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Order/disorder phase composite Fe-Pt exchange-spring film magnets

Hiroshi Kuroda[1], Takeshi Yanai[1,2], Masaki Nakano[1,2,*] and Hirotoshi Fukunaga[1,2]

[1]Graduate School of Science and Technology,[2]Department of Electrical and Electronic Engineering,Nagasaki University, 1-14 Bunkyo-machi, Nagasaki 852-8521, Japan

**Tel: +81-95-819-2555, Fax: +81-95-819-2555, E-mail: mnakano@nagasaki-u.ac.jp*

Introduction

As for thick film magnets, Aoyama *et al.* reported a 129-μm-thick Fe-Pt film magnet with coercivity of 580 kA/m and $(BH)_{max}$ of 104 kJ/m^3, respectively.[1] Recently, W. F. Liu *et al.* have reported an approximately 7 μm-thick Fe-Pt film magnet with H_c = 446 kA/m and $(BH)_{max}$ = 124 kJ/m^3, respectively.[2] On the other hand, a couple of researchers also reported Fe-Pt exchange-spring film magnets with a large $(BH)_{max}$ value. For example, J. P. Liu *et al.* reported a 58 nm-thick Fe-Pt film magnet with $(BH)_{max}$ = 420 kJ/m^3. However the thickness of almost all the exchange-spring films reported previously is less than 1 μm. In order to improve the magnetic properties of Fe-Pt film magnets, this contribution reports a fabrication of Fe-Pt exchange spring film magnets with the thickness of several microns by taking advantage of order and disorder phase transformation.

Experimental

Fe-Pt film magnets were prepared with a RF-sputtering apparatus. A target was composed of Pt chips placed on a 100-mm-diameter Fe disk. The composition of the films, which was evaluated with a SEM-EDX (Scanning Electron Microscope-Energy Dispersive X-ray spectrometer) , was controlled by the number of Pt chips and set to $Fe_{50}Pt_{50}$. As-deposited films were composed of only disorder phase, and then a post-annealing was carried out in order to bring out the order and disorder transformation. In order to obtain order/disorder phase composite Fe-Pt exchange-spring thick film magnets, the samples were heated up to about 773 K under the heating rate of 323 K/min, in the vacuum of 10^{-4}Pa with an infrared furnace and then were cooled down to room temperature without a holding time. A sample composed of only order phase could be obtained under the post annealing at 1023 K. Magnetic and thermomagnetic properties were evaluated with a VSM (Vibrating Sample Magnetometer) and microstructure observation was carried out with a TEM (Transmission Electron Microscope). The analysis of crystal structure was carried out with an X-ray diffractometer (XRD).

Results and Discussions

Figure 1 shows bright-field TEM images of a 1.7 μm-thick Fe-Pt film magnet (Sample A) annealed at 773 K. Nano-beam diffraction patterns of Figs .1 (a) and (b) indicated that the Spot Points X and Y shown in the figure are the disordered (A1) and the ordered ($L1_0$) phases, respectively, which means that the sample were composed of the both order and disorder phases.

As it was found that the annealing at 773 K enables us to synthesize exchange-spring magnets, we prepared a film annealed at 773K with 7 μ m- thicknesses. The M-H loop of the sample showed large coercivity of approximately 500 kA/m. In addition, the remanence value of approximately 0.9 T which was higher than the theoretical value of 0.7 T in the isotropic Fe-Pt alloy. In-plan and perpendicular values of remanence were almost the same, and it was clarified that the high value of 0.9 T is attributed to remanence enhancement in the sample. The above-mentioned 7 μm-thick film had a superior recoil rate compared to that of Fe-Pt film with the thickness of 7 μm composed of only order phase. This result indicates Fe-Pt exchange-spring thick films could be obtained by taking advantage of order and disorder composite phases.

References

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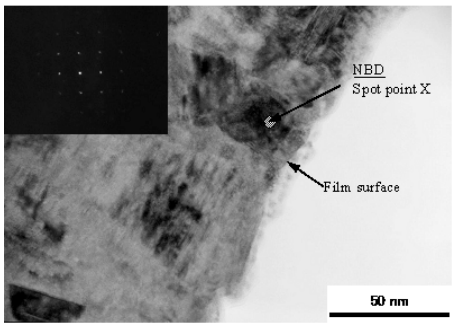

Fig. 1 (a) A1 phase.

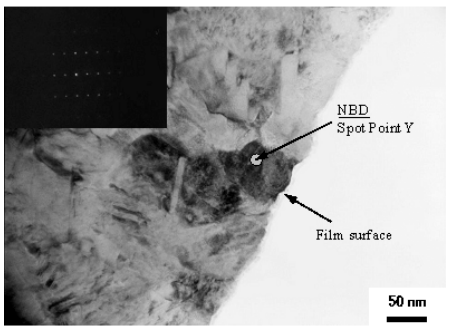

Fig. 1 (b) $L1_0$ phase.

Fig. 1 Bright-field TEM images of a Fe-Pt film magnet annealed at 773 K (Sample A). NBD (Nano Beam Diffraction) indicates a spot point of the selected area diffraction analysis and the insets are the corresponding [001] diffraction patterns.