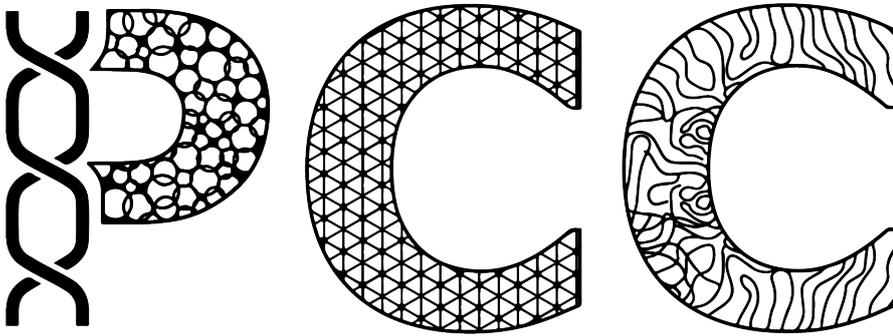
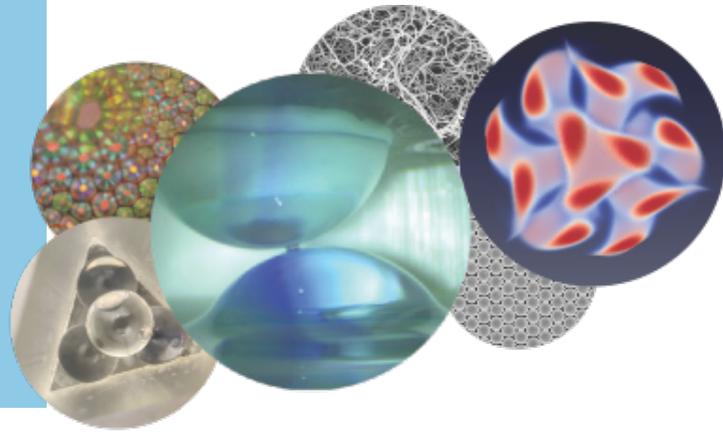


# Physical Chemistry and Soft Matter



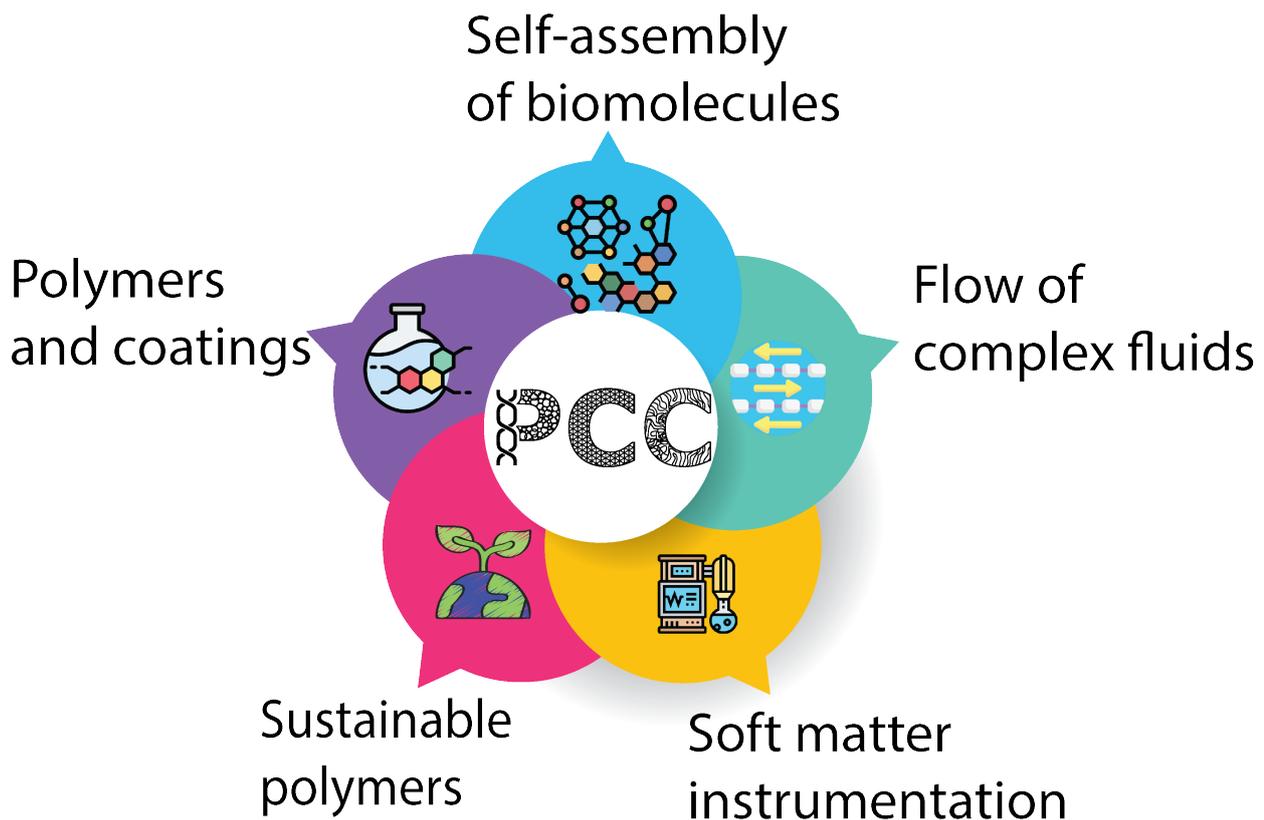
We are interested in phenomena at the nanoscale, where creative chemistry is essential, physics is a rule rather than an exception and biology comes to life

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6708 WE Wageningen

# Our research

*By bridging molecular design with macroscopic functionality and multidisciplinary, our work enables the development innovative solutions in polymer science and soft matter to address global challenges including sustainability and advanced materials.*

*Our research themes are:*



# Our Scientific Staff



## Jasper van der Gucht

When you deform a material too much, it breaks. Will you help us unravel the microscopic processes that precede macroscopic failure?

### Highlighted Publications

Li J, de Heer Kloots MHP, van Ewijk G, van Dijken DJ, de Vos WM, van der Gucht J. Evaporation-Induced Polyelectrolyte Complexation: The Role of Base Volatility and Cosolvents. *Langmuir* 2024;40. <https://doi.org/10.1021/acs.langmuir.3c02656>.

van Lange SGM, te Brake DW, Portale G, Palanisamy A, Sprakel J, van der Gucht J. Moderated ionic bonding for water-free recyclable polyelectrolyte complex materials. *Sci Adv* 2024;10. <https://doi.org/10.1126/sciadv.adi3606>.

Ruiz-Franco J, Tauber J, Van Der Gucht J. Cross-linker Mobility Governs Fracture Behavior of Catch-Bonded Networks. *Phys Rev Lett* 2023;130. <https://doi.org/10.1103/PhysRevLett.130.118203>.

## Renko de Vries

Proteins are the bricks of life. You will study properties of soft materials made out of natural and artificial proteins, with applications in food technology, biotechnology and biophysics.

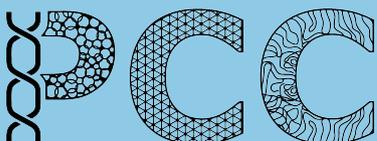


### Highlighted Publications

Janssen SWPM, Pouvreau L, de Vries RJ. Commercial plant protein isolates: The effect of insoluble particles on gelation properties. *Food Hydrocoll* 2024;154:110049. <https://doi.org/10.1016/j.foodhyd.2024.110049>.

Doshi N, Venema P, van der Linden E, de Vries R. The generality of pH-induced liquid-liquid phase separation in plant proteins extends to commercial legume flours. *Food Hydrocoll* 2025;162:110927. <https://doi.org/10.1016/j.foodhyd.2024.110927>.

Zheng C, Hussain Z, Chen C, de Haas RJ, Deshpande S, Zhang Z, et al. One-step antifouling coating of polystyrene using engineered polypeptides. *J Colloid Interface Sci* 2025;685:350–60. <https://doi.org/10.1016/j.jcis.2025.01.147>.





## Frans Leermakers

Interfaces in micro-emulsions and bilayer membranes are free of tension and therefore, their interfacial area is truly extensive. Moreover, both systems can form complex shapes and topologies. Through modelling, we hope to learn the cause of this, so we may guide experiments.

### Highlighted Publications

Shavykin O V., Mikhtaniuk SE, Fatullaev EI, Neelov IM, Leermakers FAM, Brito ME, et al. Hybrid Molecules Consisting of Lysine Dendrons with Several Hydrophobic Tails: A SCF Study of Self-Assembling. *Int J Mol Sci* 2023;24:2078. <https://doi.org/10.3390/ijms24032078>.

Leermakers FAM, Tolman Length for Binary Polymer–Polymer and Polymer–Solvent Systems. *Macromolecules* 2024;57:11565–75. <https://doi.org/10.1021/acs.macromol.4c02073>.

Leermakers FAM, Egorov SAA. No violations of critical-point wetting in ternary three fluid-phase systems with short range interactions. *J Colloid Interface Sci* 2025;679:124–34. <https://doi.org/10.1016/j.jcis.2024.10.101>.

## Thomas Kodger

The microscopic and mesoscopic structure of soft materials determines how these functions and can make them ultrasoft or even adhesive. Are you interested in designer materials with macroscopic properties?

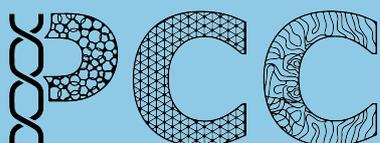


### Highlighted Publications

Safari M, Wang Q, Schreur-Piet I, de Vries R, Kodger TE. Photonic Whitener Pigments: A Sustainable Alternative to Titanium Dioxide Nanoparticles. *Adv Opt Mater* 2025;13. <https://doi.org/10.1002/adom.202401983>.

Antonelli R, Fokkink R, Sprakel J, Kodger TE. Dynamics of individual inkjet printed picoliter droplet elucidated by high speed laser speckle imaging. *Soft Matter* 2024;20:2141–50. <https://doi.org/10.1039/D3SM01701J>.

van Zwieten R, Bierman T V., Klinkhamer PGL, Bezemer TM, Vrieling K, Kodger TE. Mimicking natural deterrent strategies in plants using adhesive spheres. *Proceedings of the National Academy of Sciences* 2024;121. <https://doi.org/10.1073/pnas.2321565121>.





## Siddharth Deshpande

Biocentric, interdisciplinary research using lab-on-a-chip technology. Figuring out the fascinating self-organization in living cells. Want hands-on experience in creating synthetic cells, understanding protein phase separation, or designing biosensors using colourful crystals?

### Highlighted Publications

Ganar KA, Nandy M, Turbina P, Chen C, Suylen D, Nihoul E, Pascoe EL, van der Beelen S, Plaum M, van den Bos L, Koenraadt CJM, Dijkgraaf I, Deshpande S. Phase separation and ageing of glycine-rich protein from tick adhesive. *Nature Chemistry* 2025;17:186–197.

<https://doi.org/10.1038/s41557-024-01686-8>

Chen C, Love CM, Carnahan CF, Ganar KA, Parikh AN, Deshpande S. Regulating biocondensates within synthetic cells via segregative phase separation. *ACS Nano* 2025;19(22):20550–20563.

<https://doi.org/10.1038/s42004-024-01270-8>.

Honaker LW, Eijffius A, Plankensteiner L, Nikiforidis C V., Deshpande S. Biosensing with Oleosin-Stabilized Liquid Crystal Droplets. *Small* 2024; 2309053. <https://doi.org/10.1002/sml.202309053>.

## Francesco Simone Ruggeri

The structural and chemical properties of biomolecules and materials allow them to solve their functions. Are you ready to understand how their properties impact their function one molecule at a time by nanoscale imaging and spectroscopy?

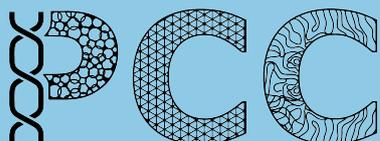


### Highlighted Publications

Miller A, Chia S, Klimont E, Knowles TPJ, Vendruscolo M, Ruggeri FS. Maturation-dependent changes in the size, structure and seeding capacity of A $\beta$ 2 amyloid fibrils. *Commun Biol* 2024;7:153. <https://doi.org/10.1038/s42003-024-05858-7>

Miller A., Chia S., Toprakcioglu Z., Hakala T., Schmid R., Feng Y., Kartanas T., Kamada K., Vendruscolo, Ruggeri F.S., Knowles T.P.J., Enhanced surface nanoanalytics of transient biomolecular processes, *Science Advances*, 2023, 9 (2), eabq3151. <https://doi.org/10.1126/sciadv.abq3151>.

Ruggeri F., Li X., Pujari S et al. Unravelling Emergence of Chirality in Click-Chemistry Polymers Down to the Single-Chain Level, 09 October 2024, Research Square, <https://doi.org/10.21203/rs.3.rs-5105035/v1>





## Uddalok Sen

How can we use soft matter physics to identify universalities in living and non-living systems? And how does that translate to addressing societal challenges? Learn more at: <https://www.physm-lab.org>

### Highlighted Publications

Thayyil Raju L, Diddens C, Rodríguez-Rodríguez J, van der Linden MN, Zhang X, Lohse D, et al. Evaporation of binary liquids from a capillary tube. *J Fluid Mech* 2024;983:A21.

<https://doi.org/10.1017/jfm.2024.122>.

Amador GJ, Klaassen van Oorschot B, Sen U, Karman B, Leenders R. Capillary adhesion of stick insects. *Ann N Y Acad Sci* 2024;1538:98–106. <https://doi.org/10.1111/nyas.15195>.

Sanjay V, Sen U, Kant P, Lohse D. Taylor-Culick retractions and the influence of the surroundings. *J Fluid Mech* 2022;948:A14. <https://doi.org/10.1017/jfm.2022.671>

## Joice Kaschuk

Transforming renewable resources into nanomaterials including nanocellulose and nanolignin. My research includes: (1) green processes for converting biomass to nanomaterials, (2) design of multifunctional materials in cutting-edge technologies.



### Highlighted Publications

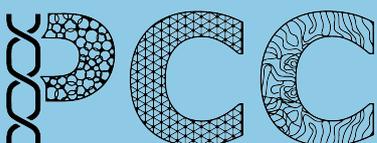
Valdez Garcia J, Boding A, Yang X, Nizamov R, Reid MS, Junel K, et al. Multifunctional nanocellulose hybrid films: From packaging to photovoltaics. *Int J Biol Macromol* 2025;292:139203.

<https://doi.org/10.1016/j.ijbiomac.2024.139203>.

Kaschuk JJ, Al Haj Y, Valdez Garcia J, Kamppinen A, Rojas OJ, Abitbol T, et al. Processing factors affecting roughness, optical and mechanical properties of nanocellulose films for optoelectronics. *Carbohydr Polym* 2024;332:121877. <https://doi.org/10.1016/j.carbpol.2024.121877>.

Banvillet G, Pritchard S, Kaschuk JJ, Shi X, Imani M, Lu Y, et al. Monolithic nanocellulose films patterned with flower-shaped and other microstructures: A facile route to modulate topographical, wetting and optical properties. *Mater Today Nano* 2023;24:100424.

<https://doi.org/10.1016/j.mtnano.2023.100424>.



## Our Technical Support Staff



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Diane Heusinkveld-te  
Brake



Raoul Fix

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Rene Hoogendam



Dirk Heering



Bart van Oort



Nicolo Alvisi

## Our Administrative Staff



Leonie Breuers



Claudia Riemsdijk-  
Cornelisse

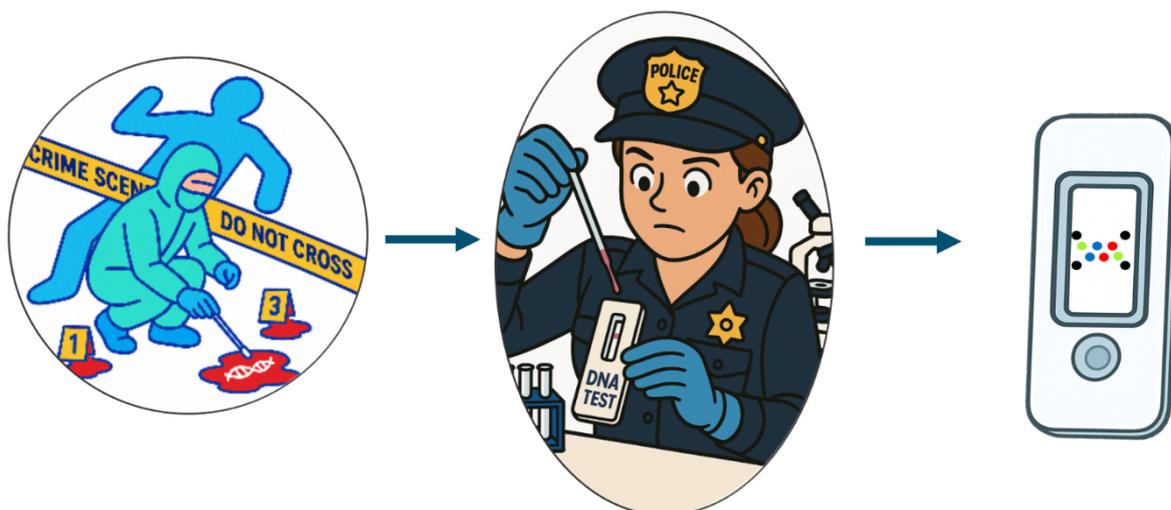
# Offered BSc/MSc Projects

## Speeding-up crime scene investigation: Rapid DNA detection by Lateral Flow Assays

**Sophie van Rooijen**, Organic Chemistry (ORC), Physical Chemistry and Soft Matter (PCC) & BioSensing and Diagnostics (BSD)

While simple single analyte Lateral Flow Assay (LFA) tests became well known to the general public due to self-testing during the COVID-19 pandemic, the LFA format also lends itself very well for detection of many analytes in other contexts. For example, in forensics it would be very valuable to rapidly screen for the presence of DNA, such that it becomes clear whether a trace contains human DNA, whether the DNA is from the victim or perpetrator, etc..

Our goal is to develop multiple diagnostic platforms for the detection of trace DNA. The project offers hands-on experience across a broad range of activities, such as LFA development and optimization, multiplex PCR, organic synthesis, nanoparticle synthesis and functionalization, DNA extraction, 3D printing, and electrochemical sensing.



This project is a collaboration with the Laboratory of Organic Chemistry (ORC), Physical Chemistry and Soft Matter (PCC) and BioSensing and Diagnostics (BSD) from Wageningen Research. Please don't hesitate to contact us if you're interested in bridging the gap between fundamental principles and applied research.

### Contact information

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BSD:  
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[aart.vanamerongen@wur.nl](mailto:aart.vanamerongen@wur.nl)

# Offered BSc/MSc Projects

## Plasticization effect of Pluronic in zein coacervate-based food packaging films

Qin Li, Physical Chemistry and Soft Matter (PCC)

Single-use plastic food packaging is a growing environmental concern which calls for an alternative. Bio-based materials are promising substitutes for these types of food packaging. Their performance however (e.g. mechanical properties and barrier properties), is still falling behind and new approaches are needed to bring their performance to the same level as traditional materials to replace them.

To enhance the mechanical performance of biobased films, experiments will be performed using Pluronic as plasticizers in zein (a major protein in corn) coacervates to fabricate food packaging films. Pluronic is a block copolymer composed of hydrophilic poly(ethylene oxide) (PEO) and hydrophobic poly(propylene oxide) (PPO), arranged in a triblock structure (PEO-PPO-PEO). Due to their tunable

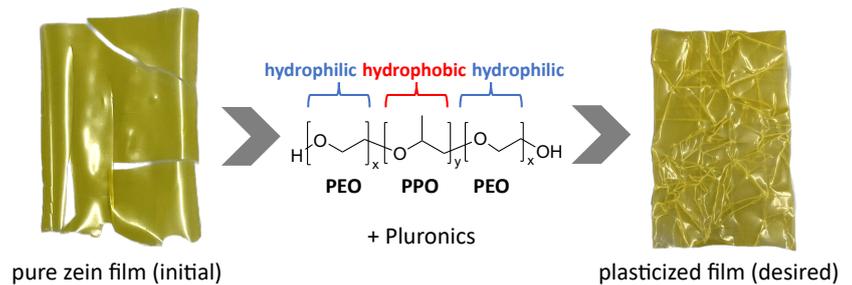


Figure 1 - Pluronic may function as plasticizers, inducing a brittle-to-flexible transition in zein coacervate films (hypothesis).

structure and amphiphilic nature, Pluronic is expected to enhance the mechanical properties of zein films while preserving their inherent hydrophobic characteristics.

In this project, you will explore the potential of Pluronic as plasticizers for zein coacervate films. The work will begin with incorporating Pluronic into zein coacervates, followed by drying the mixtures to make films. Optimization may include adjusting the composition and concentration of Pluronic. At the appropriate stage, you will zoom in and evaluate the plasticized films to validate the effectiveness of Pluronic as plasticizers.

### Learning goals:

- Using zein coacervates as a novel approach to make Pluronic-filled zein films;
- Optimizing and characterize Pluronic-filled coacervate films;
- Using techniques:
  - Rheometer (measure the rheological properties of coacervates, such as viscosity)
  - Dynamic mechanical analyzer (measure the mechanical properties of films)
  - Contact angle (measure the hydrophobicity of films)

### Contact information

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Renko de Vries  
Helix room 7056  
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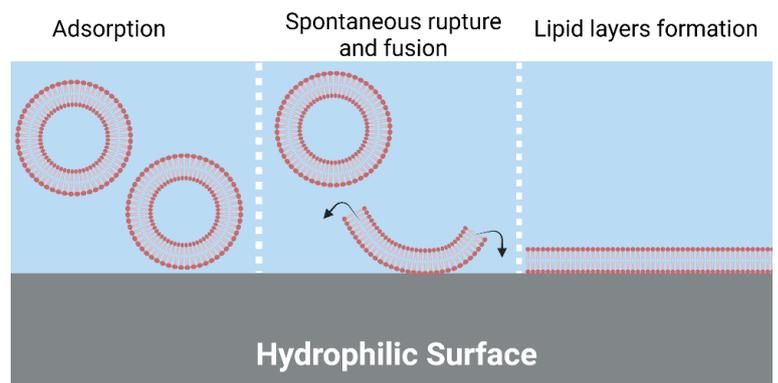
# Offered BSc/MSc Projects

## Replicating natural adhesion: creating supported lipid layers in the lab

**Alireza Kh. Kolour**, Physical Chemistry and Soft Matter (PCC) & Experimental Zoology (EZO)

Geckos and various organisms utilize surface-supported lipid layers to manage adhesion, wetting, and surface interactions. Drawing inspiration from these natural systems, our research explores how lipids engage with surfaces and proteins to establish stable and controllable adhesion.

In this project, you will replicate nature by applying lipid layers onto soft synthetic materials like PDMS (polydimethylsiloxane) and keratin-based surfaces using vesicle fusion, where lipid vesicles naturally rupture to create a supported lipid layer. Importantly, we will use micro-patterned surfaces that mimic Gecko footpads. By understanding how lipid composition and surface material influence coating quality and adhesive force, we can design advanced bio-inspired adhesive pads. The resulting supported lipid layers will be analyzed using fluorescence microscopy and indentation force measurement.



**Skills You Will Learn:** Lipid vesicle preparation and surface coating methods, DLS operation and data analysis, fluorescence microscopy for imaging lipid membranes, experimental skills, and scientific reporting.

We are looking for enthusiastic students (MSc thesis or 24-ECTS BSc thesis) who are interested in biophysical chemistry. No previous experience with lipid systems is necessary—comprehensive training will be provided.

**Research Environment:** You will be part of a collaborative and interdisciplinary research team that operates at the intersection of experimental zoology, soft matter physics, and physical chemistry.

### Contact information

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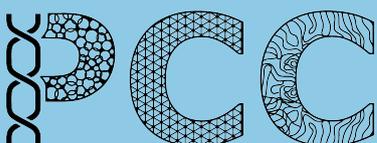
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# Offered BSc/MSc Projects

## Microfabricating bio-inspired adhesive pads

**Alireza Kh. Kolour**, Physical Chemistry and Soft Matter (PCC) & Experimental Zoology (EZO)

Geckos achieve extraordinary adhesion through millions of microscopic hair-like structures called **setae** on their toe pads. These hierarchical structures enable geckos to generate strong yet reversible adhesion on a wide variety of substrates. To translate this biological strategy into materials science and engineering, our research seeks to fabricate **artificial adhesive pads** that mimic the geometry and functionality of gecko setae.

In this project, you will employ photolithography and microfabrication methods to produce microstructured surfaces that mimic the gecko's adhesive pads. These artificial pads will be constructed from materials like PDMS (polydimethylsiloxane), Dragon Skin™, Ecoflex™, and keratin-based polymers, allowing for a comparison between synthetic and bio-derived materials. Subsequently, you will assess their adhesive performance using an in-house indentation force measurement setup.

We are looking for enthusiastic students (MSc thesis or 24-ECTS BSc thesis) who are interested in microfabrication. Prior lab or cleanroom experience is beneficial but not mandatory—you will receive training in all essential techniques.

You will collaborate closely with researchers from Experimental Zoology and Physical Chemistry & Soft Matter, gaining practical experience in a multidisciplinary and innovative research setting. Skills You Will Learn: Cleanroom and microfabrication techniques, polymer casting, microscopic imaging, and force indentation measurements.

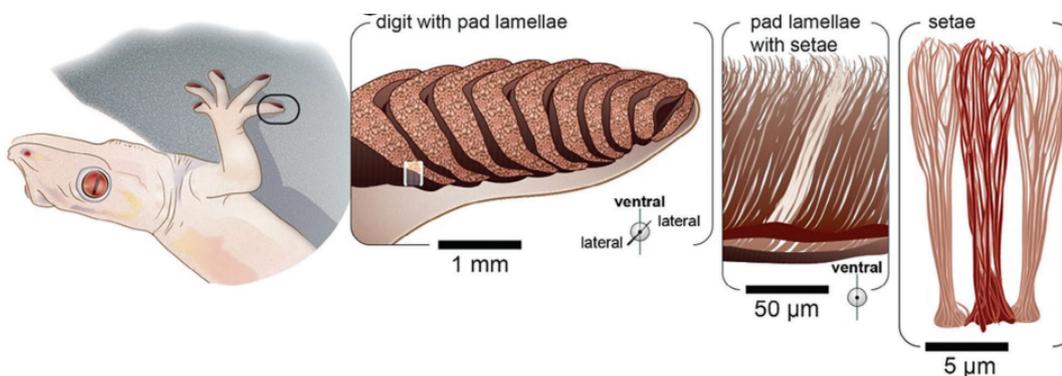


Figure 1. Image from Kasper et al., *Advanced Science*, 2023.

### Contact information

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# Offered BSc/MSc Projects

## Biochemical Characterization of Gecko Corneous $\beta$ -proteins

**Alireza Kh. Kolour**, Physical Chemistry and Soft Matter (PCC) & Experimental Zoology (EZO)

Have you ever wondered how geckos climb walls with ease—even when they're upside down? Are you keen on contributing to the development of bio-inspired technologies that could be used in agriculture, medicine, and advanced materials? If so, this might be the perfect opportunity for you!

Our research team investigates how surface-supported lipids and proteins play a role in biological adhesion. Recently, scientists discovered a corneous  $\beta$ -protein (CBP) in the gecko's adhesive toepads—a protein that could affect adhesion strength, surface interactions, and the lipid layer's stability. Gaining insight into its biochemical properties is crucial for developing advanced bio-inspired adhesive systems.

We are seeking enthusiastic students (MSc thesis or 24-ECTS BSc thesis) who have an interest in protein biochemistry, bio-inspired materials, and experimental lab work. The primary goal of this project is to express selected corneous  $\beta$ -proteins in *E. coli*, purify them, and conduct initial biochemical characterization. The purified proteins will play a vital role in ongoing experiments that explore how protein–lipid interactions facilitate gecko adhesion.

You will join an interdisciplinary team of engineers, chemists, physicists, and biologists from the Experimental Zoology and Physical Chemistry & Soft Matter research groups.

What you will learn and work with: Recombinant protein expression in *E. coli*, protein purification processes, structural and biochemical characterization of proteins, data analysis, scientific documentation, and disseminating results within a multi-disciplinary research team. No previous experience in protein biochemistry is necessary – training will be provided. The most important qualities are curiosity, motivation, and a desire to learn.

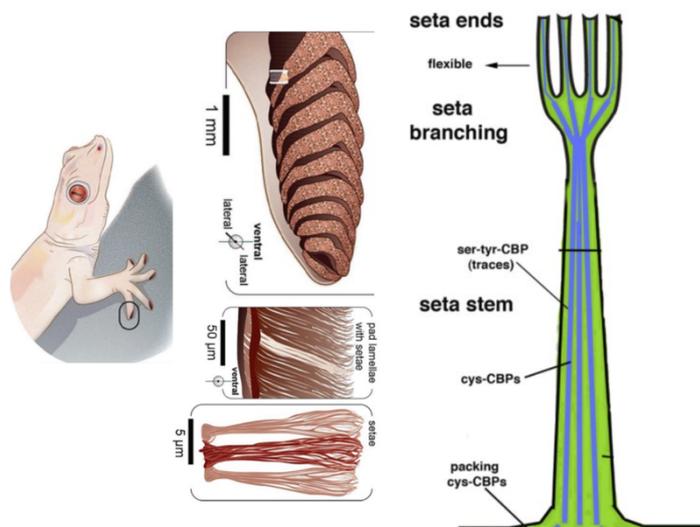


Figure 2. Images from Alibardi, *Microscopy Research and Technique*, 2020 and Kasper et al., *Advanced Science*, 2023.

### Contact information

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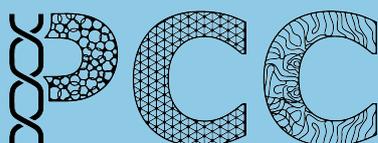
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# Offered BSc/MSc Projects

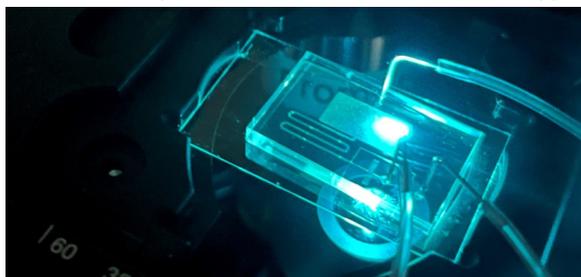
## Particle-stabilized soft materials: biocondensates

Xuefeng Shen, Physical Chemistry and Soft Matter (PCC)

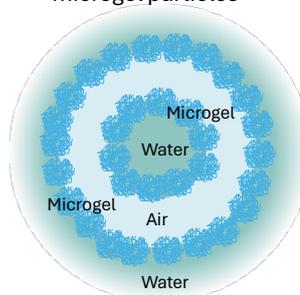
The adsorption of colloidal particles at the fluid interface is a promising route for the fabrication of new soft materials. Particle-stabilized emulsions, also known as Pickering emulsions, have promising applications in areas that require minimized use of surfactants and long-term stability including food, agriculture, and biomedicine<sup>[1]</sup>. In this work, we aim to apply and explore Pickering emulsion theory in various multiphase systems, including antibubbles and biomolecular condensates.

In this project, you will explore how to regulate biomolecular condensates via Pickering agents. Liquid-liquid phase separation and resulting condensates have emerged as a new principle for cellular organization. Protein clusters at interfaces can control the size as well as material properties of biomolecular condensates. You will use lab-on-chip techniques to regulate condensate dynamics via interfacial protein clusters <sup>[2]</sup>.

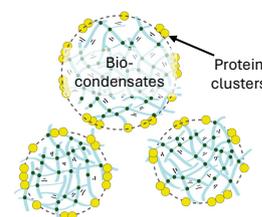
Lab-on-a-chip device with fluorescence microscopy



Antibubbles stabilized by microgel particles



Biocondensates regulated by protein clusters



**Techniques you will learn:** Microfabrication, microfluidics, emulsion production, fluorescence microscopy, image analysis

### Reference:

1. X. Shen, C. Chen, B. van der Meer, T. E. Kodger, U. Sen, S. Deshpande, J. van der Gucht, *Adv. Sci.*, 2409903.
2. W. Folkmann, A. Putnam, C. F. Lee, G. Seydoux, *Science* 2021, 373, 1218.

### Contact information

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Helix room 6056

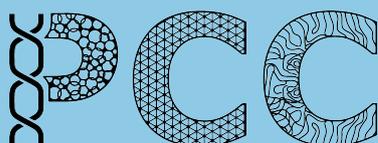
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# Offered BSc/MSc Projects

## Blood Samples from Aging Adults with Cognitive Decline: Nano-Imaging of Impact of Prebiotic Uptake

Mengsha Hu, Physical Chemistry and Soft Matter (PCC)

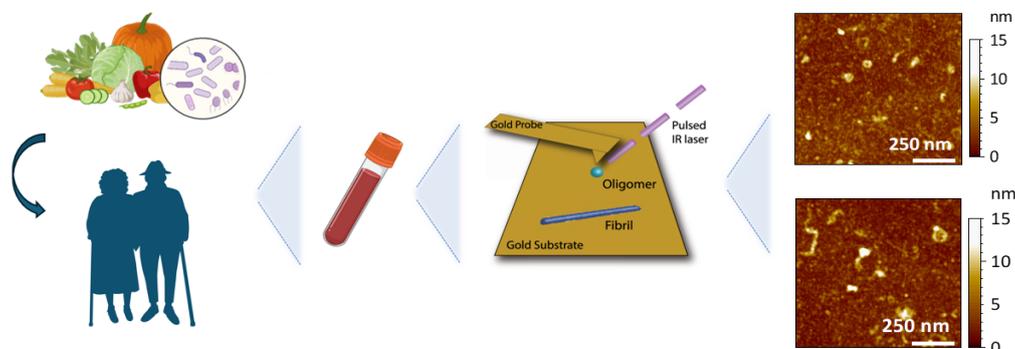


Figure 1. Nano-Imaging of blood samples from two cohorts with or without prebiotics

The burden of neurodegenerative diseases is increasing with the greying of our population. At the molecular level, neurodegeneration is associated with the misfolding and self-assembly of proteins into structures termed amyloid. Growing evidence suggests that diet and prebiotics may slow down the progression of cognitive decline, possibly by influencing underlying molecular processes, such as protein self-assembly. However, the molecular mechanisms by which diet and prebiotics may affect cognitive decline in older adults remain unclear.

In this project, you will analyze blood biofluids from two cohorts of aging individuals experiencing cognitive decline using atomic force microscopy (AFM). The goal is to determine whether dietary interventions and prebiotics can influence cognitive decline at the molecular level by examining the heterogeneity of protein aggregates in blood samples. You will gain a solid understanding of AFM principles and apply them to measure the nanoscale size distribution and morphology of protein aggregates, as well as potentially other biological components. For example, AFM can be used to characterize individual fibrils or oligomers, after which advanced software is used to detail 3D particle analysis, including measurements of height, diameter, and circularity of oligomers, and the length and periodicity of fibrils. Subsequently, statistical methods will be used to quantify and interpret differences between healthy control samples and those from individuals with cognitive impairment.

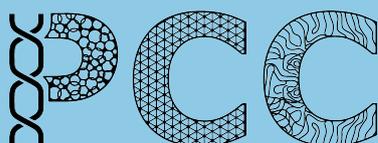
### Learning objectives:

- Study blood serum from two PRECODE project cohorts of aging individuals with cognitive decline, comparing those with and without prebiotic uptake
- Use AFM to acquire 3D maps of blood samples from the two cohorts
- Analyze the AFM maps using specialised software to do advanced particle analysis

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# Offered BSc/MSc Projects

## Investigating Blood Samples from Aging Adults with Cognitive Decline: Chemical Analysis of Impact of Prebiotic Uptake

Mengsha Hu, Physical Chemistry and Soft Matter (PCC)

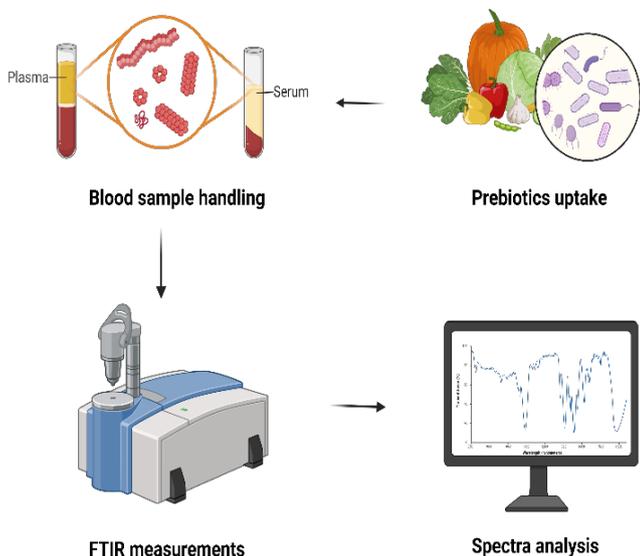


Figure 1 FTIR measurements of blood samples from two cohorts with or without prebiotics

The burden of neurodegenerative diseases is expected to increase with the greying of our population. Subjective cognitive decline (SCD) is considered the first manifestation of neurodegeneration. At the molecular level, neurodegeneration is associated with the misfolding and self-assembly of proteins into structures termed amyloid. Growing evidence suggests that diet and prebiotics may slow down the progression of cognitive decline, possibly by influencing underlying molecular processes, such as protein self-assembly. However, the molecular mechanisms by which diet and prebiotics may affect cognitive decline in older adults remain unclear.

In this project, you will be working on blood biofluids from two cohorts of aging individuals experiencing cognitive decline, provided by the

PRECODE project, which aims to assess whether diet and prebiotics can target cognitive decline and counteract the physiological changes in the human organism at the molecular level, by analyzing the amyloid presence in blood biofluids. You will gain a comprehensive understanding of the working principles of FTIR and apply this knowledge to analyze how various biological components differ as observed in an FTIR spectrum. For example, you can use FTIR to characterize proteins, carbohydrates, lipids, and small metabolites in blood plasma and serum, as well as cellular components if present. Finally, chemometrics analysis and AI techniques will be used to quantify the observed differences.

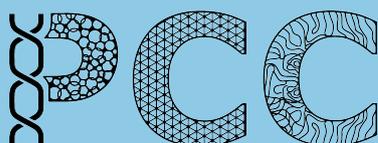
### Learning objectives:

- Study blood serum samples from two PRECODE project cohorts of aging individuals with cognitive decline, comparing those with and without prebiotic uptake
- Use ATR-FTIR to acquire the spectrum of blood samples from the two cohorts
- Analyze the FTIR spectra using OriginPro to do advanced chemometrics analysis

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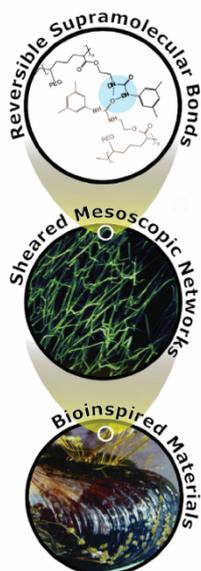
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# Offered BSc/MSc Projects

## Self-healing under stress: zooming into the response of reversible materials

Niyousha Davari, Physical Chemistry and Soft Matter (PCC)



Did you know that stimuli-responsive materials, like those found in nature, can respond to triggers like temperature, pH, or enzymes by changing their physical and chemical properties? For example, human skin heals itself through an inflammatory response that increases collagen production, helping regenerate new skin cells and tissue. Inspired by nature, researchers have created synthetic materials with dynamic, non-covalent bonds to mimic the self-healing ability of natural systems. A self-healing material is able to heal itself due to molecular interactions; however, how these bonds work together at larger scales (meso/macroscale) is not completely clear. Thus, we need detailed insights into their mesoscopic and macroscopic behaviors to fully grasp how multiscale dynamics, stimuli, bond chemistry, and healing kinetics interact. By understanding these phenomena by performing well-designed experiments, we can design effective self-healing materials for real-world applications.

During this project, you will develop and study synthetic protein-based self-healing materials to uncover their cooperative mechanisms. The project

includes:

- 1. Hydrogel Preparation:** Creating protein-based hydrogels through different approaches.
- 1. Hydrogels Characterization:** Analyzing hydrogels' recovery behavior using a rheometer and confocal microscopy.

### Possible Learning Goals include (but not limited to):

- Produce protein-based self-healing hydrogels
- Gain expertise in analytical techniques:
  - **Rheometry:** To measure material breaking and recovery
  - **Confocal Microscopy:** To observe structural changes in the materials

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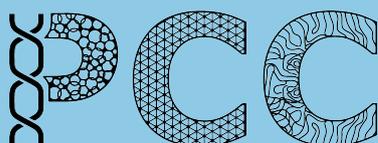
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# Offered BSc/MSc Projects

## Low-Temperature Processable Glasses – Using Polyelectrolyte Complexes doped with Small Molecules

Yongfang Lu, Physical Chemistry and Soft Matter (PCC)

Electrostatically assembled small-molecule–polyelectrolyte complexes are a new versatile platform for tuning thermomechanical properties through compositional design. In this work, you will demonstrate that introducing charged small molecules into polyelectrolyte complexes (doping) can enable precise control over the glass transition temperature ( $T_g$ ) and relaxation dynamics. By systematically varying the fraction of small molecules within the complexes, you will obtain materials with a wide range of  $T_g$  values and relaxation times. Notably, preliminary experiments show that small-molecule-doped complexes exhibit significantly reduced  $T_g$  and shortened relaxation times, which allow for fast processing at relatively low temperatures (40–80 °C) i.e. glass blowing at nearly room temperature (see Figure 1b). These features make the complexes particularly attractive for low-temperature, fast-processing manufacturing and 3D printing applications.

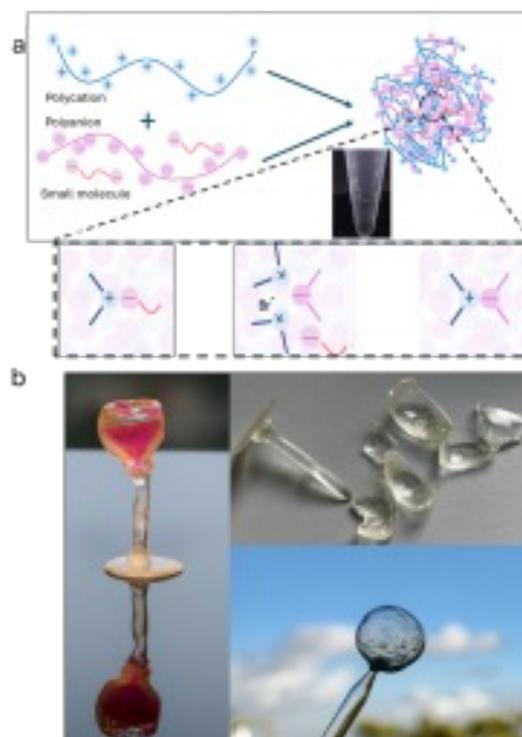


Figure 3 a. Formation of complexes, b. Wine glass (right), broken wine glass (right top), glass blowing (right bottom) of the complex.

In this project, you will work on (Learning Goals):

- Optimizing the complexation medium to make complexes with different ratios of components including some synthetic chemistry.
- Characterizing them by using techniques such as NMR, XPS, TGA...
- Investigating the thermomechanical properties of these complexes via rheology.
- Data management and data analysis.

\*Although we have already made initial progress, this project remains challenging and would be well suited for MSc thesis only.

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# Offered BSc/MSc Projects

## From garden to clinic: sustainable and greener production of nanocellulose from rose residues for medical applications

Chotiwit Sriwong, Physical Chemistry and Soft Matter (PCC)

The use of sustainable and biodegradable materials in various applications, including medical technologies, has gained significant attention in recent years. Carboxylated cellulose nanofibrils (C-CNFs) derived from agricultural waste, such as rose residues, offer a promising solution for developing high-performance, eco-friendly materials that help reduce waste. C-CNFs exhibit excellent mechanical properties, biodegradability, and tunable surface chemistry, making them ideal for diverse applications such as antimicrobial filters for respiratory systems in hospitals, bone tissue engineering scaffolds, water filtration membranes, and biodegradable packaging.

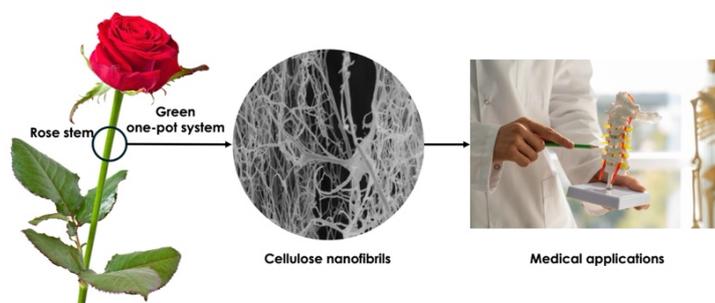


Figure 1 - Schematic illustration of converting rose stem residues into cellulose nanofibrils for medical applications.

During this project, you will work on optimizing a green "one-step process" to produce C-CNFs from biomass using environmentally friendly processes. This involves combining insights from the scientific literature with experimental techniques to enhance yield, efficiency, and material quality. Furthermore, you will investigate the self-assembly properties of CNFs to develop functional materials, tailored for specific applications. The project also provides opportunities to test C-CNFs across a range of innovative applications, contributing to the advancement of sustainable materials in modern science.

### Learning goals:

- Optimize the "one-pot" C-CNF production process through experimentation and analysis.
- Design and test C-CNF-based materials for specific applications.
- Characterize the C-CNFs using advanced techniques such as functional change (FTIR, NMR), crystallinity (XRD), morphology (SEM, TEM), zeta potential (DLS) and rheology.

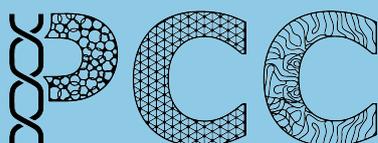
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# Offered BSc/MSc Projects

## Mechanical properties of hydrogel-based bioplastic from alginate and cellulose for food packaging

**Anggita Sari Praharasti**, Physical Chemistry and Soft Matter (PCC) & Food Process Engineering (FPE)

Bioplastics are an alternative to fossil-based plastics. They already have been produced with various compositions of biobased materials and being used for a wide range of applications including food packaging.

In this project, you will produce hydrogel-based materials combining brown seaweed (alginate) and cellulose nanofibrils. Hydrogels are excellent moisture-retention properties, which help in preserving the freshness of perishable foods. However, water vapour transition and great mechanical properties are still the main challenge on the development of such materials.

The main objective of this project is to understand how mechanical properties (tensile strength and elongation) can be altered by altering the hydrogel composition. Both biobased materials and plasticizers will be considered in the formulation of these materials.

### Learning goals:

- Producing hydrogel-based materials composed by alginate, cellulose nanofibrils and plasticizer at different concentrations.
- Understanding the effects of the compositions in mechanical properties and water interactions (swelling degree, water contact angle)
- Using analytical techniques:
  - o IR (characterization of the molecules)
  - o DMA (measurement of modulus, elongation, tensile strength)
  - o SEM (physical characterization of the resulted hydrogel-based bioplastic)



Figure 1 – Digital image of a hydrogel-based bioplastic.

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# Offered BSc/MSc Projects

## Toughening Polyelectrolyte Complexes with Modified Silica Nanoparticles

Yongfang Lu, Physical Chemistry and Soft Matter (PCC)

The goal of this project is to develop plastics based on polyelectrolyte complexes (PECs) and enhance their toughness by incorporating modified nanoparticles. Coulomb's (electrostatic) interactions between charged microdomains of two oppositely charged polymers result in the formation of polyelectrolyte complexes (PECs). PECs can be liquids (when hydrated), elastic PECs (when wet) and, often brittle and fragile, solids (when dry) as a result of strong interactions between charged groups. Though easy to prepare, PECs are extremely difficult to dry process as a result of these negative properties, thus limiting application. In this project, we first design and synthesize a novel class of polyions with bulky side group or long side chain, which will be used to form PECs with different ratios of  $\text{Pol}^+/\text{Pol}^-$ . Moreover, we envision these plastics can be easy to repair and recycle, thus contributing to the concept of circular economy.

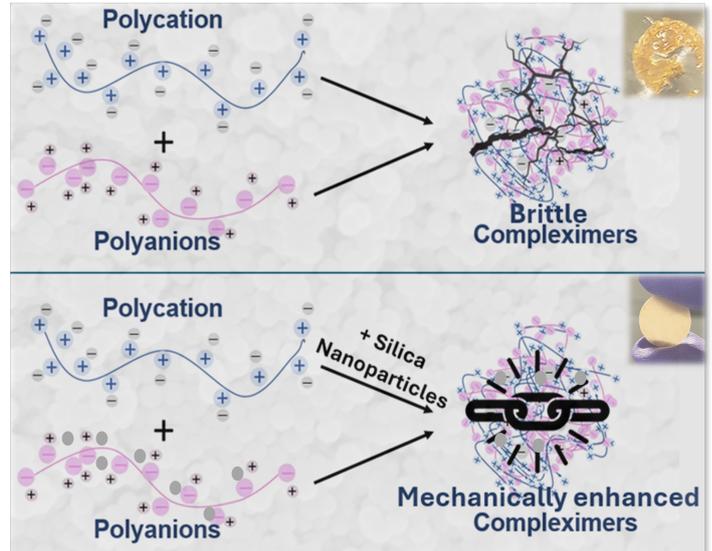


Figure 1 - Formation of composites, cationic (pink) and anionic (blue) polymers, Nanoparticles (grey circles).

In this project, you will work on enhancing the toughness of manufactured plastics by incorporating modified nanoparticles. The work mainly involves synthesizing nanoparticles, integrating them into the plastics, and using a Instrumented Indentation Tester to evaluate their impact on mechanical properties. You will explore how nanoparticle design and dispersion influence the toughness, providing insights into the development of more durable and sustainable materials.

Learning goals:

- Synthesizing nanoparticles.
- Develop composites of (PECs) and nanoparticles, and characterize them using techniques such as SEM, DLS, Zeta Potential, NMR and XPS, Indentation Measurement, TGA.
- Evaluate the mechanical properties of these composites, including toughness, using Instrumented Indentation Tester.
- Data management and data analysis

\*Although we have already made initial progress and obtained encouraging results, this project remains challenging and would be well suited for master's students interested in further exploration.

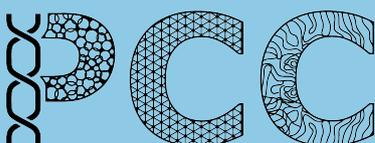
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# Offered BSc/MSc Projects

## Development of Biobased Photonic Whitener Using Hollow $\text{CaCO}_3$ Microparticles Templated by Zein Protein

Qimeng Wang, Physical Chemistry and Soft Matter (PCC)

Titanium dioxide ( $\text{TiO}_2$ ) is the world's most widely used whitener. However, increased costs and potential environmental concerns have driven a need for a sustainable replacement. Drawing inspiration from nature's coloration mechanisms, researchers have developed photonic whiteners that efficiently reflect light and address the drawbacks of  $\text{TiO}_2$ . Photonic whiteners require a disordered microstructure to scatter multiple wavelengths equally, thus requiring fabrication strategies with less exacting control over the resulting nanostructure. In this work, we plan to develop a sustainable methodology to synthesize hollow  $\text{CaCO}_3$  microparticles as photonic whiteners. Bio-resourced zein nanoparticles are synthesized and used as sacrificial templates, which will be co-precipitated with  $\text{CaCO}_3$ . After forming  $\text{CaCO}_3$ -Zein microparticles, we plan to use high-temperature calcination to remove zein sacrificial templates from the microparticles, resulting in hollow  $\text{CaCO}_3$  microparticles.

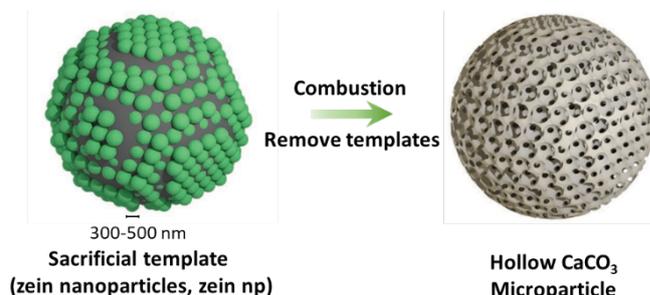


Figure 1- Scheme of hollow  $\text{CaCO}_3$  microparticle synthesis.

During this project, you will be working on optimizing the current procedures to synthesize the hollow  $\text{CaCO}_3$  microparticles. Adjust the ratio of zein nanoparticles and  $\text{CaCO}_3$  to obtain the hollow  $\text{CaCO}_3$  microparticles with closed shell and porous interior, thereby achieving better stability and a stronger whitening effect.

### Learning goals:

- Synthesizing hollow  $\text{CaCO}_3$  microparticles as photonic whiteners.
- Using co-precipitation combined with combustion to synthesize hollow  $\text{CaCO}_3$  microparticles
- Using analytical techniques:
  - o Confocal microscope (characterization of the  $\text{CaCO}_3$ -Zein microparticles)
  - o SEM (characterization of both  $\text{CaCO}_3$ -Zein microparticles and hollow  $\text{CaCO}_3$  microparticles)
  - o Combustion (a thermal treatment in a Paragon Caldera kiln, to remove the zein templates)
  - o Spectrometer (Characterization of the whitening effect of obtained photonic whiteners)

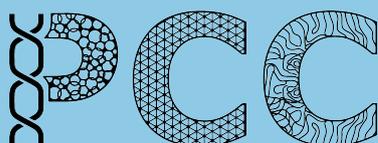
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# Offered BSc/MSc Projects

## Nano-imaging single protein self-assemblies in human blood samples to define healthy cognitive ageing

Lutger Rutten, Physical Chemistry and Soft Matter (PCC)

The global population is getting older and the prevalence of age-related neurodegenerative diseases, like **Alzheimer's** and **Parkinsons disease**, is on the rise. While we know that self-assembly of the peptides and protein are involved in cognitive decline and neurodegeneration, little is known about the **structural properties** of these assemblies at the earliest stages of these diseases and during **healthy cognitive ageing**. Furthermore, we know that the mediterranean diet can be used to promote healthy cognitive ageing. However, the mechanism behind this remains unknown.

To better understand healthy cognitive ageing, we are investigating these protein aggregates and trying to understand their **structural properties**. Additionally, we will relate the observed structural properties to the nutrition data collected during the NU-AGE study to understand how nutrition influences protein self-assembly in healthy cognitive ageing.

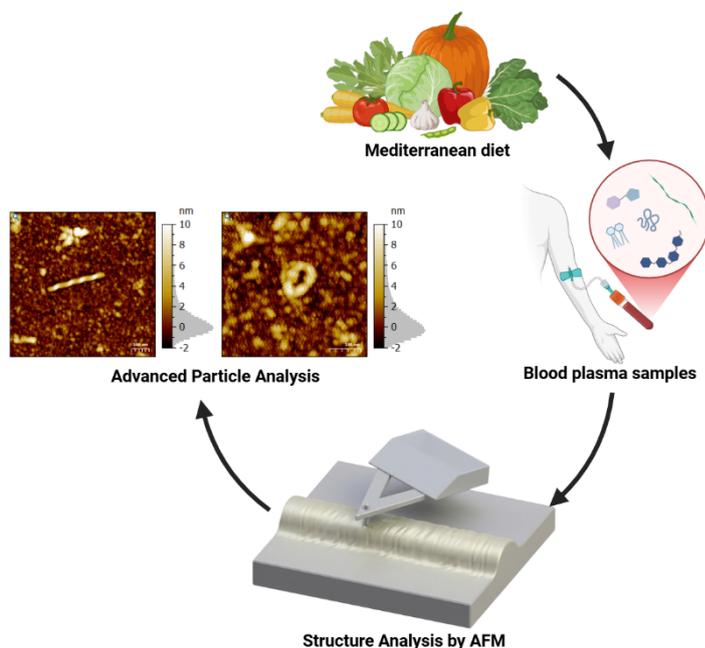


Figure 4. You will study the effects of the mediterranean diet on the structural properties of protein aggregates in blood samples of healthy ageing elders using AFM.

You will study plasma samples from people that have been ageing healthy while following a mediterranean diet for 1 year, as well as samples from a control group. Using **atomic force microscopy (AFM)** you will study the structure of **single protein aggregates** in the blood samples and using detailed **particle analysis** you will extract information on the **structural state of proteins** in the blood samples. You will identify the possible structural signature of protein self-assembly to then find patterns of this molecular process in relationship to healthy cognitive ageing and nutrition.

### Learning Objectives:

- Study blood samples of healthy ageing elders from the NU-AGE clinical trial.
- Use atomic force microscopy to acquire 3D morphology maps of blood plasma samples.
- Analyze the morphology maps with advanced particle analysis software to determine the structural properties of protein self-assembly in the samples.

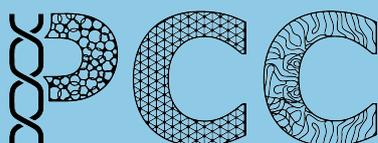
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# Offered BSc/MSc Projects

## Investigating the chemistry of human blood samples to define healthy cognitive ageing

Lutger Rutten, Physical Chemistry and Soft Matter (PCC)

The global population is getting older and the prevalence of age-related, neurodegenerative diseases, like **Alzheimer's disease** and **Parkinsons disease**, is on the rise. The NU-AGE clinical trial hypothesized that the Mediterranean diet can be used to promote **healthy cognitive ageing**, and this has recently been confirmed in a new publication. However, the exact mechanisms behind this remain unknown. While we know that self-assembly of peptides and protein is involved in cognitive decline and neurodegeneration, little is known about how the structural-chemical properties of these assemblies are influenced by **nutrition**. To better understand healthy cognitive ageing, we are investigating these protein aggregates and trying to understand nutrition's effects on their **structural-chemical properties**. As obtaining blood samples is less invasive than obtaining brain tissue or performing a lumbar puncture, it is therefore the preferred matrix to study healthy cognitive ageing. In this project, you will use state-of-the-art **attenuated total reflectance FTIR (ATR-FTIR)** to determine the general chemical state of blood samples.

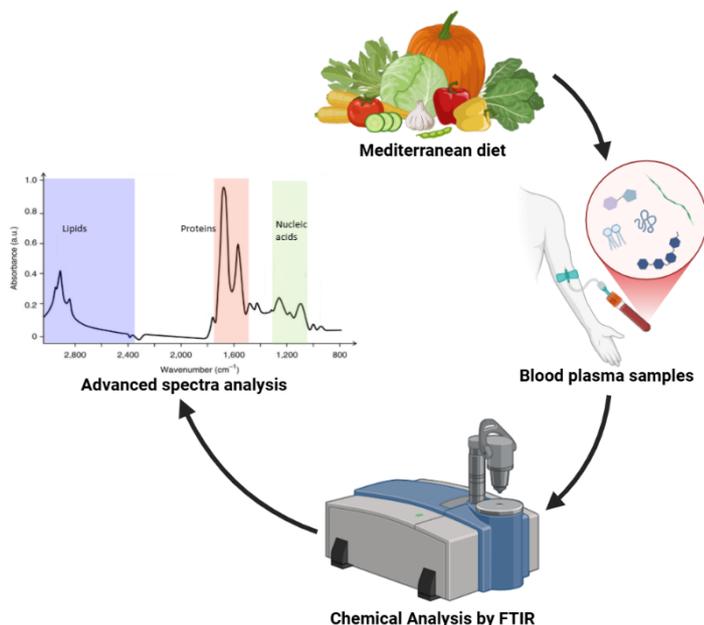


Figure 5. You will study the effects of the mediterranean diet on the blood samples of healthy ageing elders using ATR-FTIR. Spectrum obtained from (Baker et al, 2014).

You will study plasma samples from people that have been ageing healthy while following a mediterranean diet for 1 year, as well as samples from a control group. Using advanced chemometrics you will process the data to extract information on the chemical state of **proteins and metabolites** in the blood samples. You will identify the possible chemical signature of protein self-assembly to then find patterns of this molecular process in relationship to healthy cognitive ageing and nutrition.

### Learning Objectives:

- Study blood samples of healthy ageing elders from the NU-AGE clinical trial
- Use state-of-the-art ATR-FTIR to acquire the spectra of blood plasma samples
- Analyze the FTIR data with advanced chemometrics to find patterns for protein self-assembly and the possible connection to healthy cognitive ageing in relation to nutrition

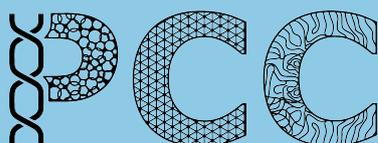
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# Offered BSc/MSc Projects

## Engineering Intracellular Communication in Synthetic Cells: A Bottom-Up Perspective

Udit Ghosh, Physical Chemistry and Soft Matter Group (PCC)

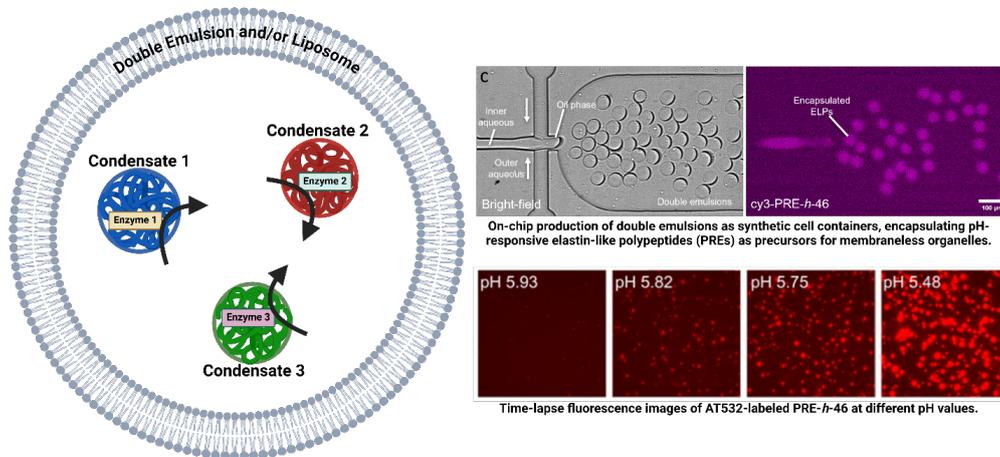


Figure 1 - A schematic illustrating membraneless organelles acting as reaction hubs.

*Are you curious about how cells compartmentalize themselves to facilitate biochemical reactions?*

Back in the 1950s, the membranous nature of optically prominent cytoplasmic compartments such as nucleus and mitochondria were discovered, each housing a distinct set of proteins enabling specialized functions. However, just over the last decade, we have begun to understand that cells also contain numerous and dynamic membraneless organelles, also known as biomolecular condensates, that form and dissolve as needed. De-mixing of multivalent biomolecules via the process of liquid-liquid phase separation are crucial to their formation and intrinsically disordered regions (IDRs) of proteins are found to play an active role in many of these condensates.

Together with you, we would like to use IDRs to compartmentalize synthetic cells – bottom-up mimics of living cells and address the intracellular communication through designer phase-separating membraneless organelles (MOs) in cell-like vesicle using on-chip microfluidic techniques, advanced microscopy, and molecular cloning. The idea is to generate multiple, functional, condensate-based compartments within synthetic cells to drive independent enzymatic reactions. The methodology involves making use of well-characterized pH-responsive elastin-like polypeptides (PREs) consisting of repetitive pentapeptide sequences and designing a family of their surfactant counterpart to stabilize the surface of corresponding MOs, preventing mixing. Furthermore, we will make use of our microfluidic expertise to make a variety of vesicles such double emulsions and liposomes in a controlled manner making it an effective setup to study the behavior of the PREs inside cell-mimicking confinements.

**Techniques you will learn:** Microfabrication, Microfluidics, Vesicle production, Protein engineering, Confocal microscopy, Image analysis.

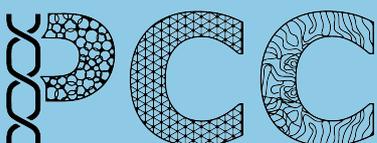
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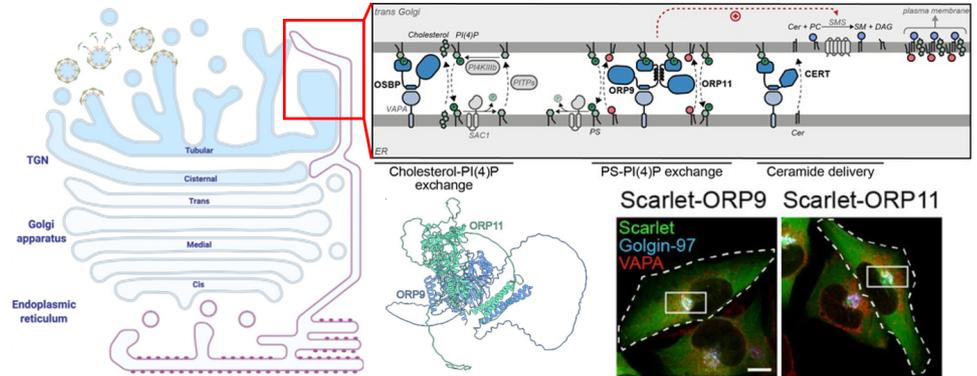


# Offered BSc/MSc Projects

## Phase Separation of Trans-Golgi Targeted Proteins ORP9-ORP11 and their role in membrane-contact site organization

Udit Ghosh, Physical Chemistry and Soft Matter Group (PCC)

Membrane contact sites are dynamic regions where organelles come into proximity to exchange lipids and signals without membrane fusion. These sites are highly crowded and must support rapid, localized biochemical reactions while remaining reversible and adaptable<sup>1</sup>. Increasing evidence suggests that liquid-liquid phase separation (LLPS) provides an effective mechanism to organize proteins at these sites by concentrating specific factors into dynamic assemblies<sup>2</sup>. Recent work on the lipid transfer proteins ORP9 and ORP11 has established their essential role in regulating sphingolipid metabolism at ER-Golgi contact sites. Studies so far have focused on their function as individual lipid exchange factors operating via protein-protein and protein-membrane interactions<sup>3</sup>. However, both proteins contain extended intrinsically disordered regions, suggesting that they could potentially phase separate to locally concentrate lipid transfer reactions and dynamically organize membrane contact site function.



Increasing evidence suggests that liquid-liquid phase separation (LLPS) provides an effective mechanism to organize proteins at these sites by concentrating specific factors into dynamic assemblies<sup>2</sup>. Recent work on the lipid transfer proteins ORP9 and ORP11 has established their essential role in regulating sphingolipid metabolism at ER-Golgi contact sites. Studies so far have focused on their function as individual lipid exchange factors operating via protein-protein and protein-membrane interactions<sup>3</sup>. However, both proteins contain extended intrinsically disordered regions, suggesting that they could potentially phase separate to locally concentrate lipid transfer reactions and dynamically organize membrane contact site function.

In this project, we aim to explore the phase separation propensity of ORP9 and ORP11 and investigate how LLPS may contribute to their cellular role. Building on preliminary observations, we will examine whether these proteins can demix into liquid-like assemblies, how this behavior depends on sequence features and environmental conditions, and how condensate formation reshapes their biochemical activity. Together with you, we will approach this question by characterizing their LLPS propensity using a combination of turbidity assays, fluorescence microscopy, and phase diagrams, reconstituting candidate condensates in synthetic liposomes to mimic membrane contact sites, and using advanced imaging to connect condensate formation with localized lipid exchange and membrane dynamics.

**Techniques you will learn:** Microfabrication, microfluidics, vesicle production, partitioning or binding assays, confocal microscopy, image analysis

### References:

1. Prinz et al. *Nature reviews Molecular cell biology* (2020)
2. Zhao et al. *Developmental Cell* (2020)
3. Cabukusta et al. *Elife* (2024)

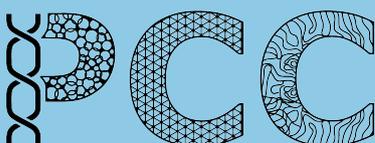
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# Offered BSc/MSc Projects

## Nanoscale Investigation of the Stability of Functional Molecular Interfaces under Stress

Masbah UI Hakim, Physical Chemistry and Soft Matter (PCC)

Surface modification using Self-Assembled Monolayers (SAMs) is widely used for controlling interfacial interactions in systems ranging from biosensors to advanced semiconductor manufacturing. However, a critical gap exists in understanding how these single-molecule-thin layers behave under physical stress at the nanoscale. When a surface is touched, rubbed, or stressed, how do the chemical bonds hold up? Understanding this mechanochemical degradation pathways is vital for designing durable functional interfaces. This project offers a unique opportunity to bridge fundamental surface physics with high-impact industrial applications, conducted in collaboration with ASML, an innovation leader in the semiconductor industry.

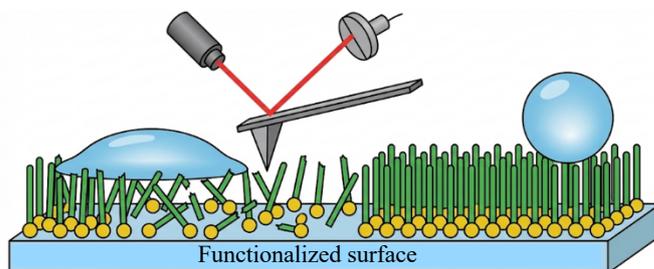


Figure 6. Visualization of SAMs Degradation.

In this project, you will perform a systematic investigation comparing uncoated and SAM-functionalized surfaces on complex geometries like SiC. Your workflow begins by establishing a chemical baseline using Contact Angle and XPS to verify the quality and coverage of the molecular assembly. You will then advance to Atomic Force Microscopy (AFM) and Peak Force Quantitative Nanomechanical Mapping (PF-QNM) to map the evolution of surface morphology and nanomechanical properties. Specifically, you will track how the low-adhesion, intact monolayer transitions into a high-adhesion state under stress, effectively performing a "molecular autopsy" to determine how the functional interface fails. These insights will bridge a critical gap in current surface science research and contribute to the development of more durable functional surfaces for precision positioning applications in semiconductor manufacturing.

### Learning goals:

1. Mastering advanced AFM techniques such as PF-QNM for mechanical surface property mapping.
2. Gaining expertise in integrating macroscopic chemical data with nanomechanical measurements.
3. Learning to analyze complex experimental datasets using image and data analysis software.

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# Offered BSc/MSc Projects

## Navigating the unknown: studying ecological response to climate change using soft matter

**Ayushi Bhatt**, Physical Chemistry and Soft Matter (PCC)

Micro algae, the unsung heroes of our ecosystems, play a pivotal role in carbon fixation and oxygen production. Beyond their ecological significance, they serve as key model organisms for studying adaptive responses to extreme and shifting environments. One of the pressing challenges in our era of rapid climate change is understanding how micro-algae navigate and thrive within habitats altered by phenomena such as glacier melting.

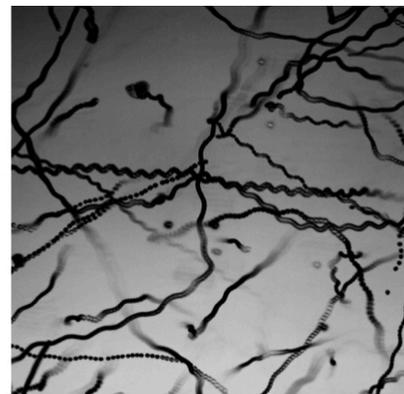


Figure 1 – Swimming of algae in a complex medium.

Glacier melting introduces complex physical and chemical changes in freshwater habitats, significantly altering confinement levels and environmental heterogeneity. For example, as glaciers rapidly melt, microalgal communities within these once-frozen glaciers will experience a drastic change in their surroundings. These transformations pose an intriguing question: How does the motility of microalgae adapt to these shifting conditions, and what are the implications for their ecological success? During this project you will aim to uncover the mechanisms dictating microalgal motility dynamics in response to rapid melting of glaciers.

### Learning goals :

- Characterize the motility of micro-algae in ice and saline water environments
- Recreate the habitat complexity resulting from glacier melting in the lab considering temperature, salinity, and nutrient availability
- Identify motility patterns and mechanisms that allow micro-algae to explore and colonise these dynamic habitats efficiently.
- Predict ecological models and changes in microalgal motility impacted by nutrient cycling, primary productivity, and broader ecosystem dynamics.
- This interdisciplinary project will employ cutting-edge tools and techniques: Microfluidic Systems, , Data Analysis and Modelling using computational models

This thesis offers a unique blend of experimental innovation and ecological exploration, making it an exciting opportunity for students passionate about climate science, biotechnology and biophysics.

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# Offered BSc/MSc Projects

## Lab-on-a-Chip Sensors: Detection of Lipid Vesicles Using Colourful Liquid Crystal Droplets

Amanuj Jaman Middy, Physical Chemistry and Soft Matter (PCC)

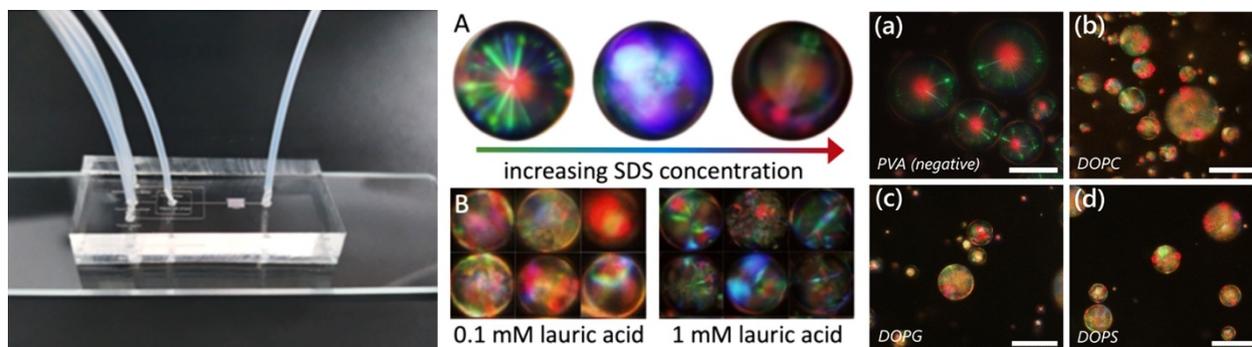


Figure 1: Lab-on-a-chip device and amphiphile-induced texture transitions of CLCs droplets.

Rapid, cost-effective, and sensitive biomolecule detection remains a major challenge in biosensing. Cholesteric liquid crystals (CLCs), with their helical mesogen arrangement, produce vivid, tunable structural colors that shift with analyte type and concentration, providing amplified, visually accessible signals. Using microfluidics, micrometer-sized droplets and shells can be precisely fabricated, and their integration into lab-on-a-chip devices enables controlled, high-throughput experiments. Combined with spectroscopy, this setup allows accurate measurement of response times and spectral shifts, establishing a compact, label-free platform for real-time highly responsive, color-changing biosensors.

In this project, we will develop a lab-on-a-chip platform where CB15-doped E7 cholesteric droplets will be generated and trapped within PDMS microfluidic devices. The chip will be engineered to stabilize droplets at predefined locations, which are then exposed to phospholipid membrane systems. The interactions between cholesteric droplets and model lipid membranes will be systematically investigated using small unilamellar vesicles (SUVs) and giant unilamellar vesicles (GUVs) with controlled lipid composition, charge, and concentration. Vesicle adsorption and membrane–interface interactions are expected to induce changes in cholesteric ordering, leading to measurable variations in droplet texture and reflected wavelength. These responses will be monitored using real-time optical microscopy and reflection spectroscopy to quantify color shifts, response dynamics, and sensitivity. By correlating vesicle properties with optical signatures, this work aims to establish structure–response relationships that underpin membrane-driven modulation of cholesteric ordering and enable color-based biosensing within microfluidic lab-on-a-chip systems.

**Techniques you will learn:** Microfabrication, microfluidics, cholesteric droplet preparation, vesicle production, optical and confocal microscopy, spectroscopy, image and data analysis

**References:** ACS Appl. Mater. Interfaces 2022, 14, 37316–37329; Lab Chip, 2019, 19, 1082–1089; Microchemical Journal 2020, 157, 105057–105057.

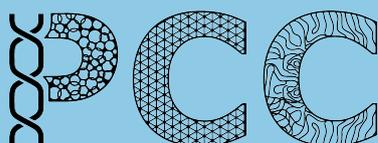
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# Offered BSc/MSc Projects

## Protein phase separation on intracellular lipid droplets

Ketan Ganar, Biobased Chemistry and Technology (BCT)

Plant cells store energy as triacylglycerols in lipid droplets (LDs), which could make up to 20–40 wt% of the cell mass in the case of oleaginous cells like in oilseeds.<sup>1</sup> A phospholipid/protein membrane efficiently protects the triacylglycerols (TAGs) against physical and chemical stresses, but on demand, like during germination, a channel on the LD membrane is formed and the TAGs are fuelled to the other organelles.<sup>2</sup> This unique metastable property of the LD membrane has sparked significant interest in using them as highly controlled carriers of therapeutics; however, the mechanism and the role of the proteins, called oleosins, and the phospholipids on this is poorly understood. Oleosins belong to a unique class of small proteins with an amphipathic helix inserted in the LD core and two disordered protein flanks that can freely move on the LD surface.

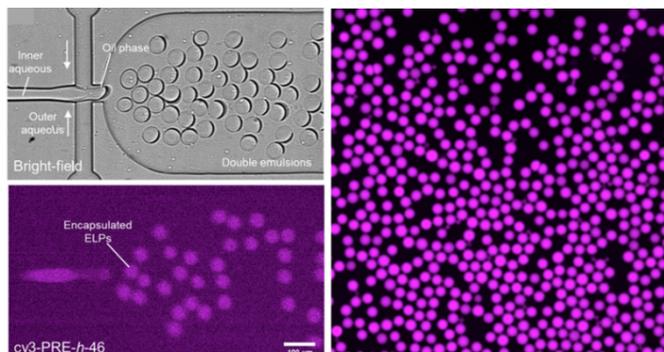


Figure 1 - Using microfluidics to create protein droplets and real-time observation with a fluorescence microscope.

**Research question:** This project will investigate the role of the disordered oleosin flanks in controlling the stability of the LDs and releasing the inner lipids. To achieve that, the phase separation mechanism of the proteins on the LD surface and the factors that can trigger it will be studied using microfluidics (Figure).<sup>3</sup> This information will help understand cells' tricks for the delicate making of tunnels on oil droplet's interfaces and will assist in forming highly controlled lipid carriers.

### Techniques you will learn:

Microfabrication, Microfluidics, Emulsion production, Fluorescence microscopy, Image analysis

### Reference:

1. C. Nikiforidis, J. Colloids and Interface Science, 20103, 274, 102039.
2. Y. Jin, Y. Tan, J. Wu, Z. Ren, Nature, 2023, 254

K. Ganar, M. Nandy, P. Turbina, C. Chen, *et al.*, Nature Chemistry, 2025, 186-18

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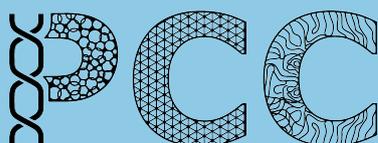
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# Offered BSc/MSc Projects

## How to make better bread (or beer or ...) with soft matter science?

**Uddalok Sen**, Physical Chemistry and Soft Matter (PCC)

Microbial fermentation is the key mechanism by which microorganisms (e.g. bacteria, yeast) break down organic compounds (e.g. sugars) into simpler products, often producing gas (e.g. carbon dioxide) during the process as well. While microbial fermentation has historically been relevant for the production of edible products (e.g. bread, beer, kombucha, yoghurt), there has also been a recent surge in developing alternative protein sources (e.g. plant-based meat) using microbial fermentation.

Some of the primary requirements of microbial fermentation are that the microorganisms should be able to move in the liquid-like medium as they search for nutrients, they should be able to grow in number via cell division, and the material should be able to release gases (often in the form of bubbles) as fermentation proceeds. A complex interplay of these processes controls the formation of structures in the medium – crucial for the quality of the final product. For example, plant-based meat products are often unacceptable to the consumer if they do not “feel” like animal-sourced meat. In this project, we will study how microorganisms move and grow in a medium during fermentation and how such microscopic processes can dictate the macroscopic structure of the final product.

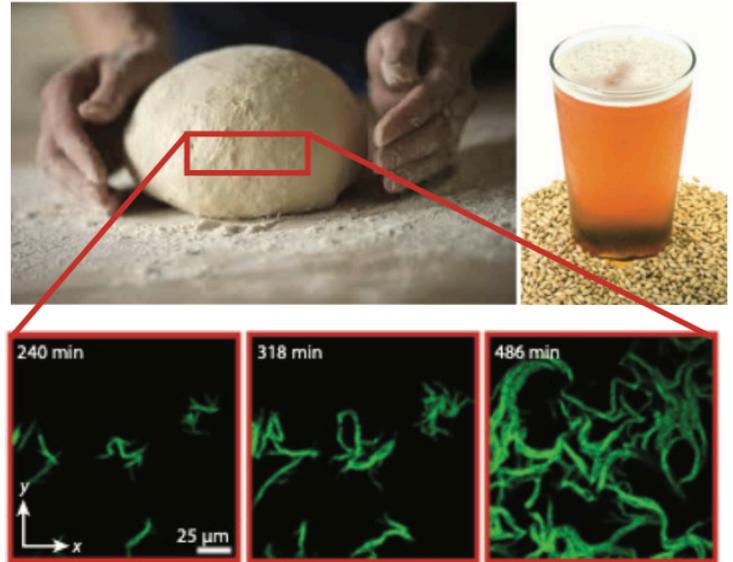


Figure 1 - Motion and growth of microorganisms are crucial for formation of structures during fermentation.

### Objectives

- Characterize the motion of microorganisms in conditions mimicking fermentation
- Understand how microorganisms move and grow in a highly complex medium that also contain growing gas bubbles
- Relate the microscopic behavior of microorganisms in complex media to the macroscopic structure formation during fermentation

This interdisciplinary technique, while addressing a highly relevant societal challenge, will also let you gain hands-on experience in state-of-the-art experimental techniques such as: Microfluidic systems, High-speed optical and fluorescence microscopy, Particle tracking and flow visualization Physical modeling

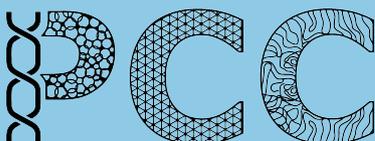
This thesis project offers a unique blend of experimental innovation and biotechnological exploration, making it an exciting opportunity for students passionate about soft matter, biophysics, biotechnology, food science, or food technology.

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# Offered BSc/MSc Projects

## Can we use coffee-stains for the assembly of designer materials?

Uddalok Sen, Physical Chemistry and Soft Matter (PCC)

The assembly of colloidal particles at fluid-fluid interfaces has been the subject of intense research, and represents a unique method for bottom-up designing of materials with highly-controllable microstructures. The fundamental mechanism driving such assembly is essentially the same as the one that results in stains appearing from spilled coffee: when a liquid containing dispersing microparticles (e.g. coffee) dries, it leaves behind the particles in a highly-ordered structure. This process can be repeated several times in a controlled manner to obtain designer materials.

The final microstructure of the assembled material can be tuned in a number of ways: by changing the solvent, the type of particles, their size, shape, concentration, and surface chemistry. A complex interplay of all these parameters determines the microstructure of the final material, which further dictates its applicability. In this project, we will study how the same colloidal particles can be controllably assembled into distinctly different structures by tuning one or more of these control parameters.

### Objectives

- Characterize the drying of liquids containing colloidal particles
- Understand how colloidal particles self-assemble when the liquid dries out
- Relate the different tuning parameters to the final microstructure of the assembled material

This interdisciplinary technique, while addressing a highly relevant societal challenge, will also let you gain hands-on experience in state-of-the-art experimental techniques such as microfluidic systems, high-speed optical and fluorescence microscopy, particle tracking and flow visualization, Raman spectroscopy and scanning electron microscopy, physical modeling.

This thesis project offers a unique blend of experimental innovation and technological exploration, making it an exciting opportunity for students passionate about soft matter, physical chemistry, food science, or food technology.

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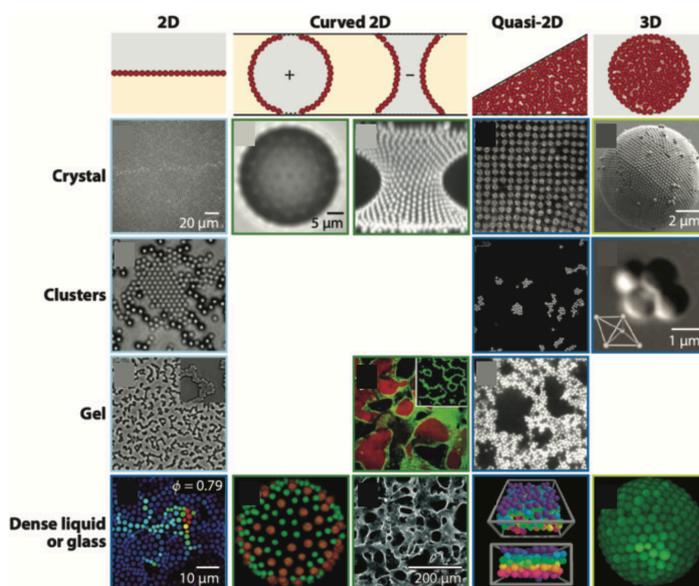


Figure 1 – Diverse self-assembled designer materials obtained from colloidal self-assembly.

# Offered BSc/MSc Projects

## Study of water interactions with cellulose porous materials

Joice Kaschuk, Physical Chemistry and Soft Matter (PCC)

Porous materials are 3D macromolecular networks with the ability to retain air (aerogels) or water (hydrogels). These versatile materials have been applied in food additives, delivery systems, water retention, and pollutant adsorbents. Nanocellulose materials stand out due to their exceptional surface area and hydrophilicity facilitating efficient absorption and retention of fluids driven by capillarity and diffusion. However, a systematic understanding of how their structure influences water mobility is still lacking.

In this project, you will produce nanocellulose aerogels with different shapes, structures and porosity to evaluate how water is absorbed and diffused through their bulk. You will study the influence of the structure of the porous materials on water absorption, capillarity and diffusion through simple yet innovative methods.

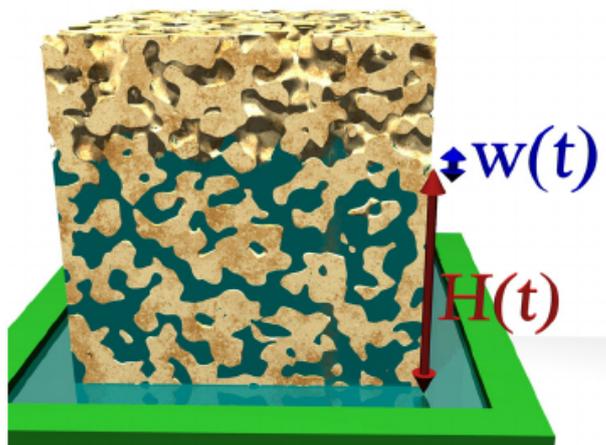


Figure 1 - Representation of how a fluid is absorbed by a porous material. Source: [www.pnas.org/cgi/doi/10.1073/pnas.1119352109](http://www.pnas.org/cgi/doi/10.1073/pnas.1119352109)

### Learning goals:

- Mastering the production of nanocellulose porous materials using the freeze-drying technique
- Quantifying the water velocity uptake by measuring weight changes over time.
- Exploring cutting-edge analytical tools:
  - o Scanning Electron Microscopy (visualize the morphology and structure of the porous material)
  - o Optical microscopy (evaluate the water absorption)
  - o Laser Speckle Imaging (visualize and quantify the water absorption dynamics in real time).

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# Offered BSc/MSc Projects

## Evaluating Deep Eutectic Solvents for the Self-Assembly of Lignin Nanoparticles

Joice Kaschuk, Physical Chemistry and Soft Matter (PCC)

Nanolignin are micelles particles with <100nm diameters produced by self-assembling the renewable and abundant biopolymer lignin. They have higher surface area and reactivity, enabling better performance in packaging, material reinforcement, and applications that require antioxidant and antimicrobial properties.

To produce nanolignin, first, the lignin is homogeneously dissolved, followed by adding water to the solution to form the nanoparticles (Figure 1). The mechanism involves intermolecular noncovalent interactions, e.g., electrostatic, hydrogen-bonding, hydrophobic, and Van der Waals interactions between the particles. In the nanoparticle structure, the hydrophobic part (phenylpropanoid) of the lignin is aggregated to form the inner micelles, and the hydrophilic part (especially the phenolic and aliphatic hydroxyl groups) self-assembles as the outer micelles. Due to the formation of the micelle, the shape of lignin changed from irregular to spherical shape (colloidal shape).

In this project, you will study how deep eutectic solvents (DES) can be used to produce nanolignin particles in three steps:

**Step 1 Dissolution of lignin in DES:** you will test different DES to dissolve lignin at varying temperatures and concentrations.

**Step 2 Self-assembly of Nanolignin:** you will understand the effects of lignin solution concentration and the velocity of pouring the solution into water to create the nanoparticles.

**Step 3 Characterization of the Nanoparticles and Colloidal Properties:** you will determine the size of the particles and correlate them with the concentration and type of DES used. You will evaluate the colloidal properties using zeta potential at different pH and time (15-30 days).

### Learning goals:

- Producing nanoparticles of lignin using a green solvent.
- Evaluating the influence of the parameters of lignin dissolution in the formation of nanolignin.
- Using analytical techniques: (Optical microscopy (evaluate the dissolution and particle formation), Zeta Potential (determine mean particle size and electrophoretic mobility)).

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Figure 1 - Representation of the method used to produce nanolignin in this project. This image was adapted from <https://doi.org/10.1016/j.ijbiomac.2021.10.094>

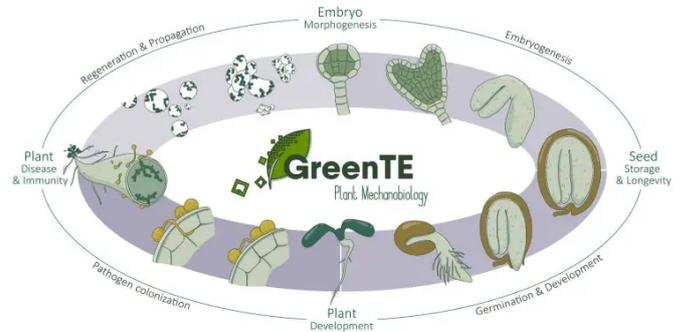
# Offered BSc/MSc Projects

## Computer Modelling Mechanosensation in plants

Justin Tauber, Physical Chemistry and Soft Matter (PCC)

Development of multicellular organisms depends on the interplay between biochemistry, mechanics, and morphology (e.g., Alan Turing, D'Arcy Thompson). Modern omics and microscopy techniques now let us explore the biochemical machinery underlying development, from molecular to tissue scales. However, we still know surprisingly little about how mechanical forces are sensed and responded to at and below the cellular level, especially in **plants**. This leads to questions such as: When and where do mechanical forces arise during plant development? How are these forces perceived at the cellular and molecular scales? And how are mechanical signals converted into biochemical changes or changes in plant shape, and vice versa?

Researchers at WUR and across the Netherlands are developing new experimental tools to tackle these questions (<https://green-te.nl/>). At PCC, we contribute by building **computational models** that help design experiments and uncover the physical principles behind plant **mechanosensation**. You will develop a model connected to an active research topic, such as seed germination (how does the embryo break through the seed coat?) and plant cell polarization (how does a cell determine its top-bottom axis?). Depending on the project, you may work with molecular dynamics, coarse-grained cell mechanics, or mathematical models. Please contact us if you are interested; we will help to identify a topic that fits your interests and skills.



### Learning goals:

- Explore how mechanical forces shape molecular and cellular processes during plant development.
- Gain proficiency in molecular dynamics, coarse-grained simulations, and mathematical modelling of biological soft materials.
- Learn to visualize, analyze, and compare computational results with theory and experiments.

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# Offered BSc/MSc Projects

## Computer modelling of soft materials

Jasper van der Gucht, Physical Chemistry and Soft Matter (PCC)

Soft materials are generally characterized by a heterogeneous microscopic structure and a complex response to external perturbations. Computer modelling can be extremely valuable in understanding the microscopic origins that underlie the macroscopic behaviour. At PCC, we perform computer modelling at different levels, from detailed molecular dynamics simulations to coarse-grained network simulations to mathematical models based on differential equations. Current topics that we work on include computer-aided protein design, simulations of mechanical stress propagation in biological materials, fracture in fibrous networks, and modelling of drying and phase separation in complex mixtures.

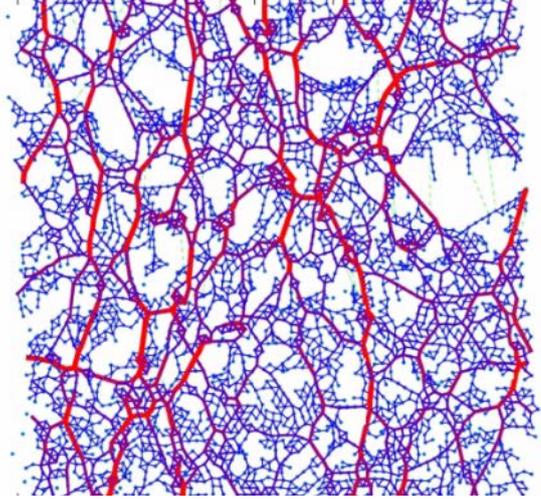


Figure 1 - Representation of stress pattern in a biopolymer network under tension.

Please feel free to contact us if you are interested in a modelling thesis. We will find a suitable topic that matches your experience and background.

### Learning goals:

- Explore how microscopic structures and interactions determine macroscopic properties like stress response, fracture, and phase separation.
- Gain proficiency in molecular dynamics, coarse-grained simulations, and mathematical models to study soft materials.
- Learn to visualize, analyze, and compare computational results to theoretical predictions and experimental data.

### Contact Information

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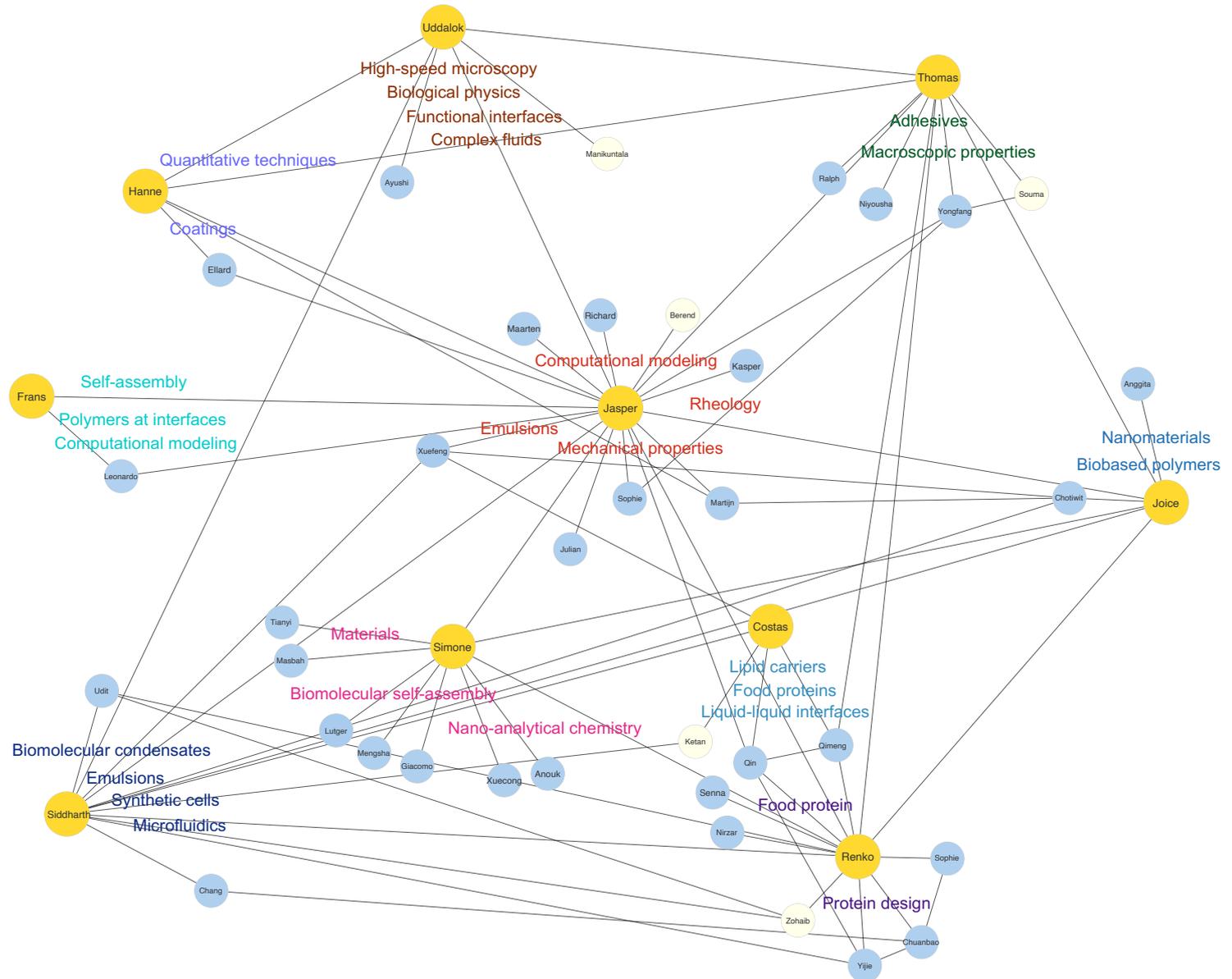
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# Still searching for the perfect topic?

No worries!

Reach out to us anytime – we would love to brainstorm and bring your project idea to life!

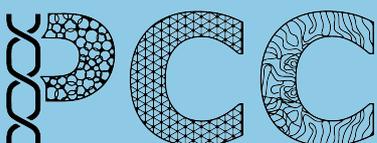
Curious to learn more about our team? Click on a name to explore their research and discover their work in detail!



Check what our students have to say about PCC:



SCAN ME



# Contributions

We sincerely acknowledge the invaluable contributions of the following individuals to this book:

**Infographic of Current PCC Members and Research:** Qin Li

**History of PCC:** Frans Leermakers

**Overview of PCC Research Over Time:** Frans Leermakers and Peter Barneveld

**Video Edition:** Raoul Fix

**Masters' testimonials:** Ivan Alcazar Salazar, Danielle Riegstra, Kenny Xie, Sjoerd Flaming, and Vaibhav Vishwanath.

## **Project Abstracts:**

Sophie van Rooijen, Alireza Kh. Kolour, Mengsha Hu, Qin Li, Niyousha Davari, Chotiwit Sriwong, Yongfang Lu, Qimeng Wang, Anggita Sari Praharasti, Xuefeng Shen, Lutger Rutten, Udit Ghosh, Masbah UI Hakim, Soumabrata Majumdar, Justin Tauber, Ayushi Bhatt, Amanuj Jaman Middy, Ketan Ganar, Renko de Vries, Thomas Kodger, Joice Kaschuk, Siddharth Deshpande, Jasper van der Gucht, Francesco Simone Ruggeri, Uddalok Sen, Bauke Albada (ORC), Aart van Amerongen (BSD), Guillermo Amador (EZO), and Costas Nikiforidis (BCT).

Their efforts have been instrumental in shaping the content and quality of this work.

