Helium Ion Beam Induced Stress on Graphene Cantilever

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Graphene is an extraordinary two dimensional (2D) material with superior electronic and mechanical properties. Due to its exceptional physical properties, graphene became a building block in different applications, such as nano-electronics, electro-mechanical sensors, and switches. Nano- and atomic-scale devices need high precision in material maneuvering. In this regard, helium ion milling (HIM)with a beam diameter of 0.25 nm is a promising fabrication technology for precisely controlled Graphene-based nano- and atomic-scale devices.

Despite its great advantage, imaging effect (due to He^+ ions interaction with graphene sheet) and substrate effect (due to He^+ ion interaction with substrate) are the main challenges facing the use of HIM technology for nano-scale graphene devices. Substrate effects such as ion forward scattering, backscattering, substrate swelling possibly can be mitigated to some extent by suspending graphene before milling. However, the minimum non-destructive dose for imaging is challenging due to the trade-off between the signal to noise ratio [1]. In this work, we investigate the imaging induced defects in by studying the evolution of stress-induced in graphene cantilever. Electron beam lithography (EBL) followed by reactive ion etching (RIE) is used to fabricate and pattern ~ 300 nm graphene nano-ribbon (GNR) cantilever with ~ 500 nm width. Buffered hydroflouric acid (BHF) wet etching is used to suspend GNRs by creating around 160 nm air gap underneath the ribbon. By imaging the device by the He+ ion beam, the rolling up of the graphene cantilever is clearly noticed. Figure 1 shows a successive imaging frame for the device under investigation, which shows clearly the evolution of graphene cantilever rolling up by continuous imaging. Rolling up can be explained by the generation of local stress due to knock-off of carbon atoms and rearrangement of the atoms. Since the rolling of suspended graphene due to residual stress can be affected by cantilever aspect ratio and metal contacts, more investigation still needed. Experimental results will be supported by the molecular dynamic simulation to get more understanding about induced-stress due to energetic He+ ions interaction with suspended graphene.

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References : [1] D Fox et. Al, Nanotechnology 24 (2013) 335702. [2] Nitul S Rajput et. al, Nanotechnology 22 (2011) 485302

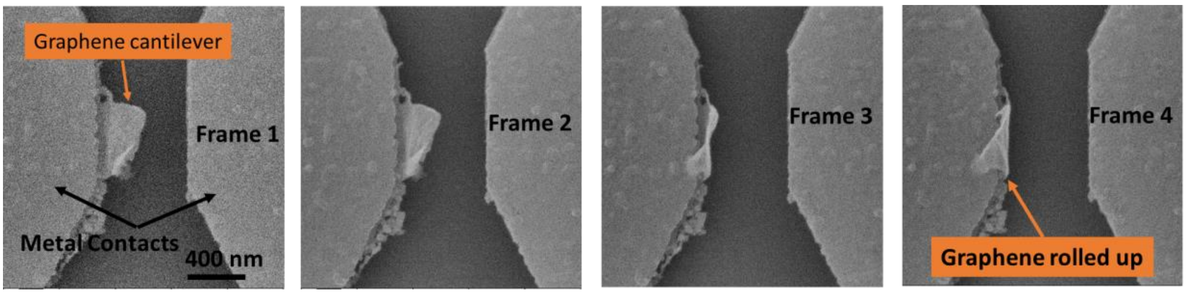

Figure 1: Graphene Cantilever with 300 nm long and 500 nm width is rolled up because of He^+ ion beam successive imaging with a beam current of 1.1 pA and dwell time 10.0 μs.