교류자기저항효과를 이용한 비정질 리본 전류센서

Current sensor application of giant magnetoimpedance in amorphous materials

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Abstract

The performance of DC current sensor based on giant magnetoimpedance (GMI) effect in amorphous ribbon has been tested. The ribbon after field annealing shows the maximum GMI ratio of 30 % at 100 kHz measuring frequency. In the sensor element of sample wound the circular form, GMI ratio and sensitivity are decreased due to internal stress. The sensor voltage output increases with applied DC current up to 1 A with a good linearity, of which direction can be known due to asymmetric characteristics.

Key Words : amorphous ribbon, DC current sensor, GMI

1. Introduction

Recently, many studies have been made on the giant magnetoimpedance (GMI) in soft magnetic Co-based amorphous wire and ribbons because they exhibit a highly sensitive MI effect. This GMI effect consists of a large change in the impedance of a magentic conductor placed in the external magnetic field, H. The large sensitivity of the MI on magnetic fields originates from the dependence of the transverse magnetic permeability upon the longitudinal external magnetic field [1, 2].

Great interest has been paid to GMI phenomenon in its sensor applications; magnetic field, current, torsion, stress, etc. [3]. In the practical application of GMI, sensitivity and linearity for the magnetic field are the most important parameters [4].

In this study, we present the performance of DC current sensor using a GMI sample wound in the circular form.

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2. Experimental

The Co-based amorphous ribbons ($Co_{66}Fe_4B_{15}Si_{15}$) were annealed at temperature of 653 K for 8 hours in open air. The annealing temperature of 653 K is optimum in the development of surface crystallization [5].The field of 3 Oe was applied during the annealing of samples. Here, the magnetic field were controlled by two setsof two-dimensional Helmholtz coils; one set was used for the compensation of earth's magnetic field and the other for the application of annealing field of 3 Oe. The direction of annealing field is regarded as positive.

The absolute value of impedance Z was measured by using a HP4192A impedance analyzer with four terminal contacts. The cyclic magnetic field was applied by a Helmholtz coil using a step-like changing current. The AC probe current of 100 kHz frequency was kept at a constant value of 5 mA during the impedance measurements. The GMI ratio profile was obtained by plotting $\Delta Z / Z(\%) = (Z(H) - Z_{sat}) / Z_{sat} \times 100$ for the cyclic applied field, where *Zsat* was the impedance at maximum field strength of cyclic field.

Figure 1 shows the current sensor setup using GMI effect. For the DC current sensor in the circular form, the annealed sample of 70 mm long was wound on a cylindrical support, 10 mm radius. The feeding and sensing probes were connected to sample in same way as the four terminal methods. The DC current was applied to the axial direction of the sample form. The sample voltage output was measured by lock-in amplifier as function of applied DC current in various operating frequencies.

3. Results and discussion

The GMI sensor is based on the dependence of impedance Z on external magnetic field. Under the low field regime,

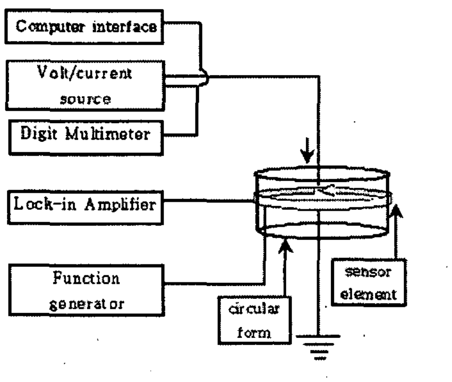

Fig. 1. DC current sensor set-up based on GMI effect of amorphous ribbon

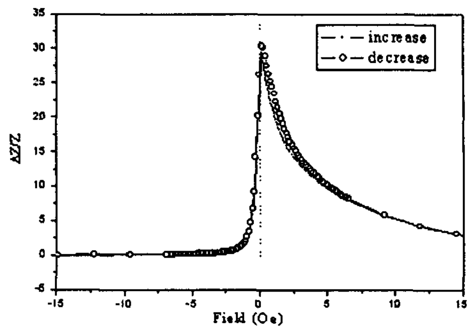

Fig. 2. GMI profile for the annealed sample.

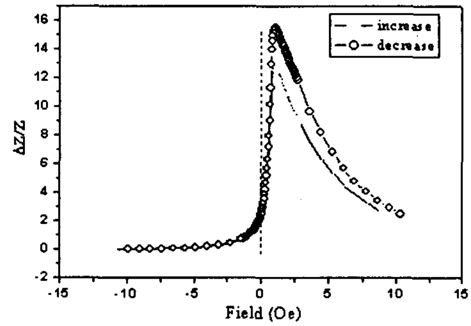

Fig. 3. GMI profile for the annealed sample wound the circular form.

the sensitive response to magnetic field without hysteresis answers the propose of technical application. Figure 2 shows the GMI ratio profiles under a cyclic magnetic field. Values as high as 30 % are obtained for the annealed sample and sensitivity of more than 35 % per Oe are obtained at low field. Here, the directionof positive field is equal to that of annealing field.

Figure 3 shows the GMI profile for the annealed sample wound the circular form. The profile is modified after winding the circular shape. The linearity for field is still good, but the profile shift to positive field direction. The maximum GMI ratio value is reduced down to 15 % and sensitivity to 22 % per Oe.

In a sample of free applied stresses the volume averaged stress anisotropy is absent.

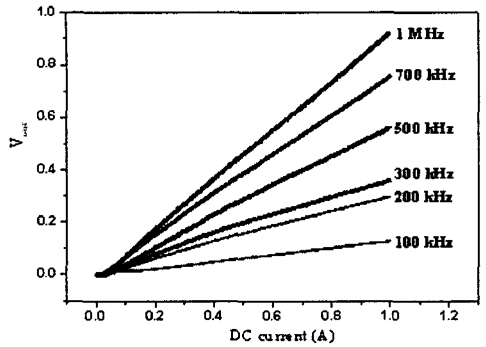

Fig. 4. Current sensing characteristics of the GMI sensor in positive field direction at various measuring frequencies.

An anisotropy is developed by annealing under an applied stress [6, 7], which causes the change in domain structure. The stresses in circular shape change its sign in inside and outside of wounded sample, the detail analysis of domain structure is not simple. But the modification of GMI profile is due to the bending stress of circular shape sample.

A DC current in a straight wire produces a circular magnetic field around the current axis. The direction of the field is determined by Ampere's right-hand law. The magnitude of magnetic field at a distance r cm from the current axis is given by $H = 2i/10r$ (Oe), where i is the current in amperes.

Figure 4 shows the performance of GMI sensor for applied current to produce the positive field. As the applied current increasesup to 1 A, the circular field increases up to 0.19 Oe. As a result, the voltage output linearly increases with DC current. However, there is no voltage change when the direction of current is reversed, that is, the current induces the negative magnetic field on sensor sample. It indicates that the current direction can be determined when the sample with asymmetric GMI characteristics is used for sensor element.

4. Conclusions

The performance sensitive DC current sensor has been tested based on asymmetric GMI effect in amorphous ribbon. The sensor voltage output increases with applied DC current up to 1 A with a good linearity. The sensitivity for current is 0.13 volt/A for 100 kHz operating frequency, and increases up to 0.94 volt/A at 1 MHz operating frequency. Finally, the asymmetric GMI,which reveals the excellent sensitivity and linearity for the magnetic field, is useful for sensor devices.

Acknowledgement

This work partially supported by the Korean Science and Engineering Foundation through the Research Center for Advanced Magnetic Materials at Chungnam National University.

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