XPS and NEXAFS observations on Si_xC produced by ion implantation

Yuji BABA*, Iwao SHIMOYAMA, Tetsuhiro SEKIGUCHI, Krishna G. NATH
Japan Atomic Energy Research Institute, Tokai-mura, Naka-gun, Ibaraki-ken 319-1195, Japan

Introduction

Recent rapid progress in semiconductor technology is accelerating the search for new two-dimensional (2D) semiconductor materials. Silicon carbide, one of the well-investigated semiconductors, tends to form three-dimensionally spread lattice with sp^3 bond. However, the recent theoretical study on 2D layer of SiC has revealed that the exactly flat 2D-SiC layer with graphite-like structure possibly exists [1]. In order to confirm the existence of such 2D-SiC, we have investigated the local electronic and geometric structures of Si^+-ion implanted graphite (HOPG). In the previous report, we showed that the NEXAFS spectra at the Si *K*-edge for Si^+-implanted HOPG has polarization dependence [2]. Here we report the X-ray photoelectron spectroscopic as well as NEXAFS spectroscopic observations on this system, and show the geometric structure of the Si-C bonds.

Experimental

The experiments were performed at the BL-27A station. The synchrotron beam was linearly polarized in horizontal direction. Atomic Si^+ ions were bombarded on HOPG single crystal from surface normal up to 1.4×10^{15} atoms/cm^2. For comparison, diamond-like carbon (DLC) without orientation was also used as substrate. The Si 1s-XPS was taken with hemispherical electron energy analyzer (VSW Class-100) using 2100 eV photons. The NEXAFS spectra were taken by the total electron yields.

Results and discussion

Figure 1 shows the XPS spectra around the Si 1s region excited by 2100-eV photons. The surface C/Si ratios of the Si^+-ion bombarded HOPG and DLC were estimated to be 0.01 on the basis of the C 1s/Si 1s peak intensity ratios. The binding energy of the Si 1s for Si^+-ion implanted DLC is almost the same as that for the SiC, suggesting that the amorphous Si_xC composed of sp^3 bonds is formed. While the Si 1s peak for Si^+-ion implanted HOPG shifts to higher binding energy by 1.3 eV than that for SiC, which suggests that the Si^+-ion implanted HOPG forms new layer where carbon atoms are more negatively charged than those in normal SiC.

Figure 2 displays the polarization dependence of the Si *K*-edge NEXAFS spectra for the Si^+-ion implanted HOPG (a) and DLC (b) at a fluence of 7×10^{13} atoms/cm^2. For Si^+-ion implanted HOPG, remarkable polarization dependence is observed for the peak A. The intensity of the peak A increases with the decrease in the incident angles of the synchrotron beam. On the other hand, no polarization dependence is observed in the spectra for Si^+-ion implanted DLC.

Considering the polarization dependence of peak A in fig.2(a), it is elucidated that the final state orbitals represented by the peak A are perpendicular to the basal plane of graphite sheet, i.e., parallel to the c-axis of graphite Thus it is presumed that some of the carbon atoms in graphite are substituted by the implanted silicon atoms, and the Si-C σ-bond thus produced is nearly parallel to the basal plane of the graphite sheet. The present results reveal that the two-dimensional Si_xC layer surely exists at low Si concentration.

References

[1] M. Fuentes-Cabrera et al., Model. Simul. Mater. Sci. Eng. **7**, 929 (1999).
[2] Y. Baba et al. Photon Factory Activity Report 2000 18 (2001).

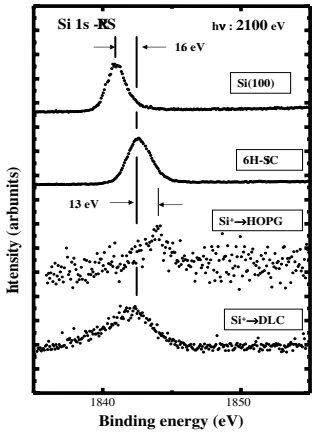

Fig.1 X-ray photoelectron spectra around Si 1s region excited by 2100-eV photons.

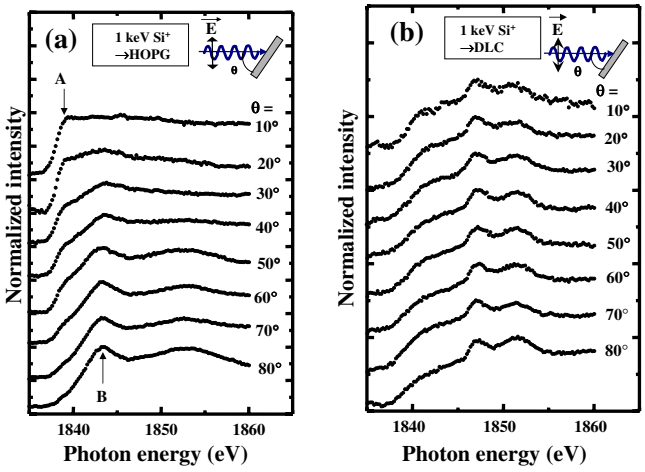

Fig.2 Polarization dependencies of Si *K*-edge NEXAFS spectra for (a) Si^+-ion implanted HOPG, and (b) Si^+-ion implanted DLC.

*ybaba@popsvr.takai.jaeri.go.jp