The Department of Civil and Environmental Engineering at the University of Houston presents...

CIVE 6111 Graduate Seminar

AFM-Based Mechanical Characterization of Nanomembranes

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Friday, April 14, 2023
2:45pm-3:45pm
Classroom Business Building (CBB) - Room 104
Zoom: https://uh-edu-cougarnet.zoom.us/j/94589160391

Abstract

Nanomembranes are slender structures with a nanoscale thickness (from a few ångströms to a few hundred nanometers) and with a giant aspect ratio (i.e., lateral size is 2~3 orders of magnitude greater than thickness). The category of structures has aroused tremendous research interest as the principal building block of basically all living organisms, micro-/nano- electromechanical systems (MEMS/NEMS), and epidermal/implantable bio-electronic/photonic devices. For the application of nanomembranes in nanotechnology, it is essential to develop research to characterize the interfacial (adhesion strength and slippage ability) or mechanical (Young's modulus, Poisson's ratio, and bending stiffness) properties of nanomembranes. In the talk, I will start with recent advances in state-of-the-art measurements of nanomembranes based on the atomic force microscopy (AFM) technique, including bulge testing, spontaneously formed blister testing, and nanoindentation testing. Next, I will discuss several recent studies on AFM-based nanomembrane characterization: 1) Shape characteristics of 2D crystal blisters. At 2D crystal interfaces, we observed a unique pattern where satellite nanoblisters surround a parent microblister. AFM revealed that the blister shape transits from self-similar to size-dependent as its base radius decreases. We theoretically explained that the blister shape characteristics are governed by 2D crystal behaviors (membrane vs. plate) and interface behaviors (Griffith type vs. cohesive zone type). By conducting coarse-grained molecular dynamics (CG-MD) simulations, we verified the significance of the size of the process zone of van der Waals (vdW) interactions between 2D crystals and substrates in small-sized blisters. We also found a limiting blister height corresponding to one molecular layer of confined substances through CG-MD simulation results, suggesting a transition of confined substances' phases from the liquid state to the monolayer-lattice state. 2) Nanoindentation of freestanding nanomembranes. Extracting precise knowledge of the shear stress between nanomembranes and substrates from the AFM-based nanoindentation data is challenging. For this purpose, we established a theoretical model including the AFM-tip/nanomembrane and the nanomembrane/supporting-substrate interactions. Theoretical studies found that the influence of the AFM tip vanishes when tailoring the deflection of nanomembranes in nanoindentation measurements. I will conclude the talk with challenges and perspectives on the mechanical characterization of nanomembranes.

Bio

Yifan Rao is a Ph.D. candidate in engineering mechanics, at the University of Texas at Austin (UT Austin), working under Professor Nanshu Lu. Her research interests are in the mechanics of nanomembrane characterization, assembly, and application. Throughout her dissertation, she investigates how blistering occurs in a wide range of nanoscale films, including ultra-stiff and ultra-soft films. She addresses the following key questions: 1) how wettability affects blister shape and size? 2) how to bridge the gap between the blister model based on film/substrate molecule interactions and that based on the adhesion strength of film/substrate interfaces? The findings benefit the metrology of interfacial properties and nanomembrane properties, as well as the strain engineering of nanomembranes. She is currently working on probe measuring and manipulating nanomembranes/nanoblisters to explore potential applications.

For the past four years, Yifan Rao has taught seminars in two undergraduate-level courses: Statics and Mechanics of Solids. She organized the Lu research group activities in Explore UT, which are open to the general public. Her research has been published in, among others, Journal of the Mechanics and Physics of Solids, International Journal of Solids and Structures, Matter, and Nature Communications. She has two papers forthcoming in Journal of the Mechanics and Physics of Solids and Chemical Reviews. Prior to arriving at UT Austin, Yifan Rao holds B.S. and M.S. degrees in engineering mechanics from Tongji University, China.