V-6

Surface magnetic properties of annealed $Co_{66}Fe_4B_{15}Si_{15}$ amorphous ribbons

L. Jin*, Y. W. Rheem, B. S. Lee, C. G. Kim, C. O. Kim

Department of Materials Engineering, Chungnam National University

1. Introduction

Recently an asymmetric giant magnetoimpedance (GMI) profile has been observed in Co-based amorphous ribbons annealed at the weak field [1-4]. This phenomenon has attracted a large interest due to its practical application to sensitive magnetic sensors. It is known [5, 6] that in magnetic materials, the magnetoimpedance is caused by the effect of the magnetic field on the transverse magnetic permeability of a near-surface layer. In consequence of it, the value of the magnetoimpedance depends strongly on near-surface magnetic properties of the sample. So, the study of the near-surface magnetic properties of magnetic materials is very important task on the understanding of asymmetric GMI. In this work the investigation of near-surface magnetic properties of the as-cast and annealed $Co_{66}Fe_4B_{15}Si_{15}$ amorphous ribbons was carried out by using magneto-optical magnetometer, as function of annealing time and surface etching.

2. Experiments

The $Co_{66}Fe_4B_{15}Si_{15}$ amorphous ribbon was annealed for various time, t_{ann}, in open air at temperature 380 . t_{ann} was varied form 1 up to 10 h. The field H_{ann} = 3 Oe was applied along the ribbon length during the annealing of the samples. The annealed samples were etched in hydrofluoric acid solution, where the etching time, t_{etch}, was varied from 10 up to 600 seconds. The measurements of near-surface hysteresis loops of the ribbon were carried out employing magneto-optical magnetometer by means of the Meridional Kerr effect (MKE).

3. Results and discussion

Figure 1 shows hysteresis loops obtained for the as-cast and annealed sample for various time, t_{ann} = 0, 3, 5 and 10 hours. The as-cast sample has the coercivity H_c and saturation field H_s about 15 and 60 Oe, respectively. The shape of the hysteresis loops is modified with increasing annealing time, that is, the initial permeability decrease, but the value of H_c and H_s increase. In particular, for the annealed for 10 h sample, H_c and H_s are equal to 150 and 900 Oe, respectively. One can note that for t_{ann} = 12 h, the further increase of H_c and H_s (up to 0.6 and 1.5 kOe, respectively) was observed. These data are evidence of the appearance of a hard near-surface magnetic layer in the annealed samples. According to [4], this layer has microcrystalline structure. It should be pointed out that the asymmetric GMI profile was observed only at the sample annealed for $t_{ann} \geq 8$ h [1-4].

In order better to understand this phenomenon we have measured the near-surface magnetic properties of the annealed for 8 h amorphous ribbons after their etching in hydrofluoric acid solution. Figure 2 displays hysteresis loop obtained for the samples with various etching time. With increasing t_{etch} up to 40 s, the shape of the hysteresis loops does not change but the value of H_c and H_s increase and, consequently, the hard magnetic layer near the sample surface retains. These data allow to deduce that the ribbons have the inhomogeneous (with respect to the sample thickness) near-surface magnetic properties that can be ascribed to inhomogeneous microcrystalline structure of the near-surface layer.

For t_{etch} > 50 s, the influence of the amorphous ribbon core on the magnetic properties is observed. This effect retains up to t_{etch} ~ 120 s. In this case, there are two steps of the magnetization reversal of the near-surface layer. For the first step, the magnetization of the soft phase switches at the field H < 60 Oe. For the second step, the reversal of the remaining hard phase in the near-surface layer is completed at $H \sim 1.2$ kOe. At the same time we have discovered that the magnetic properties of the etched for t_{etch} > 120 s ribbons coincide with those of the as-cast sample. That indicates that the hard microcrystalline near-surface layer in these ribbons was removed completely. The estimations showed that the thickness of the hard microcrystalline layer is nearly equal to 1 μm.

4. Conclusions

The magneto-optical investigation of the $Co_{66}Fe_4B_{15}Si_{15}$ amorphous ribbons showed that there is drastic variety in the magnetic properties of both the annealed and etched samples. The observed loops by MOKE system allowed to deduce that the annealed ribbons have the inhomogeneous near-surface magnetic properties, which was ascribed to inhomogeneous microcrystalline structure of the near-surface layer. The influence of the amorphous ribbon core on the magnetic properties of the samples was revealed after their etching for t_{etch} > 50 s. The magnetic properties of the etched sample for t_{etch} > 120 s were identical to those of as-cast ribbon. The thickness of the hard microcrystalline layer was estimated to be about 1 μm after 8 h annealing at temperature 380

5. References

[1] C. G. Kim, K. J. Jang, H. C. Kim, S. S. Yoon, J. Appl. Phys. 85 (1999) 5447.

[2] K. J. Jang, C. G. Kim, S. S. Yoon, K. H. Shin, IEEE Trans. Magn. 35 (1999) 3880.

[3] C. G. Kim, C. C. Kim, S. S. Yoon, H. C. Kim, S. J. Ahn, J. Magn. Magn. Mater. 239 (2002) 557.

[4] Y. W. Rheem, C. G. Kim, C. O. Kim, Y. Choi, Korean J. Magnetics 6 (2001) 86.

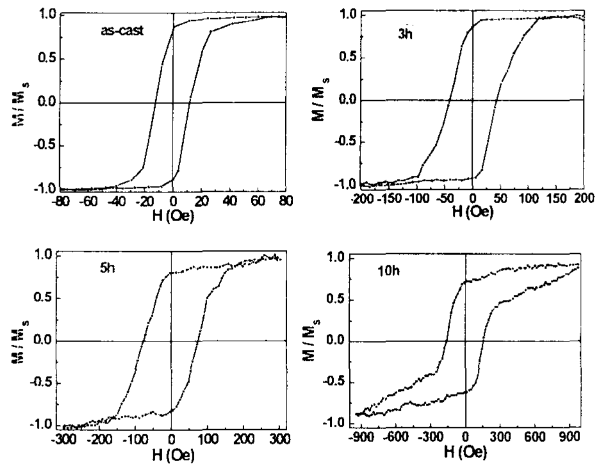

Fig. 1. The near-surface hysteresis loops by MOKE system for the as-cast and annealed for various time i open air at a temperature T = 380 °C.

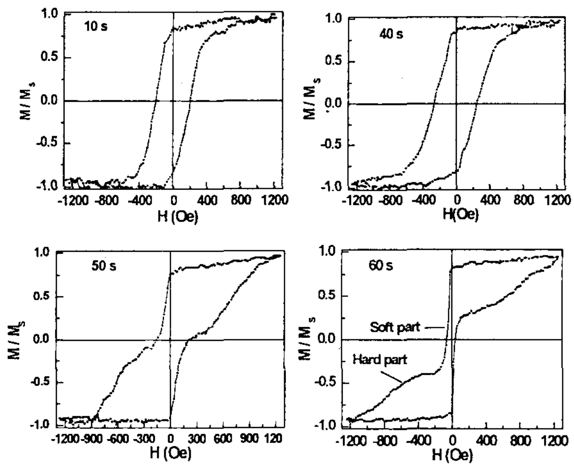

Fig. 2. The near-surface hysteresis loops, observed afte etching for different time of the annealed for 8 h at H_{an} = 3 Oe $Co_{66}Fe_4B_{15}Si_{15}$ amorphous ribbons.