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Electronic Structure of Mn/4H-SiC Interface by SXFS

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Introduction

Silicon carbide (SiC) is one of candidate materials in hard electronics such as high-power, high-frequency, high-temperature and high-radiation field because of high saturation electron velocity and high breakdown electric field compared with silicon (Si). For the application of electronic devices it is necessary that the physical properties of metal-SiC contact system are clarified. In this report the partial density of states for Mn/4H-SiC(0001) Si-face contact system is studied by soft X-ray florescence spectroscopy (SXFS).

Experimental

The samples were prepared as follows.
(i) A wafer of 4H-SiC(0001) Si-face was cleaned by being rinsed in ethyl alcohol, dipped in 5% HF solution and flashed under ultra-high vacuum (UHV) condition. (ii) Mn metal was evaporated on the surface of this substrate by heating of tungsten boat with Mn chunks. (iii)The sample of Mn/4H-SiC(0001) contact system was thermally treated with direct Joule heating at 400-800°C for 30 minuets. The film thickness of evaporated Mn was about 50nm. X-ray emission spectra were obtained in an SXFS apparatus, which is installed to a beamline BL-19B at synchrotron radiation facility of Photon Factory in KEK [1]. Si $L_{2,3}$ and C K emissions were induced by 135 and 350eV photons, respectively. Photon energies were calibrated against 4f signals and Fermi edge of Au. This SXFS is characterized considering partial density of states in the total energy states due to dipole selection rule of electron transitions.

Results and Discussion

A shape and peak energies of the Si $L_{2,3}$ florescence spectra obtained from (a) thermal-treated specimens in 400-800°C for Mn/4H-SiC(0001) Si-face contact system were compared with reference ones obtained from specimens of (b) a pressed powder of $MnSi_2$ and (c) a 4H-SiC(0001) Si-face. The spectrum of (c) is characterized by a hump of 86.5eV, a main peak of 91.7eV and plateau region from 93eV to 99eV including a small peak at 97eV. The spectrum of (b) has two peaks at ~91.3 and ~96.2eV with the similar intensity. The spectra of (a) have the similar characteristics as (c), but are entirely different from one of (b) for spectrum shape and peak energies, where incident photon beam angle to the specimen surface normal is 45°.

Next, we have performed the depth profiling analysis by varying the angle of incident photons. For the specimen annealed at 500°C, the Si $L_{2,3}$ florescence spectrum obtained at the incident angle of 80° to the specimen surface normal indicates the results that the hump of 86.5eV disappears and the other have the similar characteristics as 4H-SiC spectrum. Therefore, surface layer may be covered by very thin reacted materials. But a component of reacted products cannot be specified due to be buried under major substrate signal. Also the Si $L_{2,3}$ SXF spectrum obtained from the incident angle of 75° to the specimen surface normal for specimen annealed at 800°C has the same characteristics as 4H-SiC(0001) Si face. Therefore it is considered in this case that Mn metal has been evaporated from the substrate surface and/or diffused under the surface region due to high annealing temperature.

A spectrum shape and peak energies of the C K florescence spectra obtained from (a) thermal-treated specimens in 400-800°C for Mn/4H-SiC(0001) Si-face contact system were compared with reference ones obtained from specimens of (b) a 4H-SiC(0001) Si-face and (c) a graphite plate. The spectrum of (a) is characterized by a main peak at 280.7eV, a small peak at 270.7eV and a shoulder at 275.7eV. The spectrum of (b) has a main peak at about 281eV and a shoulder around 276eV. The spectrum of (c) has a single peak at 278eV and a shoulder around 282eV. The spectra (a) have the similar characteristics to one of (b) in respect of spectrum shape and peak energies. Therefore, it is concluded from a comparison with characteristics of these spectra that C K SXF signals does not indicate possible formation of carbides and/or graphite.

Summary

These results are summarized as follows. The Si $L_{2,3}$ SXF spectra obtained from specimens of thermal-treated Mn/4H-SiC(0001) Si-fase contact system are the same one as 4H-SiC to the exclusion of 500°C. It is concluded that the C K spectra obtained from thermal-treated samples are the same one as a carbon signal of the substrate and different from a graphite spectrum.

References

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