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URP 2025: Molecular-level Control of Polymer Properties

Polymer materials are ubiquitous in our society, motivating the development of new functional capabilities enabled by organic chemistry. Our summer research will focus on molecular level control of polymer and material properties.

Highly extensible hydrogels via polymer chain unfolding

Biological materials like muscles are highly elastic and extensible due to the unfolding of individual protein domains when the material is under tension. This molecular-level release of stored length is what allows your muscles to extend and then recover after experiencing stress. In contrast, ***most synthetic materials lack an analogous mechanism for stress relief and recovery***. Inspired by proteins, we will investigate using folded polymers in materials (Figure 1), which we hypothesize will unfold and release stored length under stress. Our goal is to create tougher and more extensible hydrogel materials, which have many biomedical applications, but are typically brittle. This material design also provides opportunities for fundamental understanding of the role of topology (the way that polymer chains are connected) in determining the mechanical behavior.

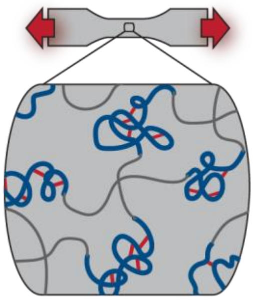

Figure 1: The design strategy for a hydrogel material made from folded polymers (blue lines).

To achieve these goals, there are two research questions we will investigate. One student will be hired for each research question. There will be 2 students hired through URP to work with Dr. Barbee on this project this summer.

1.) How do we design and synthesize the folded polymers? Students focusing on this research question will continue previous work conducted by our group to select and test intra-chain cross-linking methodologies. This student will work on using silyl ether bonds to reversibly fold polymer chains and may also synthesize a new monomer for disulfide bonding.
2.) How can the folded polymers be incorporated into a hydrogel material? Students focusing on this question will investigate strategies for synthesizing polymer networks with covalent attachments to folded polymers. This student will continue working on prior work to use RAFT polymerization to grow a polymer network from the chain ends of a previous polymer. This student will synthesize and characterize these materials.

Student outcomes:

This project provides an opportunity for students to understand how chemistry dictates material behavior. Students who work on this project will synthesize polymers and small molecules. In the past year, students in our group have characterized small molecules, polymers, and materials with a range of instrumentation techniques, including nuclear magnetic resonance (NMR), size exclusion chromatography (SEC), high-performance liquid chromatography (HPLC), UV-vis spectroscopy, mass spectrometry, IR spectroscopy, and materials testing.