Epitaxial Graphene on Silicon Carbide

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Abstract:

Graphene grown epitaxially on silicon carbide (SiC) substrates in our laboratory was characterized in the CNF using atomic force microscopy (AFM). Efforts were made towards fabricating devices on graphene for magnetotransport measurements. Studies are also ongoing on graphene-SiC heterojunction devices.

Summary of Research:

Graphene is a 2D form of carbon with a honeycomb-shaped lattice structure. It was thought to be unstable, before it was first isolated by Geim et al [1] in 2004 by mechanical exfoliation of bulk graphite. Graphene is a zero or near-zero bandgap semiconductor with a linear energy-momentum dispersion relation near the K, K' points for electrons and holes. Recently, epitaxial growth of graphene on SiC substrates has been demonstrated [2,3]. This technique involves heating up the SiC substrate under vacuum to high temperatures in the range of 1200°C – 1600°C. Silicon, on account of its higher vapor pressure, sublimes off more easily than carbon, leaving a carbon-rich surface behind, which rearranges on the hexagonal template provided by the substrate to form graphene. Graphene, from a few monlayers to several (> 50) layers thick, can be obtained.

Epitaxially grown graphene films on SiC substrates were characterized at CNF using the Digital Instruments Dimension 3100 AFM. For semi-insulating SiC substrates without any surface preparation, the AFM images show domain like features, which are indicative of nanocrystalline material (Figure 1(a)). n-epitaxial SiC surfaces, on the other hand, shows step-like features with wrinkles (Figure 1(b)). Starting with a regularly stepped surface on the C-face gave rise to a surface morphology in Figure1(c), showing hexagonal faceting. This underscores the understanding that a regularly stepped surface gives rise to a high quality epitaxial graphene film. The rms roughness of the films was observed to decrease with the growth temperature.

Graphene devices were fabricated at CNF for magnetotransport measurements. Ti-Au-Cr contacts were patterned on the graphene first using photolithography (GCA/MANN 3600F Optical Pattern Generator, GCA Autostep 200 and CVC 4500 Evaporator).

Figure 1: AFM micrographs of the surface taken after sublimation for some representative samples: (a) semi-insulating SiC at 1500°C with no surface preparation (z-scale 10 nm) (b) n-epitaxial SiC at 1600°C (z-scale 30 nm) (c) semi-insulating SiC at 1400°C with a regularly stepped surface prior to growth (z-scale 10 nm).
Then, a second step of photolithography was undertaken and oxygen plasma (PlasmaTherm 72) was used to etch and pattern the graphene. A scanning electron micrograph of a finished device is shown in inset of Figure 2. Wirebonding was performed for the finished devices using the Westbond 7400A Ultrasonic Wire Bonder. There were serious issues with the adhesion of the contact pads to graphene and so, the wirebonded pads moved around and shorted out each other in many places. The mobility measurements were unsuccessful, primarily because of the poor wirebonding, we believe. However, positive magnetoresistance was recorded for some of the devices, as shown in Figure 2, indicating we had disordered graphite [4]. This is also suggested by our Raman spectroscopy measurements.

Graphene-SiC hetero-junction devices were fabricated by evaporating metal dots on graphene using a shadow mask. I-V between two adjacent dots is shown in Figure 3 for the graphene-SiC devices before and after mesa isolation of graphene using oxygen plasma. The I-V characteristics are ohmic before isolation, while they change to back-to-back Schottky behavior (Figure 3) after the etch, along with a dramatic reduction of the current levels. Further investigations are ongoing.

References:


