Direct observation of the electronic structure at oxide/semiconductor interface by soft X-ray emission spectroscopy

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The control of SiO_2/Si(100) interfaces has been a topic of great interest because the electronic states at the interface seriously affect the performance of metal/oxide/Si (MOS) devices. Industrial gate oxide layer is currently ~ 2 nm thick and if present miniaturization trends of MOS devices continue, the gate oxide thickness will be nearing scales comparable to atomic bond lengths. Therefore, the control of the SiO_2/Si(100) interface becomes a significant role in fabricating MOS devices. Despite its fundamental and technological importance, the electronic structure at the interface has not been reported yet. Here, we therefore report first direct observation of occupied electronic states at SiO_2/Si(100) interface using soft X-ray emission spectroscopy and the interfacial electronic states being noticeably different from that of SiO_2 (see Fig. 1). Furthermore, on the comparison of the experimental results with theoretical calculations, it is found that anomalous atomic structures are formed at the interface and strain in the interfacial region, produced by lattice mismatch between Si and SiO_2, should be released by formation of these structures.

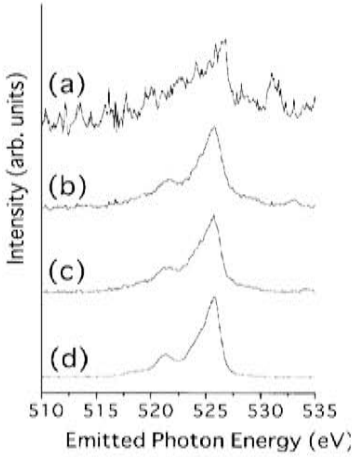

Fig. 1. O2p_O1s emission spectra of SiO_2/Si(100) as a function of incident photon energy. (a) 531 eV, (b) 532.5 eV, (c) 534 eV,(d) 537.5eV.

Mechanism on multi-charged ion formation through deep inner-shell ionization of Kr using a coincidence technique

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A number of measurements of multiply charged rare gas ions have been carried out using monochromatized synchrotron radiation. Among several techniques, coincidence measurements are very useful for clarifying formation mechanisms of these ions [1]. In the present study, multi-charged Kr ions have been observed following photoionization of 2p orbital electrons.

Measurements were performed using a high-resolution plane-grating monochromator at the c-branch of BL27SU. Electron emission spectra were observed in several kinetic energy regions using a cylindrical mirror analyzer, ESA-150-D, at some photon energies near the 2p ionization thresholds. Multi-charged ions were measured with a short time-of-flight mass spectrometer using application of a pulsed electric field or by use of signals of electrons detected above.

Examples of measured spectra are shown in Fig.1, where multi-charged Kr ions detected in coincidence with 2p photoelectrons are exhibited as a function of flight time (μs). The top panel shows the spectrum coincident with $2p_{1/2}$ photoelectrons, which indicates peaks corresponding to Kr^{4+}, Kr^{5+}, Kr^{6+}, and Kr^{7+}. The highest peak was yielded by the Kr^{6+}. The spectrum at the bottom, being coincident with $2p_{3/2}$ photoelectrons, shows a similar feature, but the peak for Kr^{4+} seems slightly higher than that at the top. That in the middle ($2p_{3/2}$ satellites) exhibits a considerably smaller peak for Kr^{4+} than the others. This finding suggests that a loosely bound electron, which is shaken-up at the initial step of the 2p photoionization, is easily shaken-off in an electron emission process of the core hole. The spectra in coincidence with normal Auger electrons were measured, which have clarified decay pathways into highly charged ions from the 2p hole state.

[1] Y. Tamenori et al., J.Phys.B, 27, 117 (2004).

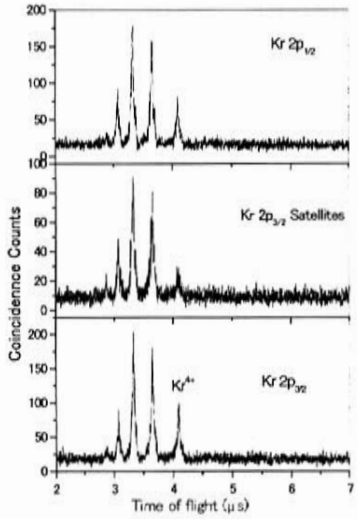

Fig.1 : Time-of-flight spectra of Kr ions coincident with energy-selected electrons.