Fracture of Two-Dimensional Materials

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Two-dimensional (2D) materials, such as Graphene, hBN and MoS_2, are promising candidates in a number of advanced functional and structural applications, owing to their exceptional electrical, thermal and mechanical properties. Understanding mechanical properties of 2D materials is critically important for their reliable integration into future electronic, composite and energy storage applications. However, it has been a significant challenge to quantitatively measure mechanical responses of 2D materials, due to technical difficulties in the nanomechanical testing of atomically thin membranes. In this talk, we will report our recent effort to determine the engineering relevant fracture toughness of graphene with pre-existing defects, rather than the intrinsic strength that governs the uniform breaking of atomic bonds in perfect graphene. Our combined experiment and modeling verify the applicability of the classic Griffith theory of brittle fracture to graphene. Strategies on how to improve the fracture resistance in graphene, and the implications of the effects of defects on mechanical properties of other 2D atomic layers will be discussed. More interestingly, stable crack propagation in monolayer 2D *h*-BN is observed and the corresponding crack resistance curve is obtained for the first time in 2D crystals. Inspired by the asymmetric lattice structure of *h*-BN, an intrinsic toughening mechanism without loss of high strength is validated based on theoretical efforts. The crack deflection and branching occur repeatedly due to asymmetric edge elastic properties at the crack tip and edge swapping during crack propagation, which toughens *h*-BN tremendously and enables stable crack propagation not seen in graphene.

Short Bio:

Jun Lou directs the Nanomaterials, Nanomechanics and Nanodevices Lab (N^3L) at Rice University. He is currently a full professor and the associate chair of the Department of Materials Science and NanoEngineering, and a professor of Chemistry. Dr. Lou was an AFOSR Young Investigator and a recipient of Charles Duncan Award for Outstanding Academic Achievement at Rice. He is a fellow of Royal Society of Chemistry (FRSC). He is also the Editor-in-Chief of Materials Today, the Elsevier flagship journal covering original research and reviews in the broader materials science community. He currently serves as the site director for the NSF industry university collaborative research center (IUCRC) of Atomically Thin Multifunctional Coatings (ATOMIC) exploring potential applications of 2D materials in different industries with commercial partners. He has published ~300 papers in high impact journals including Nature, Science, Nature Materials, Nature Nanotechnology, Advance Materials, Materials Today etc. with more than ~35,000 citations and an h-index of 86. He has been a highly cited researcher by Clarivate Analytic since 2018.