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AMORPHOUS Fe-POLYETHYLENE Co-EVAPORATED FILMS

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Abstract. – Fe-polyethylene films were prepared by simultaneous evaporation of Fe and polyethylene. It was found that these films become amorphous and exhibit softmagnetism. The minimum coercivity in these films was 2 Oe and the saturation magnetization with the minimum coercivity was 1368 G.

1. Introduction

It is well known that amorphous metallic alloys are produced through rapid quenching of alloys of amorphization elements (B, C, P, Hf, Zr, Ti, etc.) and metals or by adding amorphization elements into matrices utilizing various methods such as vapor deposition, sputtering and plating. In our previous work, we reported that Co-Cr-polyethylene(PE) co-evaporated films become amorphous and exhibit soft-magnetism [1]. It was therefore expected that the addition of a polymer would also help metals become amorphous. In order to examine this and obtain new soft magnetic materials with high saturation magnetization, we prepared Fe-PE co-evaporated films and found that these also become amorphous exhibiting soft magnetism.

In this report, we describe the crystallographic structures, microstructures and magnetic properties of Fe-PE films.

2. Experimental details

Fe and PE were simultaneously deposited onto a substrate by electron beam deposition and thermal resistance deposition, respectively. Two types of substrate were used: slide glass for measurements of crystallinity and magnetic properties, and carbon coated mica foils for observation of microstructure. During the deposition, the substrate temperature was held at 150 °C and the pressure in the vacuum chamber was held at 1 ~ 2 x 10⁻⁵ Torr. In the deposition of Fe alone, however, the pressure was kept at 2 ~ 3 x 10⁻⁶ Torr. The Fe and PE deposition rates were 20 Å/s and 0 ~ 20 Å/s, respectively.

Saturation magnetization and coercivity were measured by a vibrating sample magnetometer. The crystallographic structure was studied by both an X-ray diffraction method (XRD) with CuKα radiation in the range of 30° < 2θ < 100° and an electron diffraction (ED) method. The micro structure was studied by transmission electron microscopy (TEM). Due to difficulty in measuring the amount of PE in the Fe-PE films, the composition was obtained from the amount of Fe and C measured by means of Auger electron spectroscopy. It was noticed that each film contained 2 ~ 6 at. % 0. The composition of Fe-PE films is represented as Fe₁₋ₓCₓ.

The film thickness was within 0.5-1.5 μm.

3. Results and discussion

The Fe film exhibits (110) and (211) peaks of bcc Fe. The intensity of the (211) peak is far weaker than that of the strong (110) reflection. The Fe film preferentially grows with the (110) orientation normal to the substrate plane. As the C content increases, the intensity of both peaks decreases and a halo pattern in the range of 40° < 2θ < 50° is observed. In figure 1, the carbon concentration dependence of the intensity and the shape of the (110) peak is shown. Within x = 0.09 ~ 0.11, both the (110) peak and the halo pattern are observed. However, only the halo pattern is observed above x = 0.13.

Figure 2 shows the TEM micrographs and the ED patterns of the Fe film and the Fe-PE film with x = 0.15. The Fe film consists of microcrystals of size 200 ~ 400 Å. The sharp ring patterns of polycrystalline Fe are observed in ED. In the Fe-PE film with x = 0.15, fine grains with unclear boundaries are observed. The size of these grains are 20 ~ 50 Å. Broad rings are observed in ED.

Therefore, the Fe-PE films with x = 0.13 and above are in amorphous state.
Figure 2. - TEM micrographs and ED patterns. (a) Fe film. (b) Fe-PE film with $z = 0.15$.

Figure 3 shows hysteresis loops of the Fe film and the Fe-PE films. The coercivity of the Fe film and Fe-PE films with $x = 0.05$, 0.11 and 0.19 are 80 Oe, 31 Oe, 2 Oe and 56 Oe, respectively. It is apparent that in the Fe-PE films with approximately $x = 0.11$, the coercivity is minimum. The saturation magnetization with the minimum coercivity is 1368 G. Below $x = 0.11$, the coercivity diminishes as the C content increases. This change in magnetic properties to soft-magnetic can be explained as the result of the annihilation of the crystalline magnetic anisotropy due to the amorphization of the Fe-PE film. Above $x = 0.11$, the coercivity increases. The hysteresis loop of the Fe-PE film with $x = 0.19$ resembles one typical of a film in which stripe domains has been created. This suggests that the reason for the increase of the coercivity above $x = 0.11$ is that the domains are created due to perpendicular magnetic anisotropy. However, the reason for the creation of this anisotropy remains unclear.

4. Conclusion

Fe-PE films become amorphous above 13 at. % C. The coercivity decreases to 2 Oe around this carbon content. The saturation magnetization with the coercivity of 2 Oe is 1368 G ($4\mu M_s = 17$ kG).

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