High-*k* Thin Film Thickness Variation Under Post-Deposition Annealing Investigated By X-ray Reflectivity and X-ray Photoelectron Spectroscopy

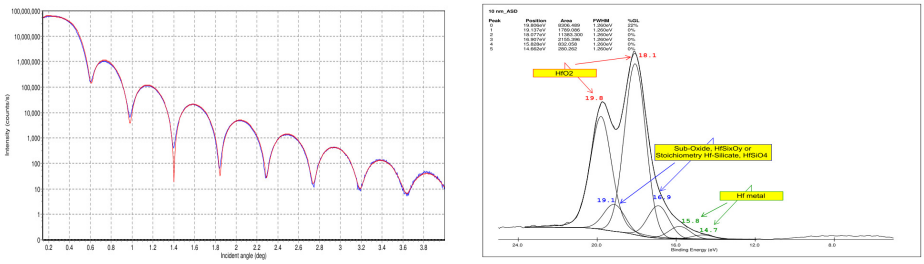
Yong-Qing Chang and Wei-En Fu*

Rm.213, Bldg.8, 321, Sec. 2, Kuang Fu Rd., 30011, Hsinchu, Taiwan
Center for Measurement Standards, Industrial Technology Research Institute (ITRI)
** Corresponding author: WeienFu@itri.org.tw*

ABSTRACT

The film structure changes and interface stability induced by thermal treatment were significant issues when HfO_2 films were used to replace SiO2 for the gate dielectric [1-2]. In this work, different material models were studied to fit GIXRR measurements for the 10 nm HfO2 film, which consists of a top layer HfO_2 (by atomic layer deposition, ALD), a native SiO_2 as an interfacial layer, and a silicon substrate. At first, a four-layer material model of HfO_2(low-density)/HfO_2/SiO_2/Si-sub was constructed to improve X-ray Reflectivity (XRR) fitting by using genetic algorithm (GA) analysis, as shown in Figure 1(a), for the as-deposited (ASD) HfO_2 samples.. Moreover, HfO_2 films were also annealed using furnaces at 550˚C, 850˚C and 1000˚C under Ar atmosphere, respectively. X-ray photoelectron Spectroscopy (XPS) was used for investigating inter-diffusion phenomenon of oxides as shown in Figure 1(b), in order to confirm the structure changes and interface thermal stability of the HfO2 films for building accurate material model in XRR fitting analysis. The curve fittings for individual element at several annealing temperatures have showed the composition changes of oxides, which attributes to formation of Hf-silicate induced by layer inter-diffusions. According to the XPS chemical analysis, a better layer structure for material model can be constructed for the XRR fitting analysis, which gives more accurate HfO2 film thicknesses.

Keywords : Thickness, HfO2, SiO2, XRR, XPS



(a) (b)

FIGURE 1. (a) XRR fitting spectrum with a four-layer model, and
(b) XPS composition analysis (surface scan) of as-deposited HfO2 10 nm films.

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