Observation of Work Function, Metallicity, Band Bending, Dipole by EUPS for Characterizing High-k/Metal Interface

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ABSTRACT

For characterizing high-k/metal gate interfaces, EUPS is being employed to evaluate work function and metallicity of various material surfaces, band-bending of Si with high-k films, and dipole at the interface.

EUPS is a novel photoelectron spectroscopy (refs.1,2), in which a sample is excited with a 4.86nm (255eV) 3-ns pulse EUV light emitted from a laser-produced plasma and an electron spectrum is analyzed with a time-of-flight (TOF) analyzer. EUPS gives information of the topmost atoms because the escape depth of photo-electrons excited by the 4.86nm light is 0.5nm. EUPS can evaluate band-bending because the peak density of the excitation light on sample is extremely high so that bended electronic bands in semiconductors can be flattened. Secondary electron spectra, which give a vacuum level of the material surface, are obtained very quickly owing to the TOF analyzer.

Metal gate is introduced in nano-electronic devices to avoid depletion effect in a poly-Si gate electrode, but nobody knew metallicity of nm films. We are evaluating metallicity of the material surface by the 2ndary electron intensity. Figure 1 shows 2ndary electron spectra for TaN films deposited on 100nm-W on Si wafer, which indicates that a TaN film thicker than 2nm has large enough metallicity. Figure 1 also indicates that work function is lower for a thinner film. These two indications have been confirmed by C-V measurements.

Figure 2, the kinetic energy of Hf $4f_{7/2}$ photo-electrons as a function of the signal intensity, is an example of the band-bending observation, showing that band bending of 0.2eV is independent on thickness of a TiN film on HfO_2.

Having the depth resolution of 0.5nm or below of photo-electrons in EUPS and 2ndary electrons, we can also characterize buried interfaces by ion-sputtering covering layers. We confirmed that our sputtering has the depth resolution well better than 1-nm. We plan to directly observe dipoles at various interfaces of nm thick layers.

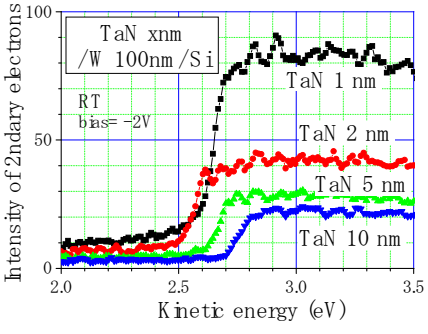

FIGURE 1. Secondary Electron Spectra for TaN xnm/W/Si.

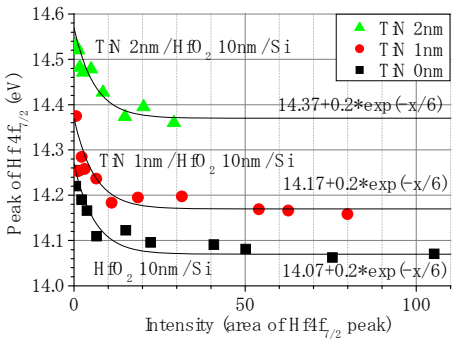

FIGURE 2. Band Bending of TiN xnm/HfO_2 10nm/Si.

REFERENCES

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Key words: EUPS, Work Function, Metallicity, Band Bending