

Study on the behavior of the photoelectrons with lower energies in the ultra thin film of silicon oxide

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1 Introduction

X-ray photoelectron spectroscopy (XPS) has been used for the quantitative and qualitative analysis methods in the developments of functional materials because of its high surface sensitivity, and it is useful to determine the thickness of the thin film. For determination of the thickness using XPS, the attenuation length (AL) of the photoelectron is an important parameter. For a long time, the inelastic mean free path (IMFP) has been used as an alternative of AL because the values of IMFP can be calculate easily using the predictive equation TPP-2M [1–3]. However the effect of the elastic scattering is not considered in the evaluation of IMFPs. Recently effective attenuation length (EAL) [1, 4, 5] is proposed and used for the practical purposes. The author has been experimentally measured the EAL of the photoelectron in the SiO₂ thin films with the energy range of 100–1000 eV [6] at old BL-13C station [7, 8].

For experimental determination of EAL in SiO₂, the SiO₂ thin film and bulk samples of Si and SiO₂ are necessary. The thickness of the thin film must be certified by another method.

As shown Fig. 1, photoelectron intensity from each sample was measured. From the bulk samples of the silicon and silicon oxide,

$$R_o(h\nu, \theta) = \frac{I_{Si}^{\infty}}{I_{SiO_2}^{\infty}} \quad (1)$$

is calculated where I_{Si}^{∞} and $I_{SiO_2}^{\infty}$ are the photoelectron intensities from the Si substrate and oxide film layer, respectively.

$$R_d(h\nu, \theta) = \frac{I_{Si}}{I_{SiO_2}} \quad (2)$$

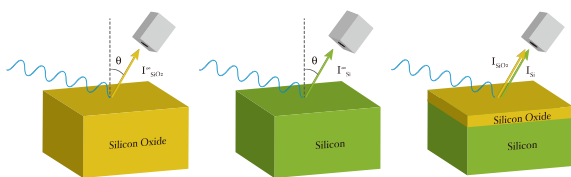


Fig. 1: Samples for EAL determination

is calculated where I_{Si} and I_{SiO_2} are the photoelectron intensities from the Si substrate and SiO₂ thin film, respectively.

The EAL is calculated from the equation below:

$$\lambda_{SiO_2}(h\nu, \theta) = \frac{d}{\cos \theta} \cdot \frac{1}{\ln\{[R_o(h\nu, \theta)/R_d(h\nu, \theta)] + 1\}} \quad (3)$$

For determination of the EAL in the SiO₂ thin film, it is important to measure the R_o precisely.

2 Experiment

The measurements of XPS spectra were carried at BL-3B using the apparatus built for the angle-resolved x-ray photoemission spectroscopy (ARPES II). In this apparatus, the hemispherical electron analyzers with a 50 mm mean radius (VSW HA54) are fixed on the goniometer, which enable the analyzer to be rotate in the vacuum chamber as shown in Fig. 2. The energy step was 0.05 eV. The pass energy was set as 10 eV. The acceptance angle was $\pm 1^\circ$. The angle between the incident x-ray and the surface normal of the sample was fixed as 55° . The emission angle of the photoelectrons from the surface normal was adjusted to 0° , 15° , 30° , 45° , 60° , and 75° by rotating the electron analyzer. The energy of the incident x-ray was set as 130 eV, 150 eV, 180 eV, and 200 eV.

As the bulk samples, Si(100) wafer with a thickness of 0.5 mm and SiO₂/Si thin film with a thickness of 100 nm prepared by a thermal process were used. The thickness 100 nm of the thin film is thick enough to avoid the photoelectron signal from the substrate and thin enough to suppress the charging. Both samples were cut as the size of 5 mm \times 3 mm

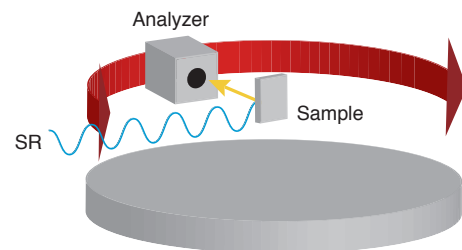


Fig. 2: Alignment of sample and analyzer

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using a diamond cutter and fixed on the same stub for the measurements using carbon tape, because two samples must be used for measurement by turns in the same condition to suppress the time dependent influence.

3 Results and Discussion

Figure 3 and 4 show the Si 2p spectra of SiO₂ and Si, respectively, which measured with the emission angle of surface normal excited by x-ray with the energy of 150 eV. Si peak and Si oxide peak are recorded clearly. To estimate the photoelectron intensities in the spectra, curve fitting procedure will be carried out using Shirley background and Gauss function. The R_o is calculated using Eq.(1) for each energy and emission angle.

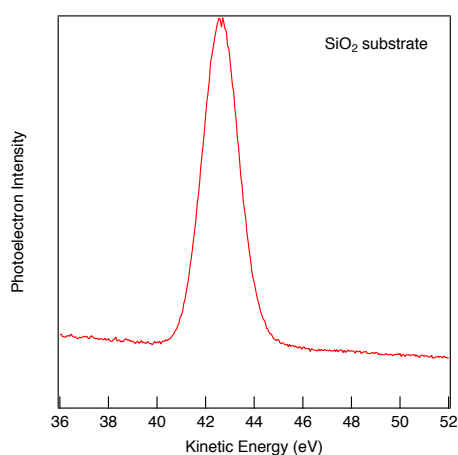


Fig. 3: XPS spectra of SiO₂

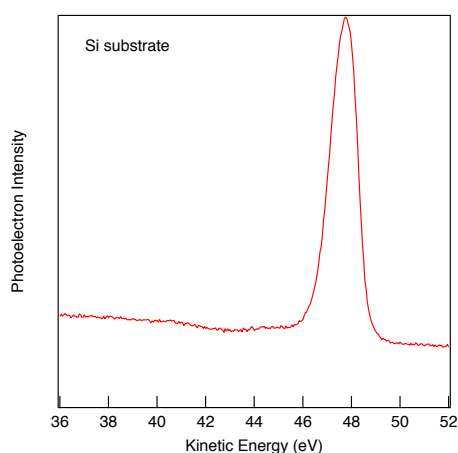


Fig. 4: XPS spectra of Si

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