Solvent-Induced Reinforcement of Polymer Gels

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3D networks of polymer chains swollen in a good solvent, known as gels, are useful for a host of applications requiring a specific combination of (i) low elastic moduli (<100 kPa) and (ii) large extensibility (> 100%). Nonetheless, in real applications, the use of gels is limited by their low resistance to fracture (i.e. brittleness). The past two decades have witnessed significant developments in toughening strategies based on network design to provide the material with dissipation mechanisms. These typically require complicated chemistries, multiple preparation steps, and costly materials. The role of the solvent in the large strain behavior and the toughness of gels has remained outside the focus of these studies for the simple reason that conventional, low-viscosity solvents only dilute and soften the network. [1]

A new generation of green solvents, called Natural Deep Eutectic Solvents (NaDES), is based on extensive hydrogen bonding between certain combinations of natural sugars, salts, and acids featuring a *deep* eutectic point. These so-called "designer" solvents are particularly interesting due to their (1) widely *tunable* physico-chemical properties (viscosity, polarity, etc.) and (2) *natural* origin. Combinations of polymers and these solvents have untapped potentials for various fields of applications from energy storage and CO_2 capture to construction materials and biomedical devices. For instance, NaDES may be used in the extraction and the processing of polymers or as solvents for gels, called Eutectogels. [2] The quality of the solvent for the polymer and the interactions between them is expected to impact the conformation of the polymer chain and thereby the bulk mechanical properties. [3]

Given the tunable viscosity of NaDES and the possibility of tuning polymer-solvent interactions, these solvents may provide a means to reinforce polymer networks and potentially make them more resistant against early failure. **The objective of this project is to probe weak molecular interactions in model polymer-NaDES systems and to explore solvent-induced reinforcement of polymer eutectogels with respect to their hydrogel counterparts.**

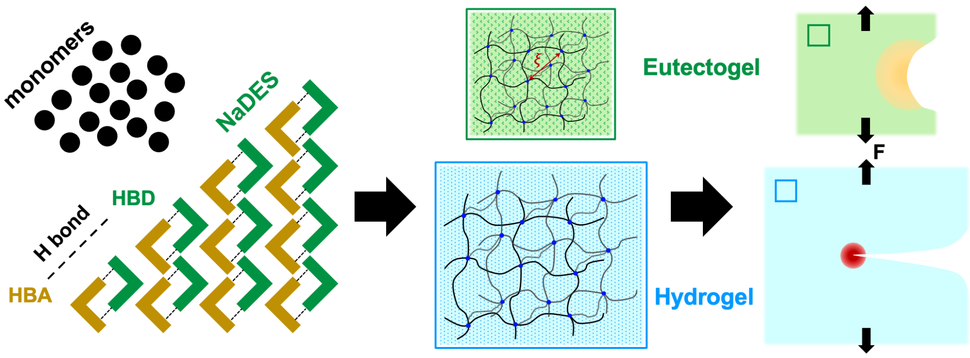

Figure 1: Schematic representation of the PhD project.

First, polymer hydro/eutecto-gels will be prepared in water and model NaDES (Fig. 1). The average number of H-bonds and their relative strengths will be assessed by Infrared Spectroscopy. The structure of the NaDES in its pure state and in eutectogels as well as the structure of the polymer networks will be studied via X-ray diffraction and linear rheology. Nonlinear mechanical properties of the gels studied via tensile and fracture experiments will be linked to their nanostructure. Understanding the reinforcement mechanism may pave the way toward solvent-induced toughening in polymer gels.

Profile: Curious, self-driven master's students with a degree in polymers or materials science and interested in polymer physics are invited to apply with a CV, motivation letter, and transcripts. Previous experience in mechanical and or structural characterization is a plus.

References: [1] Creton, Macromolecules, 2017, 50, 8297. [2] Hansen, et. al., Chem Rev, 2021, 121, 1232, [3] Vahdati, et. al., Prog Polym Sci, 2023, 139, 101649.