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Enhanced Giant Magnetoimpedance in Co-based Microwire by Pluse Nd:YAG laser

이봉상*, 김철기*, 김종오*, 임영우*, 김란*, 김기덕**, 안승준***, 윤석수****

B.S. Lee, C.G. Kim, C.O. Kim, Y.W. Rheem, Lan Jin, G.D. Kim, S.J. Ahn, S.S. Yoon

Abstract

The influence of laser annealing on gaint magnetoimpedance effect of glass-covered Co-based amorphous microwires is investigated by illuminating pulse Nd:YAG laser on the etched microwires. The maxium GMI ratio reaches maximum of around 85 % at the frequency of 5 MHz for the sample iluminated by the pulse with laser energy fo 132 mJ/pulse.

Key Words : GMI, glass-covered microwires, laser anealing

1. Introduction

Recently, the giant magneto-impedance (GMI) effect has attracted great interest owing to their possible applications as high sensitive field sensors [1-5]. The GMI effect has been studied in many materials with different geometry and structures including amorphous ribbons, wires, thin films and nanocrystalline materials [6].

Glass-covered microwires have been recently become a new family of amorphous magnetic GMI materials [6-10]. Generally, as-quenched amorphous microwires have inferior GMI effect to conventional amorphous wires due to large internal stresses caused by the glass cover and the fabrication procedure. Appropriate heat treatments have been applied on the microwires to improve soft magnetic properties by reducing the magnetoelastic coupling. In particular, the GMI effects in Joule-heated amorphous microwires have been substantially enhanced after Joule heating [8-10]. Up to now, maximum GMI ratio of about 600 % has been reported for a Joule-heated Co-based microwire at frequencies around 1 MHz [9].

In this paper, we investigate the annealing effect on the GMI of Co-based amorphous microwires by illuminating pulsed Nd-Yag laser in order to find the laser energy optimizing the GMI effect.

2. Experimental

A commercial glass-covered Co-based amorphous microwire with metallic core diameter of 27.6 μm and glass cover thickness of 3 μm were etched to remove glass cover in 60.51 % HF solution. After glass removal, the microwire, about 3 cm long, were annealed by illuminating the pulsed Nd:YAG laser beams with wavelength of 1.064 μm at various energies E between 122~172 mJ/pulse in air. The focus pointswere scanned along the wire length with 0.1 mm resolution by X-Y stage. The diameter and pulse width of the beam are respectively about 3.0 mm and 220 μs. Figure 1 shows the schematic diagram of the laser annealing system.

The absolute value of complex impedance *Z* under applied dc magnetic field *H* was measured by using a HP4192A impedance analyzer with four terminal contacts at various frequencies of ac current *f* between 100 kHz and 10 MHz. The *H* was applied along the wire axis by using Helmholtz coil. The data set *Z(H)* at fixed frequency was obtained during linear and cyclic sweep of *H* from about -40 Oe to +40 Oe.

3. Results and Discussion

Figure 2(a) and (b) show the GMI ratio profiles, $Z/Z = \{Z(H)-Z(H=40\ \text{Oe})\}\text{x}100/Z(H=40\ \text{Oe})$, at f = 100 kHz and 10 MHz for as-etched sample and laser-annealed one with laser energy of E = 132 mJ/pulse. The GMI profiles for as-etched and laser-annealed sample at low frequency of f = 100 kHz show asymmetric single peak centered at H= 0 reflecting domain wall motion mainly contributes to circumferential permeability. The profiles at f = 10 MHz show asymmetric two peaks reflecting magnetization rotation becomes maincontribution to circumferential permeability due to damped domain wall motion. The maximum GMI ratio $\Delta Z/Zm$, as defined in figure 2(a), for the as-etched sample at f = 100 kHz is about 6.8 %. The maximum GMI ratio after laser annealing decreases to about 2.7 %. The maximum GMI ratio at f = 10 MHz is about 41 % for the as-etched sample and is enhanced to about 83 % after laser annealing. In order to understand the asymmetry and hysterisis in the GMI profiles, detail study for the change of anisotropy by etching and laser annealing is needed.

Figure 3 shows the variation of frequency dependency of maximum GMI ratio with laser energy *E*. As a whole, this shows that the maximum GMI ratio decreases after laser annealing at low frequencies less than 1 MHz, but increases at highfrequencies above 5 MHz. The highest value of maximum GMI ratio reached by laser annealing is about 85 % at 500 MHz for the sample with E = 132 mJ/pulse. The enhanced GMI effect by illuminating the laser may reflect that the absorbed laser energy gives annealing effect on the microwires enhancing magnetic softness due to stress relief.

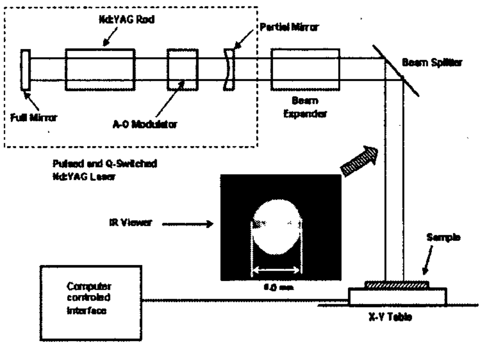

Fig. 1. Laser-anraling system.

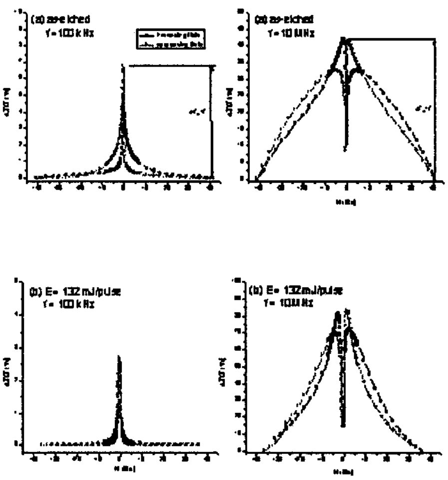

Fig. 2. GMI ratio profiles at f = 100 kHz and 10 MHz for (a) as-etched sample and (b) laser anraled sample E = *132* mJ/pulse.

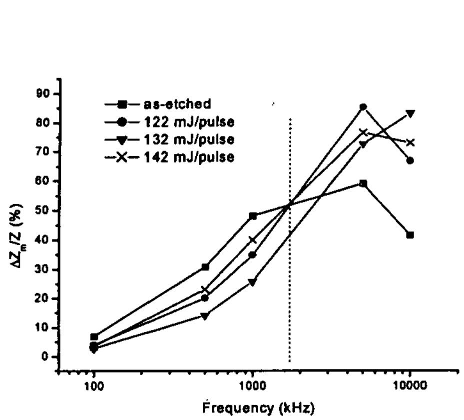

Fig. 3. Variation of the frequebcy dependency of maximum GMI ratio with laser energy.

4. Conclusion

The GMI effect of glass-covered Co-based amorphous microwires can be enhanced by illuminating pulsed Nd-YAG laser after removal of glass cover by chemical etching. The laser annealing will provide some useful annealing method because this is non-contact, short time of a few microseconds, and is performed in open air.

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