13C/2004G028

Experimental Determination of Electron Effective Attenuation Length in Al Thin Film

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Introduction

Values of effective attenuation lengths (EALs) of electrons are needed in quantitative investigations by Auger electron spectroscopy (AES) and x-ray photoelectron spectroscopy (XPS). The inelastic mean free paths (IMFPs) are often used for this purpose, with IMFPs obtained from optical data or a predictive formula. However, recent calculations have shown that elastic electron scattering is not negligible .

In this study, we measured EALs of photoelectrons of various energies in Al thin films using synchrotron radiation (SR) as an excitation source and compared these EALs with calculated EALs.

Experimental

The Al thin film was fabricated by evaporation in a high vacuum chamber. The Si(111) plate was cleaned by H_2SO_4 /H_2O_2 and 5%-HF solution and vacuumed in the load-lock chamber. After evacuation for a night, the sample was transferred to the evaporation chamber. Al was evaporated on the Si(111) plate in the preparation chamber using a K-cell. The temperature of the crucible was set at 1370K. The pressure during evaporation was $1x10^{-5}$ Pa.

SR-XPS measurements were performed at beamline 13C of the Photon Factory. The energy resolution was about 3000 for x-ray energy below 500 eV, and was about 1500 for x-ray energy over 500 eV. Photoelectron spectra were measured by using a hemispherical analyzer (PHI 1600C). The angle between analyzer axis and surface normal was 55°. The analysis area was circular with a diameter of 0.8 mm, and the analyzer acceptance angle was ±7°.

Results and Discussion

Figure 1 shows the XPS spectra of the Al thin film excited by various energy. Al2p peak from the film and Si2p peak from the substrate appear, whose intensities varies with the excitation energy. The change of the relative intensities of the peaks is caused by the change of the analysis depth which reflects the EALs of the Al. The EALs were calculated using the peak intensities of Al2p and Si2p peaks.

Figure 2 shows the EALs as a function of the kinetic energy of the electron determined from the intensities of the XPS spectra of thin film, comparing to the theoretical values calculated from the NIST database. The EALs determined from the spectra agreed with those calculated from the database in the region above 400 eV. However, in the region below 400 eV, EALs determined form the spectra show higher values than the calculated EALs. The difference might be caused by the elastic scattering of the electrons in the thin films, which is not considered in the calculation model of the database.

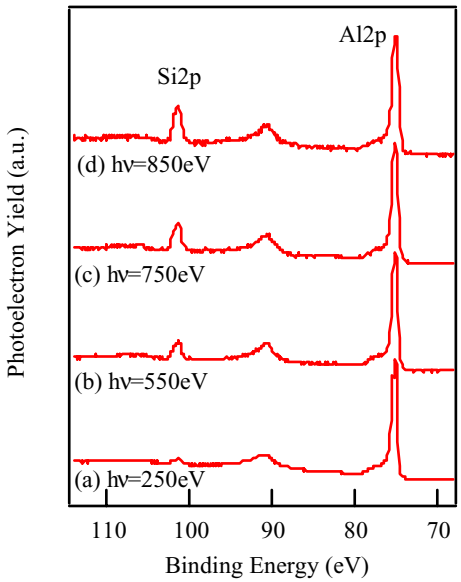

Fig.1 XPS spectra of Al/Si(111) thin film.

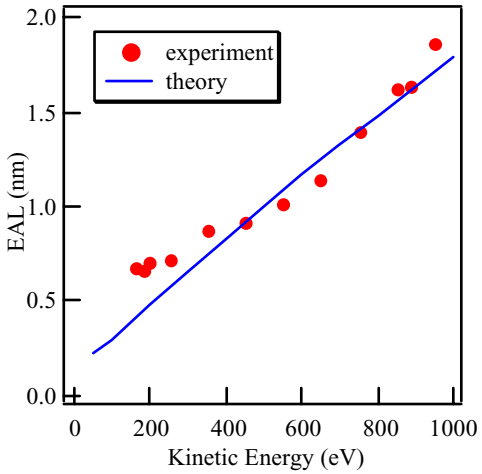

Fig.2 EALs determined from the XPS spectra and calculated by the NIST database.

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