ME Seminar

Micro/Nano Mechanics of Soft Nanofiber Contacts

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ABSTRACT

With the advent of novel architected, multifunctional materials, and the development of new experimental and computational capabilities spanning the macro, micron, and the nanometer length scales, mechanics has entered a new and exciting domain where surfaces, interfaces, and defects can be explicitly taken into account in the study of the electro-thermo-mechanical response of materials. In this talk, I will present novel experiments with closely coupled theoretical analysis to understand the mechanics of contact in nanofibrous systems encountered in a variety of applications, such as filtration membranes, scaffolds, and virtually all biological systems. This presentation will focus on the interfacial normal and shear adhesion strength of contacts between polymeric micro and nanofibers interacting through strong van der Waals forces. Towards this goal, novel experiments aided by micromachined devices, provided for the first time the critical normal and tangential pull-off forces between pairs of orthogonally crossed nanofibers with diameters in the range of 400 nm-4 μm. At slow rates ($\leq$ 12 nm/s), the work of adhesion under normal detachment was shown to be independent of the nanofiber diameter and twice the surface energy of the bulk polymer. Under shear detachment and slow sliding speeds (12 nm/s), peeling of the contact area was predicted using elastic contact models combined with linear elastic fracture mechanics (LEFM). Elastic jump instabilities during sliding could also be predicted. The shear stress threshold at which nanoscale soft contacts begin to slide, was shown to be independent of the geometrical parameters and boundary conditions, and directly related to shear yielding. Thus, the latter was established as the material parameter controlling static friction in nanoscale soft contacts that are governed by strong adhesion. Importantly, this study also investigated the effect of loading rate on the apparent work of adhesion. The adhesive normal pull-off force was found to increase with the detachment rate, reaching a plateau at high rates. The correlation between the polymer viscoelastic response and the work of adhesion will be elucidated with the aid of contact mechanics models, considering the viscoelastic time constants of the polymer and the rate of unloading of two fibers in normal contact.

ABOUT THE SPEAKER

Dr. Debashish Das is a postdoctoral researcher in Aerospace Engineering at the University of Illinois at Urbana-Champaign (UIUC), focusing on the mechanics of polymers and their composites. He received his Ph.D. (2017) in Aerospace Engineering from UIUC on the mechanics of nanostructured metallic and ferroelectric thin films, and his M.E. and B.E. degrees in Materials Engineering from the Indian Institute of Science, and Jadavpur University, respectively. Dr. Das' multidisciplinary research has led to several publications in high-impact journals and recent media mentions. He has received several honors and awards including the Best Paper award at the 2018 Society for Experimental Mechanics Conference, and the H.S. Stillwell Award recognizing the contributions of his Ph.D. dissertation research. He has been a regular reviewer for several reputed international journals. His research interests include the development of novel experimental techniques coupled with analysis to investigate the mechanics of material systems at different length and time scales, and the design of macroscale systems by taking advantage of micro and nanoscale properties.

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