Patterning of graphene on SiC using the He ion nanobeam

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The role of graphene in many future device applications depends on the creation of a bandgap. Various methods have been pursued to produce nanopatterned graphene, including e-beam lithography with HSQ resist [1], solution chemical processing [2], or growth on SiC crystallographic facets[3]. One method of bandgap opening is to pattern graphene by cutting it into ribbons[1-3] or by introducing a dot array[4], with the bandgap E_g scaling inversely with ribbon width W: $E_g \approx 1.3$eV-nm/W. The electrical properties of the nanoribbons depend on the patterning method and edge structure. Helium ion nanobeam, which has a beam diameter below 1 nm, is potentially an attractive tool for patterning graphene. It has already been used to cut exfoliated graphene, (suspended or on-substrate) [6-7] but bandgap values have not been reported.

Epitaxial growth of graphene on a SiC substrate is a particularly promising technique for device applications since it yields wafer-scale, planar areas of material[8]. Here we investigate the patterning of epitaxial graphene on SiC using a helium ion nanobeam[5]. Monolayer graphene on 6H-SiC(0001) was prepared as in [9], patterned into graphene rectangles of various sizes defined by photolithography and oxygen plasma etching, and contacted by gold electrodes[9]. (see inset Fig.1) To study the electrical and optical properties of patterned graphene, the rectangles were exposed with a He ion beam (30keV, ~1pA, <1nm diameter) with four types of patterns: cuts across the entire width, exposure of the entire rectangle to relatively low doses, patterning of the rectangle into nanoribbons, and patterning of the rectangles with an array of milled dots. As shown in Fig.1, the dose needed to begin to interrupt the conduction through the graphene between the contacts was about $2\text{x}10^{17}$ ions/cm^2. AFM analysis of our exposed samples was performed. At higher doses ($\gtrsim 10^{17}$ ions/cm^2) swelling of the silicon carbide substrate was observed.

References

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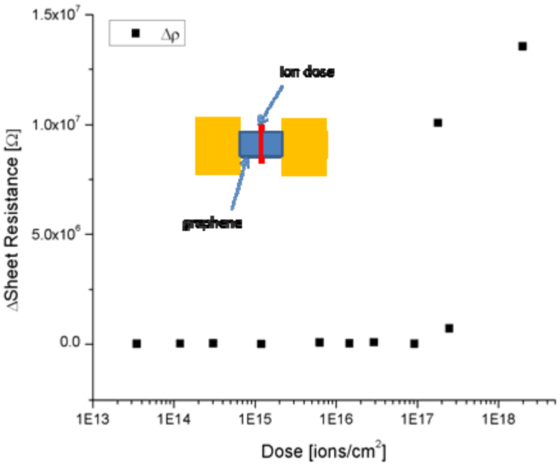

Figure 1. The change in sheet resistance of graphene vs He ion dose. The change in sheet resistance of the irradiated area of the graphene was calculated as

$$\frac{(R_{before}-R_{after})*W}{L}$$

where W is the dimension of the graphene channel perpendicular to current flow, L is the dimension of the cut in the direction parallel to current flow, and R_{before} and R_{after} are device resistances measured before and after exposure, respectively.

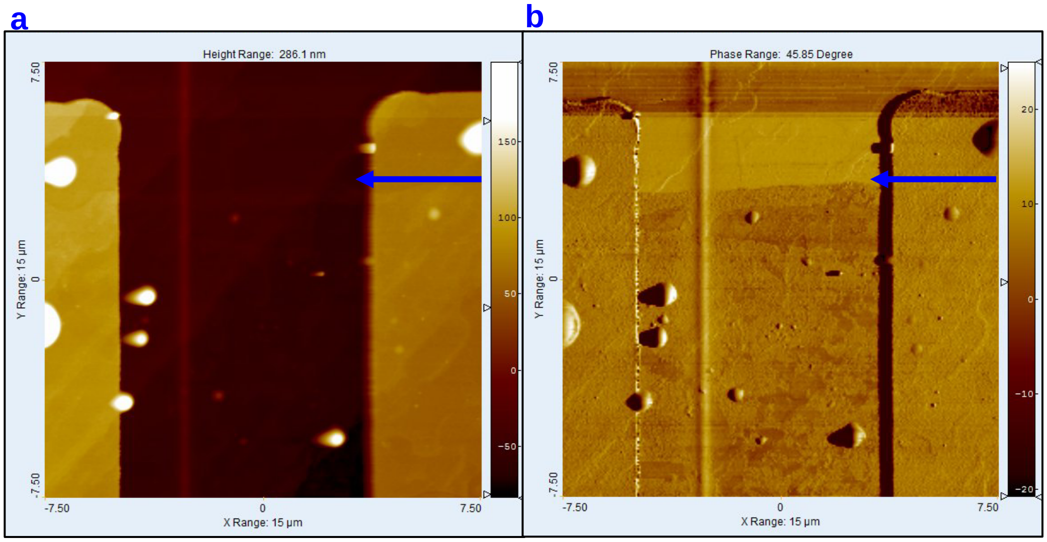

Figure 2. Atomic force microscope (AFM) image of a graphene device cut by He ion beam. (a) AFM height image showing gold contacts (large yellow areas) and irradiated area (narrow vertical bar in center). The irradiation was performed at an intermediate dose of ~3 x 10^{16} ions/cm^2, and the irradiated area is raised indicating a swelling of the silicon carbide. The graphene is not visible due to the large vertical scale. (b) The AFM phase image shows the graphene rectangle between the two gold contacts as well as the substrate swelling due to the cut line. In both (a) and (b) the top edge of the graphene is marked by blue arrows.