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Grazing incidence X-ray reflectivity of HfO_2/Si film

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Introduction

Total reflection X-ray has been considered as a powerful tool for the study of surface and interface phenomena since the last several decade. [1] In this report, grazing incidence X-ray reflectivity spectra for 200nm thick HfO_2/Si film synthesized by RF magnetron sputtering were obtained when the X-ray incident angles were below and beyond the critical angle.

Experimental

Film deposition was carried out in an ultrahigh vacuum (7×10^{-8} Pa) radio-frequency (r.f) magnetron sputtering system.[2] A 3 in. metallic Hf (99.9% purity) disc was used as the sputtering target with argon as the plasma-generating gas.

The angle resolved sample stage with an angle resolution of 0.006° was designed and employed in the measurement. A receiving slit with a same size as the front one after sample is used to eliminate the scattering effect. Halfcut procedure alignment was done to setup the initial position of the sample before every measurement. At last, the incident angle was calibrated by compared to the theoretical XRR spectrum.[3] The refection spectra were recorded as $\log(I_0/I)$, in the same way as the absorption one.

Also XPS spectra have been taken at BL-13C for the same samples and the results will be presented elsewhere.

Results and Discussion

Figure1 shows the gracing incidence X-ray reflectivity spectra for 200nm thick HfO_2/Si film at different incident angle. The spectra could be categorized into three parts according to the different incident angles. i) When the incident angles α_i are below the critical angle (α_i=0.144°, 0.194°, 0.244°, and 0.294°), the reflectivity spectra present a similar appearance to the conventional transmission mode X-ray absorption spectroscopy (fig. 2). This could be understood that under this condition, only the imaginary part $\beta(E)$of the complex refractive index $n(E)=1-\delta(E)-i\beta(E)$ contribute to the reflectivity spectra as a function of energy, which is in the same case of the conventional transmission mode. ii) When the incident angles are large than the critical angle, as shown in figure 1 (α_i=0.344°, 0.394°), the shape of the spectra become much different: the intensity increase dramatically with the increase of the incident energy. This phenomenon is due to the contribution of the real part of the complex refractive index of HfO_2. iii) When the incident angle increase to 0.444°, a periodic oscillation can be observed obviously before the absorption edge. This is because the X-ray penetration depth is up to 200 nm at this angle, reaching the Si substrate, interference occurring at interface to form the oscillation.

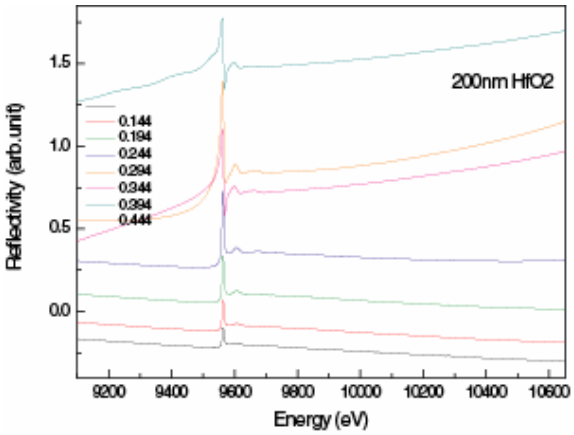

Fig 1 X-ray reflectivity spectra for 200nm thick HfO_2/Si film at different incident angle.

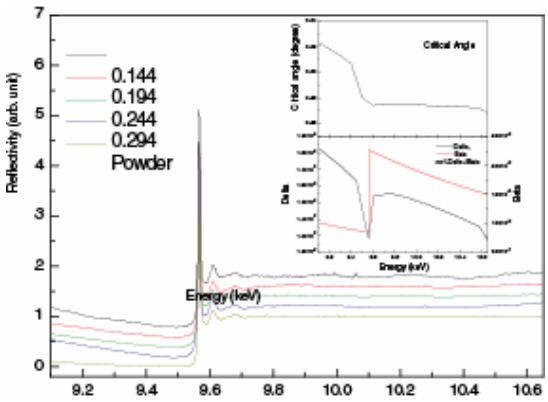

Fig 2 Normalized spectra below critical angle compared to the conventional transmission mode X-ray absorption for HfO_2 powder

References

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