Mechanical Deformation of graphene and graphene-based nanocomposites

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Graphene has received a lot of attention nowadays due to the fact that as a single, virtually defect-free crystal is predicted to have an intrinsic tensile strength higher than any other known material **¡Error! No se encuentra el origen de la referencia.** and tensile stiffness similar to graphite 0. In this work, we have been subjecting a single layer of graphene -embedded into the upper surface of a PMMA cantilever or 4-point-bend bars and covered by a ~100nm thickness polymeric film to tension and compression, while its Raman spectrum is recorded simultaneously (Fig.1). The beams can be flexed up or down by means of adjustable screws subjecting the flake to compressive or tensile loads, respectively. Graphene's strain value at each deflection level is estimated using the results of Timoshenko's theory of beams [3]. Except the significant information on the monolayer deformation - stress uptake, we determine the compression buckling strain in single graphene flakes of different geometries. In all cases the mechanical response is monitored by the shift of the G and 2D Raman lines with strain, using two different excitation laser wavelengths (514.5nm and 785nm) [4,5].

In tension, the embedded flakes seem to sustain strains up to 1.3% in a reversible manner [4]. The position of the 2D peak shifts linearly to the applied uniaxial strain using the 514.5nm excitation line having a rate of ~52 cm^{-1}/% in agreement with recent results [6]. In compression, the G and 2D band response is non-linear. The corresponding $\partial\omega_{G,2D}/\partial\varepsilon$ values decrease with strain till the eventual turn-over of the slope, which is indicative of progressive buckling that precedes the final collapse of the flake [5] (Fig.2). Pertinent analytical expressions for the critical buckling strain, ε_c^{emb} , have been developed by considering the Euler classical analysis and/or a Winker type of approach to account for the resistance to buckling provided by the surrounding matrix. Despite the infinitely small thickness of the monolayers, the results show that graphenes embedded in plastic beams exhibit remarkably high compression bucking strain compared to that of the suspended ones, due to the effect of the lateral support provided by the polymer matrix, which is indeed dramatic and increases the effective flexural rigidity of graphene. The experimental finding that one atom thick monolayers embedded in polymers can provide reinforcement in compression to high values of strain is very significant for the development of nanocomposites for structural applications [5].

Finally, in graphene/ polymer composites the stress transfer distribution was extracted in as-prepared flakes and then at various levels of applied strain. Important parameters such as the stress-transfer length and the maximum value of interfacial shear that is developed in each case were determined [6]. In the case of a monolayer graphene (1LG) supported on a SU8/ PMMA bar, evidence is provided that the peeling procedure during graphite exfoliation induces a compressive, shear-generated, residual stress distribution. The related stress-transfer lengths from the graphene edges were found to be in the submicron range and hence much smaller than originally thought. Upon application of external tensile load to the substrate, the stress appears to be transferred to 1LG not through interfacial shear but by direct normal forces. The extension of this work to fully embedded graphene/ polymer composites and related analytical modeling will be discussed.

References

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