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Hysteretic characteristics of giant magnetoimpedance due to the exchange coupling in annealed amorphous materials

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1. INTRODUCTION

Much work has been done on the giant magnetoimpedance (GMI) in soft magnetic Co-based amorphous wires and ribbons because of a high potential for the magnetic sensor applications.[1-3] An asymmetric GMI characteristics for sensor applications is desirable for the improvement of field sensitivity and linearity.

The asymmetric GMI profile, showing the GMI-valve due to bias-field, has been revealed in weak-field annealed Co-based amorphous ribbon. The bias-field is caused by a hard magnetic phase developed on the sample surface.[4] However, the role of exchange coupling on the asymmetric GMI is well not understood yet. In this work, we will discuss the measured hysteretic GMI profiles in terms of antiferromagnetic couplings and switching of the bias-field as function of dc external field and maximum driving field.

2. EXPERIMENTS

Amorphous ribbons Co66Fe4B15Si15 were annealed at temperature of 380℃ during 8 h in open air (batch-A), and vacuum (batch-B). A field of 3 Oe was applied during the annealing of both batch-A and batch-B samples. The direction of annealing field was regarded as positive in a fixed sample axis.

The absolute value of impedance Z was measured by an impedance analyzer (HP4192A) with four terminal contacts. The ac probe current of 0.1 MHz frequency was kept at a constant value of 5 mA during the impedance measurements. The GMI ratio profile was obtained by plotting Z/Z (%) = $(Z(H) - Z_{sat})/Z_{sat} \times 100$ versus the cyclic applied field, where the Z_{sat} was the impedance at maximum field strength of cyclic field. The maximum field strength of the cyclic field changed from 30 Oe to 400 Oe.

3. RESULTS AND DISCUSSION

In order to know the direction of bias-field appeared during the field annealing, the sample has been exposed in the magnetic field, H_{dc} for a few minutes. Here the field direction is opposite to the annealing field. Figs. 1(a)-(d) show the GMI profiles for H_{dc} = 0, 100, 200, and 400 Oe, respectively. There is no noticeable change in profile for the sample exposed in magnetic field of 100 Oe, as Fig. 1(b). The profile begins to change as $H_{dc} \geq$ 200 Oe. For the sample exposed in 400 Oe field., the profile changes like a horizontal reflection, indicating the change of bias-field direction. However, there is no change in the profiles when the exposed field is parallel to the annealing field. Therefore, the bias-field is considered to be same direction as that of annealing field.

Figures 2 show the GMI profiles under the various field strength of cyclic field. The profilebegins to change when the maximum driving field exceeds 200 Oe as shown in Fig. 2(c). The profiles in the inset of Fig. 2 exhibit the hysteresis for increasing and decreasing fields. Here, the peak for increasing field is positioned in negative field region, but in positive field region for decreasing field. This behavior is opposite to the general magnetic hysteretic characteristics. That is, the effect of bias-field on GMI is opposite direction to the bias-field. This hysteretic result suggests that there is an antiferromagnetic coupling of bias-field on surface layer with the magnetization of inside amorphous phase causing GMI.

4. CONCLUSIONS

An asymmetric GMI profile with a step-like change is related with the bias-field, of which direction is same as that of annealing field. The bias-field is caused by the surface crystalline layer to have a relatively hard magnetic phase. The bias-field is stable for the external field less than 100 Oe, but its direction is changed according to the external field over 400 Oe.

The GMI profile begins to change when the maximum driving field exceeds 200 Oe, where the peak of GMI for increasing field is positioned in negative field region, but in positive field region for decreasing field. This behavior is opposite to the general magnetic hysteresis characteristics. Because GMI is resulted form the magnetization of amorphous phase, this result suggests that there is an antiferromagnetic coupling of bias-field on surface layer with the magnetization of inside amorphous phase.

5. References

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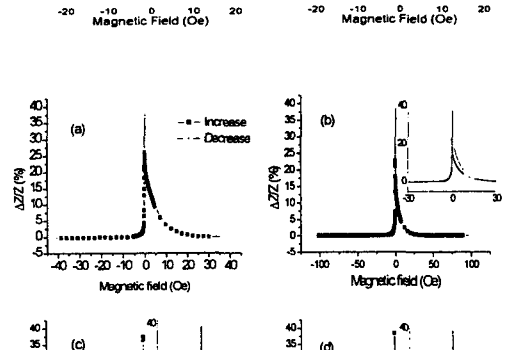

Fig. 1. GMI ratio profiles for annealed sample in batch-A exposed in various magnetic fields, (a) H = 0, (b) 100, (c) 200 and (d) 400 Oe. The solid lines and symbols (O) represent the results for decreasing and increasing fields, respectively.

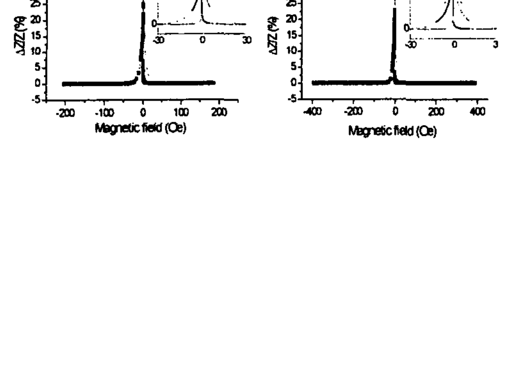

Fig. 2. GMI ratio profiles under maximum field of (a) 40 Oe, (b) 100 Oe, (c) 200 Oe and (d) 400 Oe. Inset figures represent the GMI profiles in enlarged x-scale.