Controlling the orientation of boron nitride and carbon layers in BN/graphene stackings

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Abstract

Graphene/boron nitride (G/BN) multilayers are very interesting objects because they constitute a repetition of isolated graphene layers, separated by an electrical insulator. Therefore, the outstanding physical properties of graphene can be multiplied by the number of graphene layers in the stacking. The use of boron nitride as the insulating separator is optimal because boron nitride is isoelectronic and isostructural to graphite, hence a single BN layer has a perfect geometrical match to a graphene sheet.

Apart from a few studies on G/BN multilayers produced by peeling [1] or transferring [2] followed by the stacking of the two materials, there are no results on the direct growth of these structures. A detailed work on the synthesis of high quality G/BN multilayer structures by vapor deposition techniques is still lacking.

We are using ion beam assisted deposition (IBAD) to produce carbon/BN multilayers, with the sequential deposition of carbon by simple evaporation, and boron nitride by boron evaporation simultaneous to nitrogen ion bombardment. Three critical issues which are under study are: (i) the orientation of the formed layers, (ii) their long range order and (iii) the interfacial sharpness.

With regards to carbon, its deposition takes place without ion bombardment, and it yields a preferential orientation of the basal planes parallel to the substrate surface. Long range order within the carbon layer can be controlled by the deposition temperature, with increasing perfection at higher temperatures and slower deposition rates. Raman spectroscopy confirms the formation of single or few-layer graphene under certain conditions through the ratio of the 2D to G peaks.

With regards to boron nitride, its synthesis requires the participation of nitrogen ions, resulting in a compressive stress in the films that tend to orient the basal planes perpendicular to the growth direction. This is the common growth mode of these materials, as can be observed clearly in the TEM image of Figure 1, corresponding to graphite/BN layers of about 5 nm. However, it is known that the orientation of BN can be controlled through ion bombardment and annealing treatments [3]. For the G/BN multilayers under study here, the BN planes must lie parallel to the growth direction. This is achieved by minimizing the ion energy to reduce the compressive stress, and increasing the growth temperature.

A detailed study of the texture of BN films grown with different conditions of ion bombardment and temperature is presented, based on x-ray absorption near edge spectroscopy (XANES) at different angles of incidence, a technique very well suited to study the orientation of π-bonded systems.

Finally, the growth of graphene on BN layers with different texture and long range order is examined by Raman spectroscopy.

References

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Figures

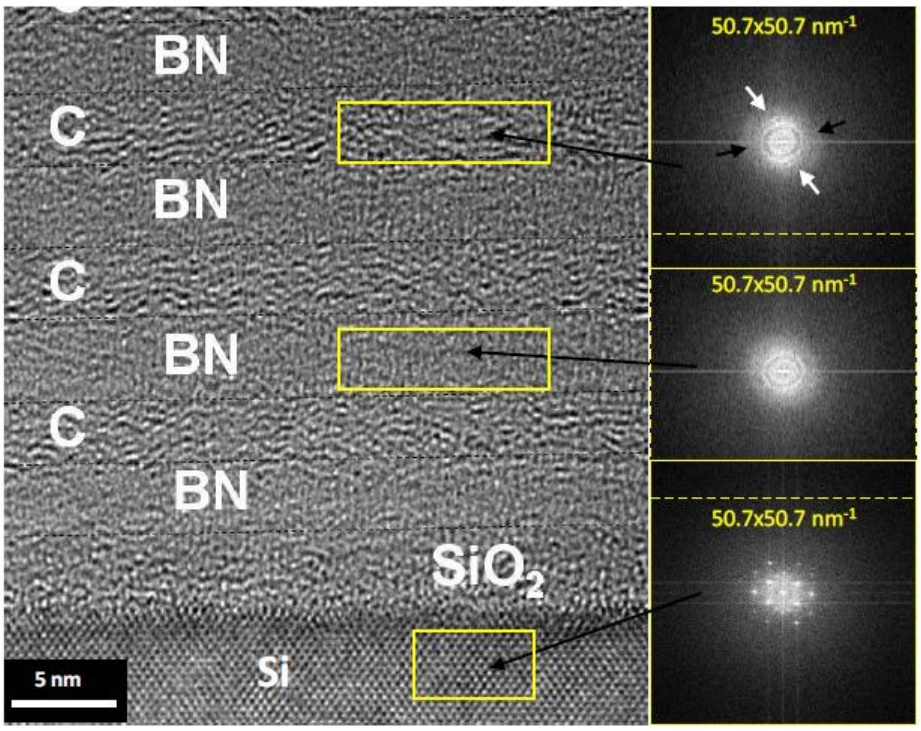

Figure 1. High resolution TEM images from a stack of nanometric carbon and BN layers produced by IBAD, evidencing the reverse texture of the forming layers. Carbon layers have the basal planes parallel to the substrate, whilst BN layers have the basal planes perpendicular to the substrate.