Growth of high quality epitaxial graphene by modified hydrogen annealing

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Epitaxial graphene (EG) on silicon carbide (SiC) is promising for fabrication of graphene field-effect transistors (GFETs) because it can be formed directly on a large size, semi-insulating substrate without any transfer procedures. Among various methods for the betterment of EG, hydrogen (H_2) annealing methods have been attracting recent attentions. First, annealing in H_2 at high temperatures (>1400 ^oC) removes the surface polishing damages and causes a uniform array of steps. Second, annealing in H_2 at low temperatures (~600 ^oC) causes a hydrogen intercalation and decouples the buffer layer from the SiC substrate. In this presentation we propose a new H_2 annealing method (modified H_2 annealing) for the formation of high quality EG. The method consists of (1) low-temperature (LT) annealing in H_2 at 500 ^oC for 5 hours for SiC surface reconstruction and (2) subsequent high-temperature (HT) annealing in Ar/H_2 at 1480 ^oC for the formation of EG. Figure 1(a) shows the AFM image of 4H-SiC(0001) after the procedure (1). A well-ordered surface with a step height of 1.1 nm and a terrace width of 1.5 μm was formed. Using this substrate, graphene was grown in Ar (1420 ^oC) or in Ar/H_2 ambient (1480 ^oC). The upper images in Figs. 1(b) and 1(c) show the AFM image of the EG grown in Ar and Ar/H_2 ambient, respectively. EG grown in Ar ambient shows a minimum-step-bunching (MSB) with a step height of 1.5 nm and a terrace width of 5.0 μm. For EG grown in Ar/H_2 ambient, a uniform large-step-bunching (LSB) with high step (~45 nm) and wide terrace (~30 μm) was formed. Moreover, the EG grown under Ar/H_2 ambient exhibits a sharper and a higher Raman G'-peak in the spectrum, which indicates formation of high quality graphene. Figure 2 compares the Hall mobility between Ar and Ar/H_2 ambient. The EG grown in Ar/H_2 ambient shows a higher Hall mobility (2095 cm^2/Vs @ n = 1×10^{12} cm^{-3}) than that grown in Ar ambient (1750 cm^2/Vs @ n = 1×10^{12} cm^{-3}). This improvement is due to the H_2-termination of the Si dangling bonds underneath the buffer layer without breakage of the Si-C covalent bond between SiC and the buffer layer, which was confirmed by the appearance of Si-H bond component in X-ray photoelectron spectroscopy (XPS) analysis. This is the first report to form EG by annealing SiC in Ar/H_2, which provides a novel, excellent method to fabricate high quality EG to be used in graphene based electronic devices.

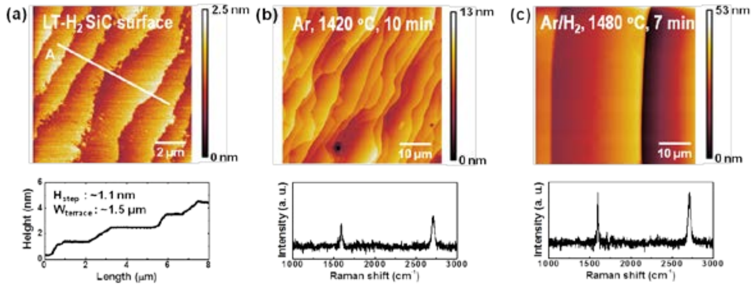

Fig.1. (a) AFM image of low-temperature H_2-annealed SiC surface. AFM and Raman spectrum of EG surface grown in (b) Ar ambient and (c) Ar/H_2 ambient.

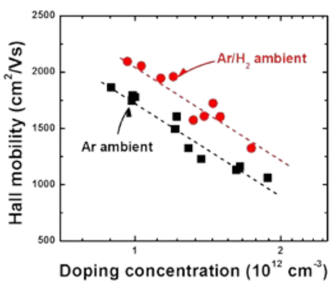

Fig.2. Comparison of Hall mobility of EG grown in Ar ambient and Ar/H_2 ambient.