Probing a buried buffer layer between metal and polymer with soft X-ray fluorescence

G. S. Chang[1], C. N. Whang[1], E. Z. Kurmaev[2], D. A. Zatsepin[2],
R. P. Winarski[3], D. L. Ederer[3], A. Moewes[4], Y. P. Lee[5]
[1]ASSRC at Yonsei University, Seoul 120-749, Korea
[2]Russian Academy of Science-Ural Division, Yekaterinburg GSP-170, Russia
[3]Tulane University, New Orleans, LA 70118, USA
[4]Louisiana State University, Baton Rouge, LA 70806, USA
[5]Hanyang University, Seoul 133-791, Korea

Metal/polymer system with large adhesion strength has attracted plenty of technical concerns as a good candidate for a multilevel interconnection system in very large scale integrated (VLSI) and highly miniaturized electronic devices. In previous study, the enhancement of adhesion strength was obtained by ion irradiated Cu/polyimide with a thin Al buffer layer, despite the complete mechanism remained controversial. The successful achievement of interfacial characterization of metal/polymer was obtained by using soft X-ray fluorescence and X-ray emission spectroscopy.

The adhesion between two materials depends on the electronic and chemical properties of the interface, and plays a key role in numerous applications of mechanical and electronic devices. Understanding the electronic and chemical structures at a deep interface is crucial for elucidating the mechanism of interfacial adhesion of metal/polymer system for that purpose. However, the surface-sensitive photoelectron spectroscopy can not avoid a deformation of the original structures, because the sputtering of overlayer is required due to a shallow escape depth of photoelectron. X-ray emission spectroscopy (XES) and soft X-ray fluorescence (SXF) provide the element-specific probe of the valence states, and are useful for examining changes in the local environment and chemical bonding of interface atoms by various chemical and physical treatments.

The experiments were carried out at Beamline 8.0, employing soft X-ray fluorescence (SXF) endstation with a 5-meter radius Rowland circle type spectrometer. The spectrometer resolution was about 0.5 eV for the measurements. Ion irradiated Cu(40 nm)/Al(5 nm)/polyimide films were used for this study. Ion irradiation was performed at room temperature with N_2^+ at an incident energy of 80 keV prior to measurements.

Cu $L_{2,3}$ XES spectra of ion irradiated Cu/Al/polyimide sample, which has larger adhesion strength than Cu/polyimide without an Al buffer layer are showed in Figure 1. The spectra of our sample show that the 60 atomic % of Cu atoms participate in the formation of the $CuAl_2O_4$ (upper panel), while the superposition of Cu and CuO can not reproduce the spectrum (lower panel). The observation of interlayer compound ($CuAl_2O_4$), known to be correlated with intermediate effect on large adhesion strength between Cu and polyimide, was confirmed for the first time.

In addition, carbon Kα SXF spectra of ion irradiated polyimide (Figure 2) show that the structural transition from carbocycloc aromatic rings (benzene) to amorphous carbon occurs with increased

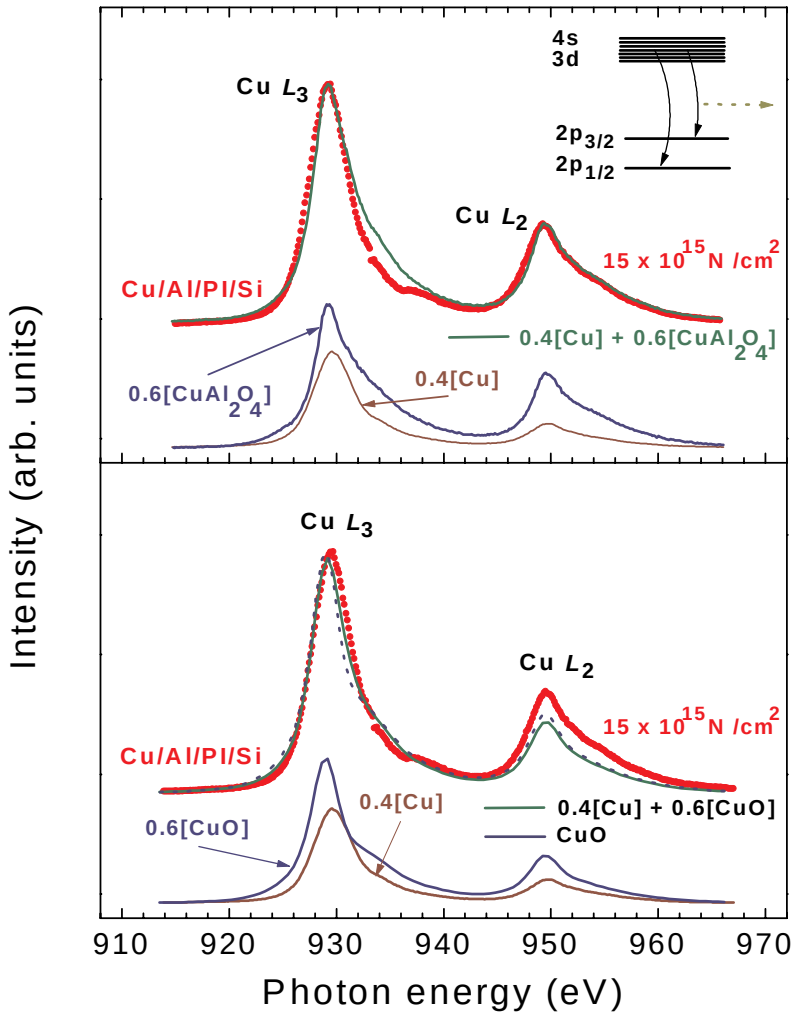

Fig. 1. Cu $L_{2,3}$ XES spectra of ion irradiated Cu/Al/PI and reference samples Cu, $CuAl_2O_4$, and CuO. The spectrum of ion irradiated sample is compared with a superposition in a ratio of 0.4 : 0.6 of the spectra of Cu and $CuAl_2O_4$ (upper panel) and Cu and CuO (lower panel), respectively.

ion dose. The decrease in adhesion strength at high ion dose, observed in previous study, can be explained by creation of chemically inert amorphous carbon.

Soft x-ray emission valence spectra showed that the formation of interlayer compound ($CuAl_2O_4$), which plays an crucial role in interfacial adhesion between Cu and polyimide, is occurred by ion irradiation, and the decrease in adhesion strength at excessive ion dose is turned out to be caused by the formation of amorphous carbon. In the spectroscopic studies of characterization of buried interfaces or embedded nano-particles, SXF and XES can offer the safe and unique experimental tools without deformation of electronic structure.

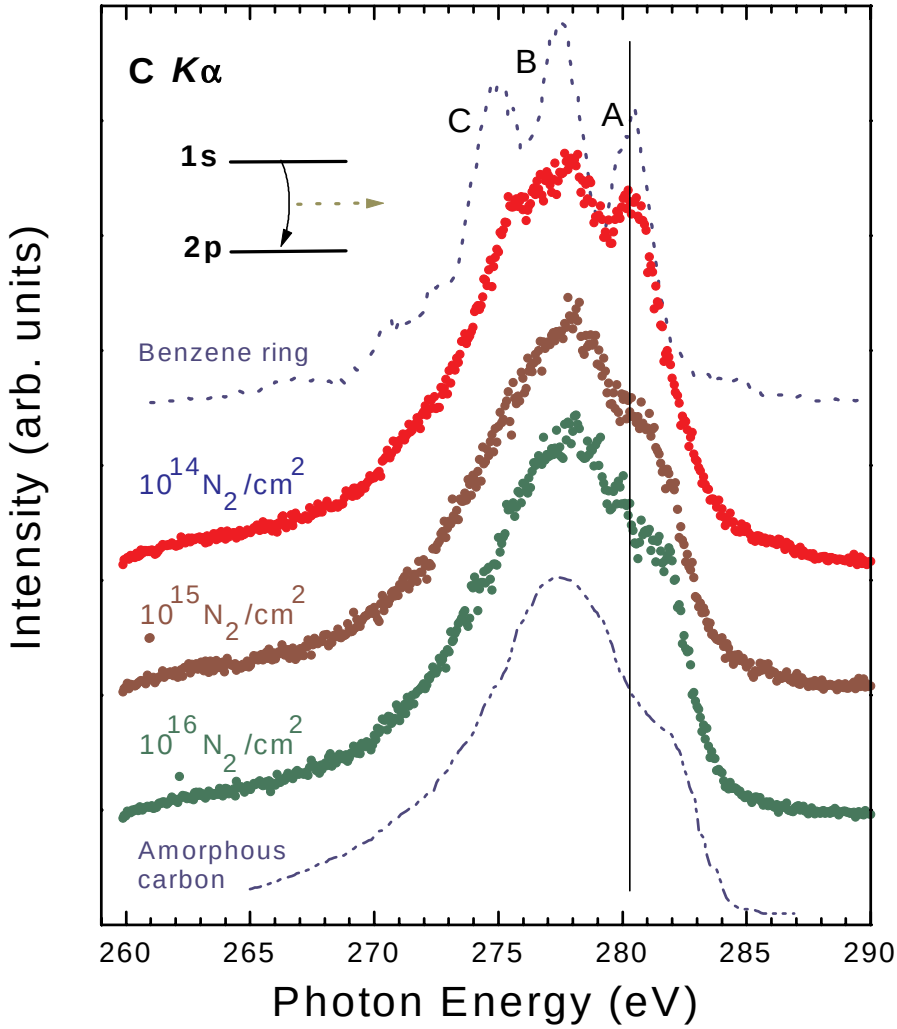

Fig. 2. Carbon Kα SXF spectra of polyimide films on Si irradiated by N_2^+ ions and of reference samples, benzene and amorphous carbon.

REFERENCES

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Principal investigator: Gap Soo Chang, Department of Physics, Yonsei University, Korea. Email: gschang@phya.yonsei.ac.kr. Telephone: 82-2-364-7941.