ENGINEERING AT THE INTERFACE OF SCIENCE

Session Organizers: Gautam Menon, Institute of Mathematical Sciences, and Huimin Zhao,University of Illinois at Urbana-Champaign

The design and manipulation of physical/chemical materials and biological materials with desirable properties, as well as the emerging field of synthetic biology, are all examples in which frontier problems in engineering confront the sciences of biology, physics and chemistry. The theme of this session, Engineering at the Interface of Science, describes how engineering and science can be mutually enriched through their interactions, with significant implications for technology. To achieve a first-principles understanding of the strength of materials, for example, one must understand how they are constituted at the level of atoms and their interactions. For industrially important materials such as polymers, modulating their properties for specific applications is as much a matter of chemistry and physics as it is of engineering. Polymers can be engineered to deliver therapeutic proteins to target cells, while RNA molecules can be engineered to form sensitive control devices, linking nano-scale device engineering with biology and chemistry. This session will highlight examples of such interactions, as described by researchers who work in frontier problems at the science-engineering interface.

Umesh Waghmare will begin by describing examples of how the vibrational modes of a (typically hard) material contribute to its response and stability. If a subset of such modes reduce in energy (become 'soft') as external parameters are varied, materials properties such as strength can be significantly altered, leading to vastly increased sensitivity to changes in electric, magnetic or stress fields. The role of such modes in the structural transitions of ferroelectrics, the mechanical failure of hard materials such as SiC and dynamic crack instability will be described as prototypical examples. The rational engineering of the microstructure, for example, the semicrystalline morphology of polymers, can affect materials response in a non-linear manner, and yield a variety of interesting and application-tunable properties, as Guruswamy Kumaraswamy will discuss. He will describe work from his group relating to the manipulation of the temperature-dependent stiffness of far-from-equilibrium semi-crystalline polymers. He will also discuss strategies to controllably engineer crystal orientation in semi-crystalline polymers, with implications for high strength sheets and fibers.

Yi Tang will describe a new approach for delivering active forms of proteins to specific cells and organs in living organisms using biodegradable nanocapsules. Such nanocapsules are prepared through interfacial polymerization around the native proteins with monomers and biodegradable crosslinkers, which result in uniform size (~20 nm) and excellent bioavailability. This approach has been demonstrated in triggering programmed cell death in various human cancer cell lines. Christina Smolke will show how RNA molecules can be designed to program cellular behavior. Motivated by the relative ease with which RNA molecules can be designed and their ability to encode diverse sensing and regulatory activities, her laboratory has developed synthetic RNA control devices that process and transmit information encoded within biological molecules, such as proteins and small molecules, to targeted protein level outputs, thus linking computation and logic to gene expression and cellular behavior.