On the extraction of accurate stiffness and strength properties of 2D materials using atomic force microscopy induced membrane deflection

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Atomic force microscopy (AFM) membrane deflection is probably the most commonly used tool to characterize the mechanical properties of 2D materials. Associated with different imaging modes that provide high quality micrographs of the studied systems, it provides accurate force/displacement data. In the present study, the mechanical properties of graphene have been investigated experimentally and with finite element simulations to consolidate the data reduction schemes. Differences between the experimental results and simulations can not only be attributed to the intrinsic structural defects such as grain boundaries, dislocations and graphene edges induced by the synthesis and transferring processes but also to instrumentation and testing sources of uncertainties. These last factors are associated to the imaging and mechanical testing limitations of AFM such as the degradation of the tip, the uncertainty on the measured displacement, on the membrane radius, on the location of the application of the load. The stiffness is for instance significantly overestimated when the tip is not well centered and an approach is proposed to circumvent this difficulty. All these parameters have been carefully investigated and quantified. The methodology was then applied to the extraction of the Young's modulus and the fracture strength of single- and bi-layer graphene to highlight the differences between both systems. The procedure was also applied to 2D hexagonal boron nitride (h-BN).