Structure of Li/Pd/Cu trilaminar layer for neutron production target of BNCT

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Introduction

The deployment of accelerator-driven neutron source for Boron Neutron Capture Therapy (BNCT) is scheduled at the beginning of 2014 in National Cancer Center, Japan. This BNCT system was designed with the production of neutrons via $^7Li(p,n)^7Be$ reaction at 25 kW proton beam with energy of 2.5 MeV. As a target material for BNCT, it is essential to develop a lithium target that is stable against heat load, radiation blistering and accumulation of radioactive ^7Be isotopes produced by $^7Li(p,n)^7Be$ reaction.

We consider that these problems can be effectively avoided by lithium/palladium/copper trilaminar structure target. The present report demonstrates in-situ vacuum deposition technique to create the trilaminar structure of lithium target for BNCT device. The layered structures and chemical states of the lithium surface and lithium/palladium interface were characterized by *in-situ* XPS and XAFS.

Experimental

Experiments were performed at the BL-27A station. Pd was deposited on a high purity Cu plate by electrochemical deposition. The thickness of the Pd layer was 0.1 μm. Li was evaporated on Pd surface in ultrahigh vacuum by electron bombardment heating. The thickness of the Li layer was precisely controlled by monitoring the positive current of the shutter that was located between the crucible and substrate. The surface and interface chemical states were analyzed by XPS and Pd L_3-edge XAFS. XAFS spectra were recorded by total electron yield mode.

Results and discussion

For Li $1s$ XPS spectra, the binding energy of the Li $1s$ for multi-layered Li on Pd/Cu surface was 52.8 eV. Up to now, reliable values of the Li $1s$ from metallic Li have not been reported. Tanaka *et al*. have reported that the binding energy of the Li $1s$ from Li_2O is located around 54 eV [1], and the peak energy shifted to lower binding energy after Ar^+ sputtering. Thus we assign that the surface of Li is not Li_2O but metallic Li.

Fig.1 shows the Pd L_3-edge XAFS spectra of Pd/Cu surface before and after the Li deposition. The most intense peak at 3176.7 eV (marked A) is due to the resonance excitation from the Pd $2p$ to valence unoccupied $4d$ states (white line). The spectral feature of the multi-layered sample is fairly different from that of metallic Pd. We consider that the spectral change is due to the formation of Pd-Li alloy at the interface on the
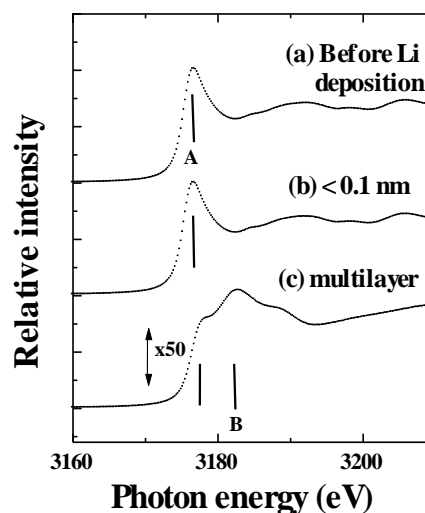

Fig. 1   Pd L_3-edge XAFS spectra for Li deposited Pd. The thickness of the Li layer is indicated in each spectrum.

basis of the following speculation. Within the single particle approximation, the oscillator strength of the white line of the L_3 edge of the d transition metals would be proportional to the hole population in the d-band [2]. Actually, in the case of Ag (next to Pd in the periodic table), the d-bands are essentially full and no white line is observed at the L-edge. Thus, the intensity of the L_3 white line is sensitive to the variation of the density of the empty states above the Fermi level. The Pd L_3-edge XAFS spectra indicate a decrease in the number of unoccupied states of Pd d-character at the Pd-Li interface. Thus the charges are transferred from lithium to the Pd d-band and contribute to the filling of the empty d-states of Pd. We consider that Pd "d-band" is being filled upon alloying with lithium. It is considered that the broad peak appeared around 3182 eV (marked B) is due to the delocalized nature of the sp continuum states. It is expected that the formation of Pd-Li alloy at the interface would contribute to the stability of the Li layer.

References
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