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Inclusion of the Amorphous Component in Bismuth nanoparticles

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Introduction

Rhombohedral bismuth has a layer structure and the bondings between the three-fold co-ordinated Bi atoms are mainly covalent. Raman-scattering measurements of bismuth nanoparticles suggest a phase transition from semimetallic rhombohedral Bi nanocrystalline to semiconducting amorphouslike nanoparticles with decreasing size[1].

Amorphization is a key issue of the phase transition, but it has not been confirmed by methods of TEM and so on. In the present study we report results of x-ray diffraction (XRD) to confirm the existence of the amorphous phase in the Bi nanoparticles.

Experimental

Thin Bi layers and NaCl layers were deposited alternately onto a water-cooled alumina substrate from an alumina crucible. The Bi nanoparticles are isolated and dispersed within the NaCl matrix

The XRD patterns were measured with synchrotron radiation at the BL-1B in the Photon Factory of High Energy Accelerator Research Organization KEK-PF. The X-ray energy used for the XRD measurements was 12.40keV. The XRD measurements of the as-deposited and the annealed samples were carried out at room temperature.

Result and Discussion

Figure 1 shows X-ray diffractions of the Bi nanoparticles. Intensities are normalized by integrated intensities of NaCl (200) peaks which do not overlap with any other peaks. All peaks are assigned to the rhombohedral Bi and the cubic NaCl.

The Bragg peaks of the Bi nanoparticles broaden with the decrease of the Bi film thickness, implying that the Bi nanoparticles become small. It is interesting that background of the X-ray diffractions increase with the decrease of the Bi film thickness. Since the ratio of the Bi film thickness to that of the NaCl film thickness is same between the samples, the total scattering intensity due to the Bi nanoparticles may be preserved. The increase of the background suggest that the Bi nanoparticles are composite of the crystalline and amorphous components.

The 0.5 nm-thick films were annealed between the room temperature and 300 °C. Figure 2 shows the peak intensities of the Bi (104) and (111) peaks of the annealed 0.5 nm-thick-films at several temperatures. The intensity does not change below 150 °C temperature anneal, but it increases above 150 °C. The increase suggests that the amorphous components change to the crystalline components, in other words the increase shows that the Bi nanoparticles compose of the amorphous components.

Figure 3 shows the film thickness dependence of the peak intensities of the Bi (104) and (111) peaks. While the intensity is constant above 10 nm, it decreases rapidly below 10 nm and that of the 0.5-nm-thick films is about one forth of that of 300 nm-thick films. The results shows also that the Bi nanoparticles compose of the amorphous components.

Reference

[1] M. G. Mitch, S.J.Chase, J Fortner, R.Q. Yu, and J. S. Lannin, Phys. Rev. Lett. **67**, 875(1991) .

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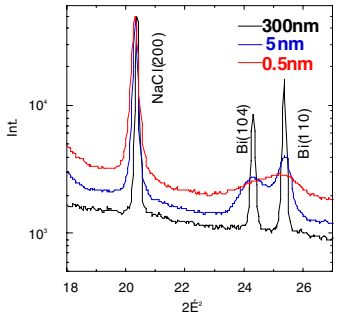

Fig. 1 The X-ray diffraction pattern of the 0.5, 5 and 300 nm-thick films.

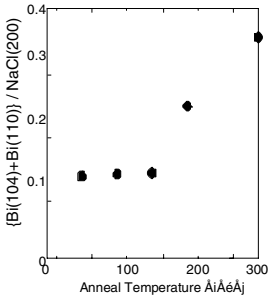

Fig. 2 The peak intensities of the Bi (104) and (111) peaks of the annealed 0.5 nm-thick-films.

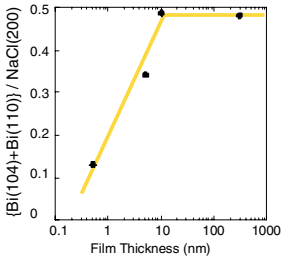

Fig. 3 The film thickness dependence of the peak intensities of the Bi (104) and (111) peaks