Mapping nanomechanical phenomena in graphene nanostructures using force modulation and ultrasonic force microscopy

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ABSTRACT

Graphene is a novel nanomaterial that possesses outstanding electrical, thermal, and mechanical properties. Whereas its electronic properties are extensively studied, mechanical properties of graphene nanostructures are much less experimentally explored even for simple graphene structures [1]. At the same time, the nanoscale morphology of atomically thin graphene films, including rippling at various length scales and inter-layer force interaction are directly modified by the substrate and local environment that in turn changes of local nanoscale mechanical properties of a graphene nanostructure [2-4]. We use a combination of force sensitive scanning probe microscopies that combines low frequency and ultrasonic vibrations and enables mapping of wide dynamic range of stiffnesses from 0.02 to 2000 N/m with the lateral resolution of few nanometres. That allowed us to investigate results of residual stresses in supported graphene layers that revealed themselves as broken mechanical contact at the interface between graphene layer and the substrate, as well as to explore nanomechanical behaviour of suspended graphene film. We directly observed the transition of graphene layer deformation from plate to stretched membrane behaviour, and to create nanoscale maps of shell instability for few layer graphene sheets, providing insight to the stresses in the free standing graphene films.

Keywords: atomic force microscopy, nanomechanics, graphene, ultrasonic force microscopy, buckling.