LETTER TO THE EDITOR

Formation of Al-Cr Quasicrystal Films by RF-Sputtering

Keywords: quasicrystal, sputtering, aluminum-chromium, X-ray diffraction, electron microscopy

Several different methods have been reported for the production of quasicrystals. These are rapid solidification, solid state reaction, crystallization of amorphous phase, and conventional chill casting. However, the formation of quasicrystals from vapor phases have seldom been reported.

In this communication, we report the formation of quasicrystals by the use of rf-sputtering. The quasicrystal formation was possible when polyimide films were used as the substrate but not when quartz glass was used as the substrate.

The rf-sputtering was performed by the magnetron type apparatus. The compositions of deposited films were controlled by the ratio of the target surface area of Cr (99.99%) to the Al (99.99%). About 10 μm thick deposited films were produced by the input power of 300 W in 10.8 ks (3 h) under Ar atmosphere. Operating pressure was 6.7×10⁻¹ Pa (5.0×10⁻³ torr). Either the quartz glass or the polyimide film on the Cu plate was used as the substrate. The composition of deposited film on each substrate was measured by energy dispersive X-ray spectroscopy (EDX). The α-phase (Al₇Cr), which was produced by chill casting, was used as a standard sample for EDX. Samples were electrolytically polished for structure observations and selected area electron diffraction in a 200 kV transmission electron microscopy (TEM). The identification of phases in as prepared deposits were performed by X-ray diffractometry using Cu Kα as a source. The slightly convergent beam diffraction was also used for the identification of the phases of small area (about 200 nm in diameter).

The X-ray diffraction curve taken from the sample of 22.3 at%Cr deposited on the quartz glass is shown in Fig. 1(a). There are no clear peaks except a broad one at 42°. On the other hand, the curve taken from the sample of the same Cr content deposited on the polyimide film shows sharp peaks as shown in Fig. 1(b). The d-spaces and the intensities obtained from the X-ray data of Fig. 1(b) are shown in Table 1. These d-spaces match well with the first 6 strong reflections of the icosahedral phase calculated by setting the “lattice” constant, a₀ = 0.470 nm. The differences in intensities from the ones obtained for the rapidly solidified Al-Mn quasicrystals may be due to the existence of preferred growth orientation in the sample deposited on the polyimide film.

Figure 2 shows TEM images of the same samples as shown in Fig. 1(a) and (b). The deposited sample on the quartz glass shows no clear contrast in the bright field image as shown in Fig. 2(a). The selected area diffraction pattern of this area shows only halo patterns which are characteristic of an amorphous phase. The peak position of the first halo pattern agreed with that of the X-ray diffraction curve.

The bright field image of the sample deposited on the polyimide film shows clear contrast and the selected area diffraction pattern taken from some part of this area shows the typical 5-fold diffraction symmetry as shown in Fig. 2(b). Figure 3 shows the typical 5 and 2 fold symmetry patterns of the slightly convergent beam diffraction taken from the other part of the same area as Fig. 2(b). These patterns are consistent with the diffraction pattern of the quasicrystal phase.

Table 1 The d-spaces and the relative X-ray diffraction intensities of the sample deposited on polyimide film. The calculated d-spaces and indices are based on the theory of the quasicrystal diffraction with a₀ = 0.470 nm. The relative X-ray diffraction intensities of Al-Mn quasicrystals formed by rapid solidification are also shown.
terns are in good agreement with those taken from the icosahedral phase in the liquid quenched Al-Mn alloys\textsuperscript{11}. Since no diffraction patterns other than those from the icosahedral phase was observed by TEM, the phase of 22.3 at\%Cr deposited on the polyimide film may be considered to be composed almost entirely of the icosahedral phase.

When the content of Cr in the sample deposited on the polyimide film was lower than 18.3 at\%, mixtures of fcc-aluminum and icosahedral phase were produced. When
the quartz glass plate was used as the substrate, mixtures of amorphous and fcc-aluminum phase were observed.

Several explanations may be possible why icosahedral phase was formed only on the polyimide film. The possible difference in the deposition temperature was denied because no change in the deposited phase was noticed when both substrates were cooled by liquid nitrogen. The polyimide film may produce less stress in the sample since it can curl itself as the deposition of sample becomes thicker. Further experiments are being performed to make clear the physical condition for the formation of icosahedral phase by rf-sputtering.

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S. R. Nishitani*, Y. Iwasa*, K. N. Ishihara** and P. H. Shingu**

*Graduate Student, Kyoto University, Kyoto 606, Japan.
**Department of Metal Science and Technology, Faculty of Engineering, Kyoto University, Sakyo-ku, Kyoto 606, Japan

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