Bulging and Poking of 2D Materials

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MAE Seminar Series

Nanshu Lu
University of Texas at Austin

Bulging and poking of thin films are widely used mechanical tests. They became particularly popular for characterizing atomically thin 2D materials, together with spontaneously formed nano-bubbles and nano-tents. This is because they are able to induce in-plane strains in 2D materials via easy-to-apply out-of-plane deformations. We measure their profiles through atomic force microscopy (AFM) and adopt the membrane limit of the Föppl-von Kármán (FvK) theory to unveil what sets the in-plane strains in terms of their shape characteristics and boundary conditions. 2D materials are sensitive to elasto-capillarity, which can be leveraged to quickly estimate 2D-material-to-substrate work of adhesion through the profiles of spontaneously formed nano-bubbles. Through a parent-satellite bubble system, we are able to determine the transition from membrane theory to plate theory and from Griffith-type interface to cohesive-zone-type interface formed with the supporting substrate. With coarse-grained molecular dynamics (CGMD) simulations, we can reveal when continuum mechanics ultimately breaks down. Moreover, we find that recent indentation results on suspended 2D materials do not follow the well-known load-cubic-deflection relation that is widely accepted for linear elastic sheets, which can be attributed to the slippage of atomically smooth 2D materials against their supporting substrates. We identify a single dimensionless governing parameter—the sliding number—defined by comparing the sheet tension (that drives the slippage) with the interfacial traction (that resists the slippage). I will showcase several useful asymptotic behaviors emerging at small and large sliding numbers.

Dr. Nanshu Lu is the Frank and Kay Reese Professor at the University of Texas at Austin. She received her B.Eng. with honors from Tsinghua University, Beijing, Ph.D. from Harvard University, and then Beckman Postdoctoral Fellowship at UIUC. Her research concerns the mechanics, materials, manufacture, and human / robot integration of soft electronics. She is a Clarivate (Web of Science) highly cited researcher and a Fellow of the American Society of Mechanical Engineers (ASME). She is on the Board of Directors of the Society of Engineering Science (SES). She is currently an Associate Editor of Nano Letters and Journal of Applied Mechanics. She has been named 35 innovators under 35 by MIT Technology Review (TR 35) and iCANX/ACS Nano Inaugural Rising Star. She has received US NSF CAREER Award, US ONR and AFOSR Young Investigator Awards, 3M non-tenured faculty award, and the Thomas J.R. Hughes Young Investigator Award from the ASME Applied Mechanics Division. She has been selected as one of the five great innovators on campus and five world-changing women at the University of Texas at Austin. For more information, please visit Dr. Lu's research group webpage at https://sites.utexas.edu/nanshulu/ and follow her on Twitter: @nanshulu.

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