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The Effect of Ag addition on Microstructure of $Fe_{93-x}Zr_3B_4Ag_x$ Soft Magnetic Thin Films

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I. Introduction

Many studies on microstructure of nanocrytalline soft magnetic materials for electronic device application have been carried out in order to enhance magnetic properties by annealing process and the addition of elements. The crystallization of Fe-base amorphous phase alloys prepared by a melt quenching technique has been intensively studied by many authors[1,2] in the range of composition, 76 a/o $\leq$Fe$\leq$ 88 a/o. Also, using addition of elements such as Ti, V, Cu, Mo, Nb and Cr, the magnetic property and the microstructure of Fe-base amorphous alloys have been investigated for potential use as electrical transformers, motors, high-frequency switching supplies, and other electrical devices[3]. In our study, the effect of Ag addition on the structural behavior of $Fe_{93-x}Zr_3B_4Ag_x$ thin films was investigated as a function of composition, Ag and annealing temperature in order to achieve the enhancement of magnetic properties such as permeability, coercivity and saturation magnetization.

II. Experimental Procedure

$Fe_{93-x}Zr_3B_4Ag_x$ thin films of about 0.5μm thick were deposited from Fe-Zr-B target and Ag chip on Si(001) substrates by using a DC-magnetron sputtering system with a base pressure of 3×10^{-6} torr and a deposition pressure of 3×10^{-3} torr. Si(001) substrates were held at 30°C during sputtering and then the films were *ex-situ* annealed in vacuum furnace having a base pressure of 5×10^{-6} torr in the range of temperature, 300°C to 700°C for 1hr. Microstructure of the films was investigated, using X-ray diffraction(XRD) and transmission electron microscopy(TEM). The permeability of the films was measured by B-H meter.

III. Results and Discussion

Figure 1 shows XRD patterns of $Fe_{93-x}Zr_3B_4Ag_x$ thin films as a function of composition, Ag. The structure of as-deposited $Fe_{93}Zr_3B_4$ thin films was observed in the form of α-Fe (110) crystalline phase. However, with increasing the amount of Ag addition into $Fe_{93-x}Zr_3B_4Ag_x$ matrix, the peak of α-Fe (110) did much broaden and its intensity decreased near 2θ = 45 °, while the intensity of crystalline peak of Ag(111) increased. This indicates that Ag addition inhibited form of Fe-base crystalline phase in $Fe_{93-x}Zr_3B_4Ag_x$ matrix during sputtering.

Figure 2 shows XRD patterns of $Fe_{89}Zr_3B_4Ag_5$ thin films with variation of annealing temperature. Microstructure of As-deposited thin films consisted of a mixture of Fe-base amorphous and Ag crystalline phases. Also, the phase transformation of as-deposited thin films occurred in order of Ag crystalline + Fe-base amorphous phase → Ag crystalline + Fe-base amorphous phase + α-Fe cluster → Ag crystalline + α-Fe nanocrystalline phase→ Ag crystalline + α-Fe crystalline phase → Ag crystalline + α-Fe + $Fe_3(Zr, B)$.

Figure 3. shows PVTEM micrograph and diffraction pattern of $Fe_{89}Zr_3B_4Ag_5$ thin film annealed at 500°C in vacuum furnace of 3×10^{-6}torr for 1hr. The grain size was approximately below 9nm. In the annealed thin films, the formation of such ultra fine crystalline phase is likely to result in the enhancement of magnetic properties[4].

IV. Conclusion

From XRD and TEM investigation, $Fe_{93}Zr_3B_4$ thin films on Si(001) substrates consisted of nano-crystalline Fe-base phase. In the presence of Ag constituent, phases of as-deposited $Fe_{93-x}Zr_3B_4Ag_x$ films were consisted of a mixture of the majority Fe-base amorphous and Ag crystalline phase. In particular, ultra fine crystalline phase of $Fe_{88}Zr_3B_4Ag_5$ films annealed at 500°C, resulting into the enhanced soft magnetic properties was observed.

Reference

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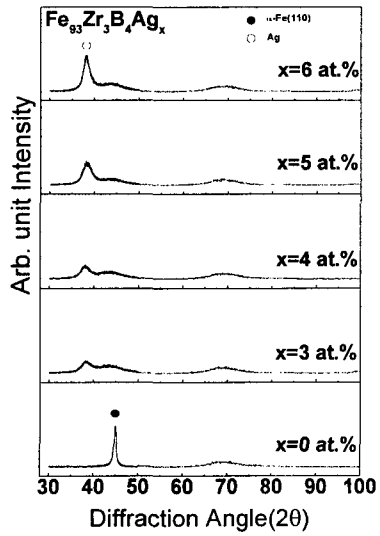

Fig. 1. Change in XRD patterns of $Fe_{93-x}Zr_3B_4Ag_x$ thin films on Si(001) substrates with variation of Ag composition, x.

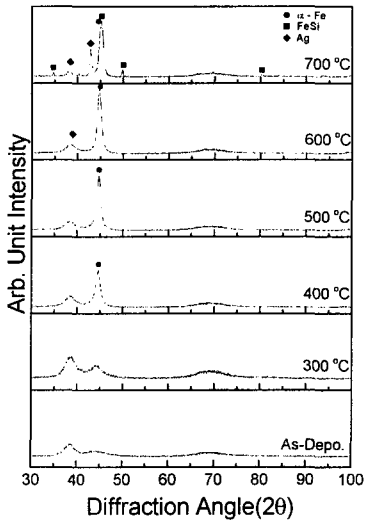

Fig. 2. Change in XRD patterns of $Fe_{89}Zr_3B_4Ag_5$ thin films as a function of annealing temperature