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Permeability spectra and asymmetrical giant magnetoimpedance in weak-field annealed Co-based amorphous ribbon

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I. INTRODUCTION

Recently, an asymmetric giant magnetoimpedance (GMI) profile, showing GMI-valve, has been reported in a weak-field-annealed amorphous ribbon due to the bias field of the magnetic layer on the specimen surface [1]. The shape of the GMI profile depends on the annealing time, the temperature, the applied field, and the atmosphere during annealing, as well as on the composition of the starting material. In this work we prepare weak-field-annealed amorphous samples as a function of the annealing temperature for the microstructural modification, and discuss the change in permeability spectra and GMI profile in term of domain modification by the bias field.

II. EXPERIMENTAL

The samples, the commercially available 2714A amorphous ribbon supplied by Allied signal Co., were annealed at various temperatures between 200 and 450 °C for 8 h in an open air. The earth's magnetic field was compensated by using two-dimensional Helmholtz coils. The annealing field of 2 Oe was applied in the direction of the sample axis direction by using solenoid. Compositional depth profiles were investigated using Auger electron spectroscopy. The impedance Z and permeability spectra were measured by using a HP4192A impedance analyzer with four terminal contacts and rectangular solenoid, respectively. The computer software was used for the control of the external magnetic field and ac measuring current. The amplitude of ac current applied to the rectangular solenoid coil was kept to constant during the frequency sweep to produce the constant amplitude of ac magnetic field on the samples. The cyclic magnetic field was applied by a Helmholtz coil using a step-like changing current. The GMI profile was obtained by plotting $\Delta Z/Z$ for the cyclic applied field.

III. RESULTS AND DISCUSSION

A. Microstructural change

The compositional-depth profiles have been investigated using Auger electron spectroscopy. The thickness of surface oxide layer is less than 70 Å in as-quenched sample. In the sample of annealing temperature T_a = 300 °C, the thickness of the oxide layer increases to 500 Å. The oxide layer formed on the annealed sample is heavily enriched in B, balanced by a depletion of this element in the underlying material. The thickness of the oxide layer increases with the annealing temperature and the profound increase of Co content in the underlying layer is revealed in the sample of $T_a \geq$ 350 °C.

The reduction of B content decreases the crystallization temperature of amorphous alloy, probably enough so that crystallization of the depleted layer can occur at the annealing temperature over 300 °C. Hence, the Co enriched layer may be crystalline single phase, crystalline multi-phase or crystallites in the sample surface. The bias field could be developed on the crystals or crystallites layer due to the annealing field, and can be exchange coupled with the amorphous core [2]. The crystallization is occurred in entire sample volume for $T_a \geq$ 450 °C even though it is annealed in vacuum [3].

B. Permeability spectra

The dependence of decomposed static permeability on annealing temperature are shown in Fig. 1. The μ_{dw} from irreversible wall motion increases at $T_a = 200$ °C sample due to magnetic softening and then decreases with T_a. However, the μ_{rot} from reversible rotational magnetization decreases at $T_a = 200$ °C sample, and then increases. As a whole, μ_{dw} decreases with annealing temperature for $T_a \geq 250$ °C due to the hindrance of wall motion and/or the decrease of longitudinal domain volume by the bias field in surface crystalline layer. However, μ_{rot} increases with T_a, and has a maximum in $T_a = 350$ °C sample.

C. GMI profile

Fig. 2 shows the GMI profiles for various T_a. The profiles in the sample of $T_a = 300$ °C show one peaks during a half cycle of magnetization but there is hysteresis for increasing and decreasing field in Fig. 2(a). For the sample with $T_a = 350$ °C, the GMI vanishes in antiparallel field region to annealing field, H_a and shows the GMI-valve in parallel field region, as shown in Fig. 2(b). The on-set field of GMI-valve for increasing and decreasing fields nearly coincides each other even though magnitude of GMI for decreasing field is smaller than that for increasing field. The GMI ratio is maximum irrespective of measuring frequency in 350 °C annealed sample.

In the 450 °C annealed sample, the GMI peak for the antiparallel field re-appears, showing two peaks as in Fig. 2(c), where the center of two peaks shifts to positive field. Two GMI peaks are caused by the small volume of rotational magnetization due to the crystallization, because the dip between two peaks near $H = 0$ reflects the damping of wall motion.

IV. CONCLUSION

The low-frequency dispersion of permeability spectra due to the irreversible wall motion decreases with the annealing temperature due to the hindrance of wall motion and/or the decrement of longitudinal domain volume by the bias field on surface crystalline layer. However, the high frequency dispersion from rotational magnetization is maximum at 350 °C annealing temperature. The distinctive GMI-valve in 350 °C annealing sample is revealed due to the influence of bias field on wall motion, indicating the optimum annealing temperature of about 350 °C for GMI-valve improving field sensitivity.

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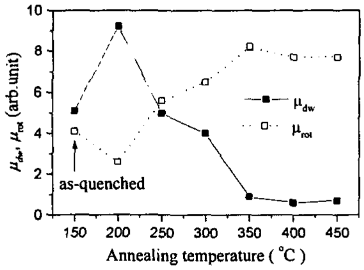

Fig. 1. Dependence of the permeability, μ_{dw} and μ_{rot} on annealing temperature.

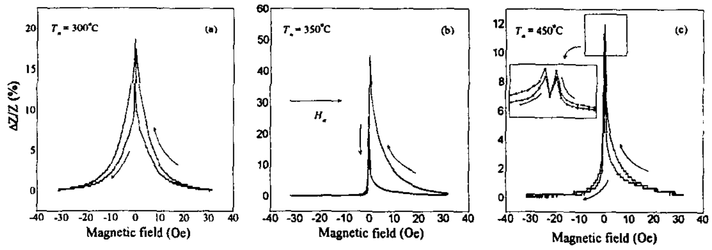

Fig. 2. The GMI profiles for the annealed samples at temperature of (a) 300, (b) 350, (c) 450 °C in open air.