MATERIALS ENGINEERING SEMINAR

Date: Monday, September 12, 2011

Time: 3:30 refreshments
3:45 - Seminar

Place: ARMS 1010

Purdue Materials: Infinite Possibilities

Molecular Origin of Nonlinear Elasticity in Physically Associating Polymer Gels: Stiffening, Softening, and Sliding Friction

by

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ABSTRACT

Nonlinear elasticity observed in shear rheometry experiments is coupled with molecular constitutive models and scaling laws to establish the relationships between the observed macroscale mechanical properties of a model physically associating gel with its underlying microstructural evolution during shear. Compared to previous studies of nonlinearity in soft materials, the work presented here benefits from studying polymer gels with well-defined molecular structures and a wide range of accessible relaxation times.
The model gel is composed of acrylic triblock copolymer molecules dissolved in a midblock-selective solvent. At elevated temperatures, the copolymer is fully dissolved and the solution behaves as a viscoelastic liquid with near Maxwellian relaxation. As the solution is cooled, the molecules self-assemble into a three-dimensional network and the relaxation time increases dramatically, such that at room temperature the system behaves as a viscoelastic material.
During shear at a constant rate, strain-stiffening behavior is observed at small strains and related to the finite extensibility of the polymer chains in the gel via a constitutive model based on an exponential strain energy function. Interestingly, the same model is also effective for describing the stiffening of various biopolymer networks, including actin and collagen. As deformation progresses, stiffening is followed by rapid, fracture-like softening in the stress response which results from the formation of highly localized regions of strain in the gel. This behavior is accurately captured by a second constitutive model that incorporates the strain energy and relaxation of individual polymer chains in the gel. At large strains, plateaus in the stress response are observed and compared with results from traditional sliding friction experiments. Scaling law arguments from this large-strain regime suggest that at the molecular level, deformation in the gel is confined to a localized shear zone with thickness comparable to the gel's mesh size.

Short Bio:

Dr. Kendra A. Erk is currently a National Research Council Postdoctoral fellow in the Complex Fluids Group at the National Institute of Standards and Technology. At NIST, she is developing new micro-rheometry methods to characterize viscous and elastic rheological properties of surfactant-stabilized fluid interfaces. Her ongoing and future research will focus on characterizing the structure-property relationships of soft polymeric materials under strong shear by rheometry and flow-visualization techniques to probe mechanical instabilities (*e.g.*, fracture, shear banding, interfacial slip and friction). Dr. Erk holds a Ph.D. from Northwestern University (Dept. of Materials Science and Engineering) and a B.S. in Materials Engineering from Purdue University.