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Dependence of GMI Profile on Size of Co-based Amorphous Ribbon

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The Co-based ribbons with different length were annealed in different magnetic field and GMI profiles were investigated in order to clarify the influence of ribbon size on GMI effect. The GMI ratio decreased with the decreasing in length and also decreased with increasing annealing field. While, the slope of GMI profiles inclined and the field range showing linearity was broadened. It shows prospect to low field sensor, especially for a navigation sensor.

Keywords : giant magnetoimpedance, amorphous ribbon, linearity, sensitivity

1. Introduction

Many scientists and engineers have taken great interests in giant magnetoimpedance (GMI) effect in Co-based ferromagnetic amorphous alloys because of its high GMI ratio [1-6]. The GMI effect is defined as, huge change in the impedance of a soft magnetic conductor in the presence of a static external magnetic field. The interest in the GMI is supported by possible use of the effect in various technological applications, in particular, for the development of weak magnetic-field sensors. The linearity and the sensitivity for the magnetic field are the most important parameters in practical applications of the GMI effect. To improve the linear characteristic of the GMI response, the asymmetric GMI is very promising [7, 8]. It has been reported that Co-based amorphous ribbons exhibit asymmetric GMI profiles, after annealing under a weak magnetic field for 8 hours in open air, due to the self-bias field developed in near surface [9, 10]. At sufficiently low frequencies, the GMI profile exhibits a drastic step-like change in the impedance near zero field (so called "GMI valve") [11]. As it shows high sensitivity at ultra low fields, it is not suitable for a low field sensor. The ribbons with long length were used in our previous work; however, modern technology requires small size sensing element with high sensitivity. In this work, ribbons with different sizes were annealed in different field and linear characteristic of GMI profiles were studied.

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2. Experiment

Amorphous ribbons $Co_{66}Fe_4Si_{15}B_{15}$ prepared by the rapid solidification technique were annealed in air at a temperature of 380°C during 8h. Various amplitudes of magnetic fields were applied along the longitudinal direction of the ribbon during annealing. The length of ribbon varies from 5 mm to 5 cm, and the width varies from 2 mm to 1 mm. The thickness of ribbon was 20 μm. The absolute value of impedance Z was measured by an impedance analyzer (HP4192A) with four terminal contacts at the frequency of 100 kHz. The AC current was kept at a constant value of 5 mA during the impedance measurements. The GMI ratio profile was usually obtained by plotting $\Delta Z/Z=\{Z(H)-Z(H_{max})\}/Z(H_{max})$ versus the cyclic applied field, where Z_{max} was the impedance at H_{max}=40 Oe. All the experiments were controlled through the GPIB interface and Labview program.

3. Results and Discussion

Figure 1 shows the GMI profiles of ribbons with different length. It can be clearly seen that the asymmetric profiles can be obtained regardless of length. It shows that there still occurs strong exchange coupling between surface crystalline layer and inner amorphous core [11, 12] when

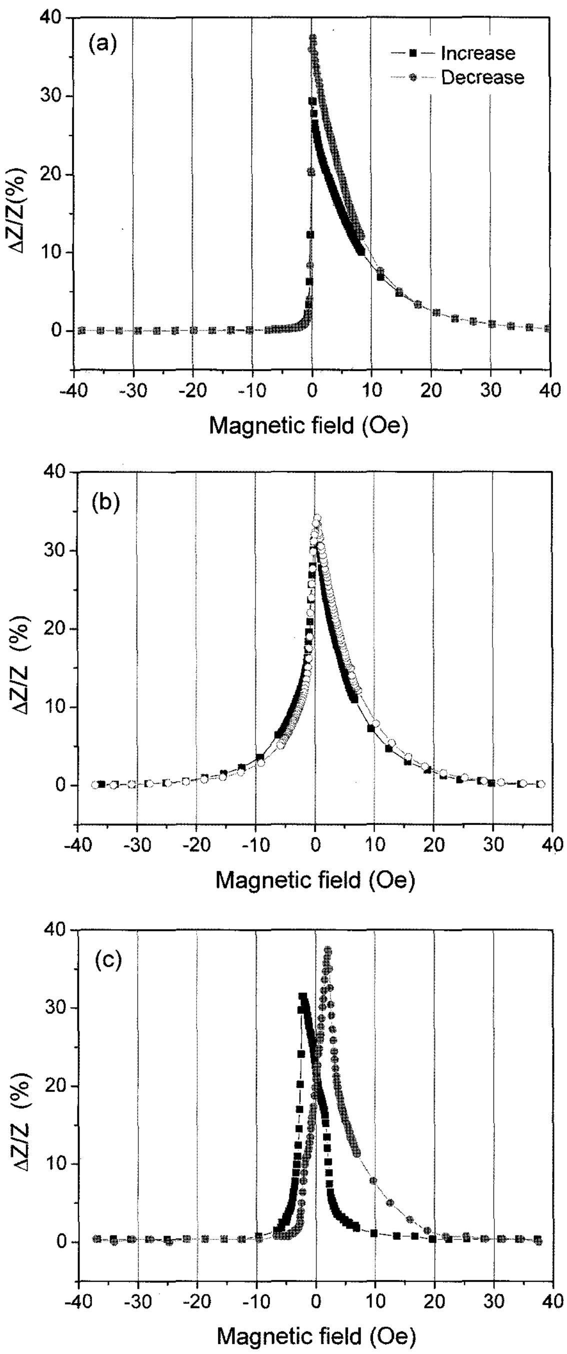

Fig. 1. GMI profiles of ribbons for various ribbon size. (a) 5 cm; (b) 2 cm; (c) 1 cm.

the ribbons were annealed in open air. While the GMI ratio tends to decrease. Besides, the slope of the curve in near zero field regions decreased then the length got smaller. Table 1 shows linearity region and field sensitivity of ribbons for three kinds of length. The linearity region gets broadened when the length of ribbon got smaller and smaller. The shorter ribbon widened the sensing field range. But the field sensitivity reduced very much from 50%/Oe to 7%/Oe.

Table 1. Linearity region and field sensitivity for various ribbon size.

3 Oe Sample	Linearity region	Sensitivity
5 cm	0.3037 Oe	50.69%/Oe
2 cm	4.71 Oe	24.526%/Oe
1 cm	3.498 Oe	7.576%/Oe

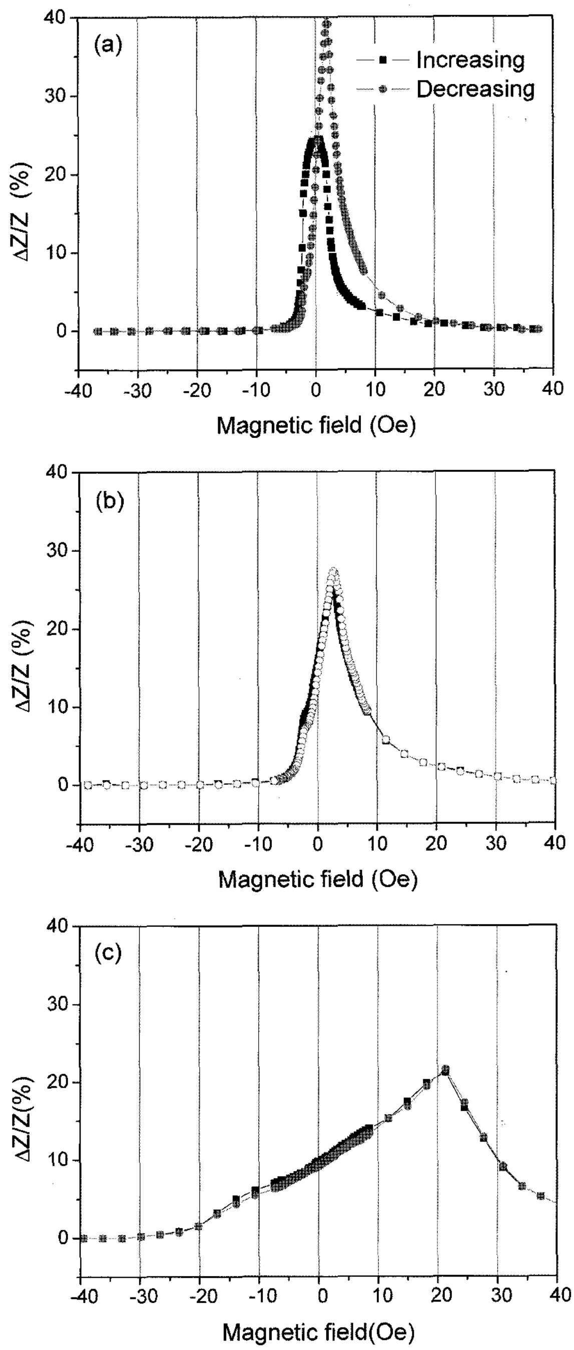

Fig. 2. GMI profiles of ribbons annealed in various fields. (a) 8 Oe, 1 cm; (b) 10 Oe, 1 cm; (c) 25 Oe, 5 mm.

We also annealed same length of ribbons in different

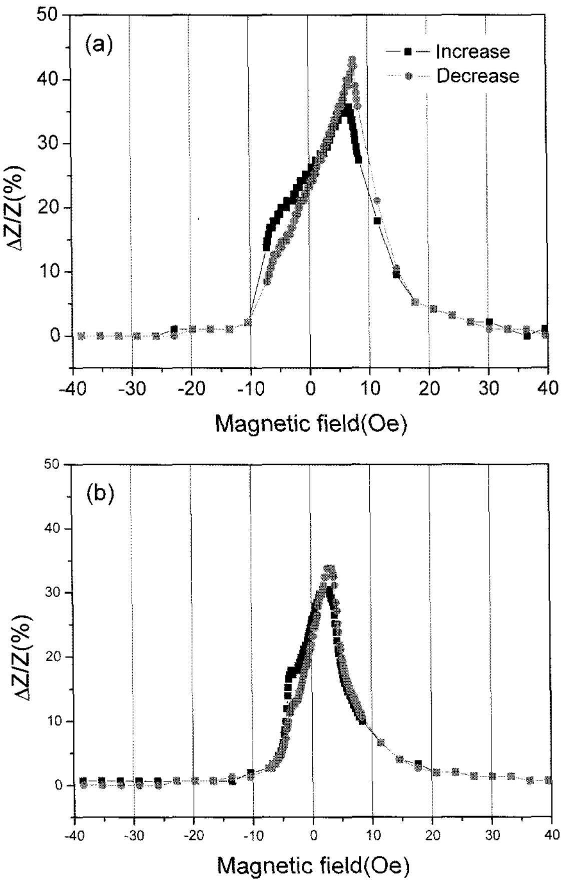

Figure 3. GMI profiles of ribbons for resized ribbons. (a) 5 mm × 2 mm; (b) 5 mm × 1 mm.

field trying to widen the sensing field range. Figure 2 shows GMI profiles of ribbons annealed in various fields. The asymmetric profiles still can be obtained, but the GMI ratio decreased with increasing annealing field. The slope of curve in near zero field declined much when the ribbon annealed in 25 Oe. We compared linearity region and field sensitivity among the ribbons annealed in different amplitude of field. The linearity region increased from 3 Oe to 16 Oe, while the field sensitivity decreased to 0.4%/Oe. It well indicates that field range showing linear characteristic of GMI can be much broadened by means of increasing annealing field for ribbons with small size.

Figure 3 shows the GMI profiles of resized ribbons measured at 100 kHz. The ribbons were resized to 5 mm

Table 2. Linearity region and field sensitivity for various annealing field.

Sample	Linearity region	Sensitivity
3 Oe, 1 cm	3.498 Oe	7.576%/Oe
8 Oe, 1 cm	3.182 Oe	10.272%/Oe
10 Oe, 1 cm	4.356 Oe	4.534%/Oe
25 Oe, 5 mm	16.002 Oe	0.435%/Oe

Table 3. Linearity region and field sensitivity for resized ribbons.

Sample	Linearity region	Sensitivity
5 mm × 2 mm	10.588 Oe	2.386%/Oe
5 mm × 1 mm	5.29 Oe	3.880%/Oe

after annealing in a field of 3 Oe, in other words, we obtained the small ribbons by chemical etching. The average GMI ratio, 40%, is as high as 5 cm. But the field sensitivity decreased much. The linearity region and field sensitivity for resized ribbons were shown in Table 3. Though the field sensitivity decreased, the linearity region of ribbon with length of 5 mm extended very much compared with 5 cm one. The ribbon of 5 mm length and 1 mm width is small enough to make a sensor showing high GMI ratio in near zero field. It indicates that we may make a smaller sensor with high GMI response by chemical etching.

4. Conclusions

The amorphous ribbons were annealed in different field ranged from 3 Oe to 25 Oe. Various amplitude of magnetic field was applied along the longitudinal direction of the ribbons during the annealing. The length of ribbon varied from 5 mm to 5 cm, and the width changed from 2 mm to 1 mm. The asymmetric profiles can be obtained regardless of length once the ribbon anneals in air. The linearity region broadens and sensitivity decreases with smaller size. Moreover, field range showing linear characteristic of GMI can be much broadened by means of increasing annealing field for ribbons with small size. Furthermore, good and small enough ribbons can be made by chemical etching.

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