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Local valence electronic states of $HfSi_2$ islands on Si(110)-16 × 2 substrate

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1 Introduction

Drastic downsizing of metal-oxide-semiconductor field effect transistor (MOS-FET) caused a critical leakage current through ultrathin silicon dioxide (SiO_2) gate film (< 20 Å) due to direct tunneling effect. Therefore, a hafnium dioxide (HfO_2, $k = \sim 25$) as high dielectric constant material is attracting high attentions as an alternative for SiO_2. The application of 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 is that hafnium silicide ($HfSi_2$) component which generates around interface of HfO_2/Si structure will cause unstable behaviors of the MOS-FET because they have narrower bandgap in comparison with HfO_2. So, it is important to reveal the local valence electric state of $HfSi_2$ depending on the size, thickness, chemical environment, and so on. [1]

In this study, we prepared $HfSi_2$ islands on a clean Si(110)-16×2 surface [i-$HfSi_2$/Si(110)] and investigated site specific local valence electronic state of i-$HfSi_2$ 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-$HfSi_2$ component.

2 Experiment

A clean Si(110)-16×2 with single domain (SD) surface was prepared by direct current heating over 1523 K in ultrahigh vacuum (UHV) less than 2.0×10^{-7} Pa [2]. After then, ultrathin Hf films with the different thicknesses of ~0.5, 1.0, 2.0, 6.0, and 8.0 ML (monolayer, 1 ML = 2.4 Å [3]) were deposited on a clean Si(110)-16×2 surface. These samples were directly turned into i-$HfSi_2$/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 $2p_{1/2, 3/2}$ core levels.

3 Results and Discussion

In Fig. 1, Si $2p_{1/2, 3/2}$ photoelectron spectra of i-$HfSi_2$/Si(110) show a Hf disilicide component ($HfSi_2$) at -0.42 eV on the relative binding energy axis. All i-$HfSi_2$/Si(110) samples show the existence of $HfSi_2$ component. The intensity of $HfSi_2$ increases as the Hf thickness before annealing increases from 0.5 to 8.0 ML.

Fig. 2 shows the Si-$L_{23}VV$-Si-$2p$ APECS spectra which selected the only $HfSi_2$ component from all i-$HfSi_2$/Si(110) samples. 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 $HfSi_2$ surface component does not depend on thickness of Hf deposition films before annealing because the $HfSi_2$ islands with random sizes are formed on Si(100)-16×2 surface.

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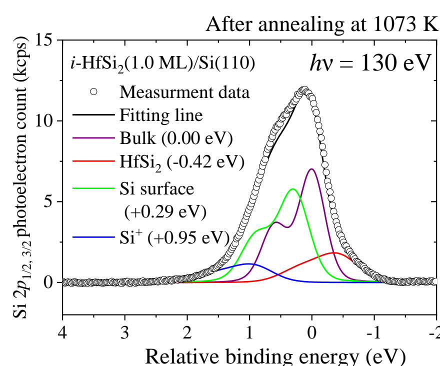

Fig. 1: Si $2p_{1/2, 3/2}$ photoelectron spectrum of i-$HfSi_2$/Si(110) substrate.

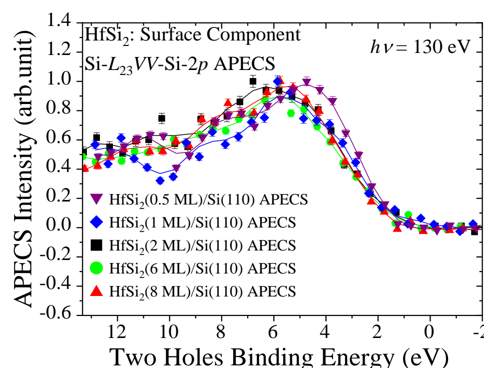

Fig. 2: Si-$L_{23}VV$-Si-$2p$ APECS obtained from i-$HfSi_2$/Si(110) with the thicknesses from 0.5 to 8 ML.