CornellEngineering
Mechanical and Aerospace Engineering

Monday, January 23, 2017

NSF CAREER Award, 2017-2022

Assistant Professor, Mills Family Faculty Fellow Meredith Silberstein

The prestigious CAREER Program, which was launched in 1996, provides support to junior faculty members and encourages the combining of research and education. Applicants submit a proposal that includes research and education plans. Awardees receive various amounts of funding, typically ranging from around $400,00 to $500,000, for a period of five years.

Assistant Professor Silberstein received a 5-yr, 500,000 award from the Division of Civil, Mechanical and Manufacturing Innovation (CMMI), NSF.

Award Abstract #1653059

CAREER: Building a Mechanistic Understanding of Mechanochemically Adaptive Polymers

Abstract: This Faculty Early Career Development (CAREER) award will investigate the physical mechanisms governing how mechanochemically responsive homopolymers adapt in response to external loading. Polymers - both plastics and rubbers - are widely used commercially and industrially. Applications include such safety-critical products as tires, helmets, playground equipment, airplanes, and medical devices. Most polymer development to date has focused on improving initial properties of the material such as stiffness and strength. However, eventually these material properties degrade. Given the diverse and somewhat unpredictable loads that these materials experience over their lifetime, it is incredibly difficult to predict when and where this degradation will occur. Currently structures are therefore overdesigned. This award supports research into polymers that would be augmented on the molecular scale to react to the onset of damage by strengthening themselves locally; these are referred to as mechanochemically responsive polymers. Such materials would have longer lifespans and in particular be less susceptible to accumulated damage through high intensity short duration loads (such as helmet impact). This material concept will lead to reduced waste, reduced weight of structures, and reduced inspection costs for safety-critical applications. Research-inspired outreach programs will be developed in coordination with the New York 4H program, resulting in a booth to be held at the NY annual state fair. A searchable database of concept questions for undergraduate mechanics of materials courses will also be developed and disseminated to other academic institutions.

Mechanochemically responsive polymers can be realized through the covalent incorporation of mechanophores - chemical units that undergo a specific chemical transformation in response to applied force. Given their distinct mechanisms, elastomers and glassy polymers are each taken as a focus area that will be approached through a combined theory, simulation, and experimental approach. For elastomers the mechanophore-based dynamic networks will be explicitly simulated, reduced to a finite element implemented constitutive model, and key aspects of the model will be experimentally validated with existing materials systems. For glassy polymers the constraint of the polymer matrix on mechanophore kinetics will be experimentally probed through light responsive mechanophores, mechanophore response to stress will be modeled and experimentally validated at the continuum level, and potential for self-strengthening and self-healing will be assessed through analytical and molecular dynamics approaches. The theory and methods developed by the PI will lay the groundwork for mechanochemically responsive polymer design. The aspects of this work that concern how bonds break within a polymer will also have implications for polymer fracture.