NEWSLETTER

FORgreensoft
SOFT MATTER MORE GREEN

2025

After three years of hard work, the FORGreenSoft program reaches its end.

FORGreenSoft was more than a research project aiming to strengthen FORTH research capacities, it was a brick in the construction of greener and more sustainable future in Europe.

All partner's collaborations were expressed through a wide range of activities that enabled us to not only enhance FORTH attractiveness based on excellent science capacities in the field of Green Soft Matter, but it also built a strong and durable partnership with researchers from diverse fields and horizons.

This adventure was possible thanks to our partners' commitments throughout the project, and thanks to the European Union for its financial support.

Anastasia Tzeiranidi – Master student

Since I was a child, I have been passionate about nature and environment. This awareness of environmental responsibility has shaped my scientific curiosity and guided me towards the Department of Material Science and Engineering. The project of FORGreenSoft checked all my boxes and was my motivation to chase a master's degree. It gave me the ability to extend my expertise in the field of soft matter (colloidal systems) and rheology and to understand how crucial it is to choose sustainable materials.

Cellulose nanocrystals (CNC), as renewable and bio-based rod-like colloids, have a strong connection to environmental issues and sustainability. Our project was based on a new method of producing cellulose nanocrystals using greener solvents (Deep Eutectic Solvents), compared to industry, and their characterization is still not much documented in the literature. Its differences with the industrial ones challenged us to try to understand the material and explore how it can be utilized. We aimed to provide insight into these cellulose nanocrystals and evaluate whether their properties are comparable to those produced by conventional methods, with the goal of the development of truly sustainable, green materials synthesized via environmentally friendly routes. We managed to fully characterize this CNCs and find methods to alter certain properties that can affect the final material (film or coating).

I especially enjoyed exploring rheology, colloidal gels, and techniques like rheology and differential dynamic microscopy (DDM), where particle motion can be visualized and analyzed. Working with cellulose nanocrystals and film formation, and navigating a novel synthetic route taught me persistence, creativity, and problem-solving. Moreover, regular reporting meetings, attending summer schools, workshops and conferences helped me stay organized, communicate my work clearly, and have meaningful discussions with experts. The feedback I received often challenged my perspective and pushed me to think more critically, improving the quality of my research.

Future research will focus on the design of antimicrobial films and coatings using cellulose nanocrystals as the structural material. As renewable materials with tunable surface chemistry and mechanical properties, CNCs provide properties for developing sustainable protective materials. Moreover, this project has provided my lab with new knowledge on how to tailor CNC-based systems, a material new to our group, and expertise in films/coatings.

Thanasis Machas — Master student

As a master student in Materials Science in the Polymer and Colloid group in the Institute for Electronic Structure and Laser in FORTH, Greece, supervised by Prof. George Petekidis, I was closely affiliated with the FORGreenSoft project within the Polymer and Colloid Science Group.

Our lab focuses on colloidal systems, specifically addressing the issue of polluting, non-renewable additives. FORGreensoft aims to offer greener alternatives while ensuring these new renewable composites maintain mechanical properties comparable to their traditional counterparts.

My primary role involved computational research to predict the properties of composite systems. I explored colloidal systems using various simulation methods, including Multi-Particle Collision Dynamics (Prof. Christos Likos, University of Vienna), Dissipative Particle Dynamics (Prof. Safa Jamali, Northwestern University), and our internal Brownian Dynamics code. By critically examining results across these different methods, we obtained educated predictions of real system dynamics, allowing us to tune parameters for experimental design.

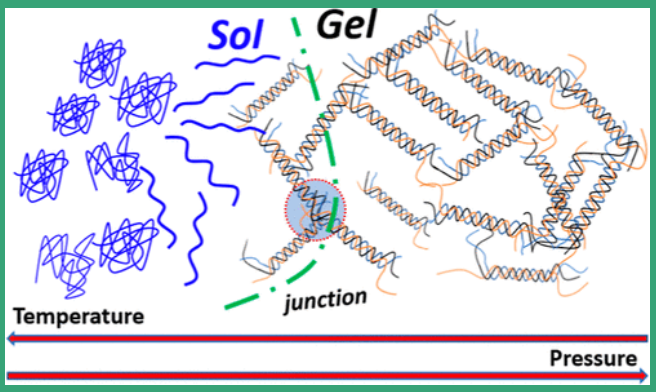
A highlight of my work was engaging with Differential Dynamic Microscopy (DDM), software developed by Prof. Roberto Cerbino's group (University of Vienna). DDM transforms microscopy videos of colloidal particles into light scattering data, granting insight into systems previously considered immeasurable via traditional scattering techniques.

I also attended several FORGreenSoft short courses. A standout session in May 2024 featured Prof. Cerbino presenting a custom instrument that combined rheometry and microscopy—a solution created because no commercial equivalent existed. Inspired by this problem-solving attitude, my supervisor and I decided to design a new setup capable of performing simultaneous rheometry and impedance measurements.

In retrospect, I found myself at a vital crossroads of knowledge exchange. This experience demonstrated that overcoming scientific hurdles often relies on collaboration and connecting with the right people.

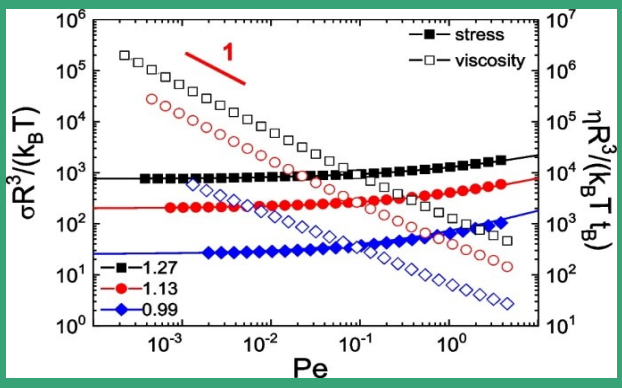
PUBLICATIONS

Our latest publications are showcasing diverse research that contributes to scientific progress. Examples are summarized below and the following pages.



The article by **Nikolaos A. Burger, Gerhard Meier, Dimitris Vlassopoulos and Benoit Loppinet**, entitled **"High-Pressure Effects on Gelatin Sol-Gel Transition"**, was published in *Industrial & Engineering Chemistry Research* (*Ind. Eng. Chem. Res.*, 2025, 64, 14, 7370-7380).

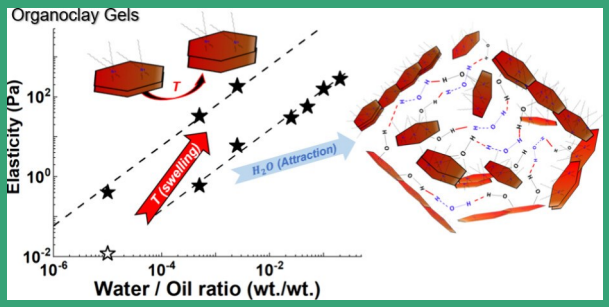
The article studies how applying high pressure affects the process where gelatin changes from a liquid-like state (sol) to a jelly-like state (gel). It shows that under pressure, gelatin forms gel faster and the temperature at which this happens increases slightly. Pressure helps stabilize the gelatin's helical structures, making the gel stronger and slower to melt. The process itself does not change, only the speed and stability improve with higher pressure. These results help understand how gelatin and similar proteins behave under pressure.



The article by **Bogri Panagiota, Pagani Gabriele, Vermant Jan, Sparkel Joris, Petekidis George**, entitled **"Orthogonal Superposition Rheometry of Soft Core-Shell Microgels"**, was published in *Industrial & Engineering Chemistry Research* (*Ind. Eng. Chem. Res.*, 2025, 64, 14, 7370-7380).

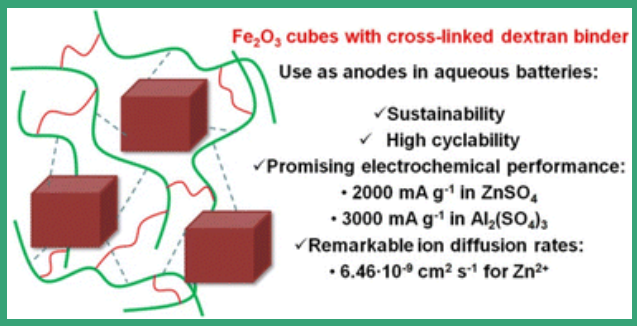
This study uses orthogonal superposition rheometry (OSR) to examine how steady shear flow affects the viscoelastic properties of soft coreshell microgels above their glass transition. Under shear, two crossover frequencies emerge in the viscoelastic spectra, shifting to higher values with increasing shear rate and revealing shear-induced relaxation times linked to cage-breaking mechanisms. Superposition of spectra across shear rates works well, with shift factors showing linear dependence on shear rate similar to hard spheres, though volume fraction effects signal a glass-to-jam transition. A new open-bottom Couette cell reveals low-frequency limits due to instrumental artifacts like pumping in yield-stress fluids, and Kramers-Kronig relations hold above these limits, indicating minimal shear-altered microstructure. Overall, soft microgels flow like hard spheres but with added deformability influencing jamming dynamics.

PUBLICATIONS



The article by **Nikolaos A. Burger, Benoit Loppinet, Andrew Clarke, George Petekidis** entitled **"How Preparation Protocols Control the Rheology of Organoclay Gels"**, was published in the *Langmuir* (*Langmuir* 2025, 41, 31, 20638–20647).

This study examines how pressure and temperature affect the flow behavior and yield stress of a model drilling fluid and its base clay dispersion. Both systems show viscosity increasing with pressure, following solvent viscosity trends. For clay dispersions, yield stress rises with both pressure and temperature, while for the drilling fluid, it rises with pressure but falls with temperature. Only the drilling fluid exhibits pressure-dependent aging of yield stress. The findings indicate that pressure primarily modifies particle–droplet interactions rather than volume fraction, offering new insights into the microscopic origins of yield stress in drilling fluids under extreme conditions.

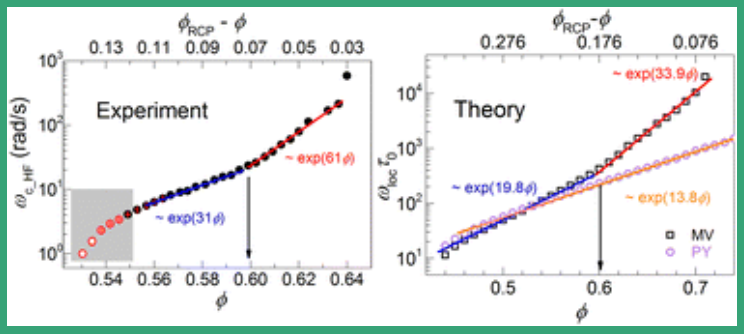


The article by **Sofi Panagiotidou, Evangelia Vasilaki, Nikos Katsarakis, Dimitra Vernardou, Maria Vamvakaki**, entitled **"Dextran stabilized hematite: a sustainable anode in aqueous electrolytes"**, was published in *Nanoscale* (*Nanoscale.*, 2025, 17, 4578-4590).

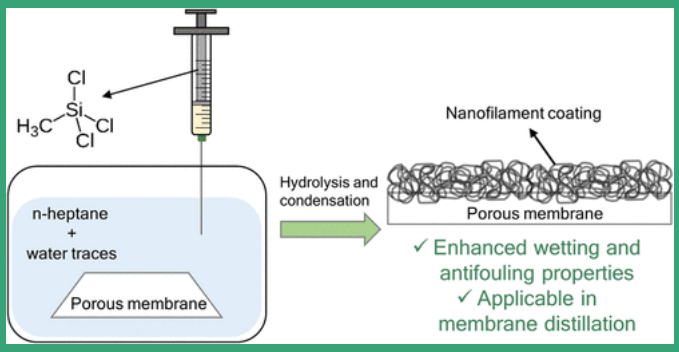
This study presents novel sustainable anode electrodes made from hematite (α-Fe_2O_3) cubes bound with cross-linked oxidized dextran (Ox-Dex) for energy storage devices. The electrodes showed best electrochemical performance in $Al_2(SO_4)_3$ electrolyte (3000 mA/g), followed by $ZnSO_4$ (2000 mA/g) and Li_2SO_4 (800 mA/g), linked to the ionic radii affecting ion diffusion rates. The hybrid anodes demonstrated excellent cycling stability with minimal capacity loss due to strong hydrogen bonding between organic binder and inorganic particles, creating a uniform structure. Cross-linking of Ox-Dex also improves electrode stability and tolerance to volume changes during cycling. These findings highlight the potential of these hybrid anodes for efficient, durable energy storage applications.

PUBLICATIONS

The article by **Thanasis Athanasiou, Baicheng Mei, Kenneth S. Schweizer, George Petekidis**, entitled **"Probing Cage Dynamics in Concentrated Hard-Sphere Suspensions and Glasses with Frequency Rheometry"**, was published in *Soft Matter* (*Soft Matter*, 2025, 21, 2607-2622)



This study investigates how particle caging and shear elasticity evolve with increasing volume fraction in hard-sphere colloidal suspensions. Using broad-range linear viscoelastic measurements, it identifies a high-frequency crossover in the dynamic response that marks the transition from liquid-like to localized, cage-confined dynamics. As concentration increases, caging strengthens and the crossover shifts to higher frequencies.
The experimental results align with theoretical predictions, revealing that the localization time and elastic shear modulus share similar exponential scaling due to many-body structural correlations, offering new insight into glassy dynamics at short timescales.

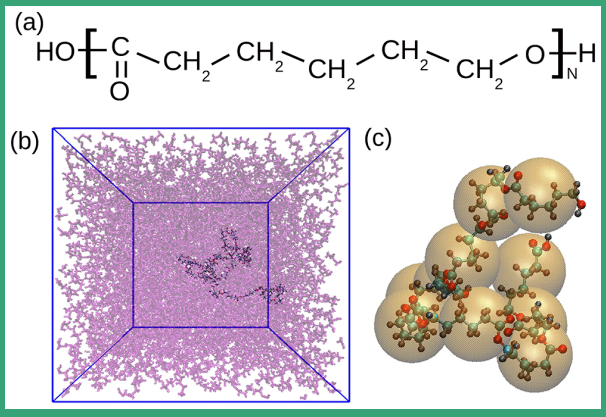


The article by **Mariana D. Sosa, Ivana K. Levy, Hans-Jürgen Butt, Michael Kappl,** entitled **"Nanofilament-Coated Membranes with Enhanced Scaling and Biofouling Resistance for Membrane Distillation"**, was published in *ACS Applied Materials & Interfaces* (*ACS Appl. Mater. Interfaces* 2025, 17, 16, 24588−24600).

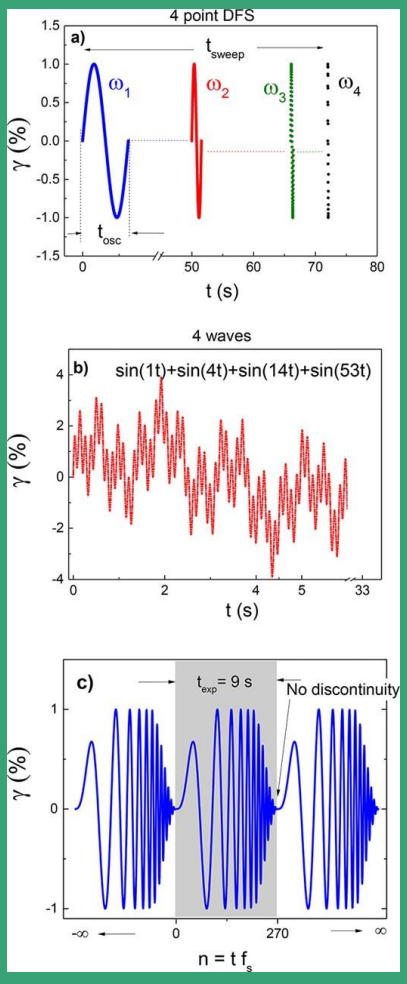
This study reports on silicone nanofilament-coated porous membranes made with a less toxic solvent, n-heptane, as an alternative to toluene for membrane distillation (MD). The nanofilament coatings provide superhydrophobic, fluorine-free membranes that resist wetting, scaling, and biofouling better than standard PTFE membranes. The coated membranes show higher contact angles (more water-repellent) and 20-50% less biofilm growth after immersion tests in scaling and biofouling environments. Membrane distillation flux and salt rejection performance are comparable or better than PTFE membranes, with sustained performance in synthetic seawater and real wastewater tests, including ammonia recovery. This work highlights the potential for sustainable, efficient MD membranes with enhanced durability
using safer coating methods.

PUBLICATIONS

The article **by Bačová P, González Huarte G, Harmandaris V and Molina SI**, entitled **"Development of systematic coarse-grained model for poly(caprolactone) in melt"**, was published in the *Open Research Europe* (*Open Res Europe* 2025, 5:296).



This study develops a systematic coarse-graining method to model poly(ε-caprolactone) (PCL) melts for use in simulating biodegradable polymers. Starting from validated atomistic simulations using the L-OPLS force field, the approach accurately reproduces PCL's structural and dynamic properties at multiple scales. The resulting model enables efficient computational studies to optimize PCL-based materials, supporting the design of sustainable polymers with lower environmental and economic costs.



The article by **Thanasis Athanasiou, Michela Geri, Patrice Roose, Gareth H. McKinley, George Petekidis,** entitled **"High-frequency optimally windowed chirp rheometry for rapidly evolving viscoelastic materials: Application to a crosslinking thermoset"**, was published in the *Journql of Rheology* (*J. Rheol.* 68, 445–462 (2024)).

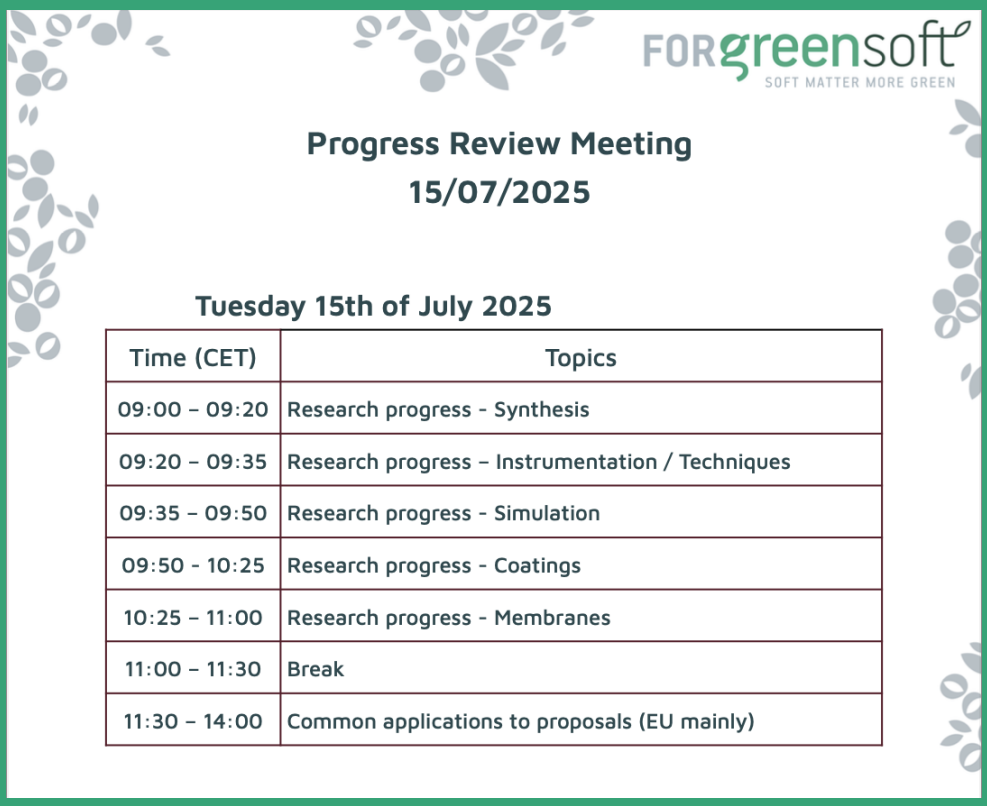
This study presents a rapid rheological method to monitor the evolving mechanical properties of curing polymers. By applying frequency- and amplitude-modulated chirped strain signals with both a custom piezo-operated rheometer and a commercial rotational rheometer, the technique captures the linear viscoelastic spectrum on subsecond timescales. This approach minimizes experimental distortion and enables high-frequency, real-time tracking of curing behavior. Validated using a vinylester resin, the method provides detailed insight into the time- and frequency-dependent development of modulus and the associated chemical network evolution.

Project review meeting

On Tuesday, July 15th, the FORGreenSoft consortium reunited to take stock of ongoing research, celebrate key breakthroughs, and spark fresh ideas for future collaboration. The energy was high, the progress impressive. Here are the Research & Innovation Highlights:

- CNC Development: Novel CNCs successfully synthesized, characterized, and benchmarked—pushing the boundaries of what's possible with bio-based materials
- Advanced Instrumentation: Cutting-edge tools for integrated rheo-microscopy are in the works
- Modeling Breakthroughs: Comparative simulations (DPC/MPCD & BD/SD) revealing new insights into colloidal dynamics
- Functional Coatings: CNC-based coatings under the microscope (literally)—with AFM analysis validating our approach
- Next-Gen Membranes: Promising membrane tests carried out at MPIP using CNC innovations

The second half of the meeting focused on strategic deliverables and laying the foundations for ambitious new collaborative proposals.



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Progress Review Meeting
15/07/2025

Tuesday 15th of July 2025

Time (CET)	Topics
09:00 – 09:20	Research progress - Synthesis
09:20 – 09:35	Research progress – Instrumentation / Techniques
09:35 – 09:50	Research progress - Simulation
09:50 - 10:25	Research progress - Coatings
10:25 – 11:00	Research progress - Membranes
11:00 – 11:30	Break
11:30 – 14:00	Common applications to proposals (EU mainly)

Summer School on Computational Methods

Group photo—Summer School on Computational Methods (FORTH)

The Summer School on Computational Methods, co-organised, by CoCoGel and FORGreenSoft, took place at IESL-FORTH, from 25th -27th of September 2025.
This event was the occasion for master and doctoral students, supervisors, and experts to gather for an intensive program in Computational Methods applied to Soft Matter.

Over three days, participants took part in lectures and hands-on sessions covering:

- Multi-scale Modeling & DPD Simulations of Soft Matter
- Mesoscopic Modeling with Multi-particle Collision & Stokesian Dynamics
- Data-driven Modeling and AI/ML Methods in Material Science

We are addressing our warmly thanking to our tutors Anastassia Rissanou (TPCI NHRF), Oleksandra Kukharenko (MPIP Mainz), Tyler Shendruk (University of Edinburgh), Joost de Graaf (University of Utrecht), and Safa Jamali (Northeastern University) for their insightful lectures and to all participants for making this Summer School a success.

Researcher's Night 2025

Our FORGreenSoft students took part in the 2025 edition of the European Researcher's Night at FORTH, and we couldn't be prouder!

Anastasia Tzeiranidi, Thanasis Machas, and Vasilaki Chrysoulaki put together a cardboard model that showed how Cellulose NanoCrystal (CNC) films can be made from natural materials like wood and paper. They explained how Deep Eutectic Solvents, which are more environmentally friendly than currently used solvents, can extract Cellulose NanoCrystals and highlighted the importance of pursuing the research towards the creation of sustainable materials.

The goal? Show people that research isn't just happening in labs far away and that we are working on real solutions for a greener future.

We thank our students for sharing their passion with the local community. This event is a great opportunity to raise environmental awareness and inspire your people to consider careers in research.

Mainz meeting

As the FORGreenSoft project comes to an end this November 2025, our consortium gathered both remotely and on-site at the Max Planck Institute for Polymer Research in Mainz to celebrate our journey together.

This meeting was the opportunity to have a general overview on the research progress on the different fields of FORGreenSoft: Simulations (Christos Likos, Anastassia Rissanou, Sandipan Chattaraj), Synthesis (Eva Vasilaki, Maria Kaliva), and Experiments (Benoit Loppinet, Mariana D. Sosa, Thanasis Athansiou, Emmanouil Glynos, Roberto Cerbino).

FORGreenSoft Final Meeting
24-25/11/2025

Monday 24th of November 2025

Time (CET)	Topics
09:00 – 09:30	Christos Likos, UNIVIE (Simulations) Locally tuned hydrodynamics of active polymers
09:30 – 10:00	Anastassia Rissanou, FORTH, (Simulations) All-atom Molecular Dynamics Models of Aqueous Solutions of Cellulose Nanocrystals
10:00 – 10:30	Coffee Break
10:30 – 11:00	Sandipan Chattaraj, FORTH (Simulations) First comparisons of DPD/MPCD and BD/SD in colloidal systems
11:00 – 11:30	Eva Vasilaki, MPG-Berlin (Synthesis) Fully biobased, degradable polymers for the controlled release of antioxidants
11:30 – 12:00	Benoit Loppinet, FORTH (Experiments) Characterization of deep eutectic solvent extracted cellulose nanocrystals
12:00 – 14:00	Lunch break
14:00– 14:30	Maria Kaliva, FORTH, (Synthesis) Membranes Based on CNC
14:30 – 15:00	Mariana D. Sosa, MPG-Mainz (Experiments) Green membranes for membrane distillation
15:00 – 15:30	Coffee break
15:30 – 16:00	Thanasis Athanasiou, FORTH (Experiments) Cellulose based coatings from deep eutectic solvents: mechanical properties and topography
16:00 – 16:30	Emmanouil Glynos, FORTH (Experiments) Atomic Force Microscopy on Green Materials
16:30 – 17:00	Roberto Cerbino, UNIVIE (Experiments) FORTH and UNIVIE: technology transfer and applications to materials for membranes and coatings
18:30	Social dinner

FORGreenSoft Final Meeting
24-25/11/2025

Tuesday 25th of November 2025

Time (CET)	Topics
09:00 – 09:40	Final WPs and deliverables – George Petekidis
09:40 – 10:20	Final report – George Petekidis
10:20 – 10:40	Coffee break
10:40 – 11:30	Future proposals & collaborations

On another hand, we discussed about administrative state and upcoming milestones of the project: review of the last deliverables, plan and coordinate the construction of the final periodic report but also to discuss future proposals and collaborations.

That's a wrap for FORGreenSoft!

All wonderful things must come to an end, and so does FORGreenSoft.

This Twinning project, gathering FORTH's Institute of Electronic Structure and Laser, the Max Planck Institute for Polymer Research, the Max Planck Institute of Colloids and Interfaces, the University of Vienna, and EUglottia, aimed to advance FORTH's research and innovation capacity in Green Bio-based Materials through knowledge and technology transfer activities in Green Chemistry, Experimental Soft Matter, and Computational Soft Matter.

Our collaboration deserves the title of a "success story":

FORGreenSoft delivered knowledge and technology transfer ranging from the use of Deep Eutectic Solvents to produce Cellulose NanoCrystals, developing fluorine-free, superhydrophobic membranes for membrane distillation to the Differential Dynamic Microscopy (DDM) software and more. This includes:

- 29 exchange visits to and from FORTH,
- 2 short courses (on bio-based materials, biodegradable polymers, polymer recycling approaches, electrospinning for green nano/micro fibrous membranes, advanced microscopy techniques for soft matter characterization, optical tweezers, and 3D electron microscopy), 1 Summer School on computational methods, and 1 Soft Skills workshop.
- These efforts resulted in 11 publications on green soft matter in high-impact journals (check our articles on our website).
- FORGreenSoft enabled FORTH and its partners to promote research in Green Soft Matter: we gave 22 lectures and presented 11 posters in different conferences, FORTH organized with the participation of FORGreenSoft the 10th International Soft Matter Conference (Chania, Greece) and participated in 3 European Researchers' Nights to engage with the non-scientific and local audiences.

As we mark the successful conclusion of this endeavor, we want to express our deepest thanks to the entire project network for the tremendous time and commitment invested. Beyond completing the deliverables, we established an invaluable, expanded professional network for all participants. The comprehensive knowledge and technology transfer we achieved together has been the true measure of our growth. Thank you for making this project a genuine accelerator, fundamentally expanding our collective horizon for future partnerships and projects. Last but not least we want to thank the European Union for its financial support.

ABOUT

FORGreenSoft is a project financed by the European Commission's research and innovation program, Horizon Europe, under the action Horizon Widera Twinning. The objective is to enhance networking and knowledge transfer between top-class leading European institutions and institutions within the Widening.

Most of our everyday materials are made out of synthetic compounds that are known to have a negative environmental impact and therefore need to be replaced. Soft Matter sciences are ideally placed to address these issues. We aim with this EU-funded FORGREENSOFT project to explore new routes to replace some of these ingredients. The focus is on bio-sourced raw materials obtained through eco-friendly processes. We will achieve this through a multilevel transfer of knowledge and research collaboration between FORTH and European centers of excellence at the University of Vienna in Austria and at the Max-Planck Institute in Germany.

Visit our website by scanning the QR code

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Grant Agreement Number: 101078989 under

HORIZON-WIDERA-2021-ACCESS-03

Funded by
the European Union