Nano-carbon structures on silicon carbide†

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1. Introduction

Graphene, a one-atom-thick carbon material, has attracted extensive research due to its novel structure and electronic properties, and to its extremely high carrier mobility for semiconducting devices [1]. Carbon-nanotubes (CNT) can be obtained by folding graphene layer(s) into a cylinder, which is famous for its outstanding electrical, thermal, and mechanical properties [2]. These novel nano-structured carbon materials can be fabricated by the SiC thermal decomposition method [3-8]. Using this method, carbon-nanotube and graphene are selectively formed on SiC just by heating the silicon carbide substrate in vacuum. In a vacuum furnace, silicon atoms are removed, and then the remaining carbon atoms form graphene layers or a nanotube film. In this study, we present crystallographic features of carbon-nanotube and graphene layers formed epitaxially on the surface of silicon-carbide, which were revealed by high-resolution transmission electron microscopy (HRTEM).

2. Experimental procedure

Graphene-on-SiC and CNT-on-SiC samples were prepared by annealing the 6H-SiC single crystal at 1450 ºC in a vacuum of 1.0×10^{-4} Torr. Detailed sample preparation procedure was described in our previous papers. The crystallographic features of graphene and CNT on SiC

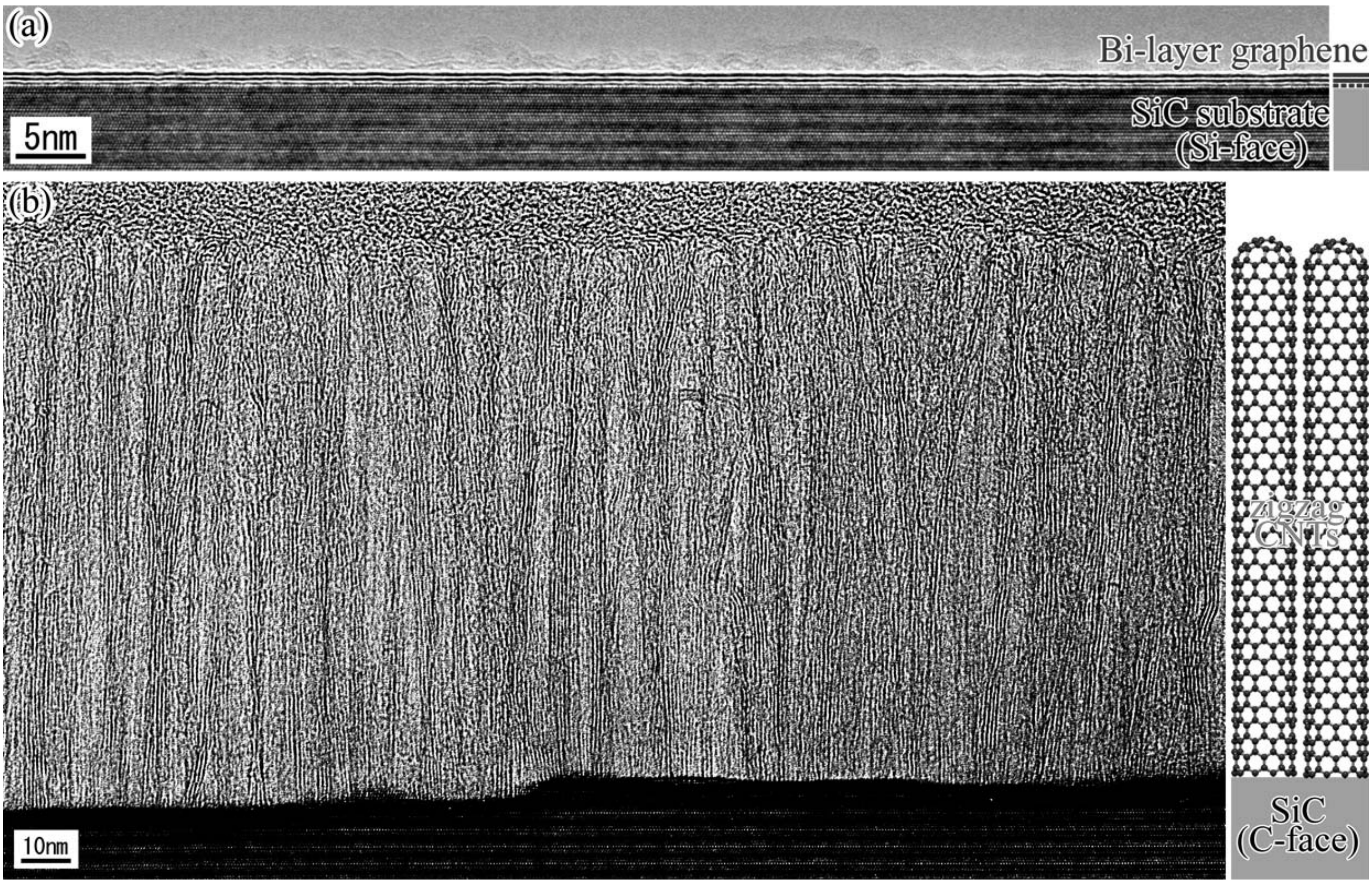

Fig. 1 (a) Bi-layer graphene formed on the Si-terminated SiC surface.
(b) Carbon-nanotube film on the C-terminated SiC surface.

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were examined by observation using JEM-2010-type and EM-002B-type transmission electron microscopes. Thin specimens for observation were made by an Ar-ion thinning method.

3. Results and Discussion

Fundamentally, graphene layers were formed on Si-terminated SiC (0001) surfaces [3-5], while CNTs were on C-terminated (000-1) surfaces [6-8]. **Figure 1** shows the HRTEM images of (a) graphene layers on SiC (0001) and (b) carbon-nanotube film on SiC (000-1). In Fig. 1(a), bi-layer graphene is observed as a dark line contrast. Graphene layers are formed covering the whole terrace of the SiC surface. In addition, similar line contrast can be seen in the interface between graphene and SiC, which is denoted by a dashed line. Carbon atoms in this layer have strong covalent bonds with silicon atoms beneath, and this layer is called a buffer layer, which doesn't have the electronic features of graphene. Elevating annealing temperature increases the number of graphene layers.

On the other hand, carbon nanotubes are formed on C-terminated SiC as shown in Fig. 1(b). Characteristic features of these carbon nanotubes are that almost all the well-aligned nanotubes are of zigzag-type and formed perpendicularly to the SiC surface, and that the density of the nanotubes is extremely high. The thickness of the carbon nanotube film can be controlled by annealing temperature and time.

Common features of graphene and CNTs on SiC are their homogeneity and their strong bonding with the substrate. These features and the selectivity of graphene or CNTs are based on the crystal structure of SiC [9]. It is suggested that after the Si removal, on the Si-face, carbon atoms make bonds parallel to the surface indicating the formation of a two dimensional graphene structure, while on the C-face they make bonds perpendicular to the surface, resulting in CNT formation.

4. Conclusions

Nano-carbon structures formed on the SiC surfaces were presented, and were investigated by HRTEM observations. On the Si-terminated face of SiC, homogeneous graphene layers were obtained. Whereas on the C-terminated face, highly-dense and well-aligned CNTs were produced.

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