

## Electronic States of Highly Al-doped 4H-SiC(0001) C-face by Using a Soft X-ray Fluorescence Spectroscopy

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### Introduction

Recently, for heavily Boron-doped SiC the property of superconductor has been discovered by Zhi-An. Ren, et al. in 2007[1], where a critical transition temperature  $T_c$  is  $\sim 1.4$ K. Therefore it is interest from the view point of electron spectroscopy how electronic states of SiC appear by heavily Boron-doping. Especially, the crystalline structure of SiC has not space-symmetry for every polytype. Because, BCS (J. Bardeen, L. Cooper, and R. Schrieffer) theory for common superconductors is explained by the pairing of electrons close to the Fermi level into Cooper pairs through interaction with the space-symmetric crystalline lattice.

We have studied electronic states of highly Aluminum-doped 4H-SiC(0001) C-face specimens by using a soft X-ray fluorescence spectroscopy (SXFS). SXF spectra have characteristics to give information of partial density of states in the valence band density of states (VB-DOS), where an electron in a shallow core level is excited by an incident photon. Because different wave functions for each element in a material under study can be separated due to the dipole selection rule in an electron transition to give rise to a photoemission. Therefore, we can obtain a specific signal for an element which can be used as a finger print, otherwise it is difficult.

### Experimental

The experimental samples were formed as follows. The epitaxial layer with film thickness of  $10\mu\text{m}$  was deposited on 4H-SiC(0001) C-face substrates. Al atoms with the dose concentration of  $2.3 \times 10^{20}$  atoms/cm<sup>3</sup> were doped by an ion-implantation into these wafers and then these impurity levels were activated by post-annealing. The experiments of SXFS were performed at the beamline 19B in Photon Factory facility, KEK.

### Results and Discussion

Fig. 1 shows the Si  $L_{2,3}$  SXF spectra; (a) an Al-doped specimen of 4H-(0001)C-face (black dots) and (b) a 4H-SiC(0001) bulk sample (red dots). Electrons within the Si  $L_{2,3}$  level were excited by photon energy of 135eV. The spectrum of (a) is characterized by a hump of 86eV, a main peak of 91eV and plateau region from 92eV to

97.5eV including a small peak at 97eV. This spectrum is compared with that of (b). Both spectra are similar to the shape and peak energy position. Therefore it is considered that the crystallographic lattice constant does not change by highly Al-doping. If the lattice constant should change, the density of states for the valence band will be affected by highly Al-doping. The Si  $L_{2,3}$  SXF spectrum reflects the partial density of states for the valence band. Because speaking with regard to the heavily Boron-doped diamond, the lattice constant changes in correspondence with the dope concentration[2]. Further the high density of states cannot be seen around 98eV in correspondence with the Fermi level as shown in Fig.1(a). Therefore it is guessed that the Al-doping concentration is lower than metallic states of SiC.

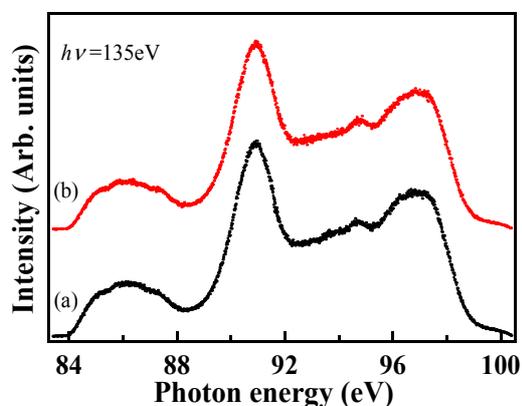


Fig. 1. Si  $L_{2,3}$  SXF spectra; (a) highly Al-doped 4H-SiC(0001)C-face sample and (b) 4H-SiC(0001) bulk sample. Incident photon energy is 135eV.

### Summary

These results are summarized as follows. The Al-doping concentration is not an extent as much as a cause for the change of spectrum shape.

### References

- [1] Zhi-An. Ren, et al., J. Phys. Soc. Jap., **76**, 103710 (2007).
  - [2] M.C. Polo, et al.; Vacuum **45**, 1014 (1994).
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