ABSTRACT

NON-TECHNICAL SUMMARY:
Applying force across molecules is a powerful way to drive chemical reactions. Such force-sensitive molecules can be used to make materials that report on their own integrity, that self-heal after damage, or that allow force to be used to control when and where a reaction takes place. Polymers are a useful platform for these types of materials because they can act as "molecular handles" for transmitting forces applied to a bulk material down to the molecular scale. However, designing polymers that efficiently and uniformly transmit forces to the molecular scale remains a significant challenge. In this project, the PI and her students will address this challenge by synthesizing and characterizing force-responsive polymers with well-defined connectivity and internal structure at the nanometer scale. This work will enable new understanding of how forces are distributed in polymeric materials and inform design of force-responsive polymeric materials for practical applications. This project will also contribute to education and broadened participation in polymer science through development of active learning classroom activities for use in undergraduate polymer science courses, creation of video demonstrations featuring diverse female role models, and establishment of a women-in-chemistry group to provide mentoring and professional development opportunities for female students in the PI's department.

TECHNICAL SUMMARY:
Designing polymeric platforms that efficiently transduce macroscopic forces to the molecular scale is critical for practical applications of mechanochemistry. In this work, the PI and her students will investigate how the network structure and nanostructure of polymeric materials determine the molecular-scale distribution of forces in polymer networks under strain. Three model systems will be developed to investigate this phenomenon. First, to test the hypothesis that more uniform networks will drive more efficient mechanochemical activation, spiropyran-containing polymers will be crosslinked into well-defined networks, and force-induced activation rates studied as a function of network connectivity, network strand dispersity, and defect content. Second, to investigate the roles of nanostructure and competing structural relaxations in physically crosslinked materials, mechanochemical activation will be studied in triblock copolymers that self-assemble into well-ordered nanoscale morphologies. Finally, new strategies will be developed to enable precise placement of mechanophores within polymer chains, and will then be used to test how chain stretching near nanoscale interfaces can be used to promote or suppress force-driven chemical processes. Together, these research aims will bring fundamental insight to molecular-scale forced distributions in polymer networks and inform design rules for functional mechanochemically-active materials.

These research aims will be integrated with several education and outreach activities aimed at broadening participation and improving education in polymer science. The PI will develop and distribute Process-Oriented Guided Inquiry Learning (POGIL) activities for polymer science. She will also create video demonstrations of important topics in polymer science featuring female presenters as role models for interested students. Finally, she will establish a women-in-chemistry group for students in her department as a mechanism for promoting new mentoring opportunities and broaden female students' participation in the scientific enterprise.

This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.