Study of Ion-Induced Defect Migration in Boron-Nitride Encapsulated Graphene

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Despite its exceptional electrical properties, the absence of a bandgap thwarts the potential applications of graphene in electronic applications. One method for modifying the electrical properties is by cutting graphene into nanoribbons using a focused ion beam. However, collateral damage caused by the ions is inevitable and therefore limits the fabrication of electronic devices. Here we study the extent of the damage in He^+-beam-irradiated encapsulated graphene using local probe techniques, i.e. Tip Enhanced Raman Spectroscopy (TERS) and Kelvin Probe Force Microscopy (KPFM).

Using the local probe techniques, we investigate the extent of He^+ induced damage in graphene that is encapsulated between hexagonal boron-nitride (hBN) flakes. Data analysis reveals that the lateral extent of the defected area induced by line-exposures depends on the He^+ dose in a monotonic fashion. Increasing the dose from 1×10^{16} to 5×10^{18} $He^+\,cm^{-2}$ increases the lateral defect migration distance to several tens of nanometers. However, doses greater than 1×10^{18} $He^+\,cm^{-2}$ are required to create an insulating region in the encapsulated graphene. The mean defect distance (L_D) in the exposed regions is estimated using the local activation model of Lucchese *et al.* [1]. We conclude that encapsulation slows down the migration of defects in graphene. These observations indicate that radiation defects in graphene do not simply reflect the original disorder created by the collisions of the primary ions. Instead, the disorder evolves after termination of the collision process; this evolution is strongly influenced by the graphene's environment [2].

With the ion beam, we fabricate graphene nanoribbon devices with one-dimensional contacts. The temperature-dependent conductance measurements show band gap opening in these nanoribbon devices.

*[1] M. M. Lucchese et al.; Quantifying ion-induced defects and Raman relaxation length in graphene; Carbon, 2010, **48**, pp 1592-1597*

*[2] Gaurav Nanda et al.; Defect Control and n-Doping of Encapsulated Graphene by Helium-Ion-Beam Irradiation; Nano Lett., 2015, **15**, pp 4006–4012*

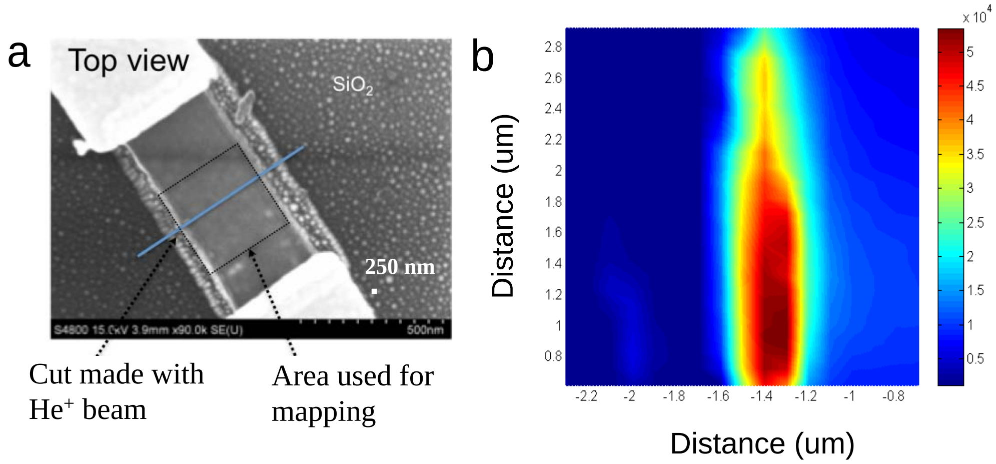

Figure 1: (a) SEM image of BN/Gr/BN heterostructure. (b) D-peak Raman intensity map (arbitrary units) of a He^+ *line-exposure, shown in (a) using micro Raman spectroscopy. The dose used is* 2×10^{18} He^+ cm^{-2}.