Epitaxial Growth of Graphene on High Topology SiC Structures Patterned by Focused Ion Beam

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Graphene films possess many of the same interesting surface and electronic properties as carbon nanotubes except in extended 2D sheets. This formation can be more useful for many applications, including integrated circuit fabrication and surface probing. The growth of epitaxial graphene (epigraphene) from single crystal SiC is an attractive fabrication alternative to the lengthy layer-by-layer exfoliation of graphite crystals [1]. In an effort to expand the capabilities of epigraphene, we have demonstrated the growth of multiple layers of graphene from a single crystal SiC sample on surfaces that have been micro-machined to levels of high topology with a focused ion beam (FIB).

A single crystal die of 4H-SiC with (0001) orientation (SiCrystal Ag) was patterned as shown in Figure 1 using a FEI D1000 dual-beam FIB. Patterns were chosen to provide flat and angled structures with variable topology provided by the technique of milling utilized. The ion current was maintained at 300pA throughout the mill. Graphene epilayers were produced by thermal annealing the patterned sample. First, the surface was cleaned by repeated UV-ozone treatments and wet etching in concentrated HF solution. The die was then heated in ultrahigh vacuum by electron bombardment of the backside surface and subsequently cooled to room temperature [2]. Figure 2 shows a SEM of the post epigraphene growth structures.

Scanning Auger spectra were taken of the sample on the surfaces indicated in Figure 3. The scans were performed at 5keV and the ratio of the C and Si signatures can be used to determine the presence and thickness of epigraphene [3]. For SiC without epigraphene growth the C:Si ratio is 1:1. Regions of high topology after extensive milling followed by graphitization show a C:Si ratio of approximately 15:1 for comparison of the signal of C (272eV) and Si (92eV). This ratio corresponds to 2 monolayers of epigraphene growth (plus 1 buffer layer). This ratio is the same as that measured in regions untouched by the ion beam. Thus we can conclude that neither the topology nor Ga surface contamination from ion beam has limited the epigraphene formation. Efforts are ongoing to further characterize the electrical properties of epigraphene over high topology and the limits of this growth. We plan to continue tests of structures of even greater topology including overhanging structures and topology created by reactive ion etching as opposed to FIB milling.

References:

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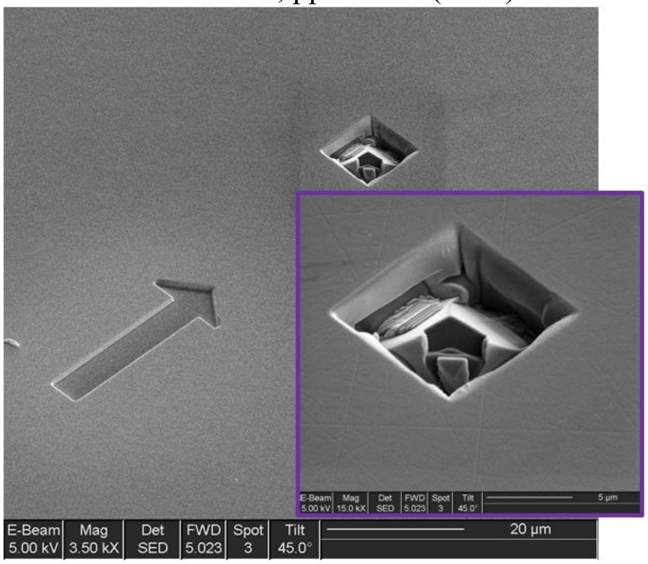

Figure 1: Scanning electron micrographs of FIB milled structures prior to epigraphene growth. The inset image is a higher magnification image of the angled structure.

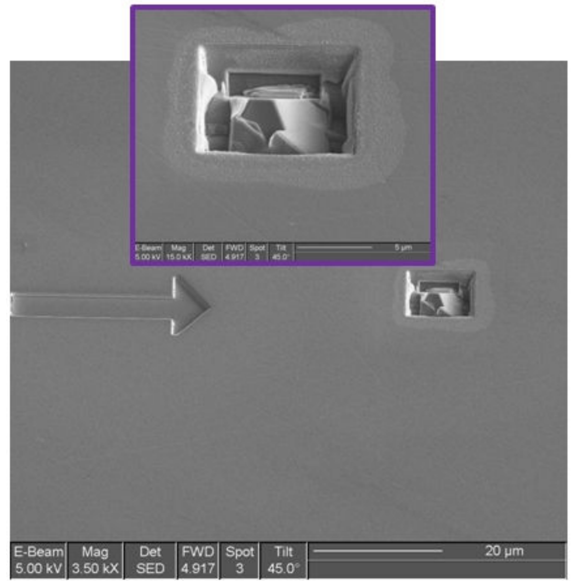

Figure 2: Scanning electron micrographs of FIB milled structures after epigraphene growth. The inset image is a higher magnification image of the angled structure. Some roughness is clear around the edges of this mill.

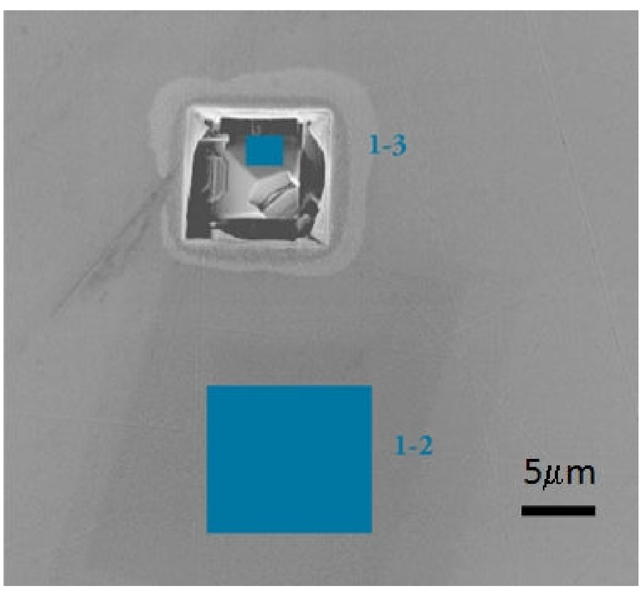

Figure 3: SEM of the high topology structures after epigraphene growth with the areas for scanning Auger spectroscopy highlighted by blue squares.

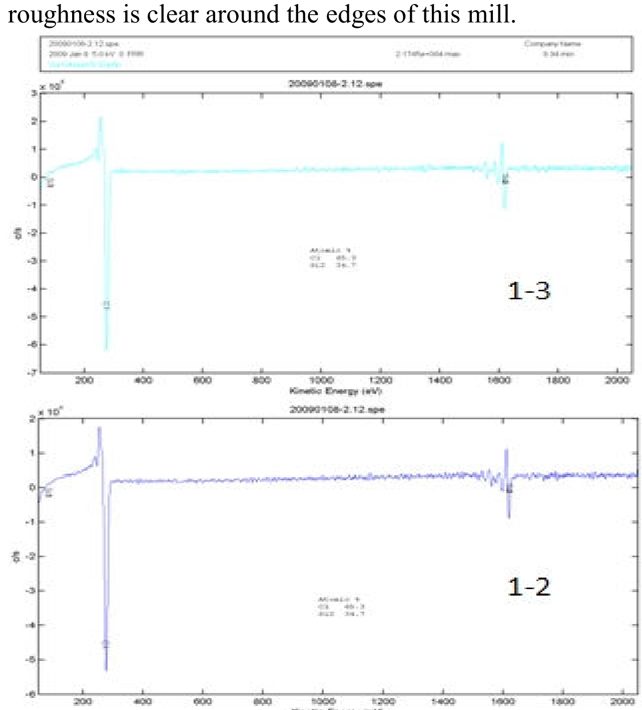

Figure 4: Scanning Auger spectra for the regions indicated in Figure 3. Region 1-2 on the planar region untouched by the FIB shows a C:Si ratio of ~15:1 and region 1-3 on a facet of the pyramid has an identical C:Si ratio. This is indicative of equivalent epigraphene growth of multiple layers. SiC without epigraphene growth has a C:Si ratio of 1:1.