Dependence on thickness in determination of effective attenuation lengths of photoelectrons in SiO_2 thin film

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X-ray photoelectron spectroscopy (XPS) is widely used for the quantitative analysis of the functional materials. Because XPS is a surface sensitive method, the knowledge about the attenuation length (AL) of photoelectrons is important. Until now, the inelastic mean free path (IMFP) has been used for the substitution of AL because the value of IMFP is easily obtained using the TPP-2M equation[1]. However, IMFP can not be used in the low energy region because the elastic scattering is not considered. Recently, effective attenuation length (EAL) is proposed for the practical purpose of the surface analysis. In this study, EAL of silicon oxide is determined from the XPS spectra of ultra thin films of silicon oxide in a wide energy range.

The silicon oxide thin films with different thicknesses were fabricated on the Si substrate by thermal or ozone oxidation. The thin films with thicknesses of 2.0 nm, 4.0 nm, and 6.0 nm were fabricated by the thermal oxidation process. The other thin films were with thicknesses of 1.5 nm, 3.5 nm, and 5.5 nm by the ozone oxidation process. The measurements of XPS spectra were carried out at a soft x-ray beamline 13C of the Photon Factory in High Energy Accelerator Research Organization (KEK-PF) in Japan. The XPS measurements were carried out in a ultra high vacuum chamber equipped with a cylindrical hemispherical electron analyzer.

Some of the spectra with different energies of exciting x-ray are shown in Fig. 1. With increasing the energy, the relative intensities of the photoelectrons from the substrate with the increase of the analysis depth. From the curve fitting procedure of the peaks, EALs were calculated for each thin film in the energy range between 100 eV and 900 eV. Figure 2 shows the calculated EALs of silicon oxide using six thin films as functions of the thicknesses. The well-known trend of the longer at the higher kinetic energies is reproduced. We also find that thinner films give longer EALs, which can be explained by the effect of the interface between the silicon substrate and the oxide film. It should be noted that there is no systematic difference in EAL results from the fabrication method.

References

[1] S. Tanuma, C. J. Powell and D. R. Penn *Surf. Interface Anal.* **21** (1993) 165.

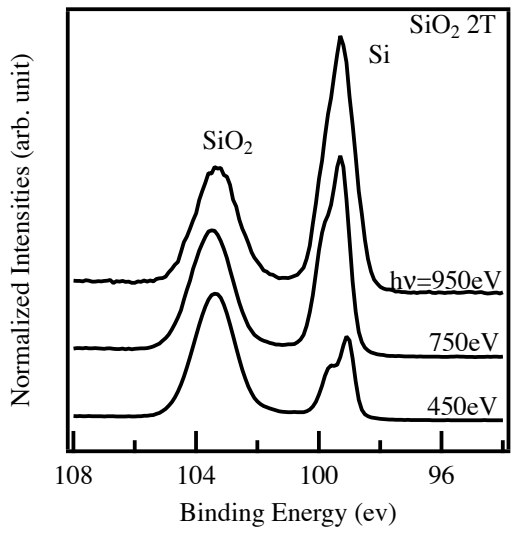

Fig.1 XPS spectra of thin film with the thickness of 2nm.

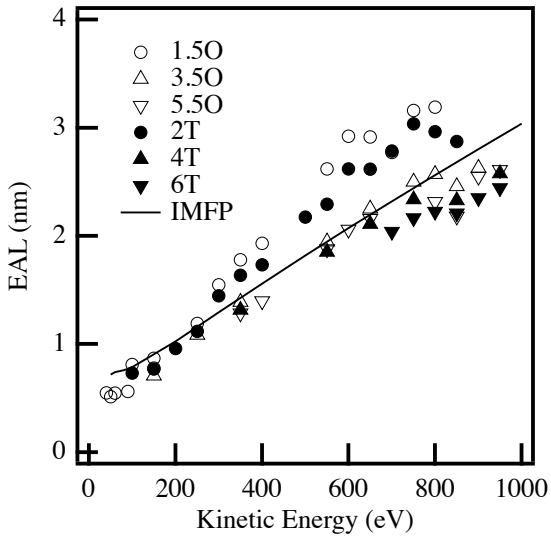

Fig.2 EALs determined from thin films with different thicknesses.