Nano-Mechanical Characterization: Exploring the mechanics of 2D Materials and their Heterostructures

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ABSTRACT

The first isolation of graphene in 2004 by Novoselov and Geim [1], has offered a new and exciting platform with extraordinary potential. The surge of two-dimensional (2D) materials has taken the world by storm and became a new research hotspot as the characterization of nanoscale properties became a necessity [2]. Lately, emphasis has been given to the synthesis of these materials and their heterostructures for mass production and integration in various applications. At the moment, their properties are mostly derived from theoretical calculations since experimental characterization at the nanoscale is limited. Therefore, in order to incorporate two-dimensional materials in the application of interest, one must first understand the full extent of their properties at the nanometer scale.

One of the most powerful techniques for nanoscale characterization is Atomic Force Microscopy (AFM), which can be practiced even at atomic scale resolution. More specifically for mechanical properties, the most widely used approach for their examination is obtained from force curves as a function of the indentation depth at the center of a freely suspended membrane. The analysis models take into consideration the existing pre-tension and the bending rigidity of the membrane, as well as the Young's modulus and the hardness of the material [3].

The purpose of this study is to investigate the mechanical properties of suspended 2D materials and their heterostructures on top of patterned substrates, with the aid of AFM. Initially, various 2D materials were directly mechanically exfoliated or transferred from CVD grown samples onto patterned SiO_2/Si substrates. Subsequently, the flakes were identified for their quality and quantity with optical microscopy and Raman spectroscopy. Finally, the freely suspended membranes allowed us to attain the mechanical properties, without the contribution of the substrate, as well as interface and layer-by-layer interactions of heterostructures. This method permits the evaluation of theoretical data and can corroborate their impact on today's applications.

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