Nanomechanical assessment of adhesion and Young's modulus in graphene: quantum mechanical confinement meets mechanics

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Graphene[1,2] has been shown to be one of the hardest and toughest materials, due to its simple structure, it is also an excellent template to investigate the quantum mechanical confinement in terms of the mechanical properties with different crystalline sizes. In our work, focused ion beam irradiation[3] was performed on CVD graphene to obtain graphene crystals with effective grain sizes down to 4 nm and the peakforce quantitative nanomechanical mapping (PF-QNM) technique in atomic force microscope (AFM) was employed to investigate the mechanical properties, i.e. adhesion and Young modulus of the graphene. Our results show that nanomechanical size effects are observed in graphene as the effective crystalline size becomes smaller than 7 nm, where the stiffness and the adhesion of graphene shows a sharp decay, whereas both properties remain constant as the effective crystalline size is more than 7 nm. The size dependent adhesion can be understood in the framework of the bond-broken model. As for the Young's modulus observation, the result corresponds well with the prediction of Zeinalipour-Yazdi[4] and could be explained by the alternation of bond lengths caused by the imposition from stable geometries of the wave functions at the edge to the geometry of inner wave functions of the graphene.

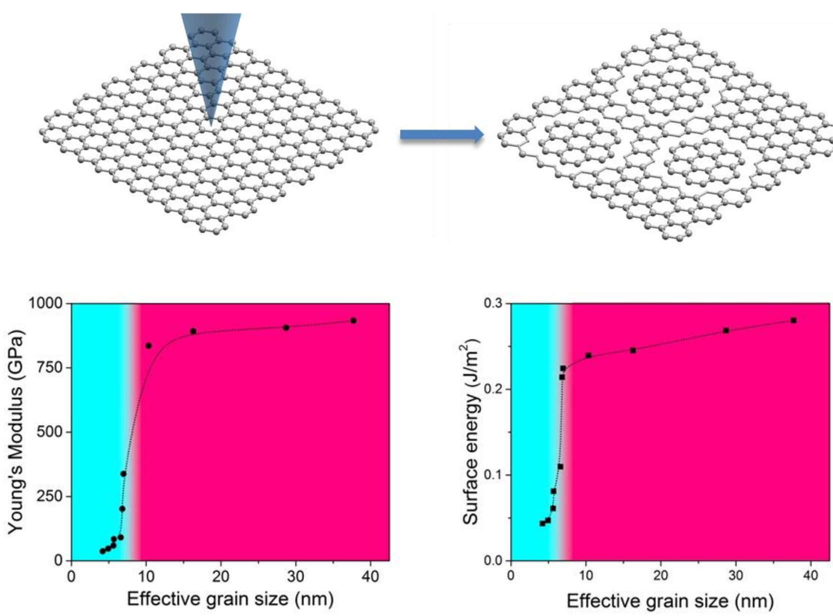

Figure. The Young's modulus and surface energy of graphene as a function of effective grain size.

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