**Synthesis, Characterization and Engineering of Two-Dimensional Materials**

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In this talk, we first report the controlled vapor phase synthesis of transition metal dichalcogenide atomic layers and their heterostructures. The atomic structure and morphology of the grains and their boundaries are examined and first-principles calculations are applied to investigate their energy landscape. More importantly, if precise two-dimensional domains of metallic, semiconducting and insulating atomic layers can be seamlessly stitched together, in-plane heterostructures with interesting electronic applications could potentially be created. Here, we show that planar graphene/h-BN/h-BNC heterostructures can be formed either by growing graphene in lithographically-patterned h-BN atomic layers or by a direct chemical conversion process. Next, we report the in situ tensile testing of suspended graphene using a nanomechanical device to measure the fracture toughness of graphene. Our combined experiment and modeling verify the applicability of the classic Griffith theory of brittle fracture to graphene. The implications of the effects of defects such as grain boundaries on mechanical and electrical properties of two-dimensional atomic layers will also be discussed. Finally, we demonstrate how self-assembled monolayers with a variety of end termination chemistries can be utilized to tailor the physical properties of single-crystalline $MoS_2$ atomic-layers. Our data suggests that combined interface-related effects of charge transfer, built-in molecular polarities, varied densities of defects, and remote interfacial phonons strongly modify the electrical and optical properties of $MoS_2$, illustrating an engineering approach for local and universal property modulations in two-dimensional atomic-layers.