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Study on ion-irradiation induced diffusion in Pd/Si system using synchrotron radiation x-ray photoelectron spectroscopy

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Introduction

It is well known that solute atoms in metal matrices diffuse more rapidly under irradiation field than under the thermal equilibrium condition. This phenomenon is called "radiation induced (or enhanced) diffusion", and has been explained as due to the interaction between solute atoms and radiation-produced defects[1,2]. To examine the electronic structure and chemical bonding state for solute atom segregation region, we have recently started experiments of an x-ray photoelectron spectroscopy for ion-irradiated Si-metal systems by using a synchrotron radiation facility. Synchrotron radiation photoelectron spectroscopy is a good tool for the study of electronic and chemical properties of material surfaces because of the wide range selectivity of high flux x-rays. In this paper, we report the result of the x-ray photoelectron measurement for Si-Pd system irradiated with 1MeV oxygen ions.

Experimental procedure

Si single crystals were coated with Pd by using rf magnetic sputtering. The Pd film thickness was about 100 nm. The specimens were irradiated from the side of Pd film at room temperature with 1MeV O ions to the fluence of $1x10^{16}/cm^2$ using 1.7MV Pelletron accelerator at Nara Women's University. For the irradiated specimens, x-ray photoelectron (XP) spectra were measured at the end station of the 27A beam line at High Energy Accelerator Research Organization (KEK). The monochromated photon energy for the measurements was just 2200.0 eV. For comparison, we also performed the same measurements for unirradiated Pd(100nm)/Si specimen, unirradiated Si crystal and Si crystal irradiated with 1MeV O ions. The incident angle of the x-ray was 35° from the specimen surface normal, and the photoelectrons of surface-normal emission were collected.

Results and discussion

Fig. 1a shows the XP spectra for the unirradiated Pd(100nm)/Si specimen. We cannot find any trace of XP spectra for Si bulk or SiO_2 layer. This result is quite reasonable because photoelectrons come only from a few layers of Pd film. The XP spectrum for Pd(100nm)/Si irradiated with 1 MeV O ions is shown in Fig. 1b. As can be seen in the figure, an XP peak appears at the binding energy of 1844.0 eV, which is 3.0 eV higher than that of bulk Si. The experimental result can be explained as originating from the diffusion of Si atoms from Si substrate under the irradiation and the resulting segregation of Si atoms at the surface of Pd film. The shift of Si 1s binding energy to a higher value suggests a chemical interaction between Si and Pd atom at surface; i. e., a charge transfer from Si atom to Pd atom. We performed the RBS measurements both for the unirradiated Pd(100nm)/Si and the ion-irradiated specimen, but we never found any effect of irradiation on RBS spectra. The Si atom segregation at Pd surface was too small to detect by RBS measurement. The present result shows that synchrotron radiation photoelectron spectroscopy is a very powerful tool to detect a small amount of irradiation-induced diffusion/segregation and to study the details in chemical status of radiation-induced segregation.

References

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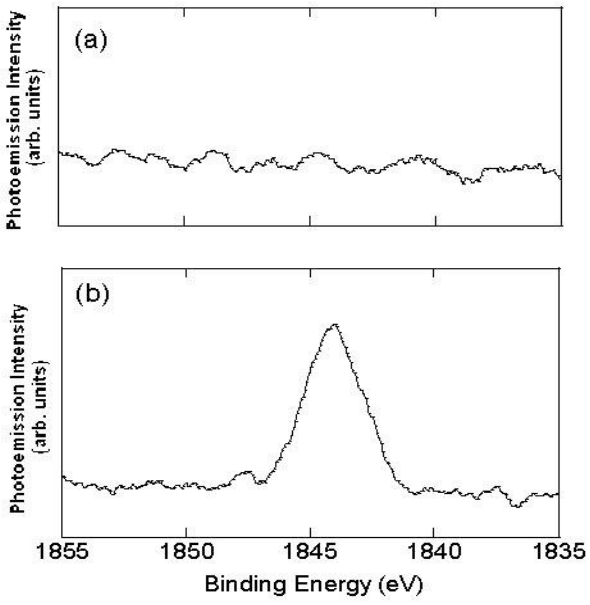

Fig. 1 (a) X-ray photoelectron spectrum for unirradiated Pd(100nm)/Si. (b) X-ray photoelectron spectrum for Pd(100nm)/Si irradiated with 1 MeV O ions to the fluence of $1x10^{16}/cm^2$.

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