Nordic Polymer Days 2025

Book of Abstracts

11-13 June 2025

Trondheim, Norway

EDITORS

Rita de Sousa Dias

Vyshnav Punnath Sivasankaran

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WELCOME TO TRONDHEIM

Dear colleagues,

On behalf of the Organizing Committee, it is my pleasure to invite you wholeheartedly to the Nordic Polymer Days 2025 meeting.

Nordic Polymer Days is the premier Nordic annual conference where researchers and professionals gather to confer around new polymer science developments and applications. Now in its 61st year, the Nordic Polymer Days continues to foster a collaborative environment and facilitate networking opportunities at the intersection of polymer science and technological development. We aim at continuing the success of previous editions by providing a stimulating environment for discussions and brainstorming. The scientific profile of this year's conference is to contribute to development of knowledge and technology to meet challenges related to renewable energy, sustainability, climate, environment, health and medicine, using polymers.

The meeting will have a combination of unified and parallel sessions, to increase the number of presented topics as well as increase opportunities for PhDs & master's students to present their research work. In addition to the invited talks, contributed oral talks in combined and parallel sessions, a dedicated poster session will take place adjacent to the lecture rooms. The posters will be up throughout the meeting and a dedicated session will take place on Thursday afternoon. The participation of young researchers has been a priority and, as recognition of the work put into their participation, the committee has decided to award two poster prizes. In the same space, commercial exhibitors will be present throughout the conference, providing opportunities for networking and future collaboration opportunities.

The success of Nordic Polymer Days 2025 is the result of the remarkable dedication, hard work, and collaboration of numerous individuals and organizations. Foremost among them is the well-established polymer science community across the Nordic countries, whose long-standing commitment has upheld this conference series for over sixty years—ensuring both scientific excellence and seamless event organization. Their enduring support has provided a strong foundation of academic rigor and professional connectivity that continues to enrich each new edition of the conference. Additionally, we extend our sincere appreciation to the knowledgeable and committed members of the program committee, whose strategic planning has been instrumental in shaping this year's successful event.

Financial premises of this year's conference were secured by our direct sponsors, including the Research Council of Norway, NTNU, SINTEF, PFI, Trondheim Kommune, Norner and the Norwegian Chemical Society. Essential scientific and technical competence contributions were provided by several exhibitors, including Waters/T-A Instruments, Houm AS, Teknolab AS, PerkinElmer Scientific, BlueScientific and NETZSCH.

Lastly, this conference owes its realization to the active engagement and contributions of its participants. We are both pleased and thankful that more than 85 individuals registered for this year's Nordic Polymer Days, a testament to the vital importance of polymers within Nordic industries.

Sincerely,

NPD 2025 Organizing Committee

Sulalit Bandyopadhyay, NTNU

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GENERAL INFORMATION

Conference Site

The conference site is the Electrical Engineering Building located on the main campus of the Norwegian University of Science and Technology, NTNU, at Gløshaugen. The street address is O.S. Bragstads plass 2. The plenary lectures will be presented in lecture hall EL6. The parallel session with oral presentations will be held in lecture halls EL6 and EL2. The poster sessions will take place in the foyer outside the lecture hall. A small food store and a bookstore are conveniently located on campus in Central Buildings I and II. Opening hours are 08:00-15:00. Please note that smoking is not allowed in any of the campus buildings.

Registration

Registration will take place on Wednesday June 11, 10:00-12:00 at the Conference Secretariat, Electrical Engineering Building, NTNU, Gløshaugen.

Secretariat during the conference

The secretariat can be found in EL1, which is located behind EL6. EL 1 can be accessed by walking around the room inside the building (see map below). The Secretariat will be happy to assist you with any practical information during your stay in Trondheim.

For academic inquiries, please contact the committee at: vyshnav.p.sivasankaran@ntnu.no, +4748653513.

For other questions regarding registration and payment, please contact NTNU Conferences at npd2025@konferanser.ntnu.no

Opening hours of the Secretariat

Wednesday, June 11	10.00- 12.30
Thursday, June 12	10.00- 12.30
Friday, June 13	10.00- 12.30

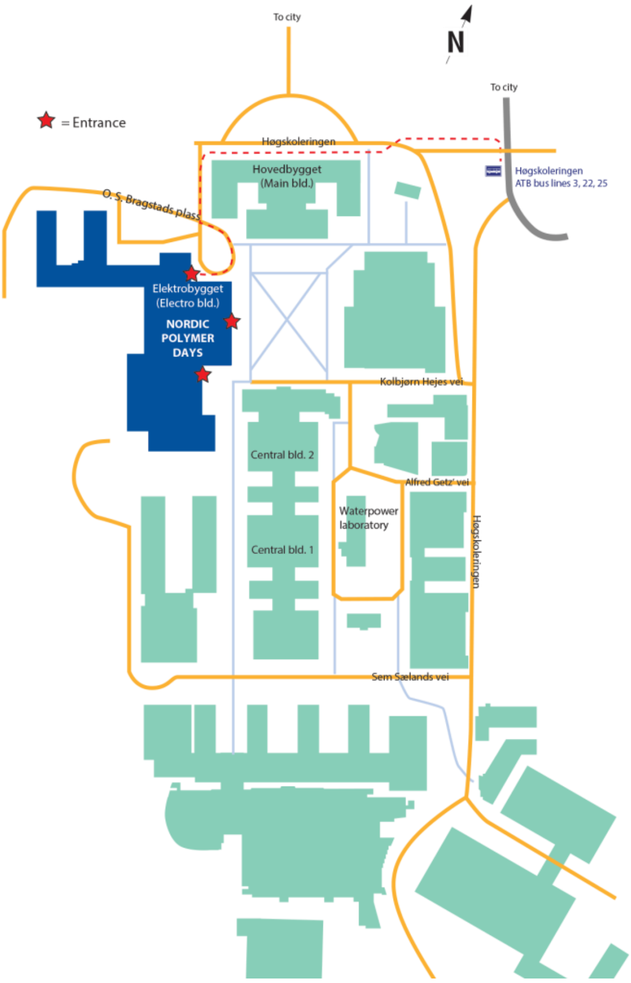
Badges

Please, wear your Nordic Polymer Days 2025 badge which you received upon registration during all conference sessions and associated activities.

Wifi Network

Eduroam and NTNU guest.

MAPS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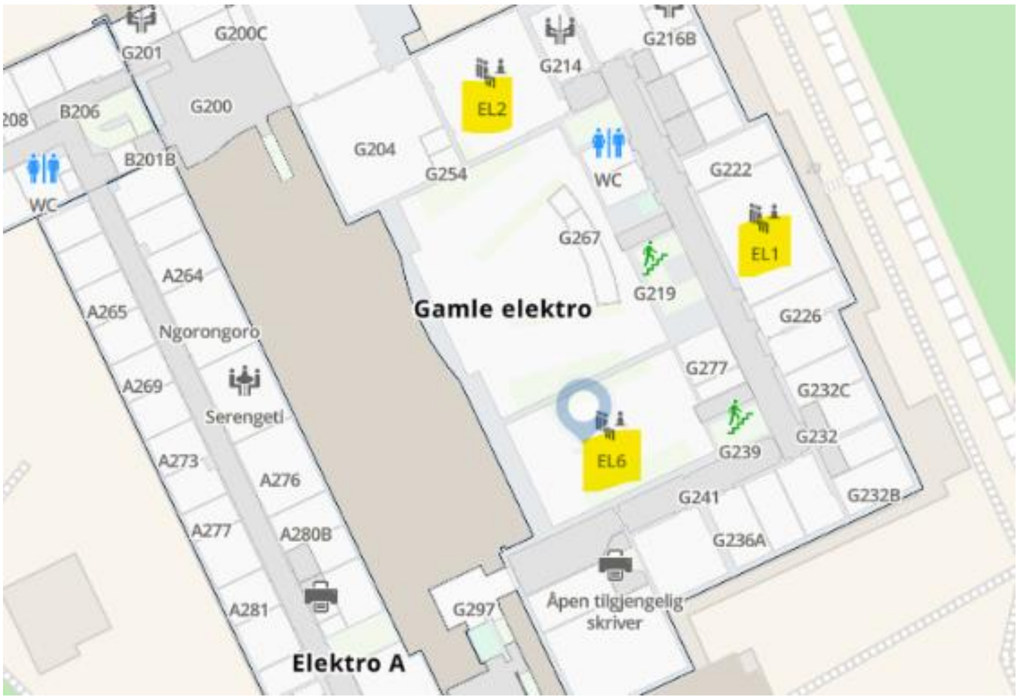
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SCIENTIFIC SESSIONS

Oral Presentations

All lectures will be held in lecture hall EL6 or EL2, located in the Elektrobygget situated on the main campus of the Norwegian University of Science and Technology, NTNU, at Gløshaugen. The lecture halls are equipped with overhead projector. All speakers are encouraged to wear the microphone provided to ensure that everyone can hear the presentation. Preview facilities is provided in the room of the Secretariat (EL1).

Each invited speaker is allocated 40 minutes, and each contributed speaker has 20 minutes. These time slots include 5 minutes for questions and discussion. We kindly ask all speakers to adhere strictly to these time limits to help keep the program running smoothly.

Poster Presentations

We have scheduled a dedicated poster session on the afternoon of Day 2, from 15:10-16:40. However, you are welcome to set up your poster starting on Day 1, and it can remain on display throughout the meeting.

Note: All posters must be removed from the poster boards by 13:30 on Friday, June 13.

Social Program

Wednesday, June 11

Organ Concert at Nidaros Cathedral 19:00 – 19:30

Evening Reception at Øx Tap room (Munkegata 26, 7011 Trondheim), 19:45 – 21:45

Øx Tap Room is located adjacent to Nidaros Cathedral

Thursday, June 12

Conference Dinner at Gubalari (Kjøpmannsgata 38, 7011 Trondheim), 19:00 – 22:00

PROGRAM SCHEDULE

Wednesday, June 11

10:00	Registration opens
11:30- 12:30	Lunch
12:30 – 12:50	Opening/welcome (Room EL6)
12:50 – 13:30	**Topic:** Hydrogels – characterization and applications (*Chairpersons:* Berit Strand and Erika Eiser)
	Invited speaker: Eiser, NTNU, Trondheim, Norway Characterizing hydrogel formation of triple-helical polysaccharide crosslinked via chitosan using microrheology
13:30 – 13:50	**Kim**, Korea University of Technology and Education Towards Next-Generation Wearable Haptics: Soft Actuator/Sensor Interfaces Enabled by Functionalized PVC Gels
13:50 – 14:10	**Schubert**, University Erlangen Nürnberg, Institute of Polymer Materials, Germany Novel opportunities to control bio-printing
14:10 – 14:30	**Kjellevold-Skallerud**, NTNU, Trondheim, Norway Viscoelastic relaxation of monodisperse Ca-alginate microgel beads via constriction in microfluidic devices
14:30 – 14:50	**Simons**, RWTH Aachen University, Germany Microgels adapt to anionic guest molecules – From nano-ions to amphiphiles
14:50 – 15:10	**Blanco**, NTNU, Trondheim, Norway How does ultrasound irradiation affect nanoparticle transport in hydrogels?
15:10	Coffee break
15:40 – 16:20	**Topic:** Polymers in solution and condensates (*Chairpersons:* Rita Dias and Maria Sammalkorpi)
	Invited speaker: Sammalkorpi, Aalto University, Finland Toward designing of biomacromolecular materials via computational modelling and phase diagrams
16:20 – 16:40	**Biswas**, Indian Institute of Technology Madras, India Understanding flash nanoprecipitation of polymer particles through multi-scale modelling
16:40 – 17:00	**Tolmachev**, Aalto University, Finland Solvent-control for glass transition of polyelectrolyte complexes
17:00 – 17:20	**Mani**, Indian Institute of Technology Madras, India Stability and rheology of telechelic polymer stabilized oil-in-water emulsions
17:20 – 17:40	**Garthe**, University Düsseldorf, Germany Influence of End Groups on the Aggregation of Polymers: A Neutron Scattering Study
19:00 – 19.30	Organ concert
19:45 – 21:45	Reception Øx

Thursday, June 12

8:30 – 9:10	**Invited speaker: Jonsson,** KTH, Stockholm, Sweden (Room: EL6) Well-defined polymers are enabling molecular engineering of the interfaces in cellulose-containing bionanocomposites	
9:15 –	**Parallel Session** (Room: EL6) **Topic:** Sustainable polymer chemistry (*Chairperson*: Ben Alcock)	**Parallel Session** (Room: EL2) **Topic:** Polymers and peptides in biomedical applications (*Chairperson*: Alexander Zelikin)
9:15 – 9:35	**Avella**, Chalmers University of Technology, Gothenburg, Sweden Dual-role of enzyme: polymerization and degradation catalyst of poly(ethylene brassylate)	**Singh,** KTH, Stockholm, Sweden Heterofunctional Cationic Polyester Dendrimers: Tunable Charge Density and Distribution for Enhanced Antibacterial Activity
9:35 – 9:55	**Głowińska,** Gdańsk University of Technology, Poland Insight into thermal and thermomechanical properties of sustainable thermoplastic polyurethane elastomers synthesized using bio-based diisocyanate mixtures	**Dannert,** NTNU, Trondheim, Norway Charge regulation in DNA – peptide-conjugated dendrimer systems
9:55 – 10:15	**Azeez,** Åbo Akademi University, Finland Sustainable Barrier Enhancement of Paperboard Using Hemicellulose-Based Latex	**Damodaran,** Tosoh Bioscience GmbH, Griesheim, Germany Molecular tale of MedTech polymers narrated by SEC/GPC with a multi detection approach
10:15 – 10:45	Coffee break	
10:45 – 11:05	**Alopaeus,** Åbo Akademi University, Finland On the compatibility of lignin derivatives with polylactic acid	**Glomm,** Dep. Biotechnology and Nanomedicine, SINTEF, Norway Design of injectable nanocomposite hydrogels for controlled release of nanoparticles
11:05 – 11:25	**Verceux,** NTNU, Gjøvik, Norway The impact of recycling on the durability of polymers: a case study on additively manufactured high impact polystyrene	**Khan,** Atta-ur-Rahman School of Biosciences, Pakistan Polymer Encapsulation of Iron Oxide Nanoparticles for the Controlled Release of Vancomycin
11:25 – 11:45	**Kamfjord,** Norner AS, PET Bottle-to-Bottle New Recycling Challenges	**Bali,** NTNU, Trondheim, Norway Insights into Flash Nanoprecipitation and Stability of Magnetic Nanocomposites
11:45 – 12:05	**Mulchandani,** Technical University of Denmark, Lyngby, Denmark Stereo-complexed Polylactides as Sustainable Thermostable Capacitors	**Garcia,** KTH, Stockholm, Sweden Photo-Curable Triazinetrione Composites with Tunable Degradation for Fracture Stabilization and Flexible Thin-Film Applications

12:05 – 13:05	Lunch	
13:05 – 13:45	**Invited speaker: Zelikin**, Aarhus University, Denmark (Room: EL6) The journey of a polymer chemist to biomedical engineering (*Chairperson:* Bjørn T. Stokke)	
13:45 – 14:25	**Invited speaker – Ansaloni,** Sintef AS, Norway Polymer selection for the gas transport network to enable safe and reliable energy transition	
	Parallel Session (Room: EL6) **Topic:** Polymers in clean energy transition (*Chairperson:* Luca Ansaloni)	**Parallel Session** (Room: EL2) **Topic:** Polymers at surfaces and interfaces (*Chairperson:* Enrico Gnecco)
14:30 – 14:50	**Gackowski,** University of Southern Denmark, Denmark Layer-by-Layer Fabrication of Polymer Film Capacitors for the Green Transition	**de Wijn,** NTNU, Trondheim, Norway Nanoscale friction simulations of polymer surfaces
14:50 – 15:10	**Bjurström,** KTH, Stockholm, Sweden Abundant Carbon-based Nanoparticles – A Novel Approach for Polyolefin Nanocomposites in High Voltage Transmission	**Ayane,** KTH, Stockholm, Sweden Self-Etching Adhesives for Enhanced Fixation of Bone Fractures
15:10 – 16:40	Poster session and coffee break	
16:40 – 17:00	**Kirch,** Umeå University, Sweden Impedance spectroscopy for characterizing the ion dynamics in polymer light-emitting electrochemical cells (LECs)	**Pekkucuk,** Bogazici University, Istanbul, Turkey Adsorption of star polystyrenes
17:00 – 17:20	**Andreassen,** SINTEF Industry, Polymer and Composite Materials group, Oslo, Norway Polymer materials for use in contact with coolants for battery and fuel cell electric vehicles	**Sivasankaran,** NTNU, Trondheim, Norway Optimizing pH-Responsive PDEAEMA Grafting on Iron Oxide Nanoparticles via Tailored SI-ATRP
17:20 – 17:40	**Pandey,** KTH, Stockholm, Sweden Carbon fiber as electrodes: A Scalable Solution for Nickel Recovery from Industrial Wastewater	**Kvikant,** Åbo Akademi University, Finland Stabilization Mechanisms of Amphiphilic Hemicellulose Derivatives in Suberin Dispersions
19:00	Dinner Gubalari	

Friday, June 13

09:00 – 09:40	**Topic:** Polymers at surfaces and interfaces (Room: EL6) (*Chairpersons:* Astrid de Wijn and Sulalit Bandyopadhyay)
	Invited talk – Gnecco, Jagiellonian University in Krakow, Poland Generation of Nanoplastics from Prolonged Scratching of Polymer Surfaces: An Experimental and Theoretical Investigation
	Topic: Polymers in environmental remediation
09:40 – 10:00	**Bonora,** Zurich University of Applied Sciences, Winterthur, Switzerland PEF/rPET-starch hydrogels from recycled sources for wastewater treatment
10:00 – 10:20	**Guzman-Gutierrez**, Department of Biotechnology and Nanomedicine, SINTEF Industry, Trondheim, Norway Innovative Membrane Technologies for the Removal of Micro- and Nanoplastics from Wastewater
10:20 – 10:50	Coffee break
10:50 – 11:10	**Sandru,** SINTEF AS, Department of Biotechnology and Nanomedicine, Trondheim, Norway Removal of Nano- and Microplastics from Cooling Water in the Energy Sector Using Biodegradable Flocculants
11:10 – 11:30	**Bolghaug,** NTNU, Trondheim, Norway UV-degradable Nylon-6 Copolymer to Mitigate Ghost Fishing and Microplastic Pollution
11:30 – 11:50	**Kelly,** NTNU, Trondheim, Norway Nanocomposite Antifouling Coatings with Graphene Nanomaterials for Marine Applications
11:50 – 12:10	**Esplandiu,** Catalan Institute of Nanoscience and Nanotechnology (ICN2), Campus UAB, Barcelona, Spain Ionomeric Polymers as Engines of Motion: Exploiting Interfacial Ion Gradients for Self-Propelled Micropumps and Nanomotors
12:10 – 12.30	Closing ceremony
12:30 –	Lunch

PLENARY LECTURES

ORAL PRESENTATIONS

Topic: Sustainable polymer chemistry

Topic: Polymers and peptides in biomedical applications

Topic: Polymers in clean energy transition

Topic: Polymers at surfaces and interface

Topic: Polymers in environmental remediation

POSTER PRESENTATIONS

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P3	**Enhancing optical properties of nanocellulose hydrogel blends** Jonatan Rönnholm and HoYoung Yoon and Tim Salomäki and Hao Zhang and Yagut Allahverdiyeva-Rinne and Chunlin Xu	66
P4	**Optimization of Mechanical Properties of PVA Hydrogels via Urea-Mediated Multiple Hydrogen Bonding** Jun Chen and Camille Lavastre and Huaitian Bu and Jianying He	67
P5	**Alginate Hydrogel Characteristics Regulate NHDF Biology** A.S. Chahal, D. Zaytseva-Zotova, H. Haslene-Hox, Ø. Arlov, A. Vikenes, A.D. Hoel, R. Mjelle, W.I. Strand, A. Akbarzadeh, G. Klinkenberg, Ø. Halaas, V. Beisvåg, H. Sletta, P. Sætrom, B.L. Strand	68
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P8	**Fundamental Investigations into Flash Nanoprecipitation: Surfactant Roles and Mapping the Ouzo Zone** Masooma Razzaq, Sulalit Bandyopadhyay, Usman Liaqat	71
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P10	**Sustainable Processing of Thermoplastic Bio-Polyurethanes: The Role of Ferulic Acid in Thermal and Oxidative Stability** Joanna Smorawska and Klaudia Furtak and Janusz Datta and Ewa Głowińska	73
P11	**Innovative Epoxy Formulations through Chemical Modification of Microbial Alginates toward Functional and Sustainable Materials** Trine Muren and Susan Maleki and Francesca Di Bartolomeo and Ashwiny Pandey and Alexander Wentzel	74
P12	**CO_2 and Propylene Oxide Copolymerization via Heterogeneous and Homogeneous Catalysts for Low-Molecular-Weight Polycarbonate Ether Polyols** Afsoon Farzan and Adina Anghelescu-Hakala and Juha Lehtonen	75

ABSTRACTS

PL1

Characterizing hydrogel formation of triple-helical polysaccharide crosslinked via chitosan using microrheology

Ana Paula Vanin[1], Marli Camassola[1], Erika Eiser[2]*, Bjørn Torger Stokke[2],*

[1]Enzymes and Biomass Laboratory, Institute of Biotechnology, University of Caxias do Sul, Caxias do Sul, RS, Brazil
[2]PoreLab, Department of Physics, NTNU, Trondheim, Norway
[3]Biophysics and Medical Technology, Department of Physics, NTNU, Trondheim, Norway

* Erika.eiser@ntnu.no

Diffusing Wave Spectroscopy (DWS) is an ideal tool to study the rheological equilibrium properties of systems that show large variations in viscosity and elasticity or are highly opaque. Examples are thermally reversible DNA hydrogels [1] and dense colloidal solutions [2]. Here I will present a microrheological characterization of aqueous solutions of the polysaccharide Schizophyllan (SPG), whose backbone is composed of consecutive β-(1,3)-linked D-glucopyranosyl residues, with single β-(1,6)-linked Dglucopyranosyl side chains attached to every third residue of the backbone [3]. They self-assemble to triple helixes and exhibit antitumor activity. SPG on itself is not known to form elastic hydrogels. Here we show that oxidization of the β-(1,3)-D-glucan with the amino groups of chitosan (CHI) enables us to crosslink the SPG helixes to form a stable hydrogel. I will present a detailed study of the viscoelastic properties of these hydrogels as function of oxidization state and concentration of SPG and the CHI-crosslinker, showing mean-squared displacements (MSDs) and corresponding elastic and loss moduil [3].

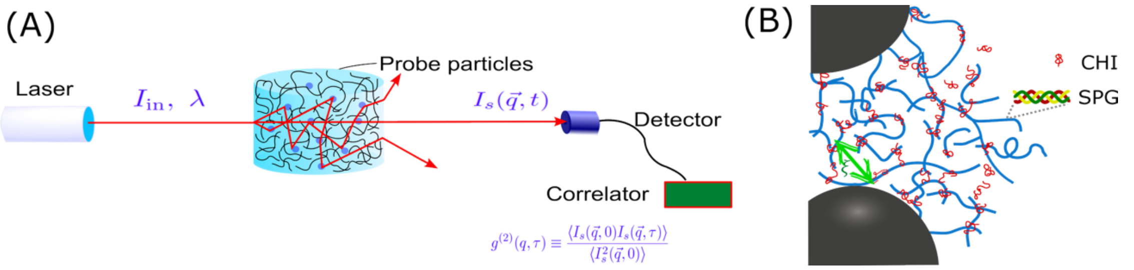

Figure 1: (A) Schematic setup of a DWS rheometer. (B) Cartoon depicting the probe-colloids embedded in a polysaccharide (SPG) hydrogel, crosslinked by Chitosan (CHI).

References:

[1] Xing, Z.; Caciagli, A.; Cao, T.; Stoev, I.; Zupkauskas, M.; O'Neill, T.; Wenzel, T.; Lamboll, R.; Liu, D.; Eiser, E. Microrheology of DNA Hydrogels. *PNAS*, **2018**, 115, 8137-8142.

[2] Kim, H. S.; Senbil, N.; Chi Zhangb, Frank Scheffoldb,1, and Thomas G. Masona, W. G. Diffusing wave microrheology of highly scattering concentrated monodisperse emulsions. *PNAS*, **2019**, 116, 7766–7771.

[3] Vanin, A. P.; Camassola, M.; Eiser, E.; Stokke, B. T. Characterization of the polysaccharide schizophyllan and schizophyllan–chitosan hydrogel formation by diffusing-wave spectroscopy. *Carbohydrate Polymers*, **2025**, *352*, 123168

PL2

Toward designing of biomacromolecular materials via computational modelling and phase diagrams

Maria Sammalkorpi[1,2]*.

[1]*Department of Chemistry and Materials Science, Aalto University, Finland,*
[2]*Center of Excellence in Life-Inspired Hybrid Materials (LIBER), Finland.*

* maria.sammalkorpi@aalto.fi

Biologically in yeast and bacterial cultures synthesized proteins offer a scalable, environmentally sustainable means to self-assembling biomacromolecular materials with, e.g. adaptive mechanical properties, adhesive characteristics, and biointeractions as advanced functionalities. Furthermore, they are a biotechnological potential replacement for oil-based polymer materials, targeting the transition towards a more sustainable economy. The high promise is enhanced by protein-based materials, such as spider silk, nacre, or barnacle cement exhibiting extraordinary properties in biocompatibility, mechanical strength, and e.g. adhesion characteristics. Characteristic to the self-assembly of biosynthetic protein materials is the condensate phase of the polymeric material, and the assembly response can be controlled via the condensate phase. In this talk, I cover our findings based on computational modelling approaches at different length and time scales combined with experimental physical characterization of self-organization of a biosynthetic block protein construct system by, for example, analytical ultracentrifuge characterization of the associative interactions between the different protein blocks, diffusion characterization, and microscopy techniques. Overall, the findings enable proposing a mechanism for the molecular assembly structure, extracting dependencies on the block composition and, e.g. protein length on the assembly response, and deducing via thermodynamics and phase diagram considerations assembly phase connections to the resulting material. I discuss how the findings may be generalized to design self-organization of other block protein systems and achieving tunable materials properties.

References:

[1] Fedorov*, D.; Sammalisto, F.-E.*; Harmat, A.L.*; Ahlberg, M.; Koskela, S.; Haataja, M.P.; Scacchi, A.; Sammalkorpi, M.; Linder, M.B. Metastable liquid–liquid phase separation and aging lead to strong processing path dependence in mini-spidroin solutions. *Advanced Functional Materials*, **2024**, 2410421.

[2] Tolmachev, D.; Malkamäki, M.; Linder, M. B.; Sammalkorpi, M. Spidroins under the influence of alcohol: effect of ethanol on secondary structure and molecular level solvation of silk-like proteins. *Biomacromolecules*, **2023**, 12, 5638-5653.

[3] Batys, P.; Fedorov, D.; Mohammadi, P.; Lemetti, L.; Linder, M. B.; Sammalkorpi, M. Self-assembly of silk-like protein into nanoscale bicontinuous networks under phase-separation conditions, *Biomacromolecules*, **2021**, 22 (2), 690-700.

[4] Lemetti, L.; Scacchi, A.; Linder, M. B.; Sammalkorpi, M.; Aranko, A. S. The liquid-liquid phase separation and assembly of silk-like proteins is dependent on the polymer length, *Biomacromolecules*, **2022**, 23 (8), 3142-3153.

PL3

Well-defined polymers are enabling molecular engineering of the interfaces in cellulose-containing bionanocomposites

Eva Malmström[1,2,3], *Åsa Jerlhagen*[1], *Alexandros Alexakis*[1,2], *Linda Fogelström*[1,2]

[1]*KTH Royal Institute of Technology, Department of Fiber and polymer technology, Sweden*
[2]*Wallenberg Wood Science Center,* [1]*KTH Royal Institute of Technology, Sweden*
[3]*FibRe – Centre for Lignocellulose-based Thermoplastics, KTH Royal Institute of Technology, Sweden*

* mavem@kth.se

By 2050, the plastic waste accumulated in nature or landfills is estimated to be around 12 billion tons, assuming that the current production and waste management trends continue. The rapidly growing environmental awareness has sky-rocketed the interest for cellulose-containing materials. Especially the nanocelluloses have attracted significant interest due to their low specific weight and their promising mechanical properties. However, to utilize their full potential in material application, it is often necessary to tailor the surface properties so as to prevent aggregation, enhance thermal and water resistance, and to impart processability, for example.

The surface properties of cellulose can be modified by polymers, either by covalent or non-covalent approaches. The covalent approach can either be performed by ring-opening polymerization of lactones for instance, from the hydroxyl groups available on the cellulose surface, or by controlled radical polymerization from an immobilized initiator. The non-covalent approach is based on adsorption of a polymer to the cellulose surface. Nanocelluloses are often charged from the manufacturing process to impart colloidal stability and the charges can be utilized to electrostatically adsorb charged polymers while maintaining the stability.

The aim of this presentation is to give some examples where well-defined polymers have been used to tailor the surface properties of nanoscopic celluloses in an effort to pave the way for nanocellulosics in new material concepts.

PL4

The journey of a polymer chemist to biomedical engineering

Alexander N. Zelikin
Department of Chemistry and iNano Interdisciplinary Nanoscience Centre
Aarhus University, Denmark
*zelikin@chem.au.dk

Research activities in my lab are highly interdisciplinary and over the past decade, we investigated diverse areas of biomedical sciences, from small molecule prodrug design to macromolecular drugs, from chemical biology to the design of artificial cells. We devoted much attention to the development of enzyme-prodrug therapies as an approach to synthesize the drug within the human body where and when needed, for localized therapeutic intervention. We also developed macromolecular (pro)drugs as broad spectrum antiviral agents, and designed implantable biomaterials that can be remotely deconstructed on demand. The most recent focus of our attention is the design of artificial biomolecules and synthetic cells. We have engineered fully synthetic receptors that are orthogonal to nature and form a dedicated route of communication to the engineered cells. Towards the design of artificial cells, we develop synthetic signaling receptors and artificial signaling cascades based on chemically programmed proteins. I anticipate that this presentation will be of interest to the broad audience with diverse research background.

Key recent publications

Adv. Mater. **2024**, 36, 2309385 (transmembrane activation of transcription in artificial cells)
Adv. Funct. Mater. **2024**, 2400048 (artificial internalizing receptors in mammalian cells)
Adv. Sci. **2023**, 2301340, early view (ADC to treat bacterial biofilms);
Nat. Commun. **2023**, 14, 1646 (artificial receptors);
Nat. Commun. **2022**, 13, 4831 (chemical zymogens);
Adv. Sci. **2021**, 8, 2004432 (artificial apoptosis-inducing receptors);
Adv. Sci. **2020**, 7, 2001395 (artificial internalizing receptors);
ACS Nano **2020**, 14, 9145 (remote dissolution of biomaterials);
Angew. Chem. Int. Ed. **2020**, 59, 7390 (prodrug cancer monotherapy);
Angew. Chem. Int. Ed. **2019**, 58, 278 (nanozymes)

PL5

Polymer selection for the gas transport network to enable safe and reliable energy transition

Luca Ansaloni[1], Vilde Andreassen[1], Thijs Peters[1], Matteo Minelli[2], Marco Giacinti Baschetti[2], Ben Alcock[1]*

[1]SINTEF AS
[2]University of Bologna.

* luca.ansaloni@sintef.no

The clean energy transition relies on the full-scale deployment of different decarbonization strategies that aim at limiting the emission of greenhouse gases, the primary cause of climate change. H_2 is a carbon-free energy carrier with great potential to decarbonize the energy and the transport sector. Hard-to-abate sectors (i.e., processes where CO_2 emissions cannot be avoided with current technology), however, will have to rely on capturing and storing CO_2 to become sustainable. The deployment of both decarbonization strategies (CCS and H_2) relies on the establishment of a gas transport system, either via repurposing existing infrastructure or building new one. In this perspective, materials integrity is key to ensure safe and reliable gas collection and distribution, and polymeric materials will play a key role in this. The thermodynamic and kinetic properties of CO_2 and H_2 are significantly different from CH_4 and higher hydrocarbons, exposing the polymeric materials present in the gas transport chain (e.g., seals, gaskets, tanks, pipes and flow coatings) to new challenges. To optimize the transport cost, the gas density needs to be optimized [1]. Dense CO_2 phases represent a challenge for non-metallic materials, as the sorption of CO_2 in polymers is thermodynamically favoured at low temperature or at high pressure, altering material properties to a significant extent compared to their original design [2]. High CO_2 sorption is typically associated with significant volumetric swelling and can lead to seals extrusion as well as loss of barrier properties when it comes to gas diffusion. On the other side, H_2 has a quite small kinetic diameter compared to other gases such as CO_2 and CH_4, leading to significantly higher permeability through polymers. Therefore, finding materials with suitable barrier properties able to prevent leakages under high pressure (> 150 bar) transport conditions might be challenging. Furthermore, even though H_2 solubility in polymer is typically low, the high-pressure conditions might still lead to significant swelling, possibly leading to extrusion of seals or softening of structural components. Results from different projects led by SINTEF, developed with the aim of supporting educated decisions regarding the selection of non-metallic materials for the clean energy transition, will be presented and discussed in detail.

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PL6

Generation of Nanoplastics from Prolonged Scratching of Polymer Surfaces: An Experimental and Theoretical Investigation

Enrico Gnecco[1], Hesam Khaksar[1], Pedro Martinez[2], Juan J. Mazo[3]*

[1]*M. Smoluchowski Institute of Physics, Jagiellonian University in Krakow, Poland*
[2]*Institute of Nanoscience and Materials of Aragon, Zaragoza, Spain*
[3]*Dept. of Structure of Matter, Thermal Physics and Electronics, Complutense University, Madrid, Spain.*
* enrico.gnecco@uj.edu.pl

The presence of nanoplastics in the environment is a problem of enormous concern not only for human health. In this contribution, we aim to address the problem at its root by presenting our ongoing work on the generation of nanoplastics from prolonged scratching of common polymer surfaces [1, 2]. Using atomic force microscopy (AFM) we have identified the formation of surface nanoripples as a first phase of the surface modification process. Numeric simulations based on an extension of the Prandtl-Tomlinson (PT) model for atomic-scale friction strongly suggest that the nanoripples are ultimately caused by a combination of elastic shear and viscoplastic indentation of the compliant surfaces [3, 4]. In a second phase, plastic nanospheres are found to originate from the crests of the nanoripples. As a last step the nanoplastics are extruded and displaced by the scratching tool far away from the generation sites. Extensions of the modeling work aimed at predicting the time and site of formation of individual nanoplastics are underway.

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O1.1

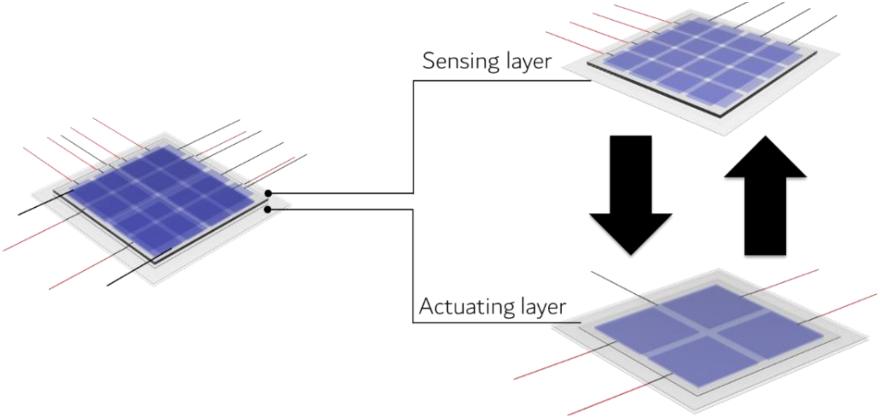
Towards Next-Generation Wearable Haptics: Soft Actuator/Sensor Interfaces Enabled by Functionalized PVC Gels

Sang-Youn Kim

Interaction Laboratory, Future Convergence Engineering, Advanced Technology Research Center, Korea University of Technology and Education

*sykim@koreatech.ac.kr

Polyvinyl chloride (PVC) gel is a highly attractive electroactive polymer (EAP) material, assessed for its superior stretchability, optical transparency, and tunable dielectric properties. Contrasting to conventional ionic, dielectric, or piezoelectric EAPs, PVC gels offer moderate driving voltage requirements, superior mechanical robustness, and versatile processability. Leveraging these characteristic properties, we present the next-generation soft haptic actuators and sensors based on hybrid and smart PVC gels to achieve multimodal tactile interactions. In this work, we developed both a soft haptic actuator and a soft haptic sensor using optimized PVC gel designs. The PVC gel was shaped into wave-like pattern to maximize dynamic deformation and restoring force, and it was sandwiched between two electrodes to form the soft and flexible haptic actuator. This structural configuration allows the actuator to produce vibrations strong enough to effectively stimulate human mechanoreceptors. Additionally, we fabricated a transparent and stretchable haptic sensor by integrating PVC gels with hydrogel-based ionic conductors. This soft sensor exhibited excellent optical transparency and stretchability. The versatility of PVC gels was demonstrated through the development of these soft, transparent, and interactive haptic devices. The exceptional electrical, dielectric, and mechanical compliance, along with the multimodal interaction capabilities of PVC gels, establishes them as highly encouraging materials for a diverse range of advanced applications.



Transparent and stretchable combined haptic module

Funding: This work was also supported by Institute of Information & communication Technology Planning & Evaluation(IITP) grant funded by the Korea government(MSIT)(No. RS-2024-00397310, Development of an AI Simulator for Creating Transparent Compounds that Can Be Altered for Tactile Sensation).and supported by Materials and Components Technology Development Program (20011013) funded by the Ministry of Trade, Industry and Energy (MOTIE, Korea).

O1.2

Novel opportunities to control bio-printing

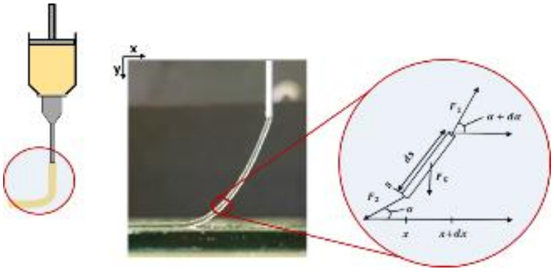
Dirk W. Schubert[1], Stefan Schrüfer[1,2], Margitta Büchner[1]*

[1]*University Erlangen Nürnberg (FAU), Institute of Polymer Materials, Martensstrasse 7, 91058*
Erlangen, Germany
[2]*RevoBITs, Martensstrasse 7, 91058 Erlangen, Germany. www.revo-bits.com*

* dirk.schubert@fau.de

Novel set-ups will be presented to control and investigate effects occurring in bio-printing. Therefore, the RevoBITs Byte1 bioprinter (available soon) is equipped with various optical systems.

With the innovative ASTRID (**A**dvanced **St**rut **I**nvestigation **D**evice) [1] system the lateral spreading of bio inks can be studied revealing valuable information on viscosity and surface tension. Utilizing additional ELSA (**E**asy **L**inear **S**trut **A**nalysis) [2] a throughput control becomes possible just by analysing how a transparent strut changes the optical image of a pattern, where the strut acts as a cylindrical lens. BERIT (**B**est **E**longation **R**heology **I**nvestigative **T**esting) [3] provides data on elongation viscosity, relevant for cell survival. Examples and fundamental physics [4] behind will be shown.



RevoBITs Byte 1 Scheme ASTRID and ELSA BERIT scheme

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O1.3

Viscoelastic relaxation of monodisperse Ca-alginate microgel beads via constriction in microfluidic devices

Embla Kjellevold-Skallerud,[1*] *Maia Lapidus Pettersen,*[1] *Kartik Totlani,*[1] *Victorien Prot,*[2] *and Bjørn Torger Stokke*[1]

[1] *Biophysics and Medical Technology, Dept of Physics, and* [2]*Biomechanics, Dept of Struct. Mechanics; The Norwegian University of Science and Technology, NTNU, Trondheim, Norway.*

* embla.kjellevold-skallerud@ntnu.no

While the viscoelastic properties of macroscopic hydrogels are known to influence eukaryotic cell growth, proliferation and differentiation, less is understood about the influence of mechanical signatures, particularly viscoelastic relaxation, of microgels in cell encapsulation. In this work, we develop a microdevice based workflow for high throughput characterization of viscoelastic relaxation of spherical Ca-alginate microgel beads post narrow-channel constriction. Monodisperse 45 μm Ca-alginate gel beads were fabricated employing the CLEX procedure in custom designed flow focusing devices. Some bead samples were processed with a surface polyelectrolyte bilayer, and induction of a gel-sol transition of the alginate core. Confocal microscopy and nanoparticle tracking were employed to characterize the coating structure and as a mechanical indicator of the core. Bead constriction was performed within microfluidic devices comprising either a bifurcated channel network or a sequential squeezing units. We analyzed the shape recovery after fluidic constriction (channel cross-section: $30 \times 34\ \mu m^2$) using high-speed video imaging (frame rates above 1000 FPS) as a proxy for viscoelastic properties. Uncoated microgels recovered their initial spherical shapes rapidly after exiting the constriction channel (e.g. within ~ ms), whereas bilayer coated microgels were observed to have a longer recovery time. The bilayer coated hydrogels with a viscous core, showed large variation in behavior, spanning from being plastically deformed, agglomerated, to recovering their shape in seconds (Fig. 1) or more rapidly. Overall, this study demonstrates that image- based tracking of shape recovery of constricted microgels offers a scalable approach towards viscoelastic characterization of microgels.

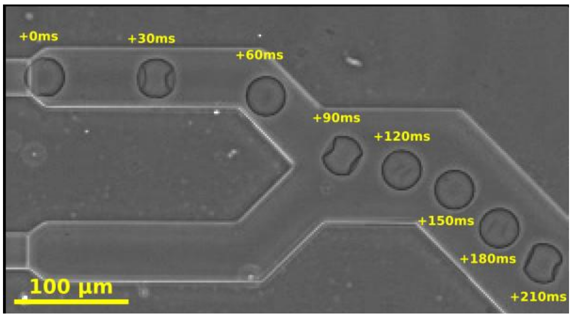

Figure 1. Composite optical micrograph showing consequetive vídeo frames of (partial) shape recovery with a bilayer coated Ca-alginate bead with viscous core after exiting a constriction domain in a microdevice with bifurcated channel network.

O1.4

Microgels adapt to anionic guest molecules – From nano-ions to amphiphiles

Jasmin Simons[1], Walter Richtering[1], Max Hohenschutz[1]*

[1]Institute of Physical Chemistry, RWTH Aachen University, Landoltweg 2, DE-52074 Aachen, Germany.

* hohenschutz@pc.rwth-aachen.de

Microgels – crosslinked polymer networks swollen by a good solvent – have the potential to serve as effective carriers for active substances, for example, in biomedical or catalytic applications due to their capacity to incorporate solutes. Due to their ability to respond to external stimuli, such as pH or temperature, solutes can be released on demand. However, the incorporation of solutes can strongly impact the swelling state, stimulus response and utility of microgels.

In order to understand how microgels adapt to solute binding, we investigate, by light scattering techniques, the influence of interface-active molecules ranging from classical anionic amphiphiles to large anions (nano-ions) lacking amphiphilic structure. The classical anionic amphiphiles and the nano-ions interact with microgels due to different water-mediated driving forces, i.e. the hydrophobic effect for amphiphiles with self-assembly [2] and the superchaotropic effect for nano-ions without self-assembly [3].

In our study, we show that millimolar nano-ion concentrations ($SiW_{12}O_{40}^{4-}$, SiW) strongly swell or deswell non-ionic microgels below the volume phase transition temperature through electric charging or physical crosslinking, depending on SiW concentration. Anionic amphiphiles induce a swelling effect that stems from micellization and the surfactant's induced charge on the polymer network. Moreover, while the volume phase transition temperature remains unaffected by POM addition, it significantly increases for anionic amphiphiles.

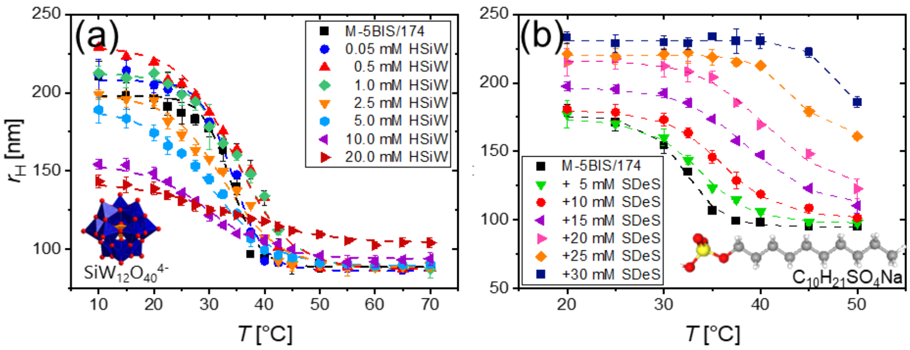

Figure 1: Hydrodynamic radius r_H of a microgel with 5 % cross-linker (M-5BIS/174) as a function of temperature at different concentrations of (a) SiW and (b) SDeS.

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O1.5

How does ultrasound irradiation affect nanoparticle transport in hydrogels?

P. M. Blanco[1], H. H. Rønneberg[1], S. B. Johnsen [1], R. S.Dias[1]*

[1]Department of Physics, NTNU - Norwegian University of Science and Technology, Trondheim, N-7491, Norway.

*pablb@ntnu.no

A major challenge in cancer chemotherapy is the targeted delivery of drugs to tumor cells. Enhanced delivery to tumor tissue can be achieved by loading drugs into nanoparticles (NPs), leveraging the enhanced permeability and retention effect, which promotes NP extravasation into the tumor. However, NPs often accumulate near blood vessels instead of spreading throughout the tissue due to diffusion limitations imposed by the extracellular matrix. Focused ultrasound, especially in combination with microbubbles, has been shown to improve drug and NP delivery to tumors [1]. Despite promising clinical results, molecular-level insights into how ultrasound affects NP transport through the extracellular matrix remain limited.

Recent in-vitro experiments tracking NP transport in agarose hydrogels showed that ultrasound irradiation moderately increases the diffusion coefficient of the NPs [2]. To bridge these experimental observations with molecular mechanisms, we designed a coarse-grained model of NP diffusing in an agarose hydrogel, mimicking the in-vitro setup. The model incorporates excluded volume, NP-hydrogel attractive interactions and an effective US-like oscillatory external force, simulating the hindered diffusion of NPs through the hydrogel. Using this model, we investigate under which conditions US can lead to an enhancement of the NP transport through the hydrogel, thereby explaining the macroscopic experimental measurements.

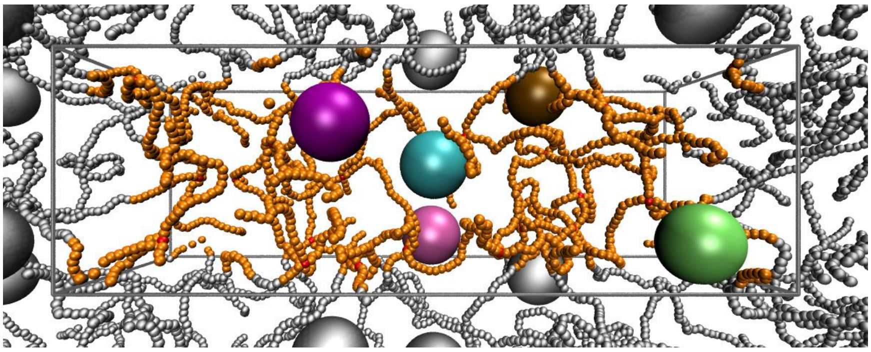

Figure 1: Snapshot of a Langevin dynamics simulation of NPs diffusing through a coarse-grained hydrogel.

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O2.1

Understanding flash nanoprecipitation of polymer particles through multi-scale modelling

Soumodeep Biswas[1], *Sulalit Bandyopadhyay*[2], *Ethayaraja Mani*[1]*
[1] *Department of Chemical Engineering, Indian Institute of Technology Madras, Chennai – 600036, India,*
[2] *Particle Engineering Centre, Department of Chemical Engineering, National University of Science and Technology, Trondheim – 7034, Norway.*
* ethaya@iitm.ac.in

Flash nanoprecipitation (FNP) has emerged as a robust method to synthesize polymer nanoparticles, which are used as drug carries for targeted delivery. In this method, a polymer solution is rapidly mixed with an immiscible anti-solvent, to precipitate polymer as particles. There have been efforts in understanding the mechanism of particle formation using FNP through either classical nucleation theory (nucleation followed by growth and aggregation) [1] or polymer-cluster formation in a convective flow field through coupled Computational Fluid Dynamics and Population Balance approach [2]. Even though the modeling of nanoprecipitation of polymer particles through spinodal decomposition has been reported [3], the deviation in the results from those observed in the experiments suggest that the spinodal decomposition alone does not explain the entire process of particle formation. We hypothesize that both the initial stages of phase separation, and aggregation of nuclei could explain the final particle size distribution (PSD).

In this study, we first model the thermodynamics of “de-mixing” using the Cahn-Hilliard equation, a fundamental theory in phase-field modelling. Flory–Huggins free energy model is used for the polymer-solvent-antisolvent ternary mixture. The solubility-dependent interaction parameter, molecular weight and the initial concentration of the polymer determine the size distribution of the initial domain sizes. The initial particle size distribution obtained from phase-field model is fed to a population balance model (PBM) to describe turbulent aggregation. The effect of turbulent conditions during mixing, flow properties and dimensions of the mixer are incorporated in the aggregation kernel. PBM is solved using fixed pivot method to yield the evolution of size distribution and number fraction of particles. A systematic parametric study is performed over a range of experimentally relevant parameters, mapped from the reported experimental studies in literature, to determine the most sensitive set of parameters that govern particle size distribution. Finally, the model is validated and compared with experimental studies for a set of solvent/polymer/antisolvent systems. This modelling approach would serve as a guiding tool for rationale design of experiments to produce polymer particles of desired PSD.

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O2.2

Solvent-control for glass transition of polyelectrolyte complexes

Dmitry Tolmachev[1], *Hongwei Li*[2], *Piotr Batys*[3], *Jodie L. Lutkenhaus*[2], *Maria Sammalkorpi*[1*]

[1] *Aalto University, Finland, and Center of Excellence in Life-Inspired Hybrid Materials (LIBER), Finland.*
[2] *Texas A&M University, United States*
[3]*Jerzy Haber Institute of Catalysis and Surface Chemistry, Polish Academy of Sciences, Krakow, Poland*

* maria.sammalkorpi@aalto.fi

Polyelectrolyte complexes (PECs), formed by the association of oppositely charged polyelectrolytes (PEs), have garnered significant attention from the scientific community for nearly a century due to their diverse applications. It is well known that dry PECs are brittle, but the addition of solvent increases the mobility of the assembly. By controlling solvent concentration, one can regulate the glass transition temperature (T_g) of PECs. Previously, using various synthetic PEs, we have demonstrated a general dependence of PEC T_g on the number of intrinsic contacts between PEs and the number of solvent molecules: $\frac{1}{T_g} \sim \ln \frac{n_{water}}{n_{intristic-ion-pair}}$ [1,2].

Molecular dynamics simulations revealed the molecular origins of this relationship. At low hydration, the solvent is immobilized around the charge groups, thereby not significantly affecting the properties of PEs. With increasing solvent concentration, solvent molecules decrease the interaction between PEs and act as plasticizers by increasing the free volume and providing lubrication for chain movement.

This mechanism was confirmed both experimentally and through simulations for water and five different alcohol solvents [2]. The concentration dependence of T_g on solvent concentration is directly related to the solvent's ability to form hydrogen bonds with the PE, which depends on the size of the solvent molecule and the number of its hydroxyl groups. This finding enables us to formulate clear and simple mechanism-based guidelines for predicting the T_g of PECs with the addition of solvent.

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O2.3

Stability and rheology of telechelic polymer stabilized oil-in-water emulsions

Roopesh P[1], *Abhijit P Deshpande*[1,2], *Ethayaraja Mani*[1,2*]
[1]*Department of Chemical Engineering, Indian Institute of Technology Madras, Chennai – 600036, India*
[2]*Center of Excellence for Biodegradable Packaging, Indian Institute of Technology Madras, Chennai – 600036, India*

* ethaya@iitm.ac.in

Polymeric emulsifiers used for stabilization of oil-in-water (O/W) emulsions typically contain hydrophilic and hydrophobic domains in the form of di- and tri-block architecture. Recent study showed that hydrophilic homopolymers can also stabilize O/W emulsions at high concentrations and high molecular weights [1]. In this work, it is demonstrated that hydrophobically modified ethoxylated urethane (telechelic-HEUR), used as a thickening agent otherwise, can be an excellent stabilizer of O/W emulsions. Telechelic-HEUR polymers are synthesized by functionalization of polyethylene oxide (PEO) at the terminals with an alkyl chain using isocyanate linkers through an addition reaction. Using n-decane as the model non-polar phase, and telechelic HEUR as stabilizer, it is shown that even lower molecular weight polymers (20kD) with hydrophobic tail can stabilize emulsions at very low concentrations (<0.5 wt%). The effect of the alkyl chain length (hydrophobic moiety), attached to terminal ends of HEUR, on the stability and rheology of emulsions is investigated. This study demonstrates that by simple chemical modification of low molecular weight hydrophilic polymers, highly stable emulsions can be prepared.

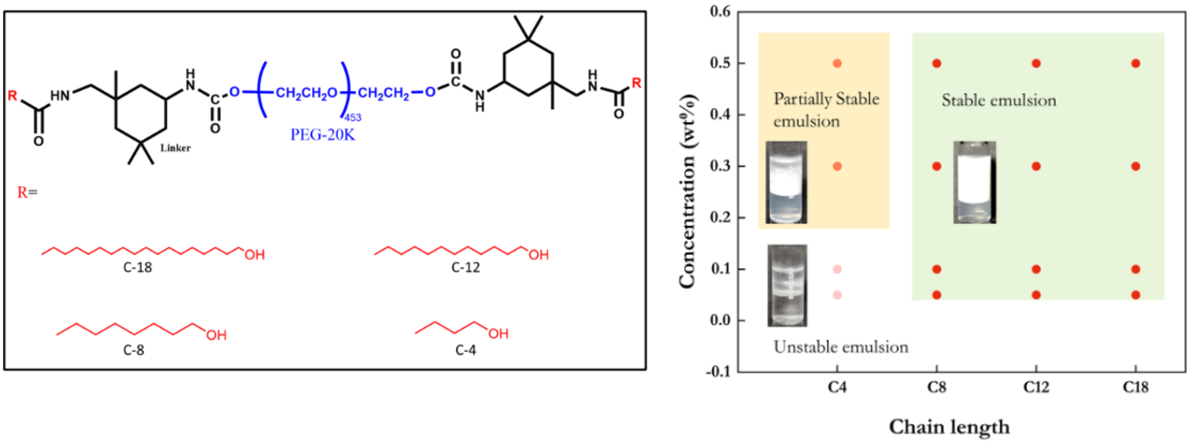

Figure 1: Telechelic HEUR with variable hydrophobe length and stability diagram for decane-water emulsions

References:

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O2.4

Influence of End Groups on the Aggregation of Polymers: A Neutron Scattering Study

Jonathan Garthe[1], *Sylvain Prévost*[2], *Matthias Karg*[1,3]*

[1]*Heinrich Heine University Düsseldorf, Düsseldorf*
[2]*Institute Max von Laue – Paul Langevin, Grenoble*
[3]*Martin Luther University Halle-Wittenberg, Halle(Saale)*

* matthias.karg@chemie.uni-halle.de

The solution structure of polymers depends strongly on polymer concentration, solvent quality, and molecular weight. Apart from these parameters, the nature of chemically different terminal groups, if present, influences the phase behavior of polymers with strong differences depending on the average chain length. Recent works found the existence of polymeric micelles when these polymers possessed hydrophobic end groups. [1] We investigated the solution behavior and the occurrence of micelle-like structures for (semi)-dilute solutions. We synthesized PNIPAM homopolymers that are hydrophobically terminated. Via aminolysis we also cleaved the hydrophobic end groups allowing for direct comparison of the same homopolymers with and without hydrophobic end group. Cloud points in aqueous solutions of those polymers were measured via extinction spectroscopy (see Figure 1, left). Small-angle neutron scattering (SANS) was used to study the structure of the polymers in solution. We were able to determine the ratio between individual polymer chains and the micelles. Our studies demonstrated that a subdominant micelle formation occurs for samples with molecular weights below 100 kDa. The aggregation number of these micelles scales inverse with the molecular weight. At low concentrations, these micelles exist as individual structures. Upon increasing the concentration micelles aggregate, leading to a distinct structure factor contribution in the scattering profile (see Figure 1, right).

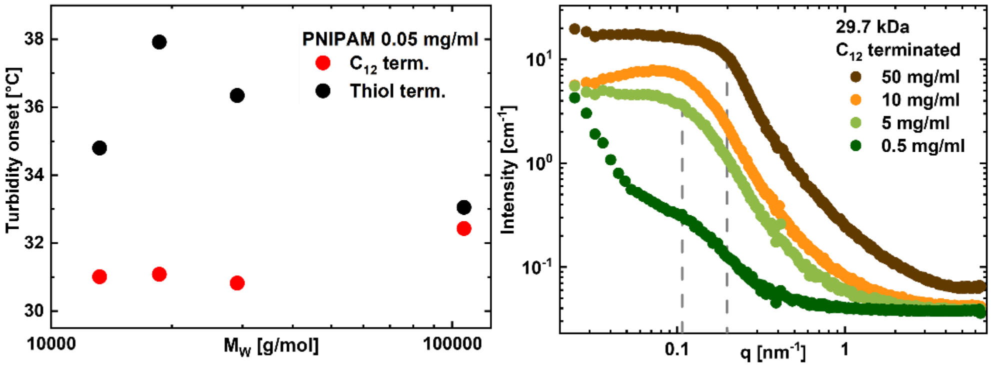

Figure 1: Left: Cloud points in dependence of molecular weight with (red) and without (black) hydrophobic end group. Right: Concentration dependent SANS profiles of PNIPAM homopolymers with hydrophobic end group.

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O3.1

Dual-role of enzyme: polymerization and degradation catalyst of poly(ethylene brassylate)

Angelica Avella[1,2]*, Giada Lo Re*[1,2]**, Rosica Mincheva, Daniela Pappalardo, Abdolrahim Rafi, Luca Deiana, Armando Córdova*

[1]*Department of Industrial and Materials Science, Chalmers University of Technology, 41258 Gothenburg, Sweden*
[2]*Wallenberg Wood Science Center, Chalmers University of Technology, 41258 Gothenburg, Sweden*
[3]*Laboratory of Polymeric and Composite Materials, University of Mons, 7000 Mons, Belgium*
[4]*Dipartimento di Scienze e Tecnologie, Università del Sannio, Via de Sanctis snc, 82100, Benevento, Italy*
[5]*Department of Natural Sciences, Mid Sweden University, Sundsvall 85170, Sweden*

* giadal@chalmers.se

To address the environmental challenges posed by plastics, there is growing interest in developing circular materials additionally to more sustainable production techniques. Ethylene brassylate (EB), a macrolactone derived from castor oil, can be polymerized via ring-opening polymerization (ROP) to form poly(ethylene brassylate) (PEB), a fully bio-based polyester. Earlier studies have demonstrated EB polymerization on a laboratory scale via solution or bulk processes and catalyzed by enzymes, organometallics, or organic bases. This study [1] investigates the synthesis of PEB through reactive extrusion (REx), a solvent-free, scalable method compatible with conventional melt-processing equipment. The process was evaluated using various catalytic systems, with two proving effective: the organic base 1,5,7-triazabicyclo[4.4.0]dec-5-ene (TBD) and immobilized enzymes, including *Candida antarctica* Lipase B (CALB) and *Pseudomonas cepacia* Lipase. As alternative to the commercially available immobilized enzymes, the biocatalyst CALB was also immobilized on microcrystalline cellulose through self-assembly in water and tested for ROP [2]. The use of cellulose as support had the aim to preserve the enzymatic activity during extrusion at 90 °C, and enable the in situ formation of cellulose–PEB composites. The presence of the cellulose support was proven critical, as full monomer conversion was only achieved with the immobilized enzyme, while the free enzyme was ineffective under the same conditions. For this relatively novel polyester, three potential end-of-life strategies were explored: mechanical recycling, enzymatic depolymerization, and composting. PEB maintained its thermal and mechanical integrity after four recycling cycles. In industrial composting conditions, PEB degraded via surface erosion, losing 93% of its initial mass after 90 days. The role of CALB in PEB degradation was also explored. PEB underwent depolymerization into monomers and oligomers when incubated in a CALB-containing solution, and degradation was similarly observed when the enzyme was embedded within the polymer matrix during synthesis.

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O3.2

Insight into thermal and thermomechanical properties of sustainable thermoplastic polyurethane elastomers synthesized using bio-based diisocyanate mixtures

Ewa Głowińska[1*], *Joanna Smorawska*[1], *Julia Habaj*[1]

[1]*Gdańsk University of Technology, Faculty of Chemistry, Department of Polymers Technology,*
Gdańsk, Poland,
* ewa.glowinska@pg.edu.pl

Nowadays, sustainability in the polymer industry plays a crucial role in the design, synthesis, processing, and recycling of materials. In polymer synthesis, the use of bio-based monomers not only increases the green carbon content but also influences processing and mechanical properties. A special class of polymeric materials includes thermoplastic polyurethane elastomers (TPUs), which are synthesized through the reaction of polyols, diisocyanates, and low-molecular-weight chain extenders (glycols or amines). TPUs can be widely modified, resulting in unique properties and applications. Notably, TPUs have a segmented structure, consisting of soft segments (SS) and hard segments (HS).

This study focuses on the modification of the hard segments of TPUs by incorporating bio-based diisocyanate mixtures and evaluating the thermal and thermomechanical properties of the resulting materials. In the first stage, sustainable TPUs were synthesized using the one-shot method with bio-based poly(trimethylene ether) glycol, bio-based 1,3-propanediol, and hexamethylene diisocyanate or hexamethylene diisocyanate/partially bio-based diisocyanate mixtures. Two types of bio-based diisocyanates were used for TPU modification, with dibutyltin dilaurate (DBTDL) serving as the catalyst. The TPUs were synthesized at an equimolar ratio of isocyanate to hydroxyl groups. In the second stage of this work, the chemical structure and thermal, thermomechanical and mechanical properties were analyzed using Fourier transform infrared spectroscopy (FTIR), differential scanning calorimetry (DSC), thermogravimetric analysis (TGA), dynamic mechanical thermal analysis (DMTA), and tensile test.

The results indicate that incorporating bio-based diisocyanates into the TPU structure enhanced their thermal stability and influenced the melting temperatures of the hard segments. Additionally, all TPU materials decomposed in two main stages and exhibited thermal stability up to approximately 260 °C. Depending on the diisocyanate mixture used, the tensile strength ranging from 15 to 24 MPa. These promising findings suggest that the synthesized TPUs may have various practical applications, such as in phone or notebook cases and watch bands.

Funding

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O3.3

Sustainable Barrier Enhancement of Paperboard Using Hemicellulose-Based Latex

Nizam P. Azeez[1]*, Andreas Schröder*[1]*, Tapani Nick*[1]*, Martti Toivakka*[1*]*, Chunlin Xu*[1*]

[1] *Laboratory of Natural Materials Technology, Faculty of Science and Engineering, Åbo Akademi University, Henriksgatan 2, 20500 Åbo-Turku, Finland*

* Chunlin.Xu@abo.fi, Martti.Toivakka@abo.fi

The packaging industry continues to depend on fossil-derived plastics, driving environmental challenges such as persistent waste and difficult recycling processes. Paperboard, as a renewable and biodegradable material, presents a promising alternative; however, its inherent hydrophilicity limits its effectiveness as a barrier to moisture, gases, and grease. Conventional plastic coatings, though effective, hinder recyclability and sustain reliance on non-renewable resources. This study investigates the development of sustainable, recyclable barrier coatings based on galactoglucomannan (GGM), a wood-derived hemicellulose. GGM was chemically modified with allyl glycidyl ether (AGE) and subsequently copolymerized with butyl acrylate (BA) at a 1:1 monomer ratio to produce surfactant-free latexes. Notably, butyl acrylate can be sourced from bio-based feedstocks, further supporting the bio-content of the system. The amphiphilic nature of modified GGM enables latex formation without commercial surfactants, replacing 50 wt% of plastics content with biomass. The resulting latexes show potential as functional barrier coatings for paperboard, offering a route toward fully bio-based, recyclable, and high-performance packaging materials aligned with circular economy principles.

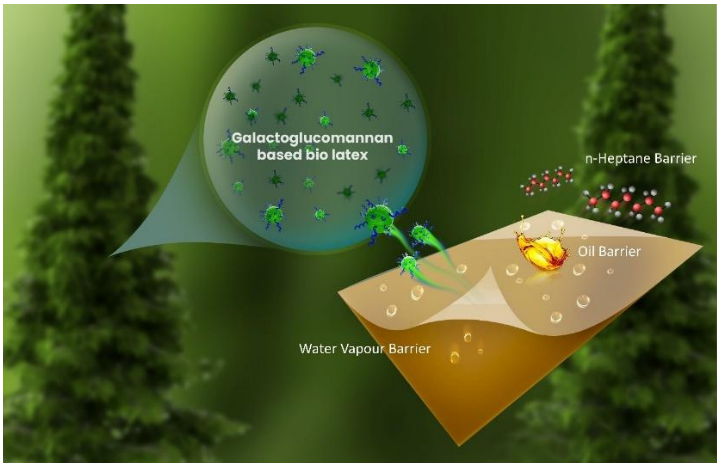

Figure 1: *Graphical abstract*

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O3.4

On the compatibility of lignin derivatives with polylactic acid

*Marie Alopaeus[1], Angelica Avella[2,3], Andrey Pranovich[3], Patrick C. Eklund[4], Giada Lo Re[2,3], Chunlin Xu[1]**

[1]Laboratory of Natural Materials Technology, Åbo Akademi University, Henrikinkatu 2, 20500, Turku, Finland,
[2]Department of Industrial and Materials Science, Chalmers University of Technology, Rännvägen 2A, 41258 Gothenburg, Sweden,
[3]Wallenberg Wood Science Center, Chalmers University of Technology, Kemigården 4, 41258 Gothenburg, Sweden
[4]Laboratory of Molecular Science and Engineering, Åbo Akademi University, Henrikinkatu 2, 20500 Turku, Finland

* chunlin.xu@abo.fi

Annually we produce over 400 million tons of petroleum-based plastics, and as most of these do not biodegrade, they accumulate in all corners of Earth as microplastics. Therefore, we need to find more sustainable alternatives. One example is the renewable thermoplastic polylactic acid (PLA), which has properties comparable to the conventional plastics polystyrene and polyethylene terephthalate [1]. Although having several advantages, PLA has a costly production, and the feedstock is competing with food resources, which limits its usage. In this work, we want to tackle this by incorporating lignin as a filler in PLA composites.

Lignin is the most abundant naturally occurring aromatic polymer and has advantageous properties for thermoplastic formulations, such as UV-resistance and antioxidant activity [[2], [3]]. When manufacturing lignin-PLA composites, the polymers' compatibility can be a limiting factor. This we want to improve by chemically modifying the lignin. More specifically, we compare how differently etherification and esterification of lignin affect the performance in PLA composites. After a thorough structural characterization on the modified lignin, the lignin-PLA composites are prepared by processing and extrusion using a micro compounder. The compatibility is assessed by microscopy of the cross-section of the extruded filaments. We further assess the important properties of thermoplastic composites such as thermal properties, tensile strength and rheology. Additionally, we determine the UV-resistance of the composites by UV spectrometry. In the end, we evaluate the sustainability of the composites by studying their industrial compostability and recyclability.

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O3.5

The impact of recycling on the durability of polymers: a case study on additively manufactured high impact polystyrene

Floriane Verceux[*], *Sotirios Grammatikos*[**]

ASEMlab – Advanced & Sustainable Engineering Materials Laboratory, Dept. of Manufacturing & Civil Engineering, NTNU- Norwegian University of Science & Technology, 2815 Gjøvik, Norway

[*] floriane.verceux@ntnu.no, [*] sotirios.grammatikos@ntnu.no

The demand for sustainable materials is rapidly growing, with the increasing industrial need in high-quality polymeric products that contain high amounts of recycled content, aiming to reduce waste while maintaining high-quality performance [1, 2]. However, the impact of recycling, on the mechanical and physico-chemical properties of a recycled-polymer-based product in time is widely unknown. As such, to increase the adoption of recycled plastics, a deeper understanding of the impact of recycling on the long-term behaviour of a recycled product is essential [3, 4]. In addition, depending on the end-use, polymers are exposed to diverse environmental factors, which may lead to different degrees of degradation [5]. Therefore, it is of particular importance to study the degradation of polymers after both recycling and service use. This study presents a comparison of the durability of virgin and mechanically recycled High Impact Polystyrene (HIPS) Additively Manufactured (AM) coupons. After production, AM coupons were subjected to freeze-thaw cyclic aging, for a total of 192 cycles between -20 and 50°C. The effects of freeze-thaw aging on the mechanical, physical and chemical performance of both the virgin and recycled HIPS coupons, were assessed by means of tensile testing, Infrared Spectroscopy (FT-IR), Dynamic Mechanical Analysis (DMA) as well as X-ray Computed Tomography scanning (CT-scan).

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O3.6

PET Bottle-to-Bottle New Recycling Challenges

Naveen Singh[1], Tomasz Czulek[1], Thor Kamfjord[1], Kjell Olav Maldum[2]

[1]Norner AS
[2]Infinitum

* Thor.Kamfjord@norner.no

This presentation comprehensively examines the complexities surrounding PET recycling and the quality of recycled PET (rPET), focusing on the impact of contaminants, CO_2 absorption, and the prevalence of 100% rPET bottles in the Norwegian recycling feedstock stream.

The study focuses on the notable hurdle encountered during the drying phase of the PET recycling process. The research shows that as more recycled PET is introduced in the bottles, it becomes increasingly susceptible to absorbing higher amounts of CO_2 from carbonated beverages.

Collaborative efforts between Norner and Infinitum have demonstrated that increased recycled content within bottles correlates with increased CO_2 absorption and a deceleration in the diffusion rate of CO_2 out of the bottles. Consequently, a foaming phenomenon emerges during drying, particularly in the finish (thread) region, precipitated by disparities in crystalline morphology between rPET and virgin PET flakes.

The presentation elucidates how this excessive CO_2 absorption profoundly impacts the efficiency of the recycling process. Moreover, particle accumulation stemming from labels, caps, and other contaminants acts as crystal nucleating agents, altering the crystallisation behaviour of PET and impeding surface (cold) crystallisation during drying, thereby affecting material properties.

Through rigorous analysis, Norner has demonstrated that increased recycled PET content corresponds to elevated crystallisation temperature and a shift in crystalline morphology, thus serving as a pivotal quality control parameter.

Importantly, it is noted that 100% rPET manifests the highest disorder in crystal morphology, implying a probable threshold lower than 100% for mechanical recycling alone. Consequently, a tailored quality control specification has been devised for Norwegian market bottles, advocating for reduced rPET content to meet stringent quality standards.

Despite persistent challenges, Norway's proactive stance in recalibrating recycled content targets underscores its unwavering commitment to sustainability by striking a delicate balance between recycled and virgin PET.

Keywords: PET, recycling, CO_2 absorption, bottle-to-bottle, thermal, nucleation, circular economy

O3.7

Stereo-complexed Polylactides as Sustainable Thermostable Capacitors

Neha Mulchandani[1], Bartosz Gackowski[2], Luciana Tavares,[2] William Greenbank[2], Thomas Ebel,[2]
*Anne Ladegaard Skov,[1]Anders Egede Daugaard [1]**
[1]The Danish Polymer Centre, Technical University of Denmark, Søltofts Plads, 2800 Kgs. Lyngby, Denmark,
[2]Centre for Industrial Electronics, University of Southern Denmark, Alsion 2, 6400 Sønderborg, Denmark,
*adt@kt.dtu.dk

Capacitors are the basic building blocks of power electronics, which are responsible for storing electrical energy by accumulating charges on two conductive plates, separated by a dielectric. Biaxially oriented polypropylene (BOPP) is a state-of-the-art dielectric material due to its high breakdown strength, low dielectric loss, and ease of manufacturing [1]. However, due to its low melting point, BOPP can tolerate a maximum of 105°C during its operation [2]. The hotspot temperatures around capacitors could be as high as 200°C under continuous operation, which raises concerns regarding the service life of capacitors.

Therefore, the current research work aims at developing sustainable and thermostable capacitors from polylactide/poly (lactic acid) (PLA), which is a well-known biobased and biodegradable aliphatic polyester. PLA has remarkable properties including high tensile strength, low dielectric loss, high dielectric strength and high thermal stability (T_m ~175°C). Further, the co-crystallization of stereoisomers PLLA (poly L-lactic acid) and PDLA (poly D-lactic acid) results in the formation of a special crystal structure stereocomplex-PLA (scPLA), which melts at ~50°C higher than homochiral (hc) PLAs [3].

In the present research, high molecular weight PLLA (>100 kDa) and PDLA (>100 kDa) are synthesized by ring-opening polymerization (ROP) of L- and D-lactides, respectively. PDLA and PLLA are further blended into 1:1 ratio to achieve scPLA blend, which has two melting points ($T_{m,hc}$ ~175°C and $T_{m,sc}$ ~220°C). Furthermore, a diblock copolymer (PDLA-b-PLLA) is synthesized by sequential ROP of D-and L-lactides, respectively, having controlled block lengths of PDLA (10 kDa) and PLLA (20 kDa). The diblock copolymer and scPLA blend are blended into PLLA in varying ratios to achieve physically crosslinked networks i.e., diblock/PLA and scPLA/PLA, respectively. The blends are spin-coated onto a conductive substrate to fabricate nano-capacitors, resulting in improved dielectric strength and energy density as compared to that of conventional PP. Furthermore, the dielectrics exhibit a self-repairing capability after breakdown and show an improved thermostability (up to 190°C).

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O4.1

Heterofunctional Cationic Polyester Dendrimers: Tunable Charge Density and Distribution for Enhanced Antibacterial Activity

Arunika Singh[1]*, Natalia Sanz del Olmo*[1,2] *and Michael Malkoch*[1*]*.*

[1]*Department of Fibre and Polymer Technology, KTH Royal Institute of Technology, 100 44 Stockholm, Sweden,*
[2]*University of Alcala, Faculty of Sciences, Department of Organic and Inorganic Chemistry, and Research Institute in Chemistry "Andrés M. Del Río" (IQAR), 28805 Madrid, Spain.*

* malkoch@kth.se

Antimicrobial resistance (AMR) presents an escalating global health threat, necessitating the development of next-generation antibacterial platforms capable of bypassing traditional resistance mechanisms[1]. Monodisperse cationic dendrimers have emerged as promising candidates due to their membrane-disruptive, non-specific mechanisms that reduce the likelihood of resistance development[2]. Among various dendritic families, polyester dendrimers are particularly attractive for biomedical applications owing to their biocompatibility and biodegradability, offering a safer alternative to cytotoxic poly(amido amine) (PAMAM) analogues[3].

While homofunctional dendrimers are often limited to only peripheral functionalization, recent advances in AB_2C-type monomer chemistry now allow precise spatial control over internal and external functionalities[4]. To expand the scope of traditional cationic constructs, heterofunctional cationic polyester dendrimers based on an AB_2C building block, featuring either exclusively internal cationic charges or a combination of internal and peripheral charges were synthesized. Robust chemistries such as copper click chemistry and fluoride-promoted esterification (FPE) or anhydride-mediated esterification were employed for the incorporation of protonated amino-functional moieties. These cationic dendrimers exhibit high structural precision and tunable charge densities. Preliminary biological assessments indicate the potential of these systems to enhance antibacterial activity and bacterial sensitivity while maintaining biocompatibility. Furthermore, their hydrolytic degradability indicates their suitability as degradable antimicrobial alternatives. Overall, this presented work details a versatile platform for advancing dendrimer-based therapeutics aimed at mitigating AMR.

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O4.2

DNA Condensation Mediated by PAMAM-peptide Conjugates: Role of pH and Amino Acid pKa

Corinna Dannert[1], Pablo M. Blanco[1], Sebastian P. Pineda[2], Peter Košovan[2], Rita S. Dias[1]*

[1]Biophysics and Medical Technology, Department of Physics, NTNU – Norwegian University of Science and Technology, Trondheim N-7491 Norway,
[2]Department of Physical and Macromolecular Chemistry, Faculty of Science, Charles University, Hlavova 8, 128 40 Prague 2, Czech Republic.

* corinna.dannert@ntnu.no

Non-viral nucleic acid delivery to cells has become increasingly important in modern medicine, and poly(amidoamine) (PAMAM) dendrimers and peptide-conjugated PAMAM are promising delivery vector candidates [1]. During transfection, PAMAM-DNA complexes, or dendriplexes, are introduced into the cell via endocytosis. As endosomes mature, the pH inside drops from approximately 7.4 to 4.7 in the late lysosomes, affecting the ionization of the dendriplexes, which in return plays a crucial role in escaping the endosomes.

We investigated the effect of amino acid pKa of peptide tails on the DNA condensation mediated by PAMAM-peptide conjugates by combining molecular simulations with experiments. By varying the pH in the range of endosomal maturation, we saw how differences in peptide composition led to significant changes in condensation behavior. Incorporating histidine residues in the peptide tails lead to a stronger pH dependency of the DNA condensation, compared to tails with lysine residues, suggesting a stronger effect of endosome maturation on the dendriplex behavior.

This can be used to fine tune the DNA condensation by PAMAM-peptide conjugates and to achieve efficient endosomal escape, a basis needed for successful non-viral nucleic acid delivery.

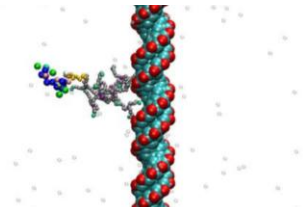

Figure 1: Snapshot of molecular simulations of PAMAM-peptide conjugates and DNA.

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O4.3

Molecular tale of MedTech polymers narrated by SEC/GPC with a multi detection approach

Libor Kostka[1], *David Gillespie*[2], *Subin Damodaran*[2*]

[1]*Institute of Macromolecular Chemistry CAS, Department of Biomedical Polymers, Prague, Czech Republic*
[2]*Tosoh Bioscience GmbH, Griesheim, Germany.*

* subin.damodaran@tosoh.com

Homopolymers or copolymers based on N-(2-hydroxypropyl) methacrylamide (HPMA) are widely being studied to apply them as drug carriers for tumour-targeted therapies due to the possibility of introducing various functional groups directly into the polymer backbone through the copolymerization of HPMA with suitable comonomers as well as their biocompatibility and non-immunogenic properties. Reversible addition−fragmentation chain transfer (RAFT) polymerization technique was employed for successful HPMA polymerization and copolymerization with 2-(6-methacrylamido-hexanoyl)hydrazine to provide optimized monomer conversion, product dispersity, and molecular weight. The drug, Ritonavir, is attached to the hydrazone bond in the copolymer. High molecular weight star-like polymer drug carrier systems to provide higher accumulation in tumor tissue were synthesized by grafting HPMA copolymers on a 2,2-bis(hydroxymethyl)propionic acid- (bis-MPA-) based polyester dendritic core.

The effectiveness of polymeric drug conjugates is determined based on the chemical composition of the polymer or copolymer and also by their supramolecular arrangement in the solution. In order to eliminate the carriers from the body, the molecular weight and hydrodynamic radius (Rh) should be below the renal threshold or alternatively the Rh of the degradation products are within the renal threshold. Size exclusion chromatography coupled with advanced detectors such as light scattering and viscometer is applied here to characterize the molecular weight, size and structure of HPMA copolymers. HPMA copolymer and the copolymer with the drug has a molecular weight between 50-60 kg/mol and the size is below 7 nm. Due to the extensive branching in the star-shaped HPMA polymer, the molecular weight obtained was 360 kg/mol but with a size of 10 nm which can keep the drug conjugate for a longer time in the blood stream and increase the accumulation of the drug in the tumour tissues.

O4.4

Design of injectable nanocomposite hydrogels for controlled release of nanoparticles

Wilhelm R. Glomm[1], Erlend Sørlie[2], Sabina P. Strand[1], Le T. Truong[1], Andreas K.O. Åslund[1]*.*

[1] Department of Biotechnology and Nanomedicine, SINTEF Industry, Sem Sælands Vei 2a, N-7034 Trondheim, Norway
[2] Department of Chemical Engineering, Norwegian University of Science and Technology, Sem Sælands vei 4, N-7034 Trondheim, Norway

* andreas.aaslund@sintef.no wilhelm.glomm@sintef.no

Nanocomposite hydrogels, *i.e.;* a combination of hydrogels and nanoparticles, have emerged as a promising platform for drug delivery owing to the high degree of design flexibility [1]. Despite the wealth of literature on nanocomposite hydrogels, there is scant experimental data on the release of drug-loaded nanoparticles from hydrogels. Here, we report on the incorporation and subsequent release of dye-loaded nanoparticles from alginate-based hydrogels. We investigated the rheological properties of alginate and alginate-poly(ethylene oxide) hydrogels as a function of nanoparticle loading, as well as the time-dependent nanoparticle release profiles. The effects of hydrogel compositional parameters and nanoparticle loading on viscosity and release profiles were investigated using principal component analysis (PCA) and partial least squares regression (PLSR), respectively. Additionally, the release profiles were fit using Zero and First-order release as well as the Higuchi, Hixson-Crowell and Korsmeyer-Peppas kinetic models for drug release [2]. We found that the effect of nanoparticle concentration on gel viscosity is strongly dependent on the alginate concentration, with nanoparticles contributing to the gel structure at higher polymer concentrations. Release of nanoparticles from the hydrogels was well fit by a modified first-order kinetic model, comprising a significant burst followed by a concentration-dependent release of nanoparticles. Collectively, our findings provide insight into how hydrogels can be used as reservoirs for controlled delivery of nanoparticles.

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O4.5

Polymer Encapsulation of Iron Oxide Nanoparticles for the Controlled Release of Vancomycin

Mahnoor Khan[1,2], Sulalit Bandyopadhyay[2], Muhammad Asghar[1]
[1]Atta-ur-Rahman School of Biosciences National University of Science and Technology, Pakistan
[2] Department of Chemical Engineering, Norwegian University of Science and Technology, NTNU

* sulalit.bandyopadhyay@ntnu.no

Flash nanoprecipitation (FNP) offers a rapid, scalable, and tunable approach to engineer polymeric nanoparticles with controlled size and high encapsulation efficiency, critical for drug delivery systems.[1, 2] The surface chemistry of nanoparticles plays a pivotal role in determining their encapsulation behaviour within polyelectrolyte-based carriers.[3] In this study, we investigate the synthesis of chitosan nanoparticles (CNPs) in a multi-inlet vortex mixer (MIVM) for the co-encapsulation of iron oxide nanoparticles (IONPs) with varied surface functionalities, bare (–OH), APTES-coated ($-NH_2$), oleic acid-coated, and carboxyl-functionalized (–COOH)—alongside the antibiotic vancomycin. Among these, COOH-functionalized IONPs exhibited the highest encapsulation efficiency and enabled co-loading of vancomycin and COOH-IONPs into stable, magnetically responsive nanoparticles. Under an alternating magnetic field using a *Magnetherm* system, localized heating facilitated vancomycin release. Drug release kinetics conformed to the Korsmeyer–Peppas model[4] with a release exponent $n>1$, indicating super case II transport driven by polymer relaxation and swelling. These findings highlight the synergistic role of nanoparticle surface chemistry and mixing dynamics in engineering multifunctional chitosan-based nanocarriers for magnetically triggered drug delivery.

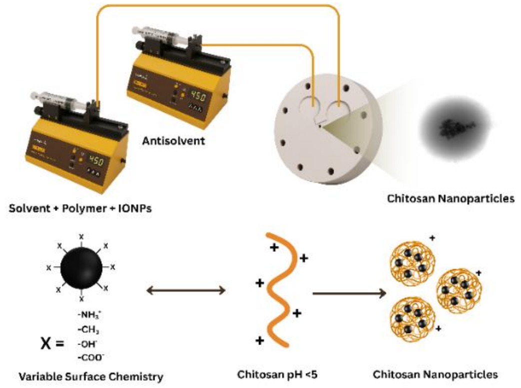

Figure 1: Graphical representation of Flash Nanoprecipitation process for the synthesis of iron oxide loaded chitosan nanoparticles.

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O4.6

Insights into Flash Nanoprecipitation and Stability of Magnetic Nanocomposites

Nesrine Bali[1], *Sulalit Bandyopadhyay*[1]*
[1]*Particle Engineering Centre, Norwegian University of Science (NTNU), Trondheim, Norway*

* sulalit.bandyopadhyay@ntnu.no

Poly(lactic-co-glycolic acid) (PLGA) nanoparticles (NPs) are extensively studied as drug carriers due to their biocompatibility, yet their slow degradation profiles can limit their efficacy in treating acute diseases. To overcome this, iron oxide nanoparticles (IONPs) can be incorporated to exploit their magnetic properties by triggering controlled drug release upon exposure to an alternating magnetic field. However, previous methods involving hydrophobic IONPs restrict the size and magnetic strength of IONPs that can be encapsulated in hydrophobic polymers via flash nanoprecipitation (FNP).[1] This study presents a straight-forward and surfactant-free method for producing stable PLGA-IONP nanocomposites based on a ternary composition diagram to provide a more streamlined and reproducible approach for the design of magneto-responsive nanocarriers. The effects of polymer concentration, flow rates, mixing conditions, and solvent types on the formation of PLGA NPs and PLGA-IONP composites were investigated. The findings demonstrate that fast mixing in FNP influences NP nucleation and growth systematically, preventing the formation of submicron aggregates. By constructing a ternary composition diagram, the Ouzo region where monodisperse PLGA NPs form spontaneously was identified. Complete encapsulation of IONCs was achieved only beyond the Ouzo domain at fast mixing conditions, yielding stable PLGA-IONPs approximately 300 nm in size. Hence, the long-term stability and magnetic properties of PLGA-IONPs, combined with their potential for functionalization, make them highly suitable for advancing personalized nanomedicine and theragnostic applications.

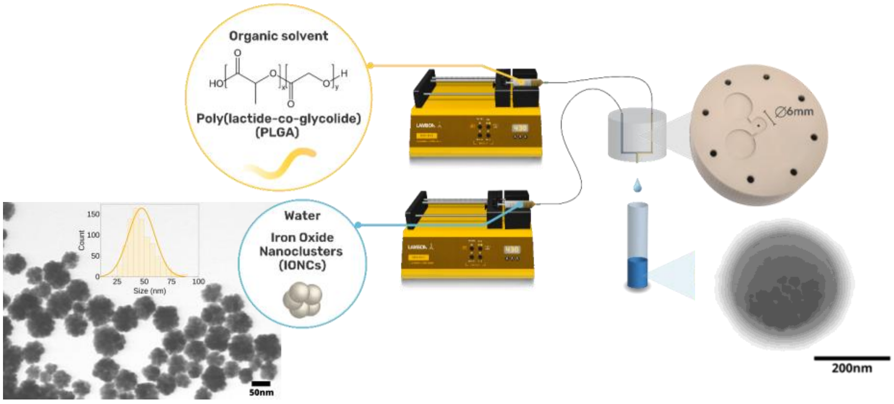

Figure 1: Flash Nanoprecipitation of PLGA-IONPs under fast mixing conditions.

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O4.7

Photo-Curable Triazinetrione Composites with Tunable Degradation for Fracture Stabilization and Flexible Thin-Film Applications

*Jorge San Jacinto Garcia[1], Natalia Sanz del Olmo[1], Daniel J. Hutchinson[1], Michael Malkoch[1] *[1]*
Department of Fibre and Polymer Technology, School of Chemical Science and Engineering, Fibre and Polymer Technology, KTH Royal Institute of Technology, Stockholm, Sweden.

* malkoch@kth.se

Open Reduction and Internal Fixation (ORIF) has long been the gold standard for fracture management, utilizing metal plates and screws to stabilize bone fragments. However, ORIF presents several drawbacks, including stress shielding, implant-related complications, and the need for secondary surgeries due to hardware removal or failure. In search of superior alternatives, advancements in polymer chemistry have yielded innovative thiol-ene-based composites that exhibit high stiffness and strength, making them promising candidates for fracture fixation.[1, 2]

Thiol-ene polymer networks offer distinct advantages over conventional metallic implants, such as tunable mechanical properties, rapid polymerization, and reduced inflammatory response.[3] By leveraging the precise control over crosslinking density, these materials can be engineered to match the mechanical demands of various fracture sites while maintaining biocompatibility.[4] Furthermore, the introduction of filler reinforcements has significantly enhanced the toughness and load-bearing capacity of these composites, bridging the performance gap between traditional polymers and metallic implants.[2]

In this work, we present the development of hybrid composites capable of degrading through different pathways by combining two strategies: the introduction of monomers with hydrolysable linkages and the reinforcement of the organic polymeric matrix with bioresorbable fillers. An exhaustive optimization of the degradable monomer molar ratio and the weight percentage of resorbable filler has been sought. The most promising formulations were evaluated as fracture fixators in conjunction with screws on porcine and ovine bones with transverse fractures. The load resistance and stability of the resulting osteosyntheses were assessed, positioning these hybrid composites as degradable and biocompatible alternatives to metal plates for bone fracture fixation.

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O5.1

Layer-by-Layer Fabrication of Polymer Film Capacitors for The Green Transition

Bartosz Gackowski[1], Neha Mulchandani[2], Thomas Ebel[1],
Anne Ladegaard Skov[2], Anders Egede Daugaard[2], William Greenbank[1]*
[1]Centre for Industrial Electronics, University of Southern Denmark, Alsion 2,, Denmark
[2]The Danish Polymer Centre, Technical University of Denmark, Søltofts Plads, 2800 Kgs. Lyngby, Denmark

* greenbank@sdu.dk

The large-scale integration of renewable energy sources such as solar and wind requires significant improvements in energy storage and power electronics components [1]. Unlike traditional fossil-fuel-based power generation, renewable energy sources are inherently intermittent, requiring efficient storage and power conditioning solutions to ensure grid stability and reliability [2]. Capacitor devices play a crucial role in regulating power flow, improving energy efficiency, and supporting load balancing in smart grids and electric vehicle applications [3].

Film capacitors consist of two electrodes separated by a dielectric material. When a voltage is applied across the electrodes, an electric field is created, storing energy electrostatically. This stored charge can then be discharged when needed, making capacitors essential for energy buffering, filtering, and power conditioning [4]. Polypropylene is one of the most widely used polymers as a dielectric due to its high dielectric performance, low losses, and long operational lifetimes, making it an essential component in power converters and pulse power applications [5]. However, conventional capacitor manufacturing processes often involve energy-intensive methods, and polypropylene itself has a relatively low dielectric constant, which decreases the overall energy density of the capacitor devices.

The layer-by-layer (LbL) assembly technique presents a novel approach to fabricating polymer film capacitors. In this method, the dielectric material is formed from the bottom-up using polymer inks, which are added layer-by-layer [6]. This technique can create thin films with precise control over thickness, composition, and structure, potentially reducing environmental impact due to lower energy consumption. This work shows that LbL can be used to incorporate nanocomposite layers within the polypropylene dielectric, substantially improving dielectric constants, breakdown strength, and energy density. Blending polypropylene with polyethylene can significantly enhance the thermal stability of the devices up to 150°C. Moreover, devices that underwent electrical breakdown exhibited a self-repairing capability after annealing at 160°C.

Overall, the layer-by-layer fabrication method offers a promising approach towards developing high-performance capacitors with enhanced energy density, thermal stability, and self-repairing capabilities, contributing to more efficient and sustainable energy storage solutions.

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O5.2

Abundant Carbon-based Nanoparticles – A Novel Approach for Polyolefin Nanocomposites in High Voltage Transmission

Anton Bjurström[1,2,3], *Fritjof Nilsson*[1,4], *Mikael Unge*[1,2,3] *& Richard T. Olsson*[1,3,*]

[1]*Department of Fibre and Polymer Technology, Polymeric Materials Division, School of Engineering Sciences in Chemistry, Biotechnology and Health, KTH Royal Institute of Technology, Stockholm, SE-100 44, Sweden.*
[2]*NKT HV Cables, Technology Consulting, Västerås, SE-721 78 Sweden.*
[3]*Wallenberg Initiative Materials Science for Sustainability, Department of Fibre and Polymer Technology, KTH Royal Institute of Technology, Stockholm, SE-100 44 Sweden*
[4]*FSCN Research Centre, Mid Sweden University, Sundsvall, SE-851 70 Sweden*

* rols@kth.se

The transition to cleaner energy sources demands efficient and reliable power transmission. High-voltage direct current (HVDC) systems offer the most efficient solution for long-distance transmission, especially in subsea applications. HVDC is commonly used to connect offshore wind farms and to enable transcontinental power transmission. Polymeric cable insulation plays a critical role in this, by shielding the electric and magnetic fields. Polyolefins, particularly polyethylene-based, are widely used as insulation due to their favorable electrical properties and processability [1]. However, as the industry aims for even higher voltages for further efficiency increase, new material development is necessary to meet the increasing demands of the future grid. Incorporation of certain nanoparticles has proven a decrease in the conductivity of polyolefin insulation nanocomposites [2]. Challenges remain, however, regarding cost and scalability. This work explores the incorporation of novel spheroidal and 2D carbon nanoparticles (CNP) into polyolefin matrices to tailor their dielectric properties. CNPs are interesting candidates due to their inherent compatibility with polyolefins, low cost, abundant nature, and novel anisotropic 2D interfaces [3]. The focus is on understanding the influence of nanostructure, dispersion, and interfacial properties on insulation behavior. Results show that a significant decrease in conductivity is achieved at very low loading amounts (0.001 wt.%). This positions CNP/Polyolefin nanocomposites as a promising candidate for insulation material in the future HVDC grid.

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O5.3

Impedance spectroscopy for characterizing the ion dynamics in polymer light-emitting electrochemical cells (LECs)

Anton Kirch[1], Joan Ràfols Ribé[1], Christian Larsen[1], Ludvig Edman[1]*

[1]The Organic Photonics and Electronics Group, Department of Physics, Umeå University, SE-90187 Umeå, Sweden

* anton.kirch@umu.se

The evolution of efficient light-emission concepts based on organic semiconductors has been a major research focus in recent decades. While the performance of organic LEDs (OLEDs) is outstanding, their fabrication requires energy-intensive vacuum processing.[1] The light-emitting electrochemical cell (LEC) is a promising candidate for implementing recyclable and low-cost illumination devices, as it can be processed from solution using biocompatible materials.

LECs are much simpler to fabricate than OLEDs. They consist of merely two electrodes that sandwich one active electrochemical layer. This layer consists of mobile ions and an organic semiconducting, emissive polymer. Under an applied voltage, these mobile ions redistribute, producing a self-organized structure of electric double layers (EDLs), electrochemically doped transport layers, and an emission zone.[2]

In this paper, we discuss how electrochemical impedance spectroscopy (EIS) can help us understand the dynamic doping structure in LECs. We show how the capacitance of the EDLs can be determined, a crucial ingredient to understand the efficient charge-carrier injection into the polymer. Further, EIS discloses the timescale at which electrochemical doping takes place. This understanding is important for mitigating exciton loss channels and developing more efficient devices.

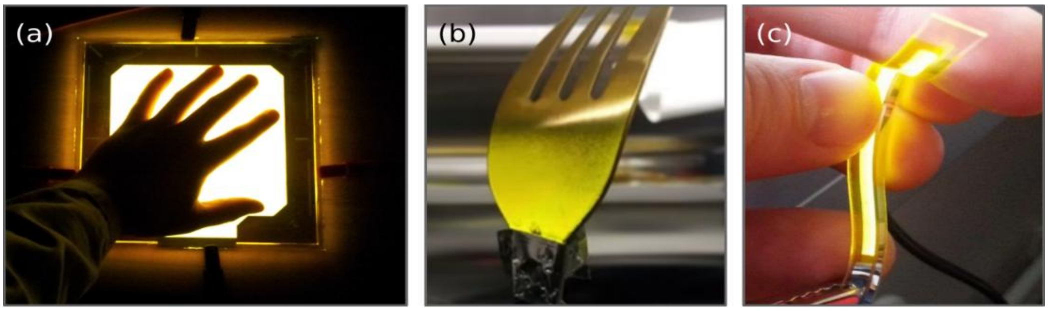

Figure 1. LECs can be fabricated from solution as (a) lighting tiles, (b) on various substrates, and (c) in arbitrary, flexible shapes.

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O5.4

Polymer materials for use in contact with coolants for battery and fuel cell electric vehicles

Erik Andreassen[1]*, *Rune H. Gaarder*[1], *Panagiotis Savva*[2]

[1]*SINTEF Industry, Polymer and Composite Materials group, Oslo, Norway*
[2]*Kongsberg Automotive, Raufoss, Norway*

* erik.andreassen@sintef.no

The motivation for this study was to assess how different polymer materials perform in contact with glycol-based coolants for electrical vehicles (EVs), in order to select the best materials for use in couplings, valves, pipes etc for use in thermal management (TM) systems for both battery EVs and hydrogen fuel cell EVs.

The role of the TM system is to ensure that the Li-ion battery, as well as the power electronics and powertrain, have the right temperature during charging and driving. For fuel cells, the TM system material requirements are even more challenging than for Li-ion batteries. In particular, the electrical conductivity of the coolant must be very low. Hence, migration of ions (or ion forming compounds) from the polymer material into the coolant must be very low. In addition, the polymer must of course be chemically resistant to the coolant.

About 15 polymer materials were studied, mainly glass-fibre-reinforced poly(phenylene sulphide) (PPS) grades, but also grades of polypropylene, syndiotactic polystyrene and polyphthalamide. Injection moulded polymer specimens (tensile specimens, type 1BA of ISO 527) were immersed in a coolant developed for fuel cells (consisting of ethylene glycol, water and additives), and also in de-ionised water. Borosilicate containers were used. The ratio of polymer specimen surface area to liquid volume was 90 mm^2/ml. The temperature was 90 °C in most tests, and the electrical conductivity of the immersion liquid was measured during and after the test (2000 h). After the test, the liquids were analysed to identify and quantify compounds that had migrated from the polymers, as well as coolant additives and glycol degradation products. The polymer specimens were also subjected to tensile testing before and after immersion.

For tests with the coolant at 90 °C, the electrical conductivity increased as function of time for all polymer materials; typically, by a factor 10-15 over the 2000 h test. The main driving factor for the conductivity increase seems to be glycol degradation. (A methodology was developed for blanketing the containers with N_2 after each measurement.) Still, some material types and grades performed better than others, regarding giving a lower increase in the conductivity. Among PPS grades, the differences could be due to polymerisation method and glass fibre sizing. For two PPS grades immersed at 60 °C, the electrical conductivity increased by less than a factor 2 during the 2000 h exposure. Regarding tensile properties, several materials maintained more than 95% of the strength after 2000 h immersion. In general, materials with good retention of tensile properties also gave a low increase in conductivity.

Compared to immersion in the glycol-based coolant, immersion in de-ionised water (at 90 °C) showed a larger increase in conductivity and a larger reduction in tensile properties. Chemical analyses of the water after exposure showed ions that probably originated from the polymer materials.

O5.5

Carbon fiber as electrodes: A Scalable Solution for Nickel Recovery from Industrial Wastewater

Annu Pandey[1], *Kåre Tjus*[2], *Anders Björk*[2] *and Richard T Olsson*[1]

[1.] *KTH – Royal Institute of Technology, Fibre and Polymer Technology – Polymeric Materials, School of Chemical Science and Engineering, Teknikringen 56-58, 100 44 Stockholm, Sweden*
[2]*IVL Swedish Environmental Research Institute, Stockholm, Sweden*

* annua@kth.se

This study presents a promising solution for industrial wastewater treatment, combining environmental sustainability with economic viability. This innovative method promotes circular resource utilization and efficient nickel recovery by addressing growing regulatory demands for heavy metal discharge limits [1]. The process utilizes cost-effective carbon fiber electrodes, which overcome the limitations of traditional materials by reducing costs, supporting scalability, and enabling continuous operation. Fourier Transform Infrared Spectroscopy (FTIR) and X-ray Diffraction (XRD) confirmed surface modifications that enhance nickel ion adsorption and reduction while Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray (EDX) analyses revealed uniform nickel coatings. Optimized conditions, 60°C, pH 3.5, and a deposition potential of 4V, achieved 90% nickel recovery efficiency with low energy consumption (3 kWh per kilogram). Carbon fibers provide an ideal platform for electrochemical recovery with their high surface area, conductivity, and mechanical durability [2]. This study highlights a scalable, cost-effective approach for recycling valuable metals from industrial effluents.

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O6.1

Nanoscale friction simulations of polymer surfaces

Robin Vacher[1,2], *Astrid S. de Wijn*[1]*.

[1]*Norwegian University of Science and Technology,*
[2]*SINTEF.*

* astrid.dewijn@ntnu.no

Nanoscale structure and mechanisms of viscoelastic deformation and plasticity in polymers are complex, and have significant impact on their mechanical properties in the bulk, but also on surfaces. We use molecular-dynamics simulations to study the relation between viscoelasticity, plasticity, and surface mechanical properties and tribology of a semi-crystalline polymer, polyvinyl alcohol (PVA).

We subject our PVA surface to a simulated Atomic Force Microscope tip. We investigate the plastic and elastic deformation during sliding, and how they relate to the structure and temperature. Directly under the tip, the polymer has a tendency to co-axially align and form a layered structure. Over time, the plastic deformation on and near the surface builds up, the friction decreases, and the polymers in the top layer align with each other in the sliding direction (conditioning). We protect our polymer from this wear using a graphene sheet. By using an unstrained, flat sheet, and one that has been crumpled before being deposited on the polymer we are able to distinguish between different types of mechanical effects.

We also study the nanoscale mechanisms of formation of surface roughness in polymers. We subjecting a big block of simulated polymer to compression and characterise its surface roughness properties. In metals, the appearance of multi-scale roughness has been linked to avalanches and plastic deformation. Polymers, however, have quite different mechanisms of plasticity. We discuss the significant differences between polymers and metals, and relate them to the viscoelasticity of the polymer.

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O6.2

Self-etching adhesives for enhanced fixation of bone fractures

Amene Tesfaye Ayane, Michael Malkoch*

Department of Fibre and Polymer Technology, School of Chemical Science and Engineering, Fibre and Polymer Technology, KTH Royal Institute of Technology, Stockholm, Sweden.

ayane@kth.se * E-mail: malkoch@kth.se

Complex and unstable bone fractures often necessitate surgical intervention involving open reduction internal fixation (ORIF) with metal plates and screws. While ORIF provides high mechanical stability, its rigid geometry limits surgical customization, and the requirement for screw fixation involves drilling into compromised bone, potentially leading to complications such as soft tissue adhesions, joint stiffness, and disability. To address these limitations, our team has developed an injectable composite that conforms to patient-specific bone geometry and loading requirements, curing *in situ* within seconds via benign and efficient thiol-ene coupling (TEC) click chemistry activated by high-energy visible (HEV) light. This composite offers the flexibility of being mechanically screwed [1] or adhesively bonded to the bone surface [2], thereby reducing surgical invasiveness.

Focusing on the adhesive bonding approach, this study introduces a new adhesive primer designed to eliminate the need for mechanical drilling. Building upon our phosphonic acid-based adhesive[2], we have engineered a primer with an optimized hydrophilic-lipophilic balance to enhance interfacial integration between bone tissue and composite fixation materials. This amphiphilic architecture facilitates superior wetting and anchoring to the heterogeneous bone surface, promoting both mechanical interlock and chemical adhesion. In this work, will present findings on the shear bond strength and fracture fixation potential of this primer utilizing the filler-reinforced adhesive patch (FRAP) technique across various fracture models. Developing an adhesive that effectively adheres to bone while maintaining the biocompatibility required for implanted materials is of paramount importance.

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O6.3

Adsorption of star polystyrenes

M. G. Kirevliyasi Pekkucuk[1]*, U. Unal*[2]*, and B. Akgun*[1,3*]

[1]*Department of Chemistry, Faculty of Arts and Sciences, Bogazici University, Bebek 34342, Istanbul, Turkey,*
[2]*Koç University Surface Science and Technology Center (KUYTAM), Sariyer 34450, Istanbul, Turkey,*
[3]*PhysChem Cell, Syensqo, Bristol, Pennsylvania 19007, United States*

*mgizem.kirevliyasi@gmail.com

Physical properties of thin polymer films ($h_{film}<4R_g$), such as glass transition temperature and diffusivity, deviate significantly from bulk, due to the presence of adsorbed chains [1, 2]. Adsorption of polymer chains proceeds through enthalpic gain due to the pinning of the polymer segments on the substrate and conformational entropy loss due to restricted chain mobility. Equilibrium adsorbed layer structure of linear polystyrene (PS) was found to be composed of two layers: a high-density inner layer with flattened segments, and a bulk-like outer layer with tail and loop segments [3]. Although there are numerous studies on the impact of enthalpy, the role of entropy that can be tuned using chain branching on the adsorbed layer structure is not clear.

Structural evolution of star and linear PS adsorbed layers as a function of annealing time (t_{ann}), annealing temperature (T_{ann}), functionality (f= 2, 4, 8), molecular weight (M_n=72-1137 kg/mol), arm-molecular weight ($M_{n,arm}$), and segment-surface interaction energy were elucidated using ellipsometry, X-ray reflectivity, and Atomic Force Microscopy. At $T_{ann}\approx T_g+50$ K, the adsorption mechanism for both topologies is based on the partial desorption of trains to create longer loops and tails to increase polymer-polymer interaction over polymer-substrate interaction, thus decreasing the entropic penalty, on SiO_x. On SiH, the equilibrium adsorbed layer structure highly depends on $M_{n,arm}$, and f. h_{film} affected the equilibrium adsorbed layer thickness due s conformations. Adsorption proceeds even at room temperature, at which PS chains are in the glassy state. Adsorbed layers of 8-arm star PS with different cores revealed that the increasing interaction energy between the core and the substrate can alter the adsorption mechanism.

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O6.4

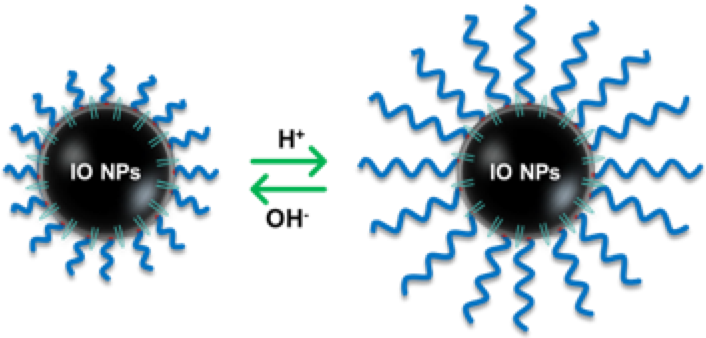
Optimizing pH-Responsive PDEAEMA Grafting on Iron Oxide Nanoparticles via Tailored SI-ATRP

*Vyshnav Punnath Sivasankaran[1], Jan Genzer[2], Sulalit Bandyopadhyay[1]**

[1] *Department of Chemical Engineering, Norwegian University of Science and Technology, Norway*
[2] *Department of Chemical and Biomolecular Engineering, NC State University, USA*

* sulalit.bandyopadhyay@ntnu.no

Stimuli-responsive polymer-nanoparticle hybrids are increasingly explored for their potential in smart materials and biomedical applications due to their tunable physicochemical properties. Surface-initiated atom transfer radical polymerization (SI-ATRP) was optimized by tailoring parameters to graft pH-responsive poly(2-(diethylamino)ethyl methacrylate) (PDEAEMA) onto hydrophobic and hydrophilic iron oxide nanoparticles (NPs) [1]. Hydrophobic NPs were synthesized via thermal decomposition of iron oleate, while hydrophilic NPs were prepared using iron acetylacetonate with tetraethylene glycol (TREG). By tuning parameters—such as initiator density, monomer concentration, and reaction time—precise control over PDEAEMA grafting density and chain length was achieved, enabling tailored pH-responsive behavior. Dynamic light scattering (DLS) confirmed pH-dependent conformational changes in the PDEAEMA chains, with chain extension observed in acidic environments due to protonation of the tertiary amine groups. Comparative analysis of SI-ATRP on different NPs revealed parameter-driven differences in polymer grafting efficiency and responsiveness. These PDEAEMA-NP hybrids demonstrate potential for applications requiring pH-sensitive materials, such as stimuli-responsive systems in drug delivery contexts, with further studies needed to explore their functional performance.



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O6.5

Stabilization Mechanisms of Amphiphilic Hemicellulose Derivatives in Suberin Dispersions

<u>Minette Kvikant</u>[1], Martti Toivakka[1], Chunlin Xu[1].*

[1]*Laboratory of Natural Materials Technology, Åbo Akademi University, Finland*

* cxu@abo.fi

Addressing environmental concerns of fossil resources demands more sustainable, high-performance packaging materials. We aim to formulate a bio-based aqueous dispersion coating stabilized with a bio-based surfactant, unlocking the potential of underutilized forest industry resources, and exploring value-added applications in packaging and coatings.

Our approach utilizes hot water extract hemicelluloses and suberin biopolymers, typically disregarded as side streams in most forest product processes. Specifically, the study uses suberin, extracted from birch bark, which naturally possesses hydrophobic properties to enhance barrier performance in fiber-based packaging.[1] However, suberin's hydrophobic nature complicates aqueous dispersion preparation. To address this, we developed hemicellulose-based surfactants to disperse suberin.[2]

Our goal was to understand the stabilization mechanisms of suberin dispersions using galactoglucomannans (GGM), the main hemicellulose type in most softwood species. GGM was functionalized via esterification, grafting naturally occurring fatty acids onto the GGM chain to create a tunable amphiphilic derivative. The GGM derivative was tested under varying pH and temperatures to prove stability mechanisms under different conditions. Additionally, suberin dispersions prepared at room temperature and in the melted state were compared, with turbidity and rheological properties evaluated. The results demonstrate the potential of bio-based surfactants as green dispersants for stabilizing aqueous dispersions.

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O7.1

PEF/rPET-starch hydrogels from recycled sources for wastewater treatment

E. Bonora[1], P. Kongseng[2], S. Cerqua[1], C. Perego[3], P. Principi[3], S. Chantarak[2], C. Brändli[1].*

[1]Zurich University of Applied Sciences (ZHAW), Winterthur, Switzerland,
[2]Prince of Songkla University (PSU), Hat Yai, Thailand,
[3]University of Applied Sciences and Arts of Southern Switzerland (SUPSI), Locarno, Switzerland.

*christof.braendli@zhaw.ch

The increasing presence of organic pollutants such as dyes, emerging contaminants (ECs), and antibiotics in water poses a global environmental threat. This study explores the development of sustainable hydrogels from recycled poly(ethylene terephthalate) (rPET) and bio-based poly(ethylene furanoate) (PEF) for wastewater remediation. rPET and PEF were depolymerized using diamines and crosslinked with materials like starch and polyvinyl alcohol (PVA) to form hydrophilic 3D networks with high water uptake.[1] By varying the PEF:starch:PVA ratios, materials with tailored properties were obtained. Dyes were selected as model pollutants to evaluate adsorption performance, serving as a benchmark for other organic contaminants such as antibiotics. Both rPET- and PEF-based hydrogels demonstrated strong affinity for cationic and anionic dyes, as shown in Figure 1, confirming their suitability for broad-spectrum pollutant removal. Notably, PEF-based hydrogels support microbial growth, potentially enhancing adsorption through bioaugmentation. This synergy between physical adsorption and microbial activity could improve removal efficiency for ECs.[2] The hydrogels' adsorption and mechanical properties can be tuned through chemical modification. Importantly, they retained structural integrity after multiple adsorption-desorption cycles, confirming their reusability. Characterization techniques included NMR, GPC, DSC, UV-Vis spectroscopy, and swelling ratio measurements. The combination of high adsorption efficiency, reusability, and compatibility with microbial activity highlights the promise of these hydrogels for wastewater treatment. Furthermore, this work supports PET waste upcycling and bio-based polymer use, aligning with circular economy principles while addressing urgent environmental challenges.

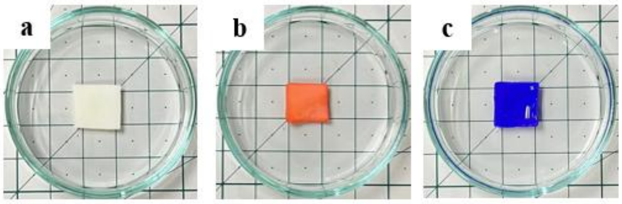

Figure 1: rPET:starch:PVA hydrogels: a) Water absorption; c) Methyl orange adsorption; c) Methylene blue adsorption.

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O7.2

Innovative Membrane Technologies for the Removal of Micro- and Nanoplastics from Wastewater

M.T. Guzman-Gutierrez, H. Johnsen, S.P. Strand, W.R. Glomm*
Department of Biotechnology and Nanomedicine, SINTEF Industry, Trondheim, Norway
**maria.teresa.gutierrez@sintef.no.*

Micro- and nanoplastics are increasingly recognized as an emerging threat to aquatic environments. Their tiny size and chemical resilience make them especially difficult to remove with conventional water treatment technologies[1-3]. The MemNoPlast project investigated the use of polymer-based membrane technologies to combat emerging pollutants, aiming to improve water quality and support a more sustainable future.

First, we developed novel surface modifications for commonly used polymer membranes, specifically polyethersulfone (PES) and polyvinylidene fluoride (PVDF). These modifications were designed to enhance particle separation, reduce fouling, and improve durability. Next, we established robust testing protocols to evaluate how well these membranes perform when exposed to micro- and nanoplastic contaminants in model dispersions and synthetic wastewater. Finally, the project entered an optimization phase, where membrane parameters such as flow rate, separation efficiency, and fouling resistance were fine-tuned to maximize performance.

The modified membranes demonstrated near-complete removal of micro- and nanoplastic particles, with separation efficiencies reaching 100% under controlled conditions. Beyond removal performance, we observed reduced biofouling, improved structural stability, and high recovery of water flux—up to 280 L/m^2h post-operation highlighting the membranes' potential for real-world implementation, compared to the unmodified membrane. These findings not only confirm the viability of polymer membrane technologies for advanced water treatment but also underline their role in mitigating plastic pollution at the wastewater level, before it reaches sensitive ecosystems.

Acknowledgment: This research was supported by the Research Council of Norway through the strategic institute project MemNoPlast, funded under SINTEF Industry's basic grant.

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O7.3

Removal of Nano- and Microplastics from Cooling Water in the Energy Sector Using Biodegradable Flocculants

S. P. Strand, M. Sandru, H. Johnsen, W.R. Glomm, E.M. Sandru, , M.T. Guzman Gutierrez
SINTEF AS, Department of Biotechnology and Nanomedicine,Trondheim, Norway
*sabina.strand@sintef.no

Plastic pollution, particularly in the form of micro- and nanoplastics, has emerged as one of the most pressing environmental issues of our time. Estimates indicate that each year, between 80,000 and 219,000 tonnes of microplastics are released into European waters[1]. These micro- and nanoplastics are difficult to capture or degrade due to their small size, chemical inertness, and high environmental mobility and vast distribution creating significant barriers to their efficient removal. Once they're in the aquatic environment, they spread rapidly and can accumulate in marine organisms, raising growing concerns about long-term impacts on biodiversity, food safety, and human health.

Removing nano- and microplastics from open water is almost impossible, indicating the urgent need for plastic pollution prevention, development of efficient removal methods and removal strategies. Industrial sites located on seashore such as ports, river mouths, and energy facilities with coastal cooling water systems are known hotspots for microplastic pollution, providing opportunities for early intervention.

We have investigated the use of coagulation combined with flocculation to remove nano- and microplastics from seawater at laboratory scale. We used aqueous model suspensions containing conditioned polystyrene and polyethylene particles with a broad size range distribution (200–3000 nm), mimicking real-world conditions as closely as possible. We tested selected coagulants and flocculants under environmentally relevant salinity, pH range, and particle load conditions using both synthetic and real seawater.

Our results showed that combining iron-based coagulants with chitosan, a biodegradable, marine-derived biopolymer, was particularly effective, achieving a removal efficiency exceeding 90%. The process worked through rapid coagulation driven by iron precipitation, followed by further growth aided by chitosan. The kinetics of the process, monitored by photometric dispersion analyser revealed rapid floc formation and the resulting flocs settled quickly, achieving water clarification in under 45 minutes. Performance was robust across different samples of sea water and particle characteristics, including variable pH and environmental conditions. These findings offer a promising, scalable and environmentally friendly method for reducing microplastic pollution at critical entry points in open water (sea, oceans). By leveraging naturally sourced, biodegradable materials, our approach represents a sustainable remediation strategy and aligns with the broader goals of reducing plastic impact in marine environments.

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O7.4

UV-degradable Nylon-6 Copolymer to Mitigate Ghost Fishing and Microplastic Pollution

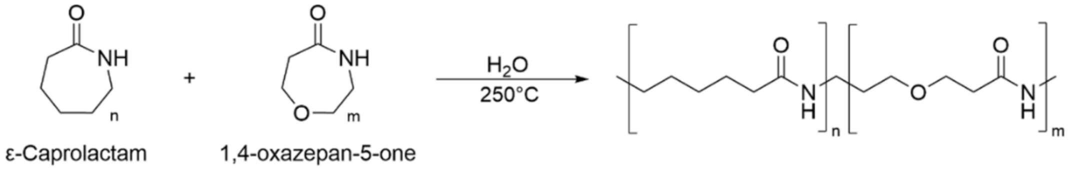
Eirik Olav Bolghaug[1], Monika Vitvarova[2,3], Kristofer Gunnar Paso[1], Elisabeth Egholm Jacobsen[1]

[1]Department of Chemical Engineering, Faculty of Natural Sciences, NTNU Trondheim, Postboks 8900, NO-7491 Trondheim, Torgarden, Norway
[2]Bowmen Consulting s.r.o, Kamýcká 234, 160 00, Praha 6, Czech Republic.

[3]University of Chemistry and Technology Prague, Dpt. of Sustainability and Product Ecology, Technicka 5, 166 28, Praha 6, Czech Republic

* eirikobo@stud.ntnu.no

Lost fishing gear contributes significantly to marine plastic pollution and ghost fishing [1]. A nylon-6-based copolymer was developed to address this issue by degrading under sunlight into fragments smaller than microplastics. Synthesized via ring-opening polymerization, the copolymer incorporates a specific comonomer fraction with caprolactam (see Scheme 1), achieving increased UV degradability while maintaining mechanical properties and durability suitable for fishing nets. The synthesis follows the Twelve Principles of Green Chemistry, emphasizing low ecotoxicity, minimal waste, and includes a pathway for chemical depolymerization [2]. A comparative cradle-to-grave Life Cycle Assessment (LCA), using Product Environmental Footprint (PEF) 3.1 methodology, evaluates the copolymer against traditional nylon-6, quantifying potential reductions in resource depletion, ghost fishing impacts, microplastic generation, and comparing end-of-life scenarios (pyrolysis, landfill, recycling) [3]. This material offers a potential approach within polymers in environmental remediation to reduce marine pollution from fisheries.



Scheme 1: Ring opening polymerization of a nylon-6-based polymer.

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O7.5

Nanocomposite Antifouling Coatings with Graphene Nanomaterials for Marine Applications

*Michael R. Kelly[1]**, *Olaug M. Aalen[1]*, *Naser Esmaili[2]*, *Ingrid G. Hallsteinsen[1]*, *Hilde L. Lein[1]*

[1]Norwegian University of Science and Technology, Trondheim, Norway
[2]Jotun AS, Sandefjord, Norway

* Michael.r.kelly@ntnu.no

Marine structures such as ship hulls, fish farms and subsea infrastructure are subject to unwanted accumulation of marine fouling such as micro- and macro-organisms, mussels and small animals. In order to prevent this, protective coatings have been deployed to prevent adsorption by various strategies. Historically, the use of toxic biocides such as tributyltin and copper-based materials have been prevalent for marine fouling prevention. However, concerns about their toxicity towards non-target species have led to an increase in the research of alternative methods of biofouling prevention [1].

Graphene based nanomaterials have shown excellent bacterial cytotoxicity [2], and the incorporation of these into polymer-based coatings as antifouling additives could promise great antifouling results, while simultaneously reducing the leaching of toxic additives in the marine environment.

Investigations into the antifouling efficacy of graphene nanomaterials embedded in polymer matrices have been done, and these have been compared with industry standard biocides and commercial coating solutions. Investigations into the mechanisms behind their cytotoxic abilities have also been done, and some of the suggested mechanisms have been explored. The graphene-based coatings have shown excellent antifouling capabilities, and they show promise as a potential substitute to the currently available industrial antifouling coatings.

Figure 1: The impact of uncontrolled accumulation of biofilms and fouling on marine vessels.

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O7.6

Ionomeric Polymers as Engines of Motion: Exploiting Interfacial Ion Gradients for Self-Propelled Micropumps and Nanomotors

María José Esplandiu[1], David Reguera[2],[3], Jordi Fraxedas1

[1]*Catalan Institute of Nanoscience and Nanotechnology (ICN2), CSIC and BIST, Campus UAB, Bellaterra, 08193 Barcelona, Spain*

[2]*Departament de Física de la Materia Condensada, Universitat de Barcelona, C/Martí i Franqués 1, 08028 Barcelona, Spain.*

[3]*Universitat de Barcelona, Institute of Complex Systems (UBICS), C/Martí Franqués 1, 08028 Barcelona, Spain..*

* mariajose.esplandiu@icn2.cat

Ionomeric polymers such as Nafion exhibit unique interfacial properties driven by ion-exchange mechanisms, making them highly attractive for the development of active polymer-based systems and as building blocks for active matter. We first investigated the aqueous interface of Nafion using colloidal tracers, revealing that the formation of their characteristic solute exclusion zones arises primarily from ion-induced electric fields, governed by differential ion diffusion[1]. These interfacial gradients were then exploited to design self-sustained ionomeric micropumps capable of generating both radial and unidirectional electroosmotic flows through nanostructuring and tailored surface engineering, with demonstrated applicability in heavy metal water decontamination[2].

Building on this principle, we also fabricated self-standing ionomeric micro- and nanoswimmers powered by salt gradients. These swimmers exhibit collective motility and self-assemble into dynamic flocks that enhance matter transport and enable efficient trapping of micro- and nanoplastics in solution[3]. Furthermore, through tailored functionalization, these swimmers have also been applied to the degradation and removal of antibiotics.

Our work bridges fundamental studies of polymer–electrolyte interfaces with the design of functional ionomeric materials, offering new opportunities in environmental microfluidics and advancing the field of synthetic active matter.

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P1

pH-Responsive PVA/Alginate Hydrogels for Salicylic Acid Delivery in Dermal Therapy

Šárka Havlíčková[1], *Tereza Weigelová*[1], *Nikola Slepičková Kasálková*[1]

[1]*Department of Solid State Engineering, University of Chemistry and Technology Prague, Prague, Czech Republic*

* Sarka.Havlickova@vscht.cz

Chronic skin conditions like psoriasis, eczema, or acne are characterized by inflammation, disrupted skin barrier, and elevated skin surface pH [1]. Topical hydrogel patches can provide an effective and patient-friendly alternative to conventional creams by offering a moist environment, improved adhesion, and controlled drug release [2-4]. In this study, we developed biodegradable PVA/alginate hydrogel films using physical crosslinking methods, incorporating glycerol as a plasticizer to improve flexibility. The hydrogels were doped with salicylic acid as a model anti-inflammatory drug. Prepared materials were characterized in terms of surface morphology, wettability, chemical composition, and material properties. Then, we evaluated their swelling behavior and drug release under physiologically relevant pH conditions (pH 5.5 for healthy skin and 8.0 for inflamed conditions and disruption of the ‚acid mantle'). The results revealed homogeneous, porous structures with good flexibility and swelling capacity. Salicylic acid release was found to be pH-dependent, with increased release at alkaline pH, mimicking inflamed skin conditions. This behavior suggests the potential of the films as pH-responsive transdermal systems for targeted treatment of inflamed or damaged skin. Our findings demonstrate that simple, eco-friendly hydrogel systems can be tailored for smart dermatological applications, offering promise for next-generation wound dressings or active skin patches.

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P2

Surface-modification of cellulose nanofibrils with polyethyleneimine to facilitate improved carbon sequestration

HoYoung Yoon [a], *Jonatan Rönnholm* [a], *Hao Zhang* [a], *Yagut Allahverdiyeva-Rinne* [b], *and Chunlin Xu* [a*]

[a] *Laboratory of Natural Materials Technology, Faculty of Science and Engineering, Åbo Akademi University, Henriksgatan 2, 20500 Åbo-Turku, Finland*

[b] *Molecular Plant Biology, Department of Life Technologies, University of Turku, Tykistökatu 6, 20520 Turku, Finland*

* Chunlin.Xu@abo.fi

Surface functionalization of wood-derived biopolymers, including cellulose and lignin, with amine-containing compounds has proven to be a promising strategy for the valorization of woody biomass towards carbon sequestration. Cellulose, the most abundant, biodegradable, chemically stable, and naturally produced biopolymer in plants, has therefore been widely utilized in the development of hydrogel-based adsorbents for CO_2 immobilization through surface-modification with various amine ligands. Although cellulose-based hydrogels functionalized with amine donors such as polyethyleneimine (PEI) or (3-aminopropyl)triethoxysilane (APTES) have shown considerable CO_2 capture capacities, there remains an unmet need for carbon capture platforms with improved performance and mechanical stability. [1,2] In this context, the aim of this research is to design advanced scaffold materials for the entrapment of photosynthetic cells exhibiting high mechanical stability, improved porosity, suitable for additive manufacturing, and efficient CO_2 capture capabilities. To this end, TEMPO-oxidized cellulose nanofibrils (TCNF) were functionalized with PEI, followed by incorporation photocurable moieties to fabricate hydrogels via light-induced 3D-printing. Structural changes in TCNF were investigated by proton nuclear magnetic resonance spectroscopy (^{1}H NMR), indicating that chemical modifications were successfully grafted onto the surface of biopolymer surfaces through covalent interactions. The proposed synergistic carbon sequestration approaches achieved by combining nanostructured hybrids with 3D-printed hydrogel provides a promising platform for the development of next-generation carbon capture technologies.

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P3

Enhancing optical properties of nanocellulose hydrogel blends

Jonatan Rönnholm[1]*, HoYoung Yoon*[1]*, Tim Salomäki*[1]*, Hao Zhang*[1]*, Yagut Allahverdiyeva-Rinne*[2]*,*
and Chunlin Xu[1*]

[1]*Laboratory of Natural Materials Technology, Faculty of Science and Engineering, Åbo Akademi University, Henriksgatan 2, 20500 Åbo-Turku, Finland*

[2]*Molecular Plant Biology, Department of Life Technologies, University of Turku, Tykistökatu 6, 20520 Turku, Finland*

*Chunlin.Xu@abo.fi

Environmental concerns regarding fossil-based ethylene production have motivated research to explore alternative manufacturing methods. One approach that has demonstrated significant potential is the utilization of modified photosynthetic microbes to generate fuels and chemicals, e.g. ethylene within a hydrogel matrix [1]. While developing a robust and biocompatible hydrogel is achievable, the challenge lies in creating an optically favourable hydrogel matrix that fully harnesses the potential of the microbes [2]. The main difficulties are microbial self-shading and high microbial proliferation that will decrease the availability of light within the hydrogel matrix [3]. Therefore, the aim of this research is to mitigate microbial self-shading and improve the optical properties of the matrix utilizing different nanocellulose hydrogel formulations and additive manufacturing design. It is proposed that the strength of TEMPO-oxidized cellulose nanofibrils (TCNF) and the high transmittance of TEMPO-oxidized cellulose nanocrystal (TCNC) would synergistically provide a hydrogel matrix with these properties. Thus far, TCNF and TCNC hydrogels optical properties have been characterized with ultraviolet-visible spectroscopy. TCNC hydrogels exhibit the highest transmittance and pH-sensitive light scattering capabilities. The transmittance of TCNF hydrogels is dependent on the degree of TEMPO-oxidation and the solid content. These findings indicate that a combined formulation of TCNC and TCNF can enhance the transmittance and introduce light scattering capabilities to the hydrogel matrix.

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P4

Optimization of Mechanical Properties of PVA Hydrogels via Urea-Mediated Multiple Hydrogen Bonding

Jun Chen[1], Camille Lavastre[2], Huaitian Bu[2,], Jianying He[1,]**

[1]Department of Structural Engineering, Norwegian University of Science and Technology (NTNU),
Trondheim 7491, Norway.
[2] Department of Materials and Nanotechnology, SINTEF Industry, Oslo 0373, Norway.

* huaitian.bu@sintef.no, *Jianying.he@ntnu.no

In this study, we employed urea to optimize the mechanical properties of Polyvinyl alcohol (PVA) hydrogels. PVA can form a gel network through physical cross-linking, and urea using can effectively increase the cross-linking density of the gel thereby improving the mechanical properties of the gel. Here, the mechanical behavior of PVA hydrogels with different urea contents in detail were evaluated through cyclic lap shear tests.

The test results show that the mechanical properties of the composite gels are enhanced in the range of urea content from 0.5% to 3%, among which 0.5% urea content shows the greatest toughness of 1051kJ/m^3, and 1% urea content shows the greatest lap shear strength of 243 kPa, both are higher than pure PVA gel of 91kPa and 271kJ/m^3. The mechanism analysis shows multiple hydrogen bonding sites of urea helps form a rigid non-covalent gel network, providing more efficient pathways for energy dissipation during deformation. In contrast, the elastic behavior is mainly driven by the long polyvinyl alcohol molecular chains, allowing the gel to partially recover its shape after large deformation.

In summary, urea further cross-links long-chain polyvinyl alcohol which supports both energy dissipation and network recovery. This work offers a tunable approach for understanding the enhance mechanism and developing viscoelastic hydrogel systems.

P5

Alginate hydrogel characteristics regulate NHDF biology

A.S. Chahal[1,2,3], D. Zaytseva-Zotova[1], H. Haslene-Hox[2], Ø. Arlov[2], A. Vikenes[2], A.D. Hoel[2], R. Mjelle[4], W.I. Strand[1], A. Akbarzadeh[1], G. Klinkenberg[2], Ø. Halaas[3], V. Beisvåg[3], H. Sletta[2], P. Sætrom[4], B.L. Strand[1]*

[1] *Department of Biotechnology and Food Science, NTNU, Trondheim, NO,*

[2] *Department of Biotechnology and Nanomedicine, SINTEF Industry, Trondheim, NO,*

[3] *Department of Clinical and Molecular Medicine, NTNU, Trondheim, NO,*

[4] *Department of Computer and Information Science/Department of Clinical and Molecular Medicine, NTNU, NO*

* berit.l.strand@ntnu.no

Alginate is a marine derived polysaccharide, which is considered an attractive extracellular matrix material for in vitro 3-dimensional (3D) cell culture [1,2]. Here, we investigated how varying hydrogel chemical characteristics influenced the viability, morphology and gene expression of normal human dermal fibroblasts (NHDF) within the gel matrices. Three gel types were tested: (A) alginate (Alg, FG 0.68, MW 237 kDa), (B) periodate oxidized UPLVG, DOX=0.08 mix with Alg (3:1), and (C) POA laterally substituted with a GRGDSP peptide, DS=0.05 mix with Alg (3:1). NHDF were cultured in the hydrogels and viability and morphology were examined using confocal laser scanning microscopy (CLSM). For RNA sequencing, RNA was isolated from cells growing within the gels. It was shown that the hydrogels A, B and C promoted different cell morphologies (Fig.1). Analysis of the RNA sequencing data revealed time and hydrogel dependent clusters in contrast to basic 2D cell culture (Fig 1, bottom). Gene enrichment was performed based on gene ontologies, and genes critical to fibroblasts in 3D environments were identified.

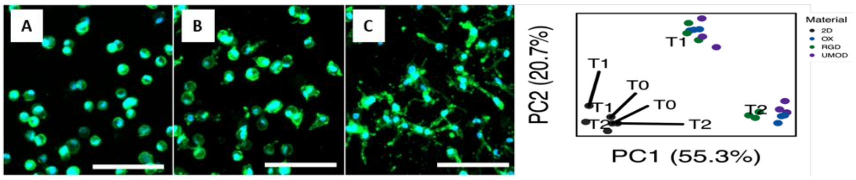

Fig. 1: (Left) Morphology of NHDF cultured within 1% alginate gels A, B and C, respectively, for 7 days. F-actin (green), cells nuclei (blue). CLSM. Scale bar – 100 µm. (Right) Principal component analysis plot highlighting differences in gene clusters.

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P6

Characterising the Interfacial Bonding in PEG-SiO_2 Hybrids from their Thermal Stability

Anders M. Schade[1 2], *Sascha Louring*[2], *Morten M. Smedskjaer*[1], *Donghong Yu*[1]*

[1]*Aalborg University, Department of Chemistry and Bioscience, Aalborg, Denmark*

[2]*PanzerGlass A/S, Hinnerup, Denmark*

*yu@bio.aau.dk

Transparent hybrid materials that combine organic and inorganic components offer the possibility to obtain properties not found in conventional materials, such as simultaneous high toughness and high strength. Covalent bonding between the organic and inorganic phases is crucial to the performance and stability of sol-gel-based hybrid materials, which in turn can be achieved through the use of coupling agents. [1] However, quantifying chemical coupling in hybrids is challenging due to the similarity between the reactive groups in the coupling agent and those in the organic components. Investigating the thermal stability of hybrid materials offers an alternative to assess chemical coupling, as polymers typically exhibit enhanced thermal stability when covalently bonded to stable inorganic entities such as SiO_2 [2].

In this study, we evaluate the thermal stability of organic-inorganic hybrid materials synthesised using sol-gel synthesis involving tetraethylorthosilicate (TEOS), polyethylene glycol 200 (PEG200), and (3-Glycidyloxypropyl)trimethoxy-silane (GPTMS). The materials were analysed using thermogravimetric analysis (TGA) and Fourier transform infrared spectroscopy (FTIR) to determine the extent of interfacial covalent bonding between the polymer and silica networks as facilitated by the coupling agent GPTMS. The TGA results indicate a systematic increase in thermal stability with increasing GPTMS content, which is due to the covalent bonding of PEG200 to the silica network according to the FTIR results. We find that a 1:1:1 molar ratio of GPTMS, TEOS, and PEG200 yields the highest thermal stability enhancement for PEG200, where 36.8% of the organics decompose at a higher temperature compared to the native organic species. These findings demonstrate the link between the physical properties and the chemical structure of hybrid materials, further increasing the value of TGA in the analytical toolkit for hybrid materials.

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P7

Framework for 3D Genomic MD Simulation

Fredrik Framhus[1], Rita Dias[1], Pablo Blanco[1], Kai Sandvold Beckwith[2]*

[1]Department of Physics, NTNU - Norwegian University of Science and Technology, Trondheim, Norway
[2]Department of Biomedical Laboratory Science, NTNU - Norwegian University of Science and Technology, Trondheim, Norway

* fredfh@stud.ntnu.no

Polymer models are used to study the molecular machinery and biophysical mechanisms governing chromatin architecture [1]. *Polychrom*, an open-source simulation framework developed by the Mirny lab, enables large-scale coarse-grained simulations of chromatin folding. It has been widely used to interpret 3D genome data using Hi-C primarily for validation [2]. While Hi-C gives an averaged snapshot of spatial chromosome architecture in a population, it does not directly match physical distances. DNA tracing methods provide single-cell resolved data that offer new constraints, allowing more accurate models.

Building on the mitotic chromatin modelling work by Beckwith et al. [3], this thesis extends the framework to study folding mechanisms during interphase, under varying epigenetic and physical conditions. This work aims to develop a modelling pipeline guided by sequencing data, LoopTrace DNA tracing, and theoretical principles, with a focus on predicting how local epigenetic changes influence structural features.

Epigenetic modifications may arise locally and spread [4]. To capture this, sequence information is modelled using Markov chains, with transitions that vary by position, and optionally by time. The sequential information is embedded in space using random walks, while pairwise interactions are defined by a configurable force field. Using Langevin Molecular Dynamics (MD), we study how heterogeneities in the polymer sequence affect the structural behaviour of experimentally informed model systems.

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P8

Fundamental Investigations into Flash Nanoprecipitation: Surfactant Roles and mapping the Ouzo zone

Masooma Razzaq[1]**, *Sulalit Bandyopadhyay*[2], *Usman Liaqat*[1].
[1]*National University of Science and Technology, Islamabad, Pakistan,*
[2]*Norwegian University of Science and Technology, Trondheim, Norway*

* masoomar@stud.ntnu.no

This research investigates the fundamental mechanisms of nanoparticle formation through Flash Nanoprecipitation (FNP) in the PLGA–THF–water system, focusing on mapping the Ouzo region and evaluating the role of surfactants. Using a Multi-Inlet Vortex Mixer (MIVM), polymeric nanoparticles are synthesized by rapidly mixing a PLGA–THF solution with an aqueous phase containing Tween 80. A key objective is to construct a ternary phase diagram to identify the boundaries of the Ouzo and spinodal regions, where spontaneous emulsification and phase separation occur. Dynamic light scattering (DLS) is being used to assess particle size distribution and stability across varying flow rate ratios. The results demonstrate that the presence of surfactant significantly influences nanoparticle morphology, size, and polydispersity, with distinct differences observed between samples synthesized with and without Tween 80. This work contributes to a deeper understanding of phase behavior, surfactant interaction, and polymer solubility in FNP systems, providing valuable insights for the controlled and scalable production of polymeric nanoparticles.

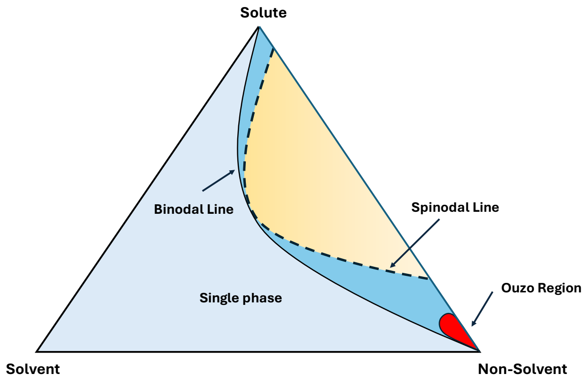

Figure 1: Ternary Phase diagram.

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P9

Investigating Controlling Factors of Encapsulation efficiency of PLGA on IONPs using FNP

Takreem Sandhu[1], Dr. Salman Haider[1], Dr. Sulalit Bandyopadhay[2]*

[1]National University of Science and Technology, Pakistan,
[2]Norweigian University of Science and Technology, Norway.

* takreemsindhu@gmail.com

This research explores the controlling factors affecting the encapsulation efficiency of poly(lactic-co-glycolic acid) (PLGA) on iron oxide nanoparticles (IONPs) using flash nanoprecipitation (FNP). Initially, the influence of the surfactant Tween 80 on the size of bare polymeric nanoparticles (PNPs) was investigated. Tween 80 slightly reduced the size of PNPs but increased the size of PLGA-coated IONPs (PIONPs), indicating complex interactions in hybrid systems.

IONPs were synthesized via thermal decomposition of iron oleate with oleic acid and 1-octadecene at 318°C for 45 minutes. These hydrophobic nanoparticles were then encapsulated with PLGA using FNP. Bare IONPs were characterized using dynamic light scattering (DLS), thermogravimetric analysis (TGA), microwave plasma-atomic emission spectroscopy (MP-AES), and scanning electron microscopy (SEM). PIONPs were characterized using DLS, TGA, and SEM.

A key objective was to formulate a mathematical expression to quantify encapsulation efficiency based on mass ratios derived from TGA and MP-AES data, incorporating both polymer and iron oxide content. Additionally, the process yield of PIONPs from a single batch was analyzed to evaluate industrial feasibility. Yield loss was assessed by calculating the nanoparticle mass before and after the washing step, identifying critical points for optimization in large-scale production. This research offers insights into the interplay of synthesis parameters, surfactant roles, and encapsulation mechanics, contributing to the development of reproducible and efficient fabrication methods for polymer-inorganic nanocomposites.

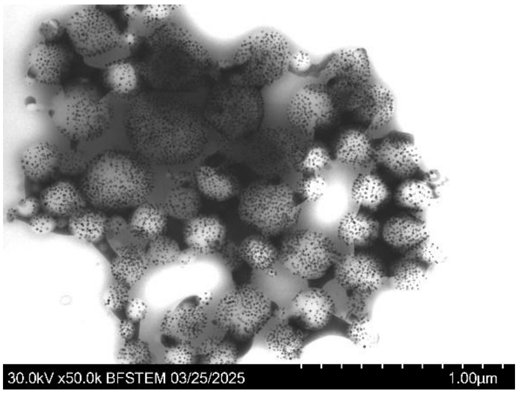

Figure 1: STEM image for encapsulated IONPs in PLGA polymer

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P10

Sustainable Processing of Thermoplastic Bio-Polyurethanes: The Role of Ferulic Acid in Thermal and Oxidative Stability

Joanna Smorawska[1]*, Klaudia Furtak*[1]*, Janusz Datta*[1]*, Ewa Głowińska*[1]

[1]*Gdańsk University of Technology, Faculty of Chemistry, Department of Polymer Technology,*
Gabriela Narutowicza 11/12 Street, 80-233 Gdańsk, Poland

* joanna.smorawska@pg.edu.pl, ewa.glowinska@pg.edu.pl

Growing concerns over plastic waste and fossil resource depletion have accelerated the development of sustainable, bio-based polymer materials. In this context, thermoplastic polyurethanes (TPUs)—versatile elastomeric materials—have become key contributors to sustainability goals. Polyols, diisocyanates, and chain extenders from renewable sources such as vegetable oils, biomass, or sugars are actively being developed—a shift that is both evident and necessary. A major advantage of TPUs is their broad processability through established techniques like injection moulding, extrusion, 3D printing, and calendaring. However, during processing, TPUs are exposed to heat, mechanical stress, and oxidation, which can cause degradation. Therefore, stabilisers are crucial to maintain performance and durability. As greener TPU components emerge, a parallel shift in processing additives is also possible. Incorporating bio-based antioxidants, thermal stabilisers, or flame retardants can further enhance the environmental profile of sustainable TPUs [1,2].

This study explores the use of ferulic acid—a natural compound found in seeds and grains—as an antioxidant in the processing of bio-based thermoplastic polyurethanes (bio-TPUs). A TPU series containing 80% bio-based components was developed. In a two-step synthesis, a urethane prepolymer was prepared using a bio-based polyether polyol, poly(trimethylene glycol) (Velvetol® H2000, Alessa, Germany), and a mixture of diisocyanates: petrochemical hexamethylene diisocyanate (HDI, Vencorex, France) and partially bio-based Tolonate™ X FLO 100 (Vencorex, France). The prepolymer, synthesized with excess diisocyanate, had a free NCO content of ~8%. The prepolymer was then chain-extended with bio-based 1,3-propanediol (Zemea®, DuPont, USA) using dibutyltin dilaurate (DBTDL, Sigma Aldrich, Poland) as a catalyst. The mixture was cast into stainless steel molds preheated to 70 °C and cured at 100 °C for 24 hours. After initial characterization, samples underwent single-cycle processing in a closed mixing chamber (Brabender, Germany) under three conditions: without antioxidant, with 0.25 wt% ferulic acid, and with 0.25 wt.% butylated hydroxytoluene (BHT). The processed TPUs were then analysed to assess the effect of antioxidant addition on their thermal and oxidative stability.

The presented research provides new perspectives on the synthesis and processing of thermoplastic polyurethanes incorporating naturally sourced bio-based compounds. Crucially, the results unequivocally confirm that ferulic acid acts as a powerful antioxidant during processing, significantly improving both the oxidative and thermo-oxidative stability of the bio-based TPUs.

[1] – Citation: Rajput, B.S.; Hai, T.A.P.;Burkart, M.D. High Bio-Content Thermoplastic Polyurethanes from Azelaic Acid. Molecules 2022, 27, 4885. https://doi.org/10.3390/molecules27154885

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P11

Innovative Epoxy Formulations through Chemical Modification of Microbial Alginates toward Functional and Sustainable Materials

Trine Muren[1], Susan Maleki[1], Francesca Di Bartolomeo[1], Ashwiny Pandey[1], Alexander Wentzel[1]*
[1]*Department of Biotechnology and Nanomedicine, SINTEF Industry, Trondheim, Norway*
* trine.muren@sintef.no

The NordiCoats project aims to develop innovative bio-based epoxy compounds tailored for high-performance applications, with a focus on sustainability and environmental responsibility. By integrating biotechnological and chemo-synthetic strategies, the project aims to reduce dependence on fossil-derived resources and promote recyclable, safer alternatives in the epoxy industry.

A key focus of NordiCoats is the utilization of alginate—a linear biopolymer composed of β-D-Mannuronic acid and α-L-Guluronic acid—known for its versatility in industrial and medical applications [1]. In addition to being found in algae, alginate can be efficiently produced through microbial fermentation [2]. In this project, side streams from brewery and aquaculture have been used as feedstock for the microbial alginate production. By fine-tuning production parameters and perform chemical or enzymatic modifications in the downstream processing, alginates can be engineered to meet the requirements needed for epoxy formulations. This approach not only supports a circular economy but also enhances the sustainability and scalability of bio-based epoxy manufacturing. Through these innovations, NordiCoats addresses critical environmental and health challenges associated with conventional epoxy compounds, contributing to a more sustainable future for the coatings industry.

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P12

CO_2 and Propylene Oxide Copolymerization via Heterogeneous and Homogeneous Catalysts for Low-Molecular-Weight Polycarbonate Ether Polyols.

Afsoon Farzan, Adina Anghelescu-Hakala, Juha Lehtonen[*]

Technical research center of Finland (VTT), Espoo, Finland.

[*]Juha.Lehtonen@vtt.fi

Carbon dioxide (CO_2) is an important carbon source due to its abundance, low cost, and non-toxic nature, making it a suitable raw material for chemical synthesis. The chemical fixation of CO_2 has gained significant attention, not only for the efficient use of carbon resources but also in response to increasing environmental concerns [1]. One particularly promising application of CO_2 is its direct incorporation into polymer synthesis. In this context, the copolymerization of CO_2 with propylene oxide (PO) was explored using both homogeneous and heterogeneous catalysts. The catalyst plays a significant role in selectively producing polycarbonate ether polyols, a kinetically controlled product, as it influences the copolymerization rate, selectivity, composition, and molecular weight of the resulting copolymer [2]. In this study, Cr-salen was selected as homogeneous catalyst, while as-synthesized Zn–Co double metal cyanide (DMC) and zinc glutarate were chosen as heterogeneous catalysts. Reaction conditions were optimized to produce low molecular weight polycarbonate ether polyols, which are valuable intermediates for polyurethane production. Furthermore, the selectivity toward producing cyclic carbonate as by-product, the weight ratio of cyclic carbonate (W_{PC}%), the CO_2 incorporation fraction (f_{CO_2}%) in polycarbonate ether polyol, and number average molecular weight (M_n) of the resulting polymers were investigated. It was found that The Cr-salen catalyst demonstrated high catalytic activity and a high f_{CO_2}%, but it provided limited control over the Mn of the polymer. Similarly, the DMC catalyst showed strong catalytic performance; however, its lower f_{CO_2}% led to a copolymer with a higher polyether content. In contrast, zinc glutarate exhibited greater selectivity for CO_2 incorporation and produced polymers with higher Mn, although it had lower catalytic activity and reduced overall yield. According to the results, DMC catalyst was selected for further investigation. The molecular weight of the final product was tailored by adjusting the reaction conditions and using specific chain transfer agents to obtain low molecular weight polycarbonate ether polyols suitable for polyurethane synthesis.

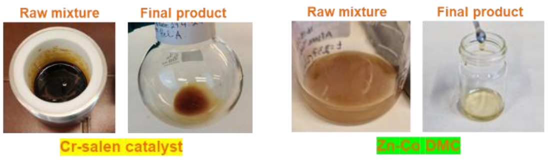

Figure 1: raw mixture and final products obtained from copolymerization of Co_2 and propylene oxide in the presence of homogeneous and heterogeneous catalysts.

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P13

The impact of accelerated aging on the morphology and surface properties of sustainable poly(ester-urethanes)

Ewa Głowińska[1*], *Joanna Smorawska*[1], *Julia Godlewska*[1], *Agata Rodak*[1]

[1]*Gdańsk University of Technology, Faculty of Chemistry, Department of Polymers Technology,*
Gdańsk, Poland,
* ewa.glowinska@pg.edu.pl

All materials used in industry and daily life are susceptible to aging during use and storage. This process involves changes in a material's properties over time and is influenced by various factors. In polymers, aging can lead to the deterioration of mechanical, optical, or chemical characteristics, thereby reducing their performance and durability. Typically, polymers undergo aging due to chemical, biological, physical, or mechanical influences, with the degradation mechanisms depending on their chemical structure.

In this study, we evaluated the changes in morphology and surface properties of bio-based poly(ester-urethanes) (bio-TPUs) subjected to hydrothermal aging. The bio-TPUs, containing a high content of bio-based components, were synthesized using the prepolymer method. Commercially available components were used: a bio-based polyester polyol (Priplast 3294), bio-based 1,3-propanediol glycol, and hexamethylene diisocyanate (HDI), or a diisocyanate mixture consisting of 80 wt.% HDI and 20 wt.% of partially bio-based diisocyanate (Tolonate X FLO 100). Hygrothermal aging was conducted in water at 70 °C for 7 days.

Both non-aged and aged materials were analyzed in terms of surface property changes using scanning electron microscopy (SEM), X-ray diffraction (XRD), and contact angle measurements. The results indicated that, regardless of hard segment structure, noticeable surface changes occurred in the TPUs after 7 days of hydrothermal aging. These changes were particularly evident in SEM and the contact angle measurements. An increase in surface free energy in aged samples also suggested structural alterations. XRD analysis confirmed that the synthesized bio-TPUs possess a semicrystalline structure. After accelerated aging, the two main diffraction peaks observed in all samples showed variations in intensity. Furthermore, the presence of a bio-based diisocyanate in one of the TPU series affected the results. This study constitutes preliminary research toward understanding the mechanisms and effects of material degradation over time, with the goal of optimizing both the production process and application potential of bio-TPUs.

Funding

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P14

Study of self-healing graphene/polyurethane nanocomposites using multiple hydrogen interactions

Justyna Gołąbek[1]*, *Natalia Sulewska, Michał Strankowski*[1]
Department of Polymer Technology, Gdansk University of Technology, Gdansk 80-233, Poland,
* justyna.golabek@pg.edu.pl

The global demand for polymer-based materials has surged, with cumulative global plastic production projected to exceed 34 billion Mt by 2050 [1]. Despite their advantages—lightweight, cost-effectiveness, and versatility—most polymers face significant end-of-life challenges due to low recyclability and slow degradation. In 2023, only 9% of plastics were recycled, highlighting the urgent need for sustainable materials and waste management strategies [2]. Polyurethanes, known for their flexibility, durability, and adaptability, are widely used across various industries. However, their susceptibility to surface damage limits their lifespan. Introducing self-healing capabilities—particularly via intrinsic mechanisms based on dynamic covalent and non-covalent interactions—offers a promising route to extend material performance. Among these, hydrogen bonding stands out for enabling healing under mild conditions, even at room temperature [3]. Moreover, polyurethane materials can be reinforced with nanoparticles like graphene to enhance their properties, making the product more sustainable [4].

In this study, we first synthesize solvent borne polyurethanes with reversible noncovalent bonds - hydrogen interactions, incorporated with nanoparticles to develop sustainable self-healing materials. To achieve these objectives, several key studies were conducted, which can be outlined as follows: investigation of the synthesis pathways and critical factors influencing the formation of polyurethanes exhibiting multiple hydrogen bonds – NCO content, NCO/OH ratio, additives; characterization of the synthesized materials in terms of thermal (TGA and DSC) and mechanical properties (standard tensile testing machine), with a particular emphasis on their self-healing capabilities (optical microscope) and structural characteristics (FTIR, SEM). In addition, the samples were subjected to 3D printing to evaluate their processability using contemporary techniques. The resulting nanocomposites demonstrated effective self-healing capabilities, achieving fast recovery and thus enhancing its service life and sustainability. This study presents a straightforward strategy for fabricating self-healing polyurethane/graphene nanocomposites with potential applications in flexible electronic devices and smart protective coatings.

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P15

Mechanical recycling of wood fibre reinforced polyethylene

Anna-Maria M. R. Persson[1*], *Nanci Vanessa Ehman*[2], *Sandra Rodríguez-Fabià*[2], *Gary Chinga Carrasco*[2], *Erik Andreassen*[1]

[1]*Polymer and Composite Materials group, SINTEF AS, Pb. 124 Blindern, 0314 Oslo, Norway,*
[2]*RISE PFI AS, Høgskoleringen 6b, 7491, Trondheim, Norway.*

* anna-maria.persson@sintef.no

Wood fibre reinforced plastic composites (WPCs) are lightweight and sustainable materials. The thermomechanical pulping process is well known from paper making as an energy efficient high-yield method to shred wood into wood fibres named thermomechanical pulp (TMP). Adding wood fibre to a plastic reduces the fossil content, and increases the stiffness and strength. Full implementation of the potential sustainability of WPCs containing non-degradable plastics (i.e. polyethylene, PE) may be ensured by planning for cyclic material flow. Mechanical recycling is a straightforward and energy efficient strategy to transform end-of-life components into new raw material. For WPCs, mechanical recycling may impact both the polymer matrix (e.g. chemical degradation, causing chain scission, which affects rheological and mechanical properties) and the fibres (shorter, but better dispersed; reduction in stiffness).

In a previous study [1], polyethylene was compounded with wood fibres in a twin extruder. High density and low-density PE (HDPE, LDPE) was combined with TMP, and with TMP and clay. The properties of the virgin material systems were presented by Ehman et al [1]. In the present study we use the same experimental design of the materials (ten in total), and address the effect of 100% mechanical recycling on the TMP-reinforced PE materials.

The materials were injection moulded, re-grinded, and recycling loops were iterated for seven cycles. The evolution of the mechanical properties with increasing number of recycling loops was characterized by tensile testing and Charpy impact testing. The evolution of rheology was followed by evaluating the effect of recycling loops on injection moulding behaviour (i.e. injection pressure). The experimental design allowed to investigate the combined effects of the constituents, the fraction of reinforcement and the number of recycling cycles.

For the LDPE30 and HDPE30 (where “30” refers to a TMP fraction of 30 wt%), the tensile properties stabilized after the second recycling. The tensile modulus was reduced 15 % and 8 %, the tensile strength was reduced 8 % and 5 % and the elongation increased 30 % and 17 % increase, respectively for LDPE30 and HDPE30.

The study was supported by the Norwegian Research Council (project number 328773).

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P16

Fabrication of N-functionalized lignin from reactive biomass fractionation

*Ruijie Wu[1], Yongchao Zhang[2], Xiaoju Wang[1], Chunlin Xu[1]**

[1]Laboratory of Natural Materials Technology, Åbo Akademi University, Henrikinkatu 2, Turku FI-20500, Finland
[2]State Key Laboratory of Biobased Material and Green Papermaking, Qilu University of Technology, Shandong Academy of Sciences, Jinan 250353, Shandong, China.

* cxu@abo.fi

Nitrogen-functionalized materials are widely used in energy, environmental, catalytic, biomedical, and other fields due to their unique structural characteristics, electronic properties, and chemical reactivity. Lignin, naturally rich in oxygen-containing functional groups (such as hydroxyl, methoxyl, and carboxyl), is renewable, biodegradable, and low-cost, making it an important precursor for the development of green nitrogen-functionalized materials. However, the Mannich reaction, a key strategy for introducing nitrogen into lignin, often suffers from low efficiency due to the limited availability of C5-active sites caused by lignin condensation during industrial extraction processes. To address this challenge, we developed a technological breakthrough: *in-situ* amination of lignin using an aniline–formic acid organic solvent system during the fractionation of lignocellulosic biomass. This reactive fractionation approach not only achieved nearly complete lignin removal from the biomass but also produced lignin with a high nitrogen density (introducing 1 formanilide per 1.2 native lignin subunits). The nitrogen-rich lignin obtained through this approach can be further processed *via* a simple anti-solvent method to produce lignin particles from microscale to nanoscale. These N-functionalized lignin particles exhibit a high specific surface area, excellent dispersibility, and facile functionalization, making them highly promising for advanced applications in energy storage, environmental remediation, and beyond, for instance, for CO_2 capturing recently reported by us[1].

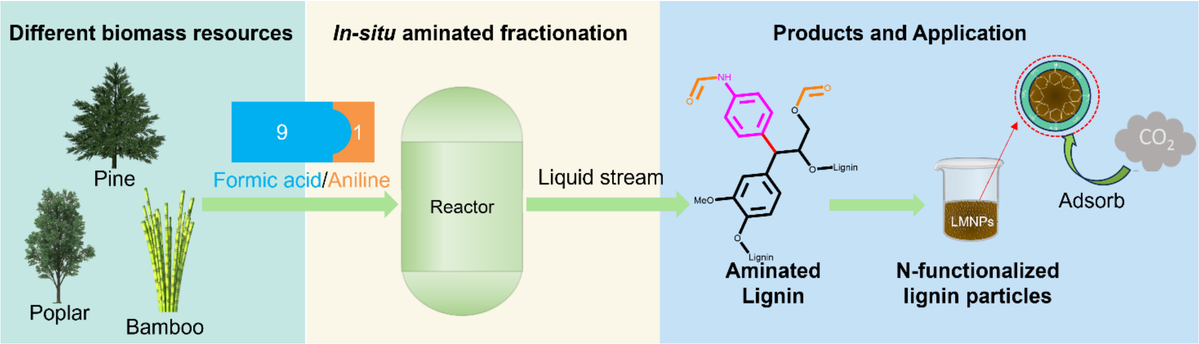

Figure 1: In-situ reactive fractionation of biomass produces high reactivity N-functionalized lignin.

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P17

Investigating Ageing Effects in Polymer Powders for Enhanced Additive Manufacturing

Niklas Eng[1], Natalie Rudolph[2], John Duffy[3], Serena Agostini[3], Candice Majewski[4], Shona Marsh[5]
[1] *NETZSCH, Scandinavia*
[2] *NETZSCH Gerätebau GmbH, Germany*
[3] *Malvern Panalytical, Worcestershire, UK*
[4] *The University of Sheffield, Yorkshire, UK*
[5] *NETZSCH Analyzing & Testing, West Midlands, UK*

Additive manufacturing, particularly powder bed fusion (PBF) of polymers, is advancing rapidly with material characterization playing a crucial role in refining processes and developing new materials. The study focuses on understanding how prolonged exposure to elevated temperatures during PBF affects polymer powders, especially regarding their refreshing strategy, which can impact processing behavior and the quality of the final product.

Utilizing Differential Scanning Calorimetry (DSC), Rheology, and Gel Permeation Chromatography (GPC), this research assesses the ageing indicators such as molecular weight and enthalpy changes in polyamide (PA12) with and without glass beads. Our comparative analysis includes virgin material versus samples aged for 24 and 96 hours.

Key findings reveal that ageing increases the complex modulus in PA powders and leads to a lower cross-over frequency of storage (G') and loss (G") moduli, indicating enhanced elastic behavior over time. This is corroborated by DSC and GPC results, showing rises in molecular weight and decrease in enthalpy, respectively. Furthermore, rheological analysis points to a shift in crystallization temperature to lower values post-ageing, suggesting modifications in processing parameters might be necessary for aged powders to achieve optimal application in PBF.

Through this compact study, we aim to highlight the significant impact of ageing on polymer powders used in additive manufacturing. Understanding these effects is pivotal for adapting manufacturing conditions to accommodate variations in powder properties over time, ensuring the consistent quality of manufactured parts. The insights gathered here are intended to guide further exploration into the resilience and performance optimization of polymer materials in PBF processes, marking a step forward in the additive manufacturing domain.

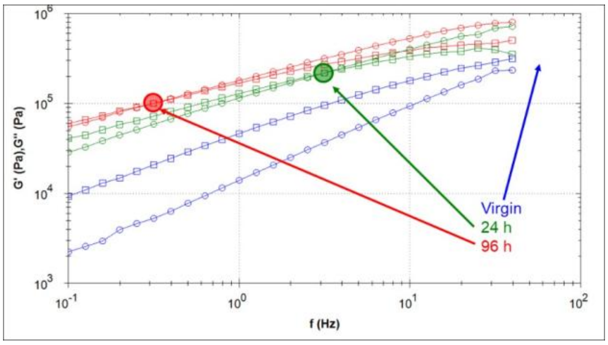

Figure 1. Storage and loss modulus measured in oscillation in a Kinexus rotational rheometer Rheology as indicator of molecular weight changes

Figure 2. Kinexus Prime lab+

P18

Overcoming Recycling Challenges: Precision in Plastics Identification and Quantification with DSC

Niklas Eng[1]*, Dr. Natalie Rudolph*[2]
[1] *NETZSCH Scandinavia*
[2] *NETZSCH Gerätebau GmbH, Germany*

The evolving landscape of plastic recycling, aimed at fostering a circular economy, highlights a pressing challenge: the precise identification and quantification of polymers within mixed recycled streams. This necessity is particularly pronounced for polyolefins like polyethylene (PE) and polypropylene (PP), which are prevalent in the global demand for plastics. Traditional methodologies such as float-and-sink and infrared (IR) spectroscopy face significant shortcomings. Float-and-sink separation struggles with the nuanced density differences among PE and PP grades, rendering it unreliable for accurate sorting. Similarly, IR techniques, while useful in the sorting process, can falter due to their limitations in distinguishing dark pigmented polymers.

The introduction of DIN SPEC 91446, which specifically recommends Differential Scanning Calorimetry (DSC) for the identification of plastics, marks a significant milestone. This standard acknowledges DSC's capability to overcome the limitations of traditional methods by leveraging the unique thermal properties of polymers.

This poster showcases Differential Scanning Calorimetry (DSC) in combination with intelligent software tools as a groundbreaking solution to these challenges. DSC differentiates polymers through their distinctive melting and solidification behaviors, opening new doors for accurate material characterization in recycling processes. The approach utilizes advanced peak separation techniques and melting temperature analysis, supported by a sophisticated, comprehensive database, to identify and quantify polymer components in mixtures. Through a detailed case study of a complex polyolefin blend, we demonstrate the software's advanced capabilities in distinguishing overlapping thermal peaks and executing refined, algorithm-driven analyses for precise component quantification. The presentation culminates in a thorough examination of the accuracy of DSC quantification, illustrating its capacity to redefine recycling efficiency and material recovery, in line with contemporary industry standards and sustainability objectives.

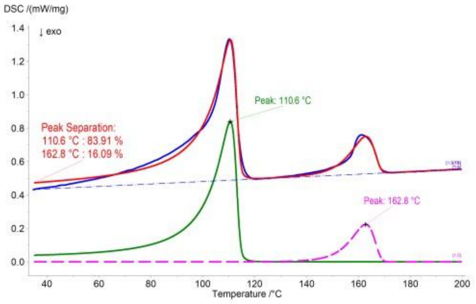

Figure 1. Peak Separation software uses intelligent algorithms to separate peaks and makes them available for further processing and analysis

Figure 2. DSC 300 *Caliris® Select* and DSC 300 *Caliris® Classic*

P19

Thermally insulating, lightweight, mechanically robust cellulosic fibril Pickering foam dried at room temperature

Nissa Nurfajrin Solihat[1], *Muhammad Farooq*[1], *Juan José Valle-Delgado*[1], *Ari Seppälä*[2], *Ari Kankkunen*[2], *Tapio Lokki*[3], *Monika Österberg*[1]*

[1]*Department of Bioproducts and Biosystems, School of Chemical Engineering, Aalto University, Espoo, Finland.*

[2]*Department of Energy and Mechanical Engineering, School of Engineering, Aalto University, Espoo, Finland*

[3]*Department of Information and Communications Engineering, School of Electrical Engineering, Aalto University, Espoo, Finland*

* monika.osterberg@aalto.fi

Biobased foams are emerging as sustainable alternatives to petroleum-derived foams, addressing environmental concerns such as poor recyclability, high emissions, and toxic additive leaching. Foam production from renewable lignocellulosic materials remains challenging due to poor mechanical strength and uneconomical drying methods like freeze-and supercritical drying. In this study, we introduce a novel approach for producing bio-based foams with strong structural integrity without the use of chemical cross-linkers. Our strategy involves the development of an interfacial-engineered Pickering emulsion containing lignin nanoparticles as Pickering stabilizer, biopolymer as a matrix, cellulose fibrils as reinforcement, and solvent as oil phase that transitions directly into dry foams at room temperature. By tuning the composition of cellulose fibrils and solvent ratio, we were able to obtain foams with low density, high porosity, low thermal conductivity, robust mechanical properties, and promising sound absorption performance. The obtained foam had competitive strength (0.63 MPa at 50% strain) and comparable thermal conductivity (41 mW $m^{-1}K^{-1}$) to freeze- (0.04 - 0.09 MPa; 35-43 mW $m^{-1}K^{-1}$)[1, 2] and oven-dried biobased foams (0.1 - 0.2 MPa; 35-47 mW $m^{-1}K^{-1}$) [3, 4]. This study presents a scalable, sustainable, and cost-effective method for producing biobased foams as viable substitutes for conventional fossil-derived foams across diverse applications.

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P20

Mapping the density of states using differential pulse voltammetry

*Joan Ràfols-Ribé[1], Thushar Salkod Mahabaleshwar[1,2], Shi Tang[1], Ludvig Edman[1,2]**

[1]*The Organic Photonics and Electronic Group, Department of Physics, Umeå University, SE-901 87, Umeå,*
[2]*Wallenberg Initiative Material Science for Sustainability, Department of Physics, Umeå University, SE-901 87, Umeå*

**ludvig.edman@umu.se*

Light-emitting electrochemical cells (LECs) operate by in situ electrochemical doping of an electroluminescent organic semiconductor (OSC) through the action of mobile ions[1]. Current drift-diffusion models applied to understand LECs assume that all injected charge carriers are of equal energy. However, in disordered systems, such as amorphous OSCs, the charge carriers exhibit an energy distribution termed density of states (DOS). Moreover, the electrochemical doping of the OSC can induce further broadening of the DOS through coulombic interactions between the ions and the electronic charge carriers. Here we measure the DOS of the HOMO and LUMO of an amorphous OSC termed “Super yellow” during electrochemical doping through differential pulse voltammetry (DPV). The DPV technique practically eliminates non-faradaic contributions, thus enabling direct access to the DOS. We find that both the HOMO and LUMO of Super Yellow feature a broad, multi-peak DOS. We apply our results in modeling LECs and compare the difference between constant mobility and DOS dependent mobility models in modeling LEC performance.

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References:

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Investigating pull-out a rod from granular matter – Experiments and a simple novel model

Veith Schubert[1,2]*

[1]*Gymnasium Fränkische Schweiz, Georg-Wagner-Strasse 17, 91320 Ebermannstadt*

[2]*University Erlangen Nürnberg (FAU), Institute of Polymer Materials, Martensstrasse 7, 91058 Erlangen, Germany*

** via dirk.schubert@fau.de*

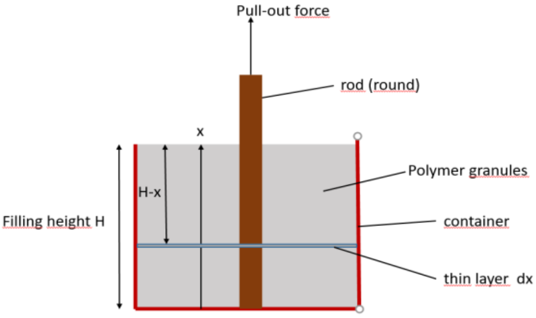
A rod (hard wood) with a circular shape is pulled out from a container filled with polymer granules. The required pull-out force is investigated. Varied experimental parameters are: the filling height of the granules, the shape of the container and the diameter of the rod. To achieve a reliable data-base each experimental set-up was repeated up to 5 times, resulting in more than 200 pull-out tests, utilizing the Zwick tensile-testing machine at the Erlangen –University.

As a main result a simple power-law was revealed for the initial pull-out force (measured force minus weight of the rod) as a function of filling height H:

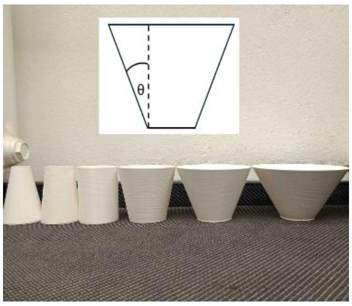
$$F_{pull-out} = constant \cdot H^2$$

Motivated by such a rather simple result a corresponding novel theoretical model was derived, combining physics from fluids and solid matter resulting in the above equation. Additionally, effects and dependencies due to the shape (angle q from -11.7 to 40°) of the container and rod diameter will be discussed, also with respect to industrial application.

Pull-out test



Containers – varying angle q



Scheme for the theoretical model

List of participants

Sl.No	Partcipant name	Company/Institution
1	Alkasalias, Hakar	WATERS / TA INSTRUMENTS
2	Alopaeus, Marie	Åbo Akademi University
3	Andreassen, Erik	SINTEF AS
4	Annu, Annu	KTH
5	Ansaloni, Luca	SINTEF AS
6	Arntsen, Marte	NTNU
7	Avella, Angelica	Chalmers University of Technology
8	Ayane, Amene Tesfaye	KTH
9	Bali, Nesrine	NTNU
10	Bandyopadhyay, Sulalit	NTNU
11	Biswas, Soumodeep	IIT Madras
12	Bjurström, Anton	KTH Royal Institute of Technology/NKT HV Cables
13	Blanco, Pablo M.	NTNU
14	Bolghaug, Eirik Olav	NTNU
15	Bonora, Eugenia	Zurich University of Applied Sciences
16	Bu, Huaitian	SINTEF Industry
17	Damodaran, Subin	Tosoh Bioscience GmbH
18	Dannert, Corinna	NTNU
19	De Wijn, Astrid Silvia	NTNU
20	Dias, Rita	NTNU
21	Eilertsen, Ingar	Teknolab AS
22	Eiser, Erika	NTNU
23	Eng, Niklas	Netzsch Gerätebau GmbH Filial
24	Eriksson, Daniel	Netzsch Gerätebau GmbH Filial
25	Esplandiu, Maria Jose	Catalan Institute of Nanoscience and Nanotechnology
26	Farzan, Afsoon	Technical research center of Finland (VTT)
27	Fliegel, Daniel	PKI
28	Framhus, Fredrik	NTNU
29	Gackowski, Bartosz	University of Southern Denmark
30	Garthe, Jonathan	Heinrich Heine University Düsseldorf
31	Glomm, Wilhelm	SINTEF Industry
32	Głowińska, Ewa	Gdańsk University of Technology
33	Gnecco, Enrico	Jagiellonian University
34	Golabek, Justyna	Gdansk University of Technology
35	Grisard, Léane	NTNU
36	Guzman Gutierrez, Maria Teresa	SINTEF Industry
37	Haugerud Carlsen, Henrik	Dipl.ing. Houm AS
38	Havlíčková, Šárka	University of Chemistry and Technology Prague
39	Hvilsted, Søren	Hvilsted Consult
40	Johnsen, Heidi	SINTEF
41	Kelly, Michael	NTNU
42	Khan, Mahnoor	NTNU
43	Kim, Sang-Youn	Korea University of Technology and Education
44	Kirch, Anton	Umeå University

45	Kirevliyasi Pekkucuk, Makbule Gizem	Bogazici University, Chemistry Department
46	Kjellevold-Skallerud, Embla	NTNU
47	Kvikant, Minette	Åbo Akademi University
48	Lo Re, Giada	Chalmers
49	Mahabaleshwar, Thushar Salkod	Umeå University
50	Mani, Ethayaraja	IIT Madras
51	Marie, Laurent	NTNU
52	Mulchandani, Neha Manojkumar	Technical University of Denmark
53	Muren, Trine	SINTEF Industry
54	Nästi, Juuso	Blue Scientific
55	Nordgård, Catherine Taylor	NTNU
56	Obregón Rebatta, Franccesco	NTNU
57	Oliveira, Alessandra	Federal University of Rio Grande do Sul
58	Olsson, Richard	KTH
59	Perez, Yomkippur	Polypure AS
60	Punnath Sivasankaran, Vyshnav	NTNU
61	Puthiyaveettil Azeez, Nizam	Åbo Akademi University
62	Razzaq, Masooma	Particle Engineering Centre
63	Rönnholm, Jonatan	Natural Materials Technology
64	Sammalkorpi, Maria	Aalto University
65	San Jacinto García, Jorge	KTH. Royal Institute of Technology
66	Sandhu, Takreem	NTNU
67	Sandru, Marius	SINTEF Industry
68	Schade, Anders M.	Aalborg University
69	Schubert, Dirk	University Erlangen Nürnberg (FAU)
70	Schubert, Veith	Gymnasium Fränkische Schweiz
71	Shimoga, Ganesh	SINTEF Industry
72	Simons, Jasmin	RWTH Aachen University
73	Singh, Arunika	KTH Royal Institute of Technology
74	Singh, Naveen Kumar	Norner AS
75	Sivasamy, Karthikai Selvan	SINTEF Industry
76	Smorawska, Joanna	Gdańsk University of Technology
77	Solihat, Nissa Nurfajrin	Aalto University
78	Stokke, Bjørn Torger	NTNU
79	Strand, Berit Løkensgard	NTNU
80	Svergja, Hanne	Houm
81	Tanase-Opedal, Mihaela	RISE PFI AS
82	Thu, Myint	NTNU
83	Tolmachev, Dmitry	Aalto University
84	Truong, Le Thuy	SINTEF AS
85	Verceux, Floriane	NTNU
86	Wita, Gerlinde	PerkinElmer Scientific
87	Wu, Ruijie	Åbo Akademi University
88	Yoon, HoYoung	Åbo Akademi University
89	Zelikin, Alexander	Aarhus University KEMI