons per year, one-third of it being low-density polyethylene (LDPE). Under the EU Packaging and Packaging Waste Directive, 55% of all plastic packaging must be recycled, with 30% plastic content in plastic packaging coming from the recycled stream by 2030. PolyOlefins (POs) undergo melt processing, usage, waste collection, and recycling.

Each of the above-mentioned steps degrades the polymer, resulting in diminished mechanical and rheological properties of POs. There has been extensive research around improving the properties of POs by blending, peroxide linkage, and the use of fillers. In this work, LDPE was artificially aged in an air-circulated oven at an elevated temperature. The evolution of chemical species in LDPE was monitored by FT-IR, and their effects on the rheological properties were assessed. Silane chemistry as the viscosity modifier (VM) was employed to improve the rheological properties of aged LDPE via reactive extrusion. Thermal, mechanical, and rheological properties of melt-modified LDPE were analysed.

It was found that neat LDPE is not responsive to silane chemistry, and a certain level of degradation, measured via the carbonyl index (CI), is essential for assessing the effect of silane modification on the rheological properties. Based on Dynamic Mechanical Thermal Analysis (DMTA), increasing the concentration of the silane viscosity modifier from 0.1 wt% to 0.75 wt% led to network formation. Based on the frequency-sweep results, silane chemistry showed great potential as a viscosity modifier for recycled LDPE.

The effect of VM on the processing properties of LDPE, such as film properties will be studied the next steps.



Q36.12 – Bio-Based Stabilization Strategies for Post-Consumer Polypropylene

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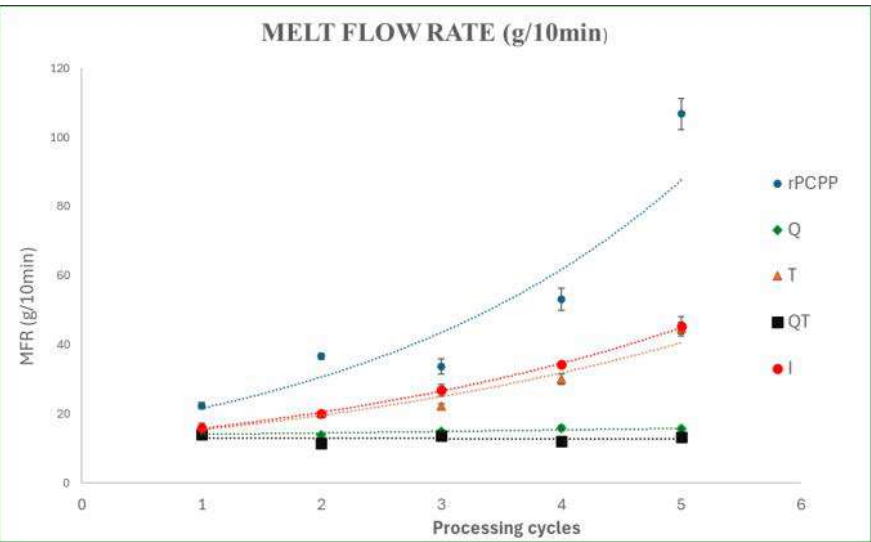
² Swedish Centre for Resource
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Borås 501 90, Sweden

The circular economy demands effective, sustainable stabilization of recycled thermoplastics against oxidation. This investigation assesses quercetin, tocopherol, and their quercetin–tocopherol combination (with secondary antioxidants) for enhancing thermal/oxidative stability and mechanical performance of recycled polypropylene (rPP) under processing and weathering conditions.

Thermal and oxidative stability were assessed by thermogravimetric analysis (TGA), oxygen induction time (OIT), and oxygen induction temperature (OOT), while mechanical strength and melt stability were monitored before and after multiple reprocessing cycles. The natural stabilizers markedly increased the thermal and oxidative resistance of rPP relative to unstabilized material, with the quercetin–tocopherol combination showing a synergistic effect, raising OIT to 67 minutes under oxygen and OOT to 260 °C.

The reprocessing studies show preserved melt strength and stability, while the DPPH assay demonstrates higher radical-scavenging efficiency than synthetic controls.

These findings highlight natural antioxidants, particularly the quercetin–tocopherol blend, as promising, sustainable alternatives for industrial stabilization of recycled polypropylene, supporting reduced reliance on fossil-based additives in circular polymer processing.



Q36.13 – Sustainable impregnation resins for high voltage rotating machines

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Electrical machines constitute a vital part of the electric grid and both electrical motors and generators are increasingly being used in society. The electrical insulation system of large rotating machines consists of a composite material of mica tape and a thermosetting resin. Vacuum pressure impregnation (VPI) is the preferred technique to impregnate mica tape with a thermosetting resin. The impregnated structure gives an insulation system with long operational lifetime and low losses. The resin also gives mechanical stability to the winding structure in the stator as well as fills small air inclusions in the insulation system to suppress the formation of internal discharges. The resin used in the VPI process is normally composed of several key components, including a thermoset polymer, a hardener that participates in crosslinking, reactive diluents for improved processability and additional additives like catalysts and stabilizers. Different chemistries have been used over the years for the VPI process. However, there are concerns regarding the environmental and occupational health and safety of some of these components.

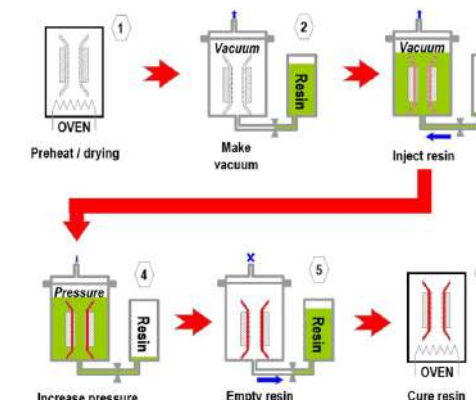
The increasing awareness of possible harmful effects of various chemicals has driven efforts to develop resins with reduced volatile organic compounds and less need for protection equipment.

Furthermore, stringent EU regulations have classified some hardeners and reactive diluents as substances of very high concern which has resulted in needs to find alternatives for these compounds.

Different alternative impregnation resins have been studied with respect to process related parameters such as curing kinetics and rheological properties. Final mechanical, thermal and electrical properties of cured resins have been evaluated.



Stator lifted from pressure vessel



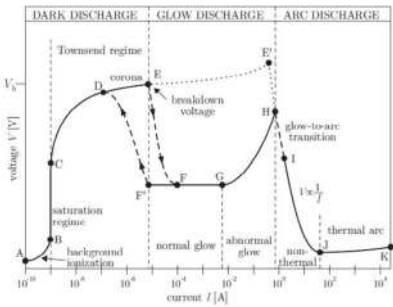
VPI process

Q36.14 – Insulator ageing in switching DC arc discharges

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¹ABB Corporate Research, Västerås, Sweden

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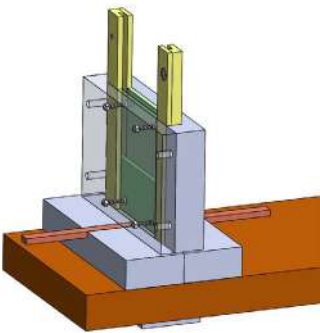


Discharge Plasma characteristic domains [2]

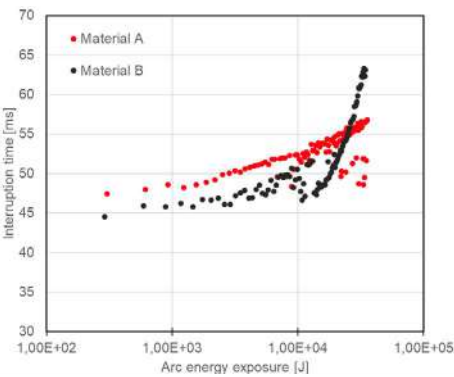
For the sustainable society there is a strong drive towards electrification on a global level, pushing the development of the electrical distribution system towards the integration of more renewable energy. This is consequentially also driving the development of low voltage direct current (LVDC) distribution system and its apparatuses towards new requirements and demands. Within LVDC air switching devices the thermal and electrical withstand of insulation play an important role for service. Therefore, the understanding of polymer- plasma interactions and the exposure ageing effect becomes of significant importance to enable long term robustness for the switching devices.[1]

This work focuses on the surface ageing of wall constricted arc discharges. The electrical insulators were accelerated aged by repeatedly exposed to DC discharges. For the evaluation, 50 A DC arcs was elongated along a polymeric surface with the speed of 2.5 m/s where both the wall material influence on electrical gap performance and surface effects was characterized. The screening methodology of the electrical characteristics showed a stable linear phase in the interruption performance until a convex ageing behavior was observed after in a sequential ageing phase. The pyrolytic degradation and consequential surface recession was thereafter fundamentally analyzed.

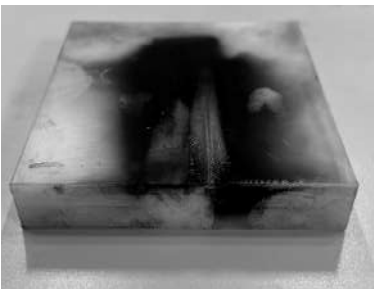
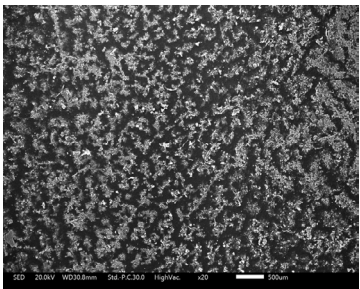
The accelerated degradation methodology for polymeric insulators based on LVDC switching arcs during elongation showed valuable performance screening suitability considering pyrolytic ageing effects.



Schematic illustration of test object configuration



Interruption characteristics for two materials tested



Illustrative overview and scanning electron microscopy (SEM) pictures after ageing

1.P. F. Hettwer, (1982) Arc-Interruption and gas evolution characteristics of common polymeric materials, IEEE Transactions on Power Apparatus and Systems, Vol.101,No. 6

2.Yoon, Jae-San,(2015) Dielectric barrier discharge plasma actuator study for low Reynolds number flow control Ph.D Thesis.

Q36.15 – Advances in In-situ NMR for Cable Assessment in Nuclear Power Plants (NPPs)

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A typical Nuclear Power Plant (NPP) contains around 1000-2000 kms of electrical cable, required to function reliably during normal operation and accident conditions. As NPPs extend their operational lifetimes beyond 40-year design basis with some now pursuing second license renewals to 80 years, cable management has become increasingly critical. Current non-destructive evaluation (NDE) methods are limited: indenter modulus, the most widely used in-situ technique, probes only the outermost jacketing material, while electrical methods such as time domain reflectometry require cables to be de-energized and disconnected. No existing portable NDE method provides direct access to the primary insulation surrounding the conductor, the layer most critical to electrical safety function.

In-situ Nuclear Magnetic Resonance (NMR) addresses this gap by measuring transverse relaxation times (T_2) of polymeric insulation, where shorter T_2 values reflect increased crosslink density and embrittlement associated with ageing.

Measurements were performed on Nuclear grade cables (sourced from Habia Cables, including both shielded and unshielded types ETFE, PEEK, SILTEM, XLPE, EVA) and EPDM Rods. In this work, we benchmark In-situ NMR T_2 values against strain at break and NMR-MOUSE T_2 for each sample. Additionally, NMR signal from intact cables, the individual contributions of the insulation and jacketing layers to the measured T_2 were investigated by sequentially isolating each cable component. This component-resolved analysis provides an understanding of how cable architecture influences the measured relaxation response and hence understand sensitivity of the instrument.

1. Furó, I., Pourmand, P., Yushmanov, P. (2021). In situ NMR condition monitoring of cable insulations in Nuclear Power Plants. SSM Report 2021:01.

2. Spencer, M.P., Elen, M., Fifield, L.S. (2023). Survey of Aging and Monitoring Concerns for Cables and Splices. PNNL-34576.

Q36.16 – Effect of Crystallinity and Morphology on the Insulation Properties of Polyolefin Films: Homo, Random, and Block Copolymers

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Polyolefins are central to modern high-voltage (HV) insulation technologies, particularly in high-voltage direct current (HVDC) cables where cross-linked polyethylene (XLPE) dominates due to its favorable electrical and mechanical properties. Despite their widespread use, the relationship between polyolefin microstructure and charge-transport behavior is not yet fully understood, limiting the design of next-generation insulation materials with reduced electrical losses. In this work, we investigate how variations in crystallinity and morphology influence the DC conductivity of several polyolefin systems, including various homo-, random- and block copolymers of ethylene. Thin films were produced by compression moulding under different cooling protocols to generate varied crystallinity and morphological features. Differential Scanning Calorimetry (DSC) and X-ray Diffraction (XRD) were employed to quantify crystallinity, while Scanning Electron Microscopy (SEM) provided visual insight into lamellar and spherulitic structures. Fourier Transform Infrared Spectroscopy (FTIR) confirmed that the processing conditions did not introduce measurable oxidation.

Electrical performance was assessed through DC conductivity measurements using a three-electrode arrangement under controlled conditions. The results demonstrate that both crystallinity and morphology significantly affect charge-transport behaviour. Comparisons across the various polymer types confirmed that amorphous-rich materials exhibit substantially higher conductivity than their more crystalline counterparts. Although, the general trend observed was that with increase in crystallinity, the conductivity decreased, the morphology of the polyolefin films were noticed to be playing a vital role and overrode the effects of crystallinity in some cases. Overall, the study highlights how processing-induced morphological changes govern the electrical response of polyolefins. These insights provide a foundation for tailoring polymer microstructures to meet the demanding insulation requirements of future HVDC systems and related high-voltage technologies.

Bjurström, A., Edin, H., Hillborg, H., Nilsson, F., Olsson, R. T., Pierre, M., Unge, M. & Hedenqvist, M. S. (2024). A Review of Polyolefin-Insulation Materials in High Voltage Transmission; From Electronic Structures to Final Products. *Advanced Materials*, 36, 52, 2401464.

Karlsson, M. E., Xu, X., Hillborg, H., Ström, V., Hedenqvist, M. S., Nilsson, F., & Olsson, R. T. (2020). Lamellae-controlled electrical properties of polyethylene–morphology, oxidation and effects of antioxidant on the DC conductivity. *RSC advances*, 10(8), 4698-4709.

Q36.17 – Epoxy Liners for Trenchless Relining: Toughness without Sacrificing Processability

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Although leakage and damage are inevitable over a pipe's service life, trenchless relining provides a superior alternative to dig-and-replace, delivering substantial economic and environmental benefits. Given these demands, epoxy systems are commonly utilised due to their good adhesion and mechanical resilience; however, extending service life without sacrificing processability requires hybrid design that couples polymers with functional inorganic nanophases.

Here we develop a liquid-processable, toughened hybrid epoxy system in which surface-functionalised nanoparticles are integrated with a model epoxy to create polymer-nanoparticles interphases tailored for durability. The nanoparticles are selected and chemically modified to covalently interact with the network, minimise additive leaching, and engineer an interfacial architecture that promotes crack deflection/bridging and energy dissipation for a better fracture toughness. Emphasis is placed on maintaining low viscosity and a predictable cure profile compatible with rapid wet-out and field handling, while delivering step-changes in damage tolerance and durability under aqueous exposures.

To ensure deployment relevance, we assess the optimised systems as epoxy blends and epoxy nanocomposites, and further as matrices within glass-fibre-reinforced polymer (GFRP) laminates, supporting interfacial integrity and laminate-level structural integrity aligned with trenchless rehabilitation needs. Collectively, the results identify practical routes that raise toughness and durability without compromising processing windows, enabling low-leach and high-performance epoxy liners compatible with existing impregnation and cure practices. The platform offers a credible path to longer-lived, lower-risk rehabilitation aligned with contemporary reliability and sustainability goals.

Q36.18 – THE HHEAA PROCESS: UNLOCKING CIRCULAR MATERIALS FROM MIXED PACKAGING AND TEXTILE WASTE

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Hrůzová¹, Theo A. Tervoort², May
Kahoush³, Nawar Kadi³, Heiko
Lange^{1,4,5}, Ulrika Rova¹, Paul
Christakopoulos¹, Leonidas
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To address the "downcycling" of mixed polymer waste caused by the incompatible properties of packaging and fibers in mechanical recycling¹, this study evaluates the efficacy of the Heated High-Ethanol Alkaline Aqueous (HHeAA) process. We utilized an experimental design to optimize the process for different materials, examining temperatures (40 to 100 °C) and reaction times (15 to 60 minutes), ethanol concentration (70 to 90 % v/v), and sodium hydroxide (NaOH) content (0.416 to 1.248 g NaOH/ g PET). The HHeAA process was applied to diverse materials, including pristine PET powder, post-consumer PET bottles, mixed plastic packaging, and polycotton fabrics (comprising 35/65 cotton/PET blends).

The optimized process yielded near-complete hydrolysis of PET (>96%), achieving high recovery rates for terephthalic acid and ethylene glycol. Notably, these results were achieved with one of the lowest recorded Liquid-to-Solid Ratios (LSR) of 5 and under significantly milder conditions with lower chemical consumption (90 °C, 20 min) than previously reported methods².

Furthermore, the process successfully separated PET from cotton in complex textiles and separated PET from polyethylene (PE) in packaging waste. Both cotton and PE were successfully recovered in suitable conditions for reprocessing.

The HHeAA process presents a robust solution for upcycling mixed polymer waste, overcoming the quality degradation associated with traditional mechanical recycling to achieve high-purity monomer recovery. The method demonstrates strong potential for industrial scalability, particularly given the feasibility of recovering and reusing process chemicals.

1. Zhao, X., Korey, M., Li, K., Copenhaver, K., Tekinalp, H., Celik, S., Kalaitzidou, K., Ruan, R., Ragauskas, A. J., & Ozcan, S. (2022). Plastic waste upcycling toward a circular economy. *Chemical Engineering Journal*, 428, 131928.
2. Pavlopoulou, K. E., Hrůzová, K., Kahoush, M., Kadi, N., Patel, A., Rova, U., Matsakas, L., & Christakopoulos, P. (2024). Textile recycling: Efficient polyester recovery from polycotton blends using the heated high-ethanol alkaline aqueous process. *Polymers*, 16(21), 3008.

Q36.19 – CLOSING THE LOOP FOR NYLON-WOOL TEXTILES VIA FIBER SEPARATION, NYLON RECYCLING AND WOOL BIOCOMPOSITES

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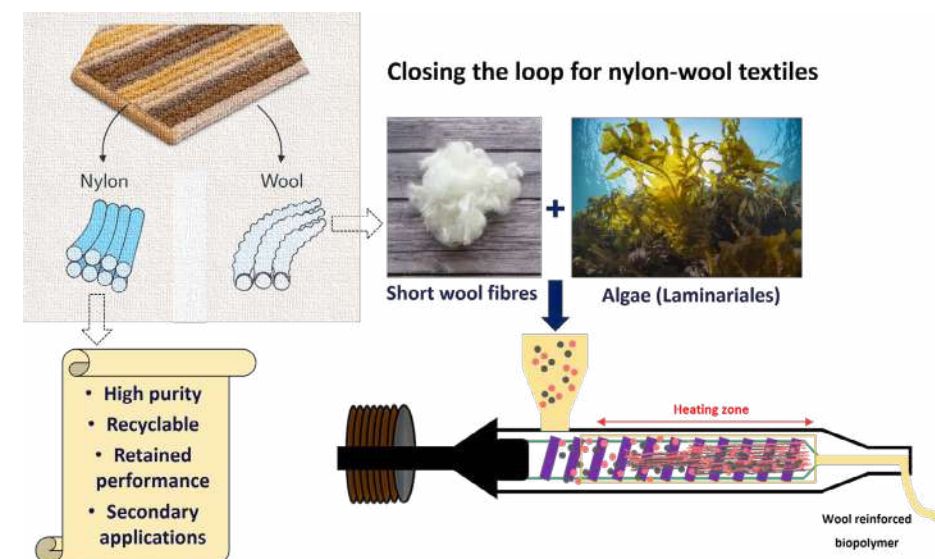
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Natural and synthetic fibres are commonly blended in textiles to balance performance characteristics and production costs while meeting diverse consumer requirements ¹. In wool textiles, nylon is frequently incorporated to enhance durability, reduce pilling, and maintain a smoother surface ². However, the different chemical structures of nylon and wool make fibre separation and recycling difficult, creating challenges at the end of the product's life.

This research addresses this challenge by adopting a chemical-based pathway that selectively separates nylon, enabling its separation from the wool fraction. The isolated nylon achieved a purity of over 95% and was successfully recycled through an industrially viable process, retaining its performance for secondary applications.

Furthermore, the isolated wool fraction was incorporated into the biopolymer matrix such as alginate, which significantly enhanced the material's mechanical and functional properties. The wool fibres acted as a natural reinforcement, improving the tensile strength

and dimensional stability of the resulting biocomposite. Overall, robust and functional wool-biopolymer composites were created for packaging applications. In summary, this work demonstrated a circular approach for nylon-wool textiles by enabling fibre separation, recycling nylon, and valorizing wool into biocomposites.



1. Sigaard, A. S., & Laitala, K. (2023). Natural and sustainable? Consumers' textile fiber preferences. *Fibers*, 11(2), 12.
2. Baird, M. E., Hatfield, P., & Morris, G. J. (1956). 12—Pilling of Fabrics: A Study of Nylon and Nylon Blended Fabrics. *Journal of the Textile Institute Transactions*, 47(4), T181-T201.

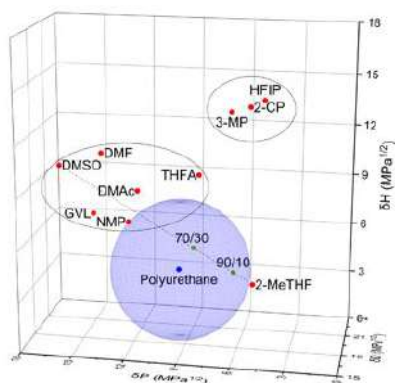
Q36.20 – Poly(urethane-urea) in Benign 2-MeTHF/DMSO Solvent System: Synthesis and Recovery Strategy for Elastane in Textiles

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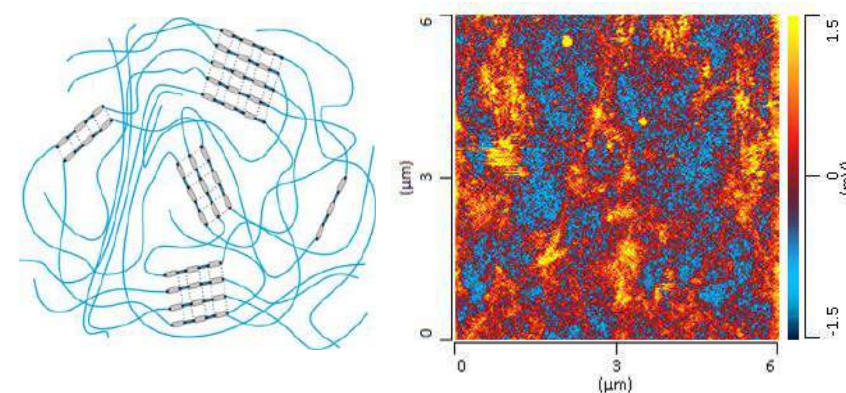


Hansen solubility space for polyurethane in various solvents [2].

Elastane, also known as spandex or Lycra, is a synthetic fiber made of poly(urethane-urea) (PUU). Typically present in only 2-10%, it provides stretch, comfort and body shaping fit to clothing. However, during recycling elastane acts as a contaminant in many mechanical or chemical processes. State-of-the-art approaches to separate elastane from fiber blends use amide solvents such as dimethylformamide (DMF) and dimethylacetamide (DMAc). They dissolve PUU effectively but pose toxicity concerns and face increasing regulation. Elastane is still commonly dry-spun from DMAc-solution into fibers.

We identified a solvent mixture comprising of dimethyl sulfoxide (DMSO) and bio-based 2-methyltetrahydrofuran (2-MeTHF) that enables selective dissolution of elastane at room temperature while preserving the main fiber components such as PET, nylon, or cotton [1]. Unlike traditional processes in which elastane is sacrificed, this mild approach allows recovery and reuse of the main fibers, elastane, and solvents. Recovery of an undamaged fiber fraction was demonstrated for PET systems [2].

In this study, we further investigate the benign DMSO/2-MeTHF solvent blend as a reaction medium for PUU synthesis. As segmented polymers with alternating hard and soft segments, PUU morphology and mechanical performance are strongly influenced by the solvent used. DMSO preferentially solvates hard segments, whereas 2-MeTHF favors soft segments. By adjusting solvent composition, polarity and viscosity can be tuned to influence phase separation. Resulting morphologies are analyzed via AFM-IR and correlated with micromechanical properties determined by DMA.



Schematic of the phase morphology showing rigid hard-segment domains dispersed in a soft-segment matrix (left). AFM-IR image at 1530 cm^{-1} , associated with hard-segment domains (right).

(1) Vonbrül L., Cordin M., Manian A., Bechtold T., Pham T. *Resources, Conservation and Recycling* (2024), 200. <https://doi.org/10.1016/j.resconrec.2023.107302>

(2) Vonbrül L., Fetz J., Manian A., Bechtold T., Pham T. *Polymer Degradation and Stability* (2025), 244. <https://doi.org/10.1016/j.polymdegradstab.2025.111846>

Q36.21 – DENIM DREAM: RECYCLING POST-CONSUMER JEANS INTO LOW-DENSITY WATER-REPELLENT CELLULOSE FOAMS

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The majority of increasingly accumulating textile waste around the globe remains underutilized due to economic and technological limitations, while the continued reliance on single-use, fossil-based packaging materials persists in the absence of viable, sustainable alternatives. Cellulose derived from cotton-based textile waste can be effectively utilized for foam production through dissolution in ionic liquids, modification with fatty acid chlorides, and precipitation of cellulose derivatives using aqueous anti-solvents.

Cotton textiles were dissolved in 1-ethyl-3-methylimidazolium acetate ([EMIM][OAc]). The cellulose was esterified in bulk using palmitoyl chloride to reduce the formation of hydrogen bonds and improve plasticity. The resulting foams exhibited densities as low as $0.17 \text{ g} \cdot \text{cm}^{-3}$, with hardnesses ranging from 60 to 93 Shore E and compressive strengths between 0.29–0.57 MPa, comparable to expanded polystyrene (0.07–0.41 MPa).

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Q36.22 – Superbase ionic liquids as solvation media for polyamides

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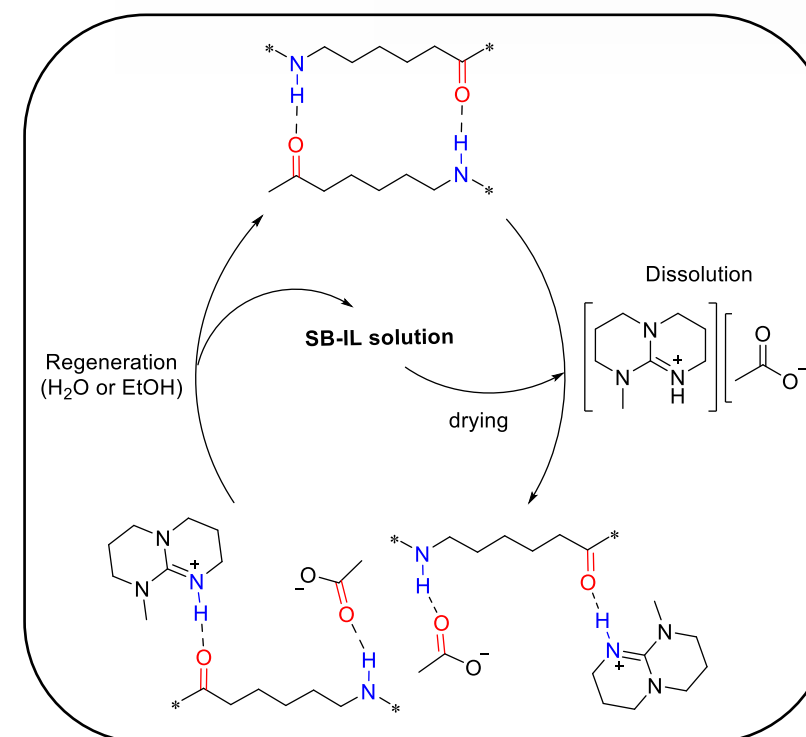
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Funding: Research Council of
Finland, No. 363823

Since their discovery by DuPont, the most common aliphatic polyamides, or nylons, have gained significant attention and today they can be found in many daily products. Their synthesis and production are well established; however, their post-consumer recycling poses many challenges. The challenges arise mainly from their high durability and chemical resistance, as well as from their poor solubility in most commercial solvents.

In this work, we explore superbase ionic liquids (SB-ILs) not only as solvation media for polyamides,¹ but also as a platform for developing a novel approach for post-consumer nylon recycling in the future.

A library of SB-ILs was synthesized and characterized, and their nylon dissolution capacity was tested against nylon 6. Structure-property relationships within the SB-ILs were examined alongside their recyclability behavior. Furthermore, the dissolved nylon 6 was successfully regenerated/isolated using water or ethanol without significant degradation or chemical modification.



Q36.23 – Solubility Prediction of Polyamides in Protic Ionic Liquids

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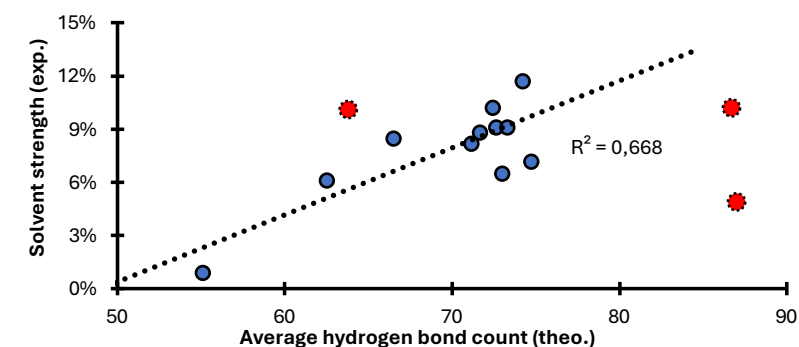
Funding: Research Council of
Finland, No. 363823

Ionic liquids have been shown to be effective solvents for a plethora of polymers. One of their biggest advantages over conventional organic solvents is that they tend to be more environment-friendly and less toxic. Recently, superbase ionic liquids (SB-ILs), a subgroup of protic ionic liquids (PILs), have been shown to dissolve especially poorly soluble polymers such as cellulose or polyamides.¹ These breakthroughs are especially valuable for industrial processing and recycling of those polymers.

The implicit solvation model COSMO-RS (COnductor-like Screening MOdel for Real Solvents) has been successfully used to predict the solubility of several classes of polymers in aprotic ionic liquids (AILs).² However, polyamides were not investigated, probably because they are usually insoluble in AILs.

Protic ionic liquids (PILs) are hard to describe theoretically, as the conventional methods fail to properly describe the exact composition, *i.e.*, the position of equilibria, of those compounds. Still, it is known that they usually have somewhat low ionicity.

Based on openCOSMO-RS,³ we designed the COSMO-PIL program to theoretically describe the composition of protic ionic liquids. We can show that molecular dynamics simulations based on the COSMO-PIL results give a correlation between solvent-polymer interaction parameters, such as amount of hydrogen bonding, and the experimentally determined solubilities of polyamides in those PILs. This allows the prescreening of possible ionic liquids for their application as polymer solvents but also gives insight into the factors that make an ionic liquid a good polymer solvent, and into the composition of PILs in general.



Correlation between theoretically determined hydrogen bonding and experimentally determined polyamide solubility. Note that some ionic liquids solidify with higher polyamide loading, meaning that the experiment may underestimate how much polyamide can be dissolved. Outliers are shown in red with dotted lines.

1. Sixta, H., Michud, A., Hauru, L., Asaadi, S., Ma, Y., King, A. W. T., Kilpeläinen, I., & Hummel, M. (2015). Ioncell-F: A High-Strength Regenerated Cellulose Fibre. *Nordic Pulp & Paper Research Journal*, 30(1), 43–57; Gazagnaire, E., Bardadym, Y., Hietala, S., Hirvonen, S.-P., Aseyev, V., Kilpeläinen, I., & Todorov, A. R. (2025). Dissolution and Regeneration of Nylons Utilizing Superbase-Acid Conjugate Ionic Liquids. *RSC Advances*, 15(56), 47930–47937.
2. Mohan, M., Keasling, J. D., Simmons, B. A., & Singh, S. (2022). *In silico* COSMO-RS Predictive Screening of Ionic Liquids for the Dissolution of Plastic. *Green Chemistry*, 24(10), 4140–4152.
3. Gerlach, T., Müller, S., González de Castilla, A., & Smirnova, I. (2022). An Open Source COSMO-RS Implementation and Parameterization Supporting the Efficient Implementation of Multiple Segment Descriptors. *Fluid Phase Equilibria*, 560, 113472.



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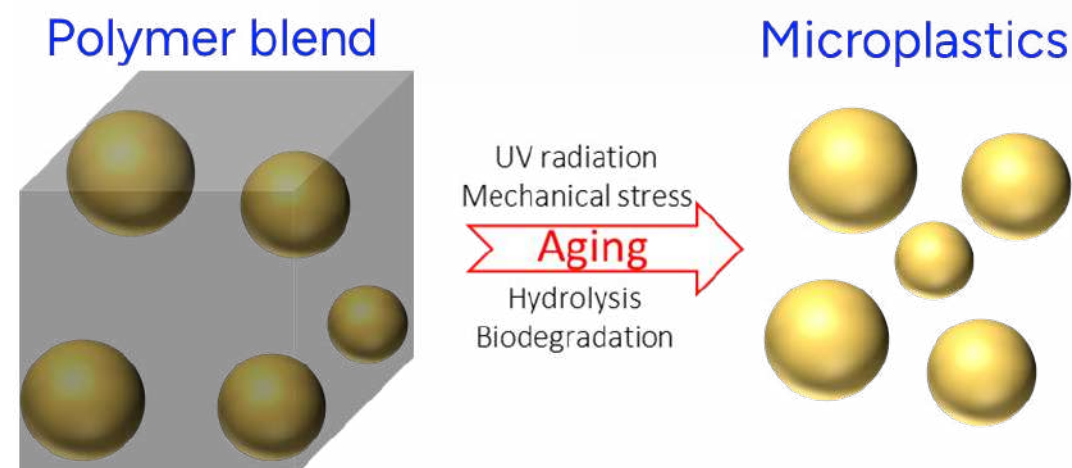
Q1.25 – Biodegradation of polymer blends and their microplastic risks

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Although biodegradable plastics are widely regarded as a promising solution to the global plastic pollution crisis, biodegradability alone does not guarantee the absence of negative environmental impacts. In practice, biodegradable polymers are frequently modified through blending with other polymers or elastomers, which may be either biodegradable or non-biodegradable. As the transition from conventional plastics to biodegradable alternatives accelerates, it is therefore critical to understand their degradation behavior and the potential environmental risks associated with microplastic formation and accumulation.



Herein, we demonstrate that both the morphology of polymer blends and the differences in biodegradability between their constituent phases strongly influence the overall biodegradation kinetics. In particular, phase-separated “sea-island” morphologies result in dispersed polymer domains that effectively behave as microplastics upon degradation of the matrix, leading to a high risk of microplastic generation from biodegradable polymer blends. These findings highlight the need for careful material design, use, and end-of-life management of biodegradable plastics. Given the scale of the ongoing paradigm shift toward biodegradable products, a comprehensive assessment of their degradation pathways and environmental fate is essential to avoid unintended ecological consequences.

1. X.-F. Wei, M.S. Hedenqvist, L. Zhao, A. Barth, H. Yin, Green Chem., (2022) 8742-8750.
2. X.-F. Wei, F. Nilsson, H. Yin, M.S. Hedenqvist, Environ. Sci. Technol. 55(8) (2021) 4190-4193.
3. A. Rusli, M.S. Hedenqvist, H. Yin, Z. Feng, B. Liu, X.-F. Wei., Chemical Engineering Journal 495 (2024) 153615.

Q1.26 – Lignin-Stabilized Reference Nanoplastics

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Inspired by eco-corona formation in natural aquatic systems, we explored the integration of a representative biopolymer during nanoparticle formation as a controlled strategy to engineer environmentally relevant nanoplastic models. To test this concept, we synthesized lignin-stabilized polystyrene (PS) nanoplastics via antisolvent nanoprecipitation, introducing different types of lignin during particle assembly to regulate surface chemistry, aggregation behavior, and colloidal stability. These lignin-stabilized PS nanoplastics provide a tunable and standardized reference platform that enables systematic investigation of how lignin chemistry influences particle size, aggregation state, and intrinsic fluorescence activity.

Three lignin types—softwood kraft lignin (SKL), hardwood kraft lignin (HKL), and acetylated lignin (ACL)—were incorporated to examine their influence on particle architecture. Transmission electron microscopy (TEM) coupled with machine learning–assisted image analysis was used to assess size distribution, aggregation behavior, and the formation of lignin-associated shells surrounding PS cores.

We developed a unique characterization approach using multiphoton excitation-emission mapping and Fluorescence Lifetime Imaging Microscopy (FLIM) to resolve the hybrid optical properties of these materials. This analysis revealed that the polystyrene-lignin interface creates distinct, hybrid autofluorescence signatures. These interactions, characterized by excitation-dependent shifts and lignin-governed emission, allow the particles to function as high-contrast 'intrinsic tags' for label-free detection.

Our results demonstrate that lignin chemistry significantly modulates particle size, colloidal stability, and the photophysical response of the hybrid nanoplastics. The intrinsic autofluorescence of lignin tunes the overall emission behavior of the particles, while the polystyrene core acts as an excitation antenna under multiphoton illumination. This coupled photophysical response establishes a promising platform for multiphoton fluorescence–based detection of nanoplastics interacting with natural biopolymers in aquatic systems.

Q1.27 – Preparation of micron-sized polyester particles and their uses as microplastic mimics and in food film welding

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Nanna B. Hartmann², Bina
Bhattarai³, Anders E. Daugaard¹

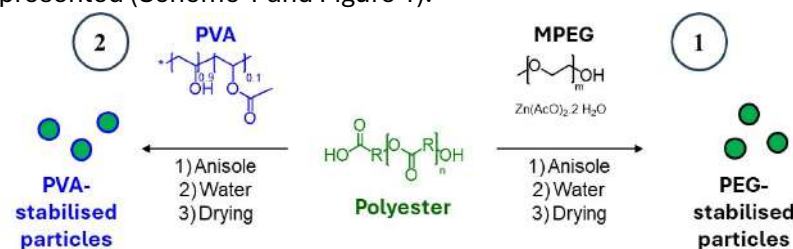
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2 simple routes to prepare micron-sized polyester particles are presented (Scheme 1 and Figure 1).



Scheme 1: Preparation of polyester particles

Route 1: Transesterification with poly(ethylene glycol) monomethyl ether (MPEG) in anisole yield MPEG-polyester block copolymers that act as stabilisers when dispersed in water. Solvent removal gives particles that are easily redispersed. Particles of glycol-modified poly(ethylene terephthalate) (PETG), polycaprolactone (PCL), poly(lactic acid), PLA as well as polycarbonate (PC) are prepared. Route 2: Stabilisation of PETG particles with 90% hydrolysed poly(vinyl alcohol) (PVA) can be achieved by mixing an aqueous PVA solution with a PETG solution in anisole.

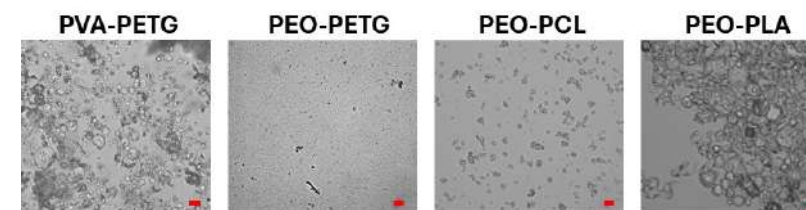


Figure 1: Microscopy images of redispersed polyester particles.

Scale bar=10 μ m

These particles have been used as mimics of polyester microplastics to examine the fate of polyesters under environmentally relevant conditions.¹ In addition, PETG is non-crystalline and allows welding at a lower temperature than PET, which is of interest in sealing food packaging. The chemistries of PET and PETG are very similar, allowing for easy recycling. However, the two synthetic routes give PETG particles with different surface chemistries. Films welded using PEO-stabilized particles have a very low peel strength, whereas films welded using PVA-stabilized particles are essentially as strong as a PET joined at higher temperature in the absence of particles.²

Madsen, J., Rech, A., Hartmann, N. B., Daugaard, A. E. (2024). Preparation of Block Copolymer-Stabilized Microspheres from Commercial Plastics and Their Use as Microplastic Proxies in Degradation Studies. *Langmuir* 40, 36, 18988-18998.

Madsen, J., Bhattarai, B., Daugaard, A. E. Micron-sized, water-dispersible polyester particles enabling strong, low-temperature sintering welding of PET films, under review (2026)

Q1.28 – Direct catalytic pathway from wood to polyesters

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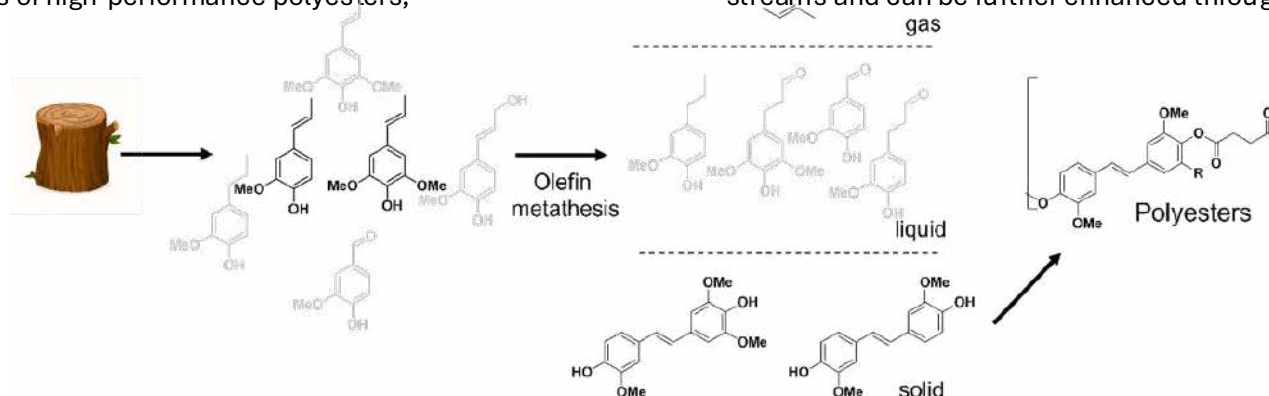
² Department of Fibre and Polymer Technology, Wallenberg Wood Science Center, KTH Royal Institute of Technology, Teknikringen 56, 100 44, Stockholm, Sweden

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Lignin is the largest renewable source of aromatic compounds, yet efficient routes for upgrading its depolymerization products into value-added materials remain limited. Here, we present a mild and selective strategy that converts lignin-derived monomers in unrefined mixtures into well-defined bisphenols, enabling direct access to building blocks for polymer synthesis.¹ Using reductive catalytic fractionation of wood, lignin is transformed into iso-eugenol- and propenyl syringol-rich oils, which are subsequently subjected to olefin metathesis without prior purification to yield readily separable bisphenols. These intermediates are then utilized for the synthesis of high-performance polyesters,

exhibiting a high glass transition temperature ($T_g = 140.3\text{ }^{\circ}\text{C}$) and excellent thermal stability ($T_{d50\%} = 330\text{ }^{\circ}\text{C}$). This approach addresses key challenges associated with complex bio-derived mixtures, including separation, selectivity, and catalyst deactivation. The resulting bisphenols serve as versatile platform molecules for further functional diversification and polymer development. Expanding their chemical scope will enable systematic studies of structure–property relationships and support applications in advanced materials, including photo-responsive systems. The strategy is broadly applicable to other biomass streams and can be further enhanced through catalyst optimization.



1. Subbotina, E., Souza, L. R., Zimmerman, J. & Anastas, P. (2024). Room temperature catalytic upgrading of unpurified lignin depolymerization oil into bisphenols and butene-2. Nature Communications 15, 5892.

Q1.29 – Optimization of Recycling Processes for Biodegradable Bioplastics: a Structure-Property Relationships Approach

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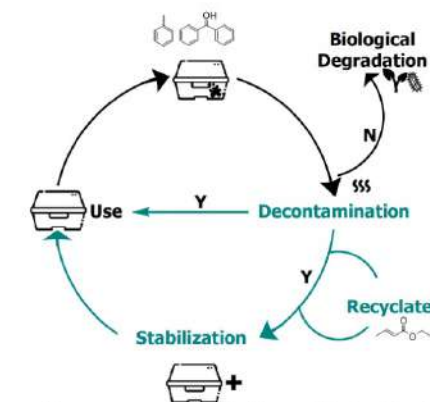
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Current research aims to foster a circular economy for biobased and biodegradable plastics, particularly for applications like food packaging. Moving beyond composting, these studies enhance recyclability through eco-design strategies that enable multiple end-of-life loops, extending material use and reducing environmental impact.¹ Key objectives are to identify polymer properties that support recyclability, focusing on decontamination and structural stability, and to develop recycling processes that preserve or improve mechanical and thermomechanical properties over cycles.

This investigation examines biopolyesters as they undergo aging, contamination, decontamination, reprocessing, and stabilization.² Advanced characterization techniques—including differential scanning calorimetry (DSC), X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FTIR), and dynamic mechanical thermal analysis (DMTA)—are employed to analyze changes in crystallinity, thermal stability, and mechanical properties. Molecular weight distribution and crystalline structure are also assessed to determine features that support stability during recycling.

By analyzing chemical degradation byproducts, particularly non-intentionally added substances (NIAS) and their interaction with contaminants, this research identifies factors affecting barrier properties, transparency, and mechanical performance.³ These insights are critical for applications demanding durability, such as food packaging.

Through these studies, a foundation for eco-designing recyclable and stable biopolyesters is created, aiming to develop plastics that maintain integrity across recycling processes and align with a circular economy. Enhanced end-of-life options thus enable biodegradable plastics to contribute sustainably to long-term economic and environmental goals.⁴



Enhanced recycling strategy for biodegradable plastics: research strategy (black + green) compared to the current situation (black).

1. N. Dahmani, K. Benhida, A. Belhadi, S. Kamble, S. Elfezazi, S. K. Jauhar J. Clean. Prod. 2021, 320, 128847.
2. I. Dedieu, S. Peyron, N. Gontard, C. Aouf Polym. Test. 2022, 111, 107620.
3. M. A. Coniglio, C. Fioriglio, P. Laganà SpringerBriefs Mol. Sci. 2019, 1-66.
4. C. Matthews, F. Moran, A. K. Jaiswal J. Clean. Prod. 2021, 283, 125263.

Q1.30 – Birch-Bark Suberin-Reconstructed Polyester Film as Packaging Materials

Raffaele Perrotta^{†,‡}, Isabella Kwan^{†,‡,§}, Veerababu Poliseti^{†,‡}, Monica Ek^{†,‡}, Anna J. Svagan[‡], and Mikael S. Hedenqvist^{†,‡,*}.

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Suberin is a biopolyester found in plants where it function as a barrier towards the surrounding environment and contributes in controlling the moisture and gas exchange with it.¹ Tree bark represents a large by-product of the forestry industry and it is rich in suberin, thus, it holds the potential to become a renewable feedstock of monomers for the development of new biobased polyesters.

In this study, suberin-extracted fatty acids were used to produce thin films, which were characterized as possible packaging materials, inspired by the natural role of suberin in plants.²



Figure 1. Sequence of picture showing the flexibility of the suberin-reconstructed film.

Figure 1 shows the suberin-reconstructed films being flexible and translucent, while providing complete shielding from UV light. The water vapor transmission rate (WVTR) was comparable to that of short-chain, industrially produced polyesters such as PLA and PCL, which are widely used in packaging. This suggests that suberin-derived films could be promising candidates for biobased packaging applications.

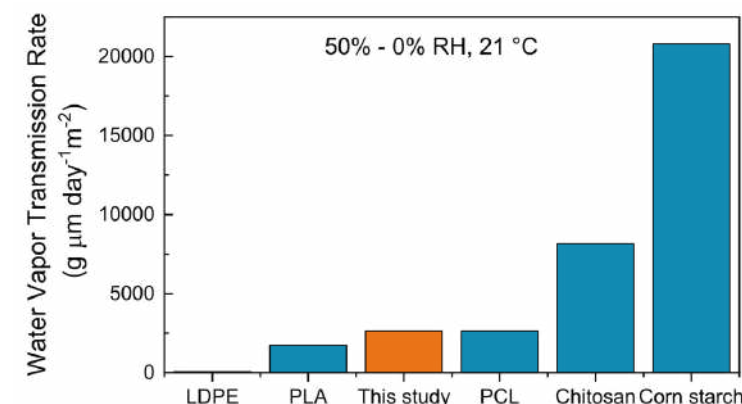


Figure 2. WVTR of widely available packaging materials compared to the one produced in this study.

1. Graça, J.; Santos, S. Suberin: A Biopolyester of Plants' Skin. *Macromol. Biosci.* **2007**, 7 (2), 128–135. DOI:10.1002/mabi.200600218.

2. Perrotta, R.; Kwan, I.; Poliseti, V.; Ek, M.; Svagan, A. J.; Hedenqvist, M. S. Birch-Bark Suberin-Reconstructed Polyester Film as Packaging Materials. *ACS Sustainable Chem. Eng.* **2025**, 13 (24), 9206–9217. <https://doi.org/10.1021/acssuschemeng.5c02590>.

Q31.24 – Polyphenol-Based Thermosets from Forestry Industry Byproducts

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The transition toward sustainable polymeric materials has accelerated interest in biomass-derived thermosets that combine high performance with safer end-of-life options. In Sweden, byproducts from forestry industry entail an abundant source of interesting compounds with potential for developing biobased polymeric materials. In this regard, lignins and tannins from tree bark comprise excellent building blocks due to their numerous hydroxy and phenolic groups, that open numerous avenues for highly crosslinked networks.¹

Recent work on lignin-based acetal networks demonstrated that thermosets with thermal and chemical resistance can be engineered. By carefully selecting the correct cross-linker structure, it is possible to mitigate the release of harmful chemicals (e.g. acetaldehyde) upon acidic hydrolysis. In addition, incorporating phenolic-rich structures, such as lignin, into the network, provides intrinsic fire-resistance to the material thanks to the inherent condensed-phase char formation mechanism that operates in aromatic structures, suppressing the combustion rate of the material.²

Building on this concept of acetal-based networks, we extrapolate this to thermosets derived from tannic acid. The resulting materials exhibit multifunctional utility, including strong adhesion to metallic substrates and intrinsic ultraviolet radiation attenuation attributed to the aromatic structure of tannic acid.

Overall, these findings highlight the enormous potential of materials based on phenolic compounds derived from forestry industry byproducts. Lignins or tannins could provide the material with intrinsic fire resistance, blocking of UV radiation or excellent adhesion properties.



1. Yan, L.; Huertas-Alonso, A.J.; Liu, H.; Dai, L.; Si, C.; Sipponen, M.H. (2025). Lignin polymerization: towards high-performance materials. *Chemical Society Reviews*, 54, 6634-6651.
2. Huertas-Alonso, A.J.; Jaworski, A.; Mensah, R.A.; Asante-Okyere, S.; Hakkarainen, M.; Sipponen, M.H. (2026). Lignin-Based Acetal Networks: Safer Degradation Pathways for Acid-, Heat-, and Flame-Resistant Circular Thermosets. *ACS Sustainable Chemistry & Engineering*, 14(7), 3317-3329.

Q31.25 – UNIFORM LIGNIN FOR BIOBASED THERMOSETS

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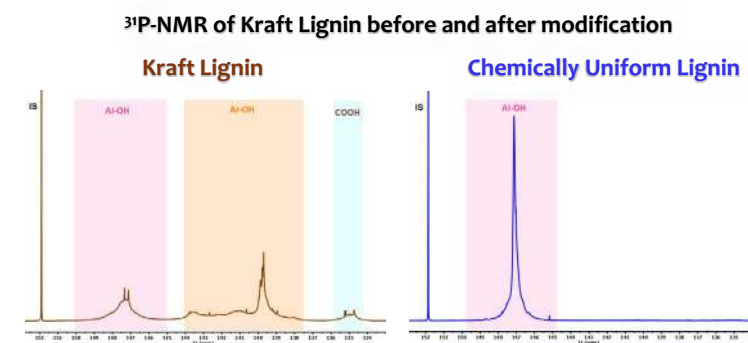
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Lignin represents the most abundant renewable aromatic resource and holds significant potential for the development of bio-based thermoset materials. However, its large-scale utilization remains limited due to pronounced chemical heterogeneity and uncontrolled reactivity, which complicate processability and reactivity control in polymer formulations.

In this work, kraft lignin was chemically homogenized via hydroxyethylation with ethylene carbonate (EC) to generate uniform and highly functional intermediates suitable for thermoset synthesis. By varying the lignin-to-EC ratio, phenolic hydroxyl groups were selectively converted into aliphatic hydroxyl groups, providing a controlled platform for subsequent polymer modification. Comprehensive structural characterization of the resulting hydroxyethylated lignins (HEL) was conducted using FTIR and HSQC NMR, confirming successful grafting of hydroxyethyl moieties onto the lignin backbone. Quantitative ³¹P NMR analysis demonstrated complete conversion of phenolic hydroxyls and carboxylic acids, evidencing the effectiveness of the homogenization strategy.

Molecular weight evolution determined by GPC indicated controlled structural modification following hydroxyethylation. Thermal analyses (TGA and DSC) revealed improved thermal behavior and enhanced processability compared to unmodified lignin. To assess industrial feasibility, the hydroxyethylation process was successfully upscaled from 1 g to 100 g without compromising structural homogeneity or thermal properties.

The resulting uniform HEL is currently being explored in crosslinking formulations for the development of bio-based thermoset networks with tunable architectures. Overall, this work establishes a scalable and application-oriented strategy for transforming industrial lignin into uniform reactive building blocks suitable for green thermoset material development.



Q31.26 – FABRICATING A FULLY LIGNIN-BASED ADHESIVE FROM IN-SITU PHENOLATION OF LIGNOCELLULOSIC BIOMASS

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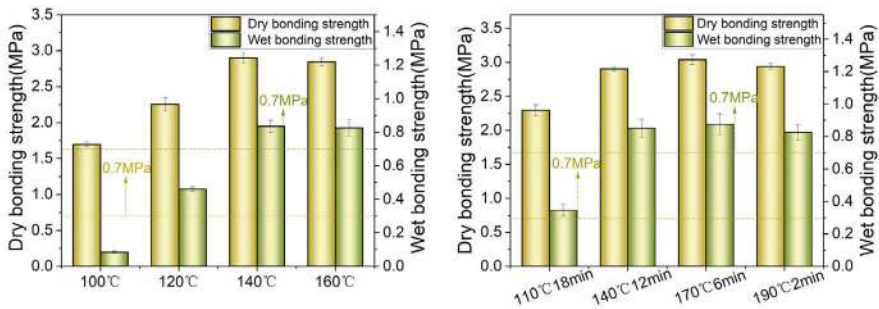
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Lignin, as the main by-product from the chemical pulping process, has suffered serious structural damage, resulting in increased condensation and reduced activity, which makes it difficult to realize high-valued applications. Herein, we proposed a facile strategy for preparing fully lignin-based adhesive directly from lignocellulosic biomass via in-situ phenolation. The in-situ phenolation that occurred during the delignification process endowed the extracted lignin with numerous phenolic hydroxyl groups, enabling the highly reactive lignin to possess the possibility as a natural lignin-based wood adhesive. The process of fabricating the lignin-based adhesive could be achieved via a simple mixing of the in-situ phenolated lignin and alkali lignin in basic solution. The plywood products prepared with the lignin-based adhesive exhibited superior performance with dry and wet bonding strengths reaching 3.09 MPa and 0.92 MPa, respectively. Mechanistic analysis revealed that hot pressing induced lignin self-polymerization and formation of new ether linkages, contributing to the enhanced adhesion.

Notably, this aldehyde-free system delivers significantly higher dry strength than most reported lignin-based adhesives, highlighting its strong potential as a sustainable alternative to formaldehyde-based wood adhesives. This work presents a facile strategy for producing a lignin-based adhesive with excellent performance, offering a promising alternative to formaldehyde-based adhesives for wood products.

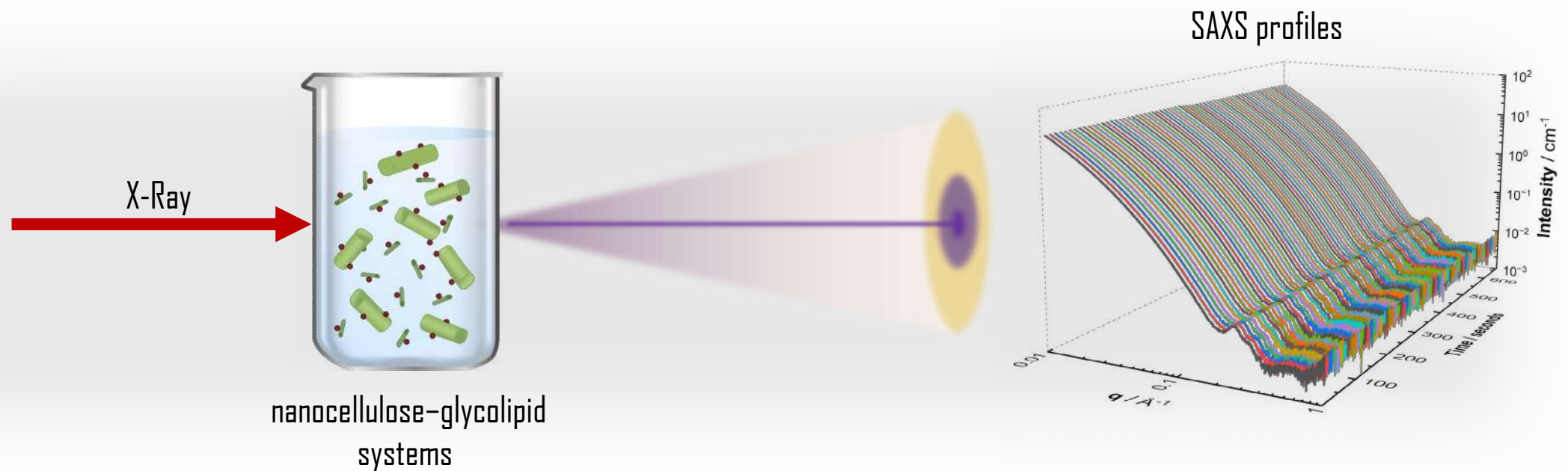


Effects of different hot-pressing conditions on their adhesion performances.

1. Wu, Y., Chen, X., Ni, S., Zhang, Y., Fu, Y., & Qin, M. (2025). Extracting light-colored lignin with high phenolic-OH from poplar by ultrasonic-assisted formic acid/phenol treatment to prepare transparent lignin/cellulose composite film. *International Journal of Biological Macromolecules*, 309, 142840.

Q31.27 – Biobased Hydrogels from Cellulose Nanocrystals and Microbial Biosurfactants: Controlling the Cholesteric–Nematic Transition and Sol–Gel Boundary

Multi-level structural insights into nanocellulose–glycolipid systems from SAXS



Speaker: Thuy-Linh Phi

**Christmas Symposium
19 December 2025**

Q31.28 – Probing the alignment of nanocelluloses in the presence of MOFs during 3D printing by in-situ scanning SAXS

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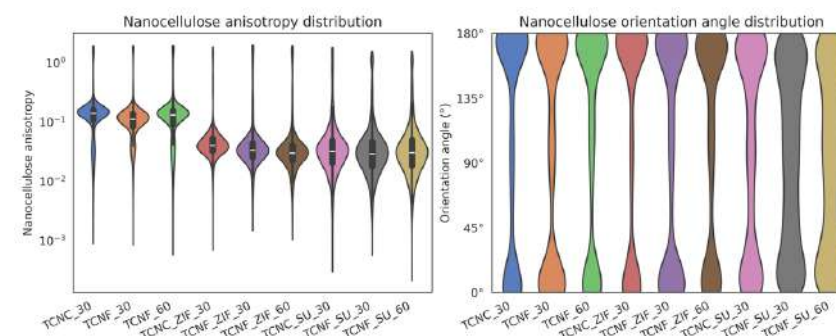
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Nanocellulose, is a promising candidate for sustainable, high-performance materials. At the nanoscale, cellulose nanofibers (CNF) and nanocrystals (CNC) offer high specific surface area, mechanical stiffness, low density, dimensional stability, chemical stability, low thermal expansion, and tunable surface chemistry. Realizing these advantages at the macroscale requires controlled assembly into ordered, anisotropic architectures¹. Gel-based 3D printing can induce such alignment², yet the effect of incorporating functional nanoparticles such as metal–organic frameworks (MOFs) on nanocellulose alignment remains unclear.

Here, we investigate how in-situ synthesized MOFs influence nanocellulose alignment during extrusion printing. Two MOFs with distinct morphology were studied: nanoscale polyhedral ZIF-8 and microscale rod-like SU-101. Alignment of TEMPO-oxidized CNF (TCNF) and CNC (TCNC) was analyzed using *in situ* small-angle X-ray scattering (SAXS) during printing at two speeds (30 mm/s and 60 mm/s) and *ex situ* wide-angle X-ray scattering (WAXS) after post-processing.

In situ SAXS showed that rigid TCNC attains higher alignment than the entangled TCNF network in the wet, extruded state. However, *ex situ* WAXS revealed relaxation of TCNC orientation during post-processing, whereas the entangled TCNF network more effectively “locks in” alignment. SU-101 rods introduced stronger hydrodynamic disturbances than ZIF-8 nanoparticles, despite SU-101 preferentially aligning with the flow. These results establish design guidelines linking nanocellulose morphology, MOF particle geometry, and processing conditions to achieve structurally anisotropic, multifunctional bio fibrillar composites.



Acknowledgement: The authors acknowledge all collaborators, Prajaktha Manal, Agnes Åhl, Houssine Khalili, Mika H. Sipponen, Lennart Bergström

1. Li, K., et al., *Alignment of cellulose nanofibers: harnessing nanoscale properties to macroscale benefits*. ACS nano, 2021. 15(3): p. 3646–3673

2. Sultan, S., et al., 3D printed scaffolds with gradient porosity based on a cellulose nanocrystal hydrogel. Nanoscale. 2018. 10(9): p. 4421-31

Q31.29 – IMAGE ANALYSIS FOR AUTOMATIC DETECTION OF SPIRAL GRAIN IN X-RAY CT IMAGED WOOD MATERIAL

Sheng Leslie Joevenller^{1*},
Johannes Huber²

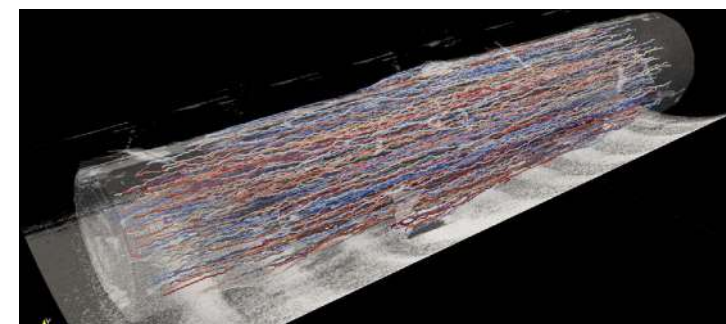
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Spiral grain refers to the helical orientation of wood fibres around a tree trunk, it severely compromises the mechanical properties and dimensional stability of sawn timber, frequently causing warping, twisting, and strength reduction during drying and sorting. Traditional manual detection methods are time-consuming and spatially constrained, creating a need for high-speed, automated quantification to optimize industrial wood processing. While industrial computed tomography (CT) scanning has been adopted by modern sawmills for non-destructive log evaluation, current proprietary algorithms fail to reliably quantify spiral grain. Previous research successfully utilized gradient-based methods to estimate fibre orientation around knots; however, spiral grain deviations present significantly subtler density variations. Despite this subtlety, qualitative visual assessment of longitudinal CT image sequences reveals discernible spiraling density patterns, including characteristic directional shifts at the juvenile wood boundary.

Therefore, we hypothesize that optical flow techniques which leverage gradient-based spatiotemporal analysis, could successfully detect and quantify spiral grain. By tracking coherent density regions aligned with anatomical growth characteristics along the longitudinal axis, this approach aims to provide robust, automated data extraction for sawmill decision-making.



Fiber orientation estimated in a pilot study.

Huber, J. A. J., Broman, O., Ekevad, M., Oja, J., & Hansson, L. (2022). A method for generating finite element models of wood boards from X-ray computed tomography scans. *Computers & Structures* 260, 106702.

Huber, J., Abdeljaber, O., Oja, J., & Olsson, A. (2023). Evaluation Of Models of Fibre Orientation in Sawn Timber Using Synchronised Computed Tomography and Optical Scanning Data. In *World Conference on Timber Engineering (WCTE 2023)* (pp. 421–427)

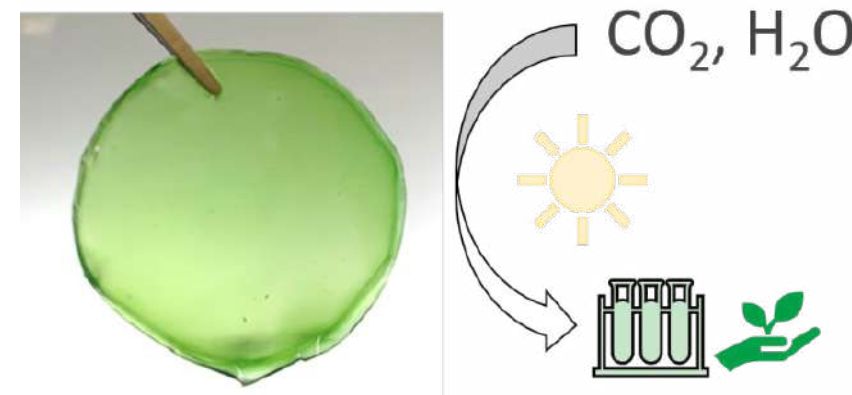
Q33.25 – Nanocellulose-based photosynthetic biohybrids for chemical production

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Through numerous metabolic pathways based on photosynthesis, cyanobacteria and microalgae transform dissolved and atmospheric carbon into biomass and various products of economic interest, such as biofuel. Additionally, they can be genetically engineered to produce an even wider range of chemical compounds. Immobilisation into biocompatible matrices ensures good cell density and light irradiation, thus increasing cell-specific activity and metabolic carbon conversion [1]. In this respect, nanocellulose is particularly attractive as it is environmentally compatible, chemically versatile, and forms hydrated networks with tailored structure. Using an interdisciplinary approach at the interface between material science and microbiology, this presentation described photosynthetic biohybrids based on carboxylated cellulose nanofibers prepared by osmotic dehydration [2]. This approach provides tailored, solid content and porosity. The structure-property relationship between the matrix and the microbial growth has been evaluated in terms of porosity, gas-fluid transport and chemical production. This presentation offers an interdisciplinary perspective on how to enhance chemical production towards a carbon-neutral society.



[1] V. Rissanen, S. Vajravel, S. Kosourov, S. Arola, E. Kontturi, Y. Allahverdiyeva, T. Tammelin. Nanocellulose-based mechanically stable immobilization matrix for enhanced ethylene production: a framework for photosynthetic solid-state cell factories. DOI: 10.1039/D1GC00502B

[2] V. Guccini, J. Phiri, J. Trifol, V. Rissanen, S. M. Mousavi, J. Vapaavuori, T. Tammelin, T. Maloney, E. Kontturi. Tuning the Porosity, Water Interaction, and Redispersion of Nanocellulose Hydrogels by Osmotic Dehydration. DOI: 10.1021/acsapm.1c01430

Q33.26 – Biomimetic Design of Biowaste-Derived Hybrid Nanomaterials for Sustainable Agriculture

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¹ Dept. Chemical Materials and Production Engineering, University of Naples Federico II

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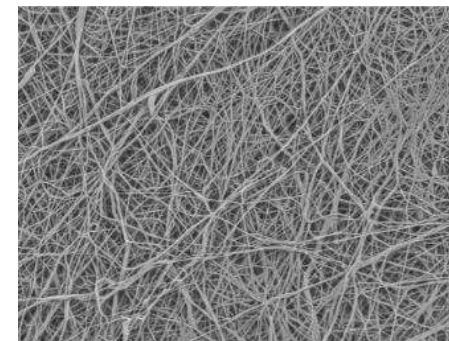
⁴ Institute of Atmospheric Pollution Research (IIA)-CNR, Montelibretti, Rome, Italy

⁵ Department for Innovation in Biological, Agrofood and Forest Systems (DIBAF), University of Tuscia

Nano-fertilizers can heavily support transition towards a more sustainable farming system, by exploring eco compatible materials able to enhance nutritional efficiency, biotic and abiotic stress tolerance, and/or crop quality. At the same time, BWs are emerging as a cheap and abundant source of chemical and biological richness, in view of their multiple properties including metal ion chelating, as well as intrinsic red-ox behaviour involving antioxidant and antimicrobial activity. Among BWs, lignin and humic acids exhibit great efficacy in improving plant growth and nutrition¹. Furthermore, molecular combination of BWs with an inorganic nanostructured phase can address the issues related to high heterogeneity, provide stability and boost intrinsic bioactive features². In this context, hydroxyapatite (HA), is an ideal component for forming hybrids with lignin (L), expanding its applications. Moreover, encapsulation of hybrid nanostructures into electrospun fibers can provide with 2D and 3D constructs mimicking soil structure. Herein, it is highlighted the bio-stimulant potential of hybrid nanomaterials derived from BW valorisation. Notably, hybrid BW-apatite (HA-L) nanostructures have been designed and encapsulated into electrospun polylactic acid (PLA) fibers (Figure 1).

Obtained nanostructured materials exhibit marked antioxidant activity as well as widespread potent biocide action towards phytopathogenic bacteria and fungi. Furthermore, they promote proliferation of microorganisms beneficial to the soil microbiome. Following a holistic approach to sustainability, this study provides with organo-mineral systems with multifunctional activity and boosted efficacy.

SEM micrography of PLA-HA-L mats



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1. V. Venezia, G. Pota, B. Silvestri, G. Vitiello, P. Di Donato, G. Landi, V. Mollo, M. Verrillo, S. Cangemi, A. Piccolo, G. Luciani (2022). A study on structural evolution of hybrid humic Acids-SiO₂ nanostructures in pure water: Effects on physico-chemical and functional properties. Chemosphere 292 133451

2. V. Venezia, G. Pota, G. Luciani, L. Panzella, A. Napolitano et. al Int. (2024), Design of a hybrid nanoscaled skin photoprotector by boosting the antioxidant properties of food waste-derived lignin through molecular combination with TiO₂ nanoparticles, Int. Journal of Biological Molecules 280 135946

Q33.28 – Nanocellulose from cellulose esters: consider the stability

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Nanocellulose are nanofibers that have attracted great attention within the research community. To date, many different types of nanocelluloses are known with a range of dimensions and surface functionalities affecting the properties of the material and which applications they can be used for. One type of nanocellulose can be made through simultaneous esterification and hydrolysis of cellulose with oxalic acid and results in a cellulose ester that has a carboxylic acid attached through an ester bond. In this study, the stability of the cellulose oxalate ester towards base-catalysed hydrolysis was investigated pH ranging from 6 to 10. The results show that the ester is rapidly hydrolysed already within 24 h at pH above 8. The results from this study show that stability of the ester needs to be carefully considered when working with cellulose oxalate and other esters of cellulose, although each ester needs to be evaluated individually.

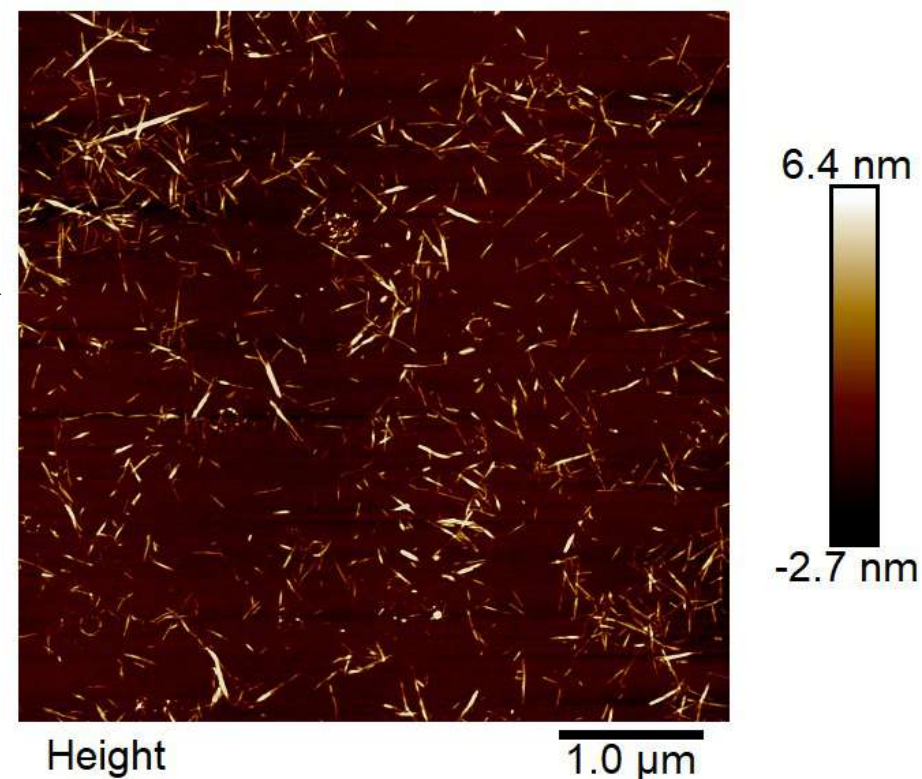


Figure 1. AFM image of oxalic acid nanocellulose

Swensson, B., Ek, M. Base-catalysed hydrolysis of cellulose oxalate significantly affects its long-term stability. *Cellulose* 33, 1329–1338 (2026).
<https://doi.org/10.1007/s10570-026-06948-x>

Q33.29 – Non-Ionic Strategies for Controlling Water Retention of Cellulose Fibres

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Hornification is defined by the reduction of water retention of cellulose fibres upon drying. Consequently, it causes closure of pores within the fibre cell wall and reduced fiber flexibility, ultimately leading to brittle and poorly bonding fibres. To increase water retention of cellulose fibres, a common strategy is to increase the charge of the fibre. However, charged moieties are generally highly sensitive to changes in pH and the ionic strength of the surrounding medium, adding complexity to the system.

Here, we aim to increase the water retention of cellulose fibres without ionic contribution by attaching end-modified hygroscopic polyethylene glycol (PEG) onto a cellulose model thin film, representing the fibre surface. The end-wise attachment of amine-terminated PEG to a cellulose nanocrystal thin film was obtained through both ionic and covalent interactions.

The adsorption of amine-terminated PEG and swelling of the cellulose model film were studied with a quartz crystal microbalance with dissipation monitoring (QCM-D). Our findings suggested an increased water uptake by the fibres upon attachment of the hygroscopic and hydrophilic PEG chain. Moreover, we observed an intriguing relationship between PEG chain length and swelling of the thin film, where shorter chain lengths led to a more pronounced swelling. Our results indicate that short oligomeric PEG chains could be attached through ionic interactions, whereas longer chains can only be attached by covalent means. These differences could be attributed to the interplay between the strong solvation of PEG chains and the driving forces required to adsorb these highly solvated PEG chains onto cellulose. Additionally, we studied the equilibrium water content of the swollen thin films, thereby revealing more details of how highly hygroscopic molecules, such as PEG, affect water retention of a cellulose fibre network.

Sellman, F. A., Benselfelt, T., Larsson, P., & Wågberg, L. (2023). Hornification of cellulose-rich materials: A kinetically trapped state. *Carbohydrate Polymers*, 318, 121132.

von Schreeb, A., Sjöstrand, B., Ek, M., et al. (2025). Drying and hornification of swollen cellulose. *Cellulose*, 32, 5179–5189.

Q33.30 – Influence of size polydispersity on the yield stress behaviour of Microfibrillated Cellulose suspensions

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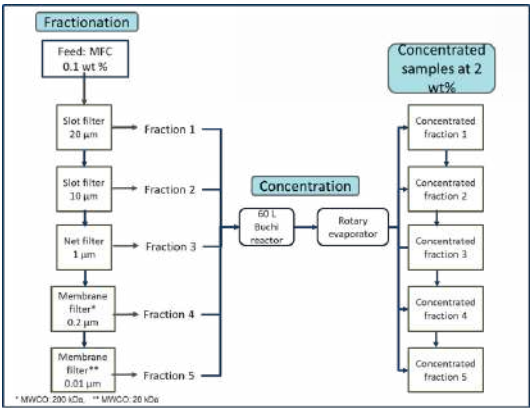
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Microfibrillated cellulose (MFC) is increasingly adopted across packaging , coatings, emulsions and rheology modification applications. The industrial use of MFC is hindered by variability in fibrillation level, size distribution and rheological behaviour. Yield stress is widely recognized as an indicator of network strength^{1,2}. A quantitative link between yield stress and underlying fibril size remains poorly understood.

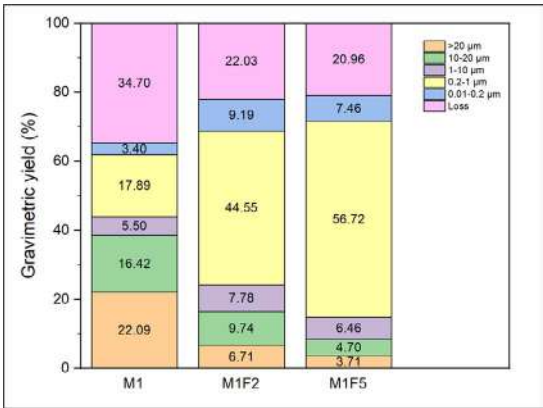
In this work, a correlation between yield stress and size fractionated components of MFC produced from cellulose rich kraft pulp was investigated. MFC suspensions were fractionated into distinct size fractions using a sequential combination of slot, net and membrane filters. To quantify the extent of recovery after fractionation and up-concentration of MFC, gravimetric analysis was performed. All the size fractions were characterized using rheology to measure yield stress using amplitude sweep tests.

Our results show that yield stress of finer fractions are dominating over coarser fractions, especially for highly fibrillated MFC grades; confirming that yield stress is correlated with fibrillation level.

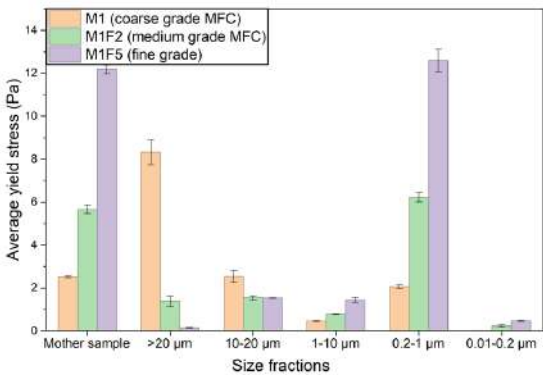
Fractionation overflow



Gravimetric analysis



Yield stress – size fraction plot



1. Cinar Ciftci, G., Larsson, P. A., Riazanova, A. V., Øvrebø, H. H., Wågberg, L., & Berglund, L. A. (2020). Tailoring of rheological properties and structural polydispersity effects in microfibrillated cellulose suspensions. *Cellulose*, 27(16), 9227-9241.

2. Larsson, P. A., Riazanova, A. V., Cinar Ciftci, G., Rojas, R., Øvrebø, H. H., Wågberg, L., & Berglund, L. A. (2019). Towards optimised size distribution in commercial microfibrillated cellulose: a fractionation approach. *Cellulose*, 26(3), 1565-1575.

Q34.22 – Efficient Recycling of Fiber-Reinforced Polymers Through Advanced Pyrolysis and Upgrading Routes : A technoeconomic analysis study

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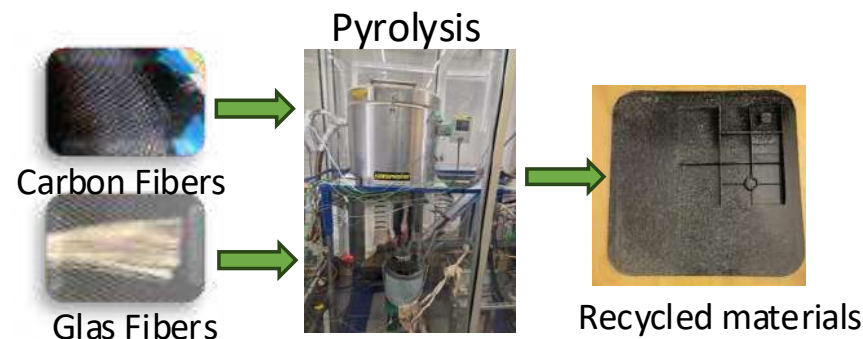
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The rapid growth of fiber reinforced polymers (FRP) in transport, energy and construction sectors has led to an urgent need for sustainable, high value recycling technologies. This project advances the pyrolysis based recovery of fibers and polymer fractions from both production waste and End of Life composite products.

Experimental results demonstrate that pyrolysis enables the recovery of high quality carbon fibers with largely retained mechanical properties, while glass fibers show reduced strength but remain suitable for secondary applications after post treatment. The project also confirms that pyrolysis yields significant amounts of oil rich in phenolics, bisphenol A and anhydrides — compounds with strong potential for synthesis of new thermoset resins.



The Relys project expands these findings by systematically improving pyrolysis yields, upgrading resin precursors, removing contaminants from aged composite waste, and developing routes for reintegration of recovered fibers and resins into new FRP, including SMC materials and fiber reinforced thermoplastics. The techno economic and climate assessments quantify process efficiency, energy demand and CO₂ reductions.

A holistic techno-economic and environmental assessment indicates that the proposed recycling approach is economically viable and offers significant potential for reducing CO₂ emissions. These findings contribute to advancing sustainable recycling strategies and support the transition toward a more circular use of composite materials. Total cost of recovering of glass fiber were estimated at €619/ton of recovered fiber, with OPEX accounting for approximately 65% of the total.



Q34.23 – Recyclability of barrier layers of LCP in a PE recycling stream

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Liquid crystalline polymers, LCP, have shown potential as packaging coating materials with good barrier properties against both oxygen and hydrogen. In addition, LCP materials show excellent mechanical and chemical stability. This work has investigated a route for recycling of LCP materials.

In order to simulate a potential recycling stream for LDPE polymers, both native and remelted LCP and LDPE pellets were used. The LCP-pellets and the LDPE-pellets, originally supplied in pellet form were mixed, extruded and pelletized. The resulting material was then remelted in the extruder together with an additional amount of LDPE-pellets to simulate a potential recycling stream for LDPE. Various fractions of LCP and LDPE as well as different fractions of (LCP+LDPE) re-blended into LDPE were evaluated as simulated recycling scenarios. All pelletized samples were then hot-pressed into films for material characterization. The recycled blends were compared to native LDPE and recycled LDPE regarding mechanical and water barrier properties.

The Water Vapor Transmission Rate (WVTR) showed generally low values for all samples indicating good water barrier properties. Recyclability seemed to have no major effect on the WVTR for the LDPE samples. Adding LCP in the recycling process only had minor effects, and lower amounts gave a small decrease in WVTR compared to pure LDPE. The mechanical properties showed some deterioration with recycling.

Q34.24 – Biosolvent-based recycling of ABS into high-purity SAN: process optimization and spectroscopic validation

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Recycling of post-consumer acrylonitrile–butadiene–styrene (ABS) remains technically challenging due to its multiphase structure and additive content, which hinder selective recovery of its polymeric components. Although selective dissolution of the styrene–acrylonitrile (SAN) fraction has been demonstrated in virgin ABS using bio-based solvents identified through computational screening and experimental validation [1-2], translating this feasibility into a reproducible purification route for real heterogeneous waste streams requires robust process refinement capable of delivering high-purity materials from complex feedstocks, such as waste electronic and electric equipment (WEEE), whose additive load often exacerbates the problematics associated with recycling technologies.

Here, we report the optimization and medium engineering of a dissolution–precipitation route for the selective recovery of SAN from WEEE-derived ABS. Key process parameters and separation strategies were systematically refined to ensure reproducibility under mild conditions. SAN was recovered with high yields, reduced residual color, and effective removal of inorganic fillers and polybutadiene rubber (PBR). Comprehensive characterization by NMR, FTIR, Raman, DSC, TGA and XRD confirmed preservation

of SAN chemical structure and thermal properties. A complementary FTIR/Raman methodology enables rapid estimation of residual PBR content and shows excellent agreement with quantitative NMR analysis, consistently indicating < 2 wt.% PBR in the recovered material. This provides a practical approach for routine quality control.

Overall, the results demonstrate that controlled medium engineering enables recovery of high-purity SAN from heterogeneous ABS waste, supporting dissolution-based recycling as a technically viable route for engineering plastics within the circular economy.

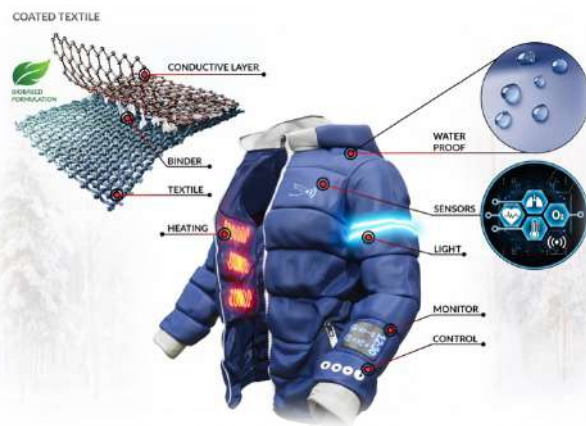
Acknowledgments: This work was developed within the scope of the project CICECO-Aveiro Institute of Materials, UID/50011/2025 & LA/P/0006/2020 & UID/PRR/50011/2025, financed by national funds through the FCT/MCTES (PIDDAC). The FCT is acknowledged for the research contract to AMF, FHBS and AFS (CEECIND/00361/2022, CEECIND/07209/2022, and CEECINSTLA/00002/2022). The European Commission is acknowledged by VP for a doctorate grant, and CFA for a research contract, under Horizon Europe ABSolEU Project (HORIZON-CL4-2021-RESILIENCE-01-Project: 101058636).

[1] V. de Paula, et al., Proceedings, 2026 136(1), 27.

Q34.25 – Toward robust electrical heating bio-based textiles

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The textile industry has transitioned significantly, moving beyond traditional clothing and garments toward the development of smart electronic textiles, integrating cutting-edge materials, technologies, and functionalities. Looking ahead, the development of wearable electronics will center on multifunctional, user-friendly systems that prioritize comfort and user acceptance, driven by the progress of electronic textile platforms. In this work, we specifically focus on Electrical Heating Textiles (EHTs), which are widely used to enhance thermal insulation in cold-weather gear such as protective clothing, outdoor blankets, and sleeping bags. Traditionally, EHTs are manufactured by integrating metal nanoparticles onto the fabric surface or by weaving in conductive wires made of copper or silver. However, these methods come with significant drawbacks; metal wires can compromise fabric flexibility, comfort, and are prone to breaking under repeated movement. Similarly, metal nanoparticles are vulnerable to being worn away through rubbing or washing. To address these issues, conductive inks formulated with carbon-based materials like graphene and carbon nanotubes combined with appropriate polymeric binders offer a promising alternative.

This work investigated the formulation of conductive inks composed of carbon-based fillers combined with bio-based polymeric binders. These inks were characterized and subsequently applied onto cellulose-based textile substrates using various coating methods. The influence of coating technique, binder type, and filler selection on the performance of the coated fabrics was examined. Specifically, the Joule heating performance was evaluated in the different coating ink formulation set-ups. Then, comparative studies with synthetic binders, particularly polyurethane (PU), revealed that while bio-based coatings delivered superior electrical performance, they exhibited lower durability under washing and abrasion. To address the low durability of the bio-based coating, a hybrid sandwich coating approach was developed by layering synthetic and bio-based inks. This sandwich configuration successfully optimized conductivity and durability, offering a synergistic balance between performance and sustainability. Furthermore, the impact of environmental factors, such as relative humidity and ambient temperature, on the heating efficiency was assessed to better reflect real-world operating conditions for Joule heating textiles.

B. Abdi, A. Tarhini, H. Baniyasi, A. R. Tehrani-Bagha, Developing Graphene-based Conductive Textiles Using Different Coating Methods. *Adv. Mater. Technol.* 2024, 9, 2301492.

B. Abdi, H. Baniyasi, A. Tarhini, A. Tehrani-Bagha, Enhancing Electrical Conductivity in Cellulosic Fabric: A Study of Bio-Based Coating Formulations. *Adv. Mater. Technol.* 2025, 10, 2400258.

Abdi, B., & Tehrani-Bagha, A. R. (2025). Toward Robust Electrical Heating Textiles: Factors Influencing Electrical Heating Performance and Durability. *ACS Omega*, 10(43), 51354-51367.

Abdi, B., Gebeyehu, E. K., & Tehrani-Bagha, A. R. (2025). MWCNT-coated textiles for heating and temperature sensing under varying environmental conditions. *RSC Adv.*, 15(56), 47735-47750.

Q34.26 – From Bioplastic to Sound Harvesting

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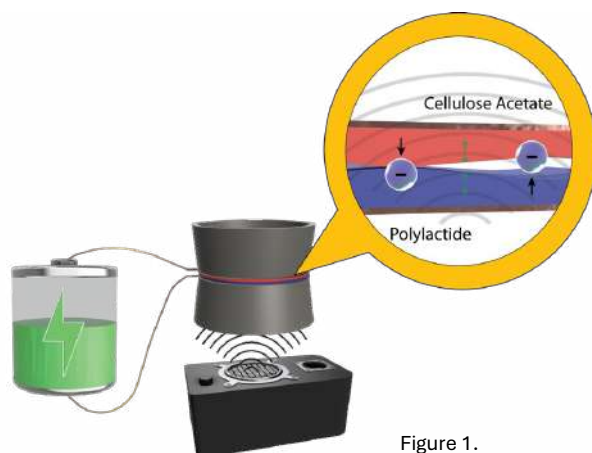


Figure 1.

Energy harvesting captures energy from environmental sources such as solar, thermal, and mechanical motion and converts it into electric power. In this work, we exploit sound waves to create a **sound harvester**¹ based on triboelectric nanogenerators (**TENGs**), which are typically made from fossil-based plastics due to their durability and ability to retain surface charge. Our **objectives** are (i) to enhance the sustainability of sound-triggered TENGs by identifying bioplastic material pairs and (ii) to optimize device design to maximize harvested charge across a broad sound frequency spectrum. The best pair, experimentally identified for this purpose consists of cellulose acetate (CA) and polylactide (PLA) films². The thicknesses of PLA and CA were optimized by contact–separation tests using a texture analyzer: the best combination was 0.02 mm CA with 0.08 mm PLA (Fig. 2a). Using this pair, the power output as a function of load resistance showed a maximum at 7 MΩ (Fig. 2b). Sound tests were then performed with a setup similar to that shown in Fig. 1. Figure 2c reports the voltage response of a PLA–Teflon pair at 95 Hz, used as a reference because Teflon is highly tribonegative, with peak voltages around 2 V.

Figure 2d shows the response of the PLA–CA pair at 95 Hz in direct contact, where peak voltages reach about 10% of the Teflon-based reference, demonstrating that sound waves can be detected by this biobased system. Figures 2e (95 Hz) and 2f (123 Hz) present signals obtained with a modified setup including a sound-channeling cylinder and a stabilizing ring to prevent membrane slippage. In these cases, the signals are larger but less stable due to the rudimentary design, which still requires optimization. Overall, these results indicate promising potential for a more sustainable, biobased triboelectric system for green energy harvesting.

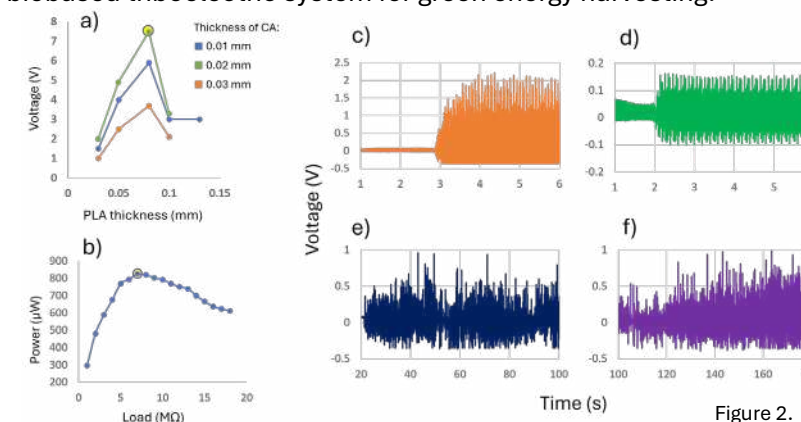


Figure 2.

1. Fan, X.; Chen, J.; Yang, J.; Bai, P.; Li, Z.; Wang, Z. L. Ultrathin, Rollable, Paper-Based Triboelectric Nanogenerator for Acoustic Energy Harvesting and Self-Powered Sound Recording. *ACS Nano* 2015, 9 (4), 4236–4243. <https://doi.org/10.1021/acsnano.5b00618>
2. Meng, H.; Yu, Q.; Liu, Z.; Gai, Y.; Xue, J.; Bai, Y.; Qu, X.; Tan, P.; Luo, D.; Huang, W.; Nie, K.; Bai, W.; Hou, Z.; Tang, R.; Xu, H.; Zhang, Y.; Cai, Q.; Yang, X.; Wang, Z. L.; Li, Z. Triboelectric Performances of Biodegradable Polymers. *Matter* 2023. <https://doi.org/10.1016/j.matt.2023.09.017>

Q34.27 – Thermotropic polymer blends for use as smart window coatings

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Temperature responsive smart windows are an appealing solution to reduce energy consumption and improve thermal management of buildings. Current responsive materials are deficient in at least one of the required performance criteria such as high solar light modulation, durability, or low baseline transmittance, which has constrained commercial implementation of such devices.

Here we describe a novel blend of polymers with a LCST type phase separation behavior that shows reversible optical cloudiness and is highly suitable for film lamination. A variety of blend compositions are studied to achieve a good balance of transparency, appropriate switching temperature in the range 40 – 70 °C, and good durability over >100 heating cycles. The films can be conveniently prepared by solvent casting over relatively large areas. Atomic force microscopy and rheology are also used to study the phase separation process. In a practical demonstration, the thermotropic coating reduces the internal temperature of a solar light irradiated box by up to 5 °C.

