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Mechanical properties of 2D materials: The role of interfaces and structure property relationship

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2D materials, e.g., graphene, and heterostructures have extraordinary properties compared to their 3D counterparts and have great potential for a broad range of applications, including flexible electronic devices, nanocomposites, and transistors. The mechanical properties of 2D materials and heterostructures are both fundamentally and practically important to achieve both high performance and mechanically stable (flexible) devices. The in-plane mechanical properties of 2D materials are primarily dominated by the in-plane bonds in the materials while the out-of-plane mechanical properties are significantly affected by the interfaces between 2D materials and other materials (e.g., substrates). We first develop a first-principles calibrated contact resonance atomic force microscopy (CR-AFM), which is sensitive to mechanical property change arising from one atomic layer difference and is very powerful to investigate the interfacial defects in 2D materials and heterostructures. The measured nanomechanical property can be quantitatively correlated to the local atomic structure through a combined ab initio and continuum mechanics simulations. Furthermore, we discover that the out-of-plane mechanical properties of graphene can be engineered through self-assembled monolayers (SAMs) in the graphene-substrate interfaces. The surface energy of SAMs can be used to modulate the number of water molecules at the graphene-SAM interface, which affects the graphene-SAM interaction strength and the pecking order of SAMs. We further discover the out-of-plane mechanical properties of 2D hybrid organic-inorganic perovskites (HOIPs) depend on the structural parameters of the materials. Finally, the in-plane mechanical properties of 2D HOIPs are a function of the thickness due to interfacial sliding.

Biography

Tu is an expert on solid mechanics, 2D materials and scanning probe microscopy. His PhD research focuses on the interfacial properties of 2D materials and heterostructures by scanning probe microscopy, which won the outstanding dissertation award from Pratt School of Engineering at Duke University. He is currently a postdoc at Northwestern University Atomic and Nanoscale Characterization and Experimental (NUANCE) center. He is investigating the structure-property relationship of 2D hybrid organic inorganic perovskites and developing novel scanning probe microscopy techniques for nano- and bio-materials characterizations.

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