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Local Valence Electronic State of $\mathrm{HfSi_2}$ Surface Component on Low-Indexed Si(110) Substrate

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1 Introduction

Downsizing of metal-oxide-semiconductor field effect transistor (MOS-FET) in development of silicon semiconductor industry has achieved large integration, high speed processing, light weighting, and on. On the other hand, it has led to a critical issue that a leakage current through ultrathin silicon dioxide ($\mathrm{SiO_2}$) film (< 20 Å) as gate insulating film happens due to direct tunneling effect. Therefore, a hafnium dioxide ($\mathrm{HfO_2}$, k = ~25) as high dielectric constant material is attracting high attentions as an alternative for $\mathrm{SiO_2}$ in order to prevent the leakage current. The application of $\mathrm{HfO_2}$ into MOS-FET will offer that the physical thickness of the gate oxide film could be increased for reduction of serious leakage current. Nevertheless, a matter that arises here is that hafnium silicide ($\mathrm{HfSi_2}$) component which inevitably generates around interface of $\mathrm{HfO_2}$/Si structure will cause unstable behaviors of the MOS-FET because they have narrower bandgap in comparison with $\mathrm{HfO_2}$. Therefore, it is important to reveal the local valence electric states of $\mathrm{HfSi_2}$/Si structure depending on the size, thickness, chemical environment, and so on. [1]

In addition, the MOS-FET structure renewed from 2 dimensions (Ds) to 3Ds will be another approach so as to keep up with the development of MOS-FET performance. Therefore, low-indexed Si(110) substrate which shows unique single domain (SD) structure with atomic scaled 3Ds concave-convex is also an promising candidate for next generation.[2, 3]

In this report, we prepared $\mathrm{HfSi_2}$ islands on a clean Si(110)-16×2 surface [i-$\mathrm{HfSi_2}$/Si(110)] and investigated site specific local valence electronic state of i-$\mathrm{HfSi_2}$ surface component with Si $L_{23}VV$ Auger-electron – Si 2p photoelectron coincidence spectroscopy (Si-$L_{23}VV$-Si-2p APECS). The core-valence-valence (CVV) Auger electron spectrum measured with Si-$L_{23}VV$-Si-2p APECS can provide the two holes valence electronic structure in the vicinity of a specific i-$\mathrm{HfSi_2}$ component.

2 Experiment

A clean Si(110)-16×2 with SD surface was prepared by direct current heating over 1523 K in UHV less than 2.0×10^{-7} Pa. After then, ultrathin Hf films with the different thickness of ~2, 6, and 8 ML (monolayer, 1 ML = 2.4 Å [4]) were deposited on the clean Si(110)-16×2 surface by means of electron bombardment method. They were directly turned into i-$\mathrm{HfSi_2}$/Si(110) structure by annealing at 1073 K.

Si-$L_{23}VV$-Si-2p APECS measurements were performed with a handmade electron-electron-ion coincidence analyzer at BL-11D in PF, KEK. The photon energy ($h\nu$) was fixed at 130 eV for ionization of Si 2p core levels.

3 Results and Discussion

Fig. 1 shows the Si-$L_{23}VV$-Si-2p APECS spectra which selected the only $\mathrm{HfSi_2}$ surface component from some i-$\mathrm{HfSi_2}$/Si(110) structures. These are drawn on two-holes binding energy scale of Si $L_{23}VV$ Auger final states. When comparing these results, they are mostly the same spectral distributions. This indicates that the local valence electronic state at $\mathrm{HfSi_2}$ surface component does not depend on the thickness of Hf deposition films because the $\mathrm{HfSi_2}$ islands with random sizes are formed after annealing at 1073 K.

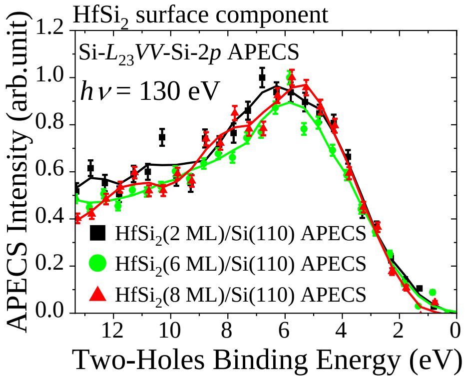

Fig. 1: Si-$L_{23}VV$-Si-2p APECS spectra obtained from i-$\mathrm{HfSi_2}$/Si(110) which made from ultrathin Hf deposition films with the different thicknesses of ~2, 6, and 8 ML by annealing at 1073 K.

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