Graphene_ing^3: Cracking, Buckling and Wrinkling

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ABSTRACT

Graphene is a planar nanomaterial under current and intensive research because of its excellent mechanical, thermal, optical and electrical properties. The use of graphene in nanocomposites and technological nano-devices makes it always loaded under a given stress state, either tensile or compressive. In case of tension, the hexagonal latticed structure of graphene gets extremely stiff but the breakage of the first C-C atomic bond leads to the onset of crack and its evolution, which depends on the tensile loading direction (either armchair or zigzag). Despite being extremely stiff in its plane, the atomic structure of graphene sheets is very prone to out-of-plane deformations, which may occur when the sheet is being compressed. Buckling phenomena of graphene sheets also decreases their load carrying capacity and may limit their application in some technological nano-devices. However, it is also seen that the capacity of graphene sheets to sustain compressive loads depends much on the loading direction (either armchair or zigzag). Sometimes, because of their low out-of-plane stiffness, graphene sheets are attached to elastic substrates in order to increase their stiffness. However, the sheet may also wrinkle if the substrate shortens. This wrinkling phenomenon, which induces the formation of many wrinkles, may also affect the intended purpose of the graphene sheet.

The main objective of this lecture is to show how these three types of failure (cracking, buckling, wrinkling) affect the mechanical behaviour of graphene, namely its anisotropy, nonlinearity, stiffness, strength and toughness. For this purpose, molecular dynamics models were developed and controlled simulations were carried out. Some remarkable differences between the behaviour of graphene at nanoscale and their continuum counterparts (at macroscale) are highlighted. Finally, some relevant conclusions about the graphene anisotropy and nonlinearity are also drawn.

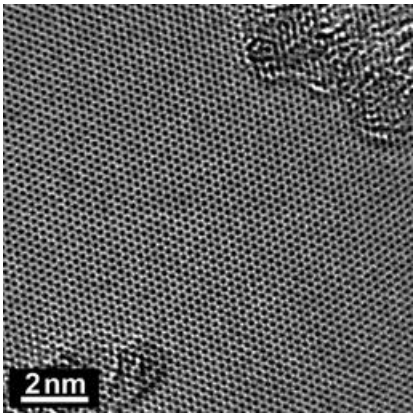

Figure: High-resolution TEM on graphene (http://www.cen.dtu.dk/Research/Projects/ACTUAL-High-Resolution-TEM-on-graphene)