Illuminating interfacial mechanics: 
Coupling microscopy and mechanical testing to understand soft interfaces

**Chelsea S. Davis**
Assistant Professor, School of Materials Engineering
Purdue University

Many properties of polymeric systems are determined almost exclusively by the interfaces between various material components. This seminar will focus on various polymer interfaces and strategies to characterize their contact formation and debonding behavior. First, we investigate the role of surface roughness and contact time on the adhesion of viscoelastic materials. A method is presented that quantifies the dependence of adhesion on contact time by utilizing a custom-built testing apparatus that allows unprecedented control over key aspects of a contact adhesion test (approach and retraction velocities, maximum contact pressure, and contact time). Second, we utilize a mechanically-activated dye molecule covalently bound across the interface of a fiber-reinforced polymer composites (FRPC) to highlight interfacial stress transfer and debonding. The goal here was to develop a straightforward technique derived from commercially available materials that allows characterization of an FRPC interface by *in situ* mechanical deformation of single fiber model composites. Next, instrumented scratch experiments were performed on mechanophore-containing thermoset epoxy films to calibrate and quantify the fluorescence activation response of our mechanophore. This *in situ* mechanophore/mechanical deformation approach allows a diffraction-limited optical microscope to probe nanoscopic interfacial features in a powerful new way.

The talk will conclude with more recent work, performed at Purdue University, that utilizes buckling instabilities as a novel way to measure thin glassy film delamination from soft substrates. Quantifying the strength of a particular film-substrate interface is challenging due to the brittleness of glassy films which can greatly complicate sample preparation, handling, and testing. Here, a method for measuring the adhesion of glassy thin films to soft elastomeric substrates is explored that exploits an understanding of surface buckling instabilities, specifically the transition from wrinkling to delamination (W2D). The adhesion (given by the critical strain energy release rate ($G_c$)) for two model materials interfaces is quantified by determining the critical delamination strain for two different polymer thin films (polystyrene (PS) and poly(methyl methacrylate) (PMMA)) and an elastomeric substrate (poly(dimethyl siloxane) (PDMS)). The $G_c$ values determined for the PS-PDMS and PMMA-PDMS systems by W2D transition are $0.029 \pm 0.01$ J/m$^2$ and $0.025 \pm 0.01$ J/m$^2$, respectively. Overall, our work will enable the development of new techniques to probe soft interfaces and deepen our understanding of reversible adhesion and separation mechanisms.

Dr. Davis’s contact information: Phone - 765.494.9216 Email - chelsea@purdue.edu
Dr. Chelsea Davis’s research focuses on the surface properties and interfacial mechanics of soft matter. Utilizing mechanoresponsive fluorescent sensors coupled with established mechanical properties characterization methods, her work seeks to further our understanding of contact formation and separation physics between dissimilar materials. Potential applications of her research are self-reporting damage sensors for fiber reinforced composite systems and adhesion control/enhancement of thin film polymer coatings on metal and ceramic parts for corrosion resistance.

Dr. Davis received a B.S. degree in Textile Engineering from North Carolina State University in 2005. She obtained her M.S and Ph.D. in Polymer Science and Engineering from the University of Massachusetts Amherst in 2007 and 2012, respectively supervised by Dr. Alfred Crosby. While at UMass, Dr. Davis was an NSF-IGERT Graduate Fellow. Her doctoral dissertation focused on the use of surface instabilities for adhesion control. From 2012-2013, Dr. Davis was a Michelin Postdoctoral Research Fellow at the ESPCI in Paris working with Dr. Costantino Creton and Dr. Anke Lindner on the development of an adhesion testing device to probe the impact of dwell time on polymer-polymer adhesion. She then completed a National Research Council Postdoctoral Fellow at the National Institute of Standards and Technology (NIST) in the Polymers and Complex Fluids Group from 2013-2015. At NIST, Dr Davis worked with Dr. Jeffrey Gilman to develop methods to probe the interface of composites and nanocomposites utilizing advanced optical microscopy techniques. In 2016, she transitioned to the role of Materials Research Engineer within the Materials Science and Engineering Division at NIST. In January 2017, she joined the faculty of the School of Materials Engineering at Purdue University as an assistant professor where her lab focuses on in situ optical microscopy and mechanical testing experiments to probe polymer interfacial mechanics.

Outline:
- B.S. Textile Engineering, North Carolina State University (2005)
- M.S and Ph.D. Polymer Science and Engineering, University of Massachusetts Amherst (2007 and 2012, respectively)
  - Advisor: Dr. Alfred Crosby
  - NSF-IGERT Graduate Fellow
- Michelin Postdoctoral Research Fellow - ESPCI in Paris (2012-2013)
  - Collaborators: Dr. Costantino Creton and Dr. Anke Lindner
  - Collaborator: Dr. Jeffrey Gilman
- Materials Research Engineer - Materials Science and Engineering Division, NIST (2016)
- Assistant Professor - School of Materials Engineering, Purdue University (2017-)