Tailoring of magnetic softness and Giant Magnetoimpedance effect in amorphous microwires

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We provide our latest attempt on optimization of the magnetic softness and Giant Magnetoimpedance, GMI, effect in glass-coated magnetic microwires by appropriate annealing. After conventional annealing, a transformation of a linear hysteresis loop into a rectangular one with a higher coercivity, H_c, is observed. A remarkable GMI ratio improvement up to 735% is observed after annealing of Co-rich microwires at appropriate conditions. The stress-annealing allows preventing magnetic hardening. Properly stress-annealed samples present almost unhysteretic loops with coercivity about 2 A/m and magnetic anisotropy field about 35A/m. Observed magnetic softening and GMI ratio improvement have been discussed considering the internal stresses relaxation, induced magnetic anisotropy and a change in the magnetostriction coefficient sign and values with increasing of annealing temperature

Keywords: Magnetic microwires; amorphous wires; GMI effect; magnetic softness; annealing.

1. Introduction

Studies of amorphous microwires have attracted attention due to their unique properties such as their magnetic softness and magnetic bistability, giant magnetoimpedance (GMI) effect, as well as good mechanical properties and high corrosion resistance [1,2].The fabrication technique allows the preparation of amorphous microwires with diameters from 100 nm to 100 µm [1]. The main interest in the GMI effect is associated with its giant sensitivity to the applied magnetic field, H: a change in impedance, Z, over 600 % under applied magnetic field about 800 A/m was experimentally observed [1]. The efficiency of sensors and devices using the GMI effect critically depends on the GMI ratio value. Consequently, we provide our latest attempts on optimization of the magnetic softness and GMI effect in Co-rich glass-coated magnetic microwires

2. Results and discussion

We studied the effect of annealing (at temperatures, T_{ann}, up to 350 ºC) on the hysteresis loops and GMI ratio, ΔZ/Z, of Co-rich glass-coated microwire prepared using Taylor-Ulitovsky method. Using X-ray diffraction we observed that all prepared microwires are amorphous. Low and negative magnetostriction coefficients, λ_s, of as-prepared microwires (between -0.9×10^{-6} and -0.3×10^{-6}) are obtained using the small-angle magnetization rotation method. In $Co_{72}Fe_4B_{13}Si_{11}$ as-prepared microwire with metallic nucleus diameter, d, about 40 µm and total diameter 45 µm rather soft magnetic properties: coercivity, H_c, about 20 A/m and magnetic anisotropy field, H_k, about 170 A/m (see Fig.1a). After annealing we observed that the main change of the hysteresis loops consists of a decrease in H_k –value up to H_k ≈75 A/m, while the H_c remains almost unchanged (H_c ≈24 A/m, see Figs 1a). High GMI ratio (ΔZ/Z ≈400 %) is observed in as-prepared sample. A remarkable GMI ratio improvement up to above 700% is observed after annealing at appropriate conditions (see Fig.1b).

In thinner $Co_{69.2}Fe_{3.6}Ni_1B_{12.5}Si_{11}Mo_{1.5}C_{1.2}$ microwire with d ≈ 19.8 µm a transformation of the linear hysteresis loop into a rectangular and elevated H_c (about 100 A/m) are observed upon annealing (Fig. 1c). Such magnetic hardening can be suppressed using stress-annealing: after stress-annealing

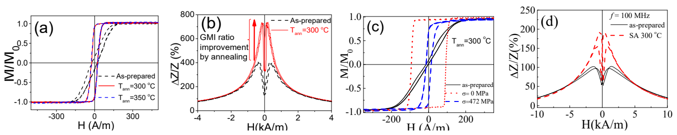

Figure 1. Hysteresis loops of as-prepared and annealed at different T_{ann} $Co_{72}Fe_4B_{13}Si_{11}$ (*a*) and $Co_{69.2}Fe_{3.6}Ni_1B_{12.5}Si_{11}Mo_{1.5}C_{1.2}$ (c) microwires (a), effect of annealing on ΔZ/Z(H) dependencies of $Co_{72}Fe_4B_{13}Si_{11}$ (*b*) and $Co_{69.2}Fe_{3.6}Ni_1B_{12.5}Si_{11}Mo_{1.5}C_{1.2}$ (d) microwires.

smaller H_c (H_c ≈15 A/m for T_{ann} =300 ºC and H_c ≈2 A/m for T_{ann} =350 ºC) is observed. Although thinner $Co_{69.2}Fe_{3.6}Ni_1B_{12.5}Si_{11}Mo_{1.5}C_{1.2}$ microwire presents lower GMI ratio (about 100%), after stress annealing a substantial increase in GMI ratio is observed (Fig.1d). After annealing, a change in λ_s from low negative to low positive values is observed in both studied microwires. The observed change in the hysteresis loop shape, λ_s -value and sign and in *ΔZ/Z* - value and magnetic field dependence upon annealing must be attributed to the internal stresses relaxation and modification in the magnetostriction coefficient sign and values.

References

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