

Synthesis of lithium nitride for neutron production target of BNCT by in-situ lithium deposition and ion implantation

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Introduction

Many types of pilot innovative accelerator-based neutron source for Boron Neutron Capture Therapy (BNCT) were designed. As to the target materials for neutron production, two layered lithium targets were proposed [1]. However, the lithium target faces serious problems such as radiation blistering and evaporation. As to the lithium evaporation problem, we consider that it can be reduced by synthesis of Li₃N on the surface of Li layer, because Li₃N is thermally stable up to 1086 K.

Present paper demonstrates *in-situ* Li deposition and nitridation technique to create the layered structure of lithium target for BNCT apparatus. The surface compositions and chemical states were analysed by X-ray photoelectron spectroscopy (XPS).

Experimental

Experiments were performed at the BL-27A station. Li was evaporated on Pd surface in ultrahigh vacuum by electron bombardment heating. After Li deposition, the sample surface was bombarded with nitrogen ions using a cold-cathode ion gun. The energy of the N₂⁺ ions was 1.0 keV. The surface chemical states were analyzed by XPS using 2000 eV photons and X-ray tube with yttrium anode (Y M_α line, hv=132.3 eV).

Results and discussion

Fig. 1 shows the XPS spectra in the Li 1s region for lithium surface before and after N₂⁺ ion bombardment. Before the bombardment, the binding energy of the Li 1s peak is 52.8 eV (marked A), which is due to the metallic Li [2]. After N₂⁺ ion bombardment, the Li 1s binding energy shifted to 55.1 eV (marked B). Up to now, there have been no reliable data about the Li 1s binding energy for stoichiometric lithium nitride (Li₃N). As to the Li-N compounds, it was reported that the Li 1s binding energy of lithium azide (LiN₃) is located at 54.8 eV [3]. Although the chemical states of lithium in Li₃N is not exactly same as that in LiN₃, both compounds are formed with ionic bonds due to the high positive nature of lithium compared with nitrogen. So we tentatively assign that the peak B originates from lithium nitride.

Fig. 2 shows the XPS spectra in the N 1s region for lithium after N₂⁺ ion bombardment. A sharp intense peak is observed at 396.0 eV (marked A). There have been no reliable data about the binding energy of the N 1s peak for lithium nitride. As to the metallic nitrides, many data have been reported, and it was shown that the binding

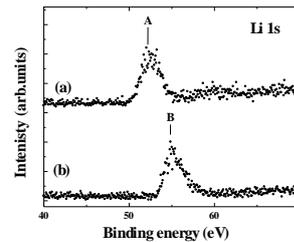


Fig.1 Li 1s XPS spectra for lithium layer before (a) and after (b) 1 keV N₂⁺ ion implantation. The photon energy was 2000 eV. The fluence of the N₂⁺ ions was 6.3×10¹⁷ atoms·cm⁻².

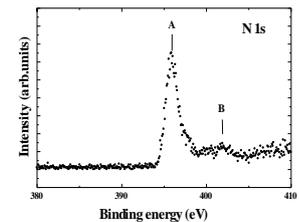


Fig.2 N 1s XPS spectra for lithium layer after 1 keV N₂⁺ ion implantation. The photon energy was 2000 eV. The fluence of the N₂⁺ ions was 6.3×10¹⁷ atoms·cm⁻².

energies of the N 1s in metallic nitrides are located in the range between 396 eV and 397 eV. So we assign that the peak A is due to lithium nitride. In order to estimate the stoichiometry of lithium nitride, we calculated the atomic ratio of nitrogen to lithium, n_N/n_{Li} on the basis of the XPS peak intensities. The value of n_N/n_{Li} is calculated by

$$\frac{n_N}{n_{Li}} = \frac{I_{N\ 1s} / \sigma_{N\ 1s}}{I_{Li\ 1s} / \sigma_{Li\ 1s}} \quad (1)$$

where I (cps) is the intensity of the photoelectrons and σ (barn) is the photoionization cross sections by 2000 eV photons for the respective core levels. From figs. 1 and 2, we obtain n_N/n_{Li}=0.21 using equation (1). The value is far from the ratio of lithium azide (n_N/n_{Li}=3.0), but rather close to that of lithium nitride (n_N/n_{Li}=0.33), so we conclude that a nearly stoichiometric Li₃N layer is formed at the surface.

References

- [1] For example, B.F. Bayanov *et al.*, Appl. Radiat. Isot. **61**, 817 (2004).
- [2] S. Ishiyama *et al.*, Nucl. Instrum. Meth. Phys. Res. B **288**, 18 (2012).
- [3] C.D. Wagner *et al.*, Handbook of X-ray Photoelectron Spectroscopy, Perking-Elmer Corporation (1979).

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