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Anisotropy Change Due to Magnetoelastic Effect by Thermal Annealing in Amorphous Thin Films of Giant Magnetostrictive Sm-Fe-B Alloy

SungKyunKwan University S. M. Na*, S. J. Suh
KIST S. H. Lim, H. J. Kim

거대자기변형 Sm-Fe-B 비정질 합금박막의 자기탄성 효과에 따른 이방성의 변화

성균관대학교 나석민*, 서수정
한국과학기술연구원 임상호, 김희중

1. Introduction

Thin films of giant magnetotrictive R-Fe (R: rare earth elements) based alloys, which exibit a large magnetostriction at a low magnetic field, were recently developed and they were shown to be suitable for Si-based microdevice applications [1]. With a large magnetostriction, the magnetoelastic contribution to the total energy in these films will be large. In order to prove magnetoelastic effect causing the anisotropy change, it is important to understand the type and magnitude of various residual stress, which is a source of magnetoelastic anisotropy by coupling to magnetostriction.

2. Experiments

Negative magnetostrictive Sm-Fe-B thin films were coated onto Si substrates by rf magnetron sputtering. Field sputtering (sputtering under an applied magnetic field) was carried out to form induced anisotropy. The other sputtering conditions used in this work are the base pressure of below 7×10^{-7} Torr, the target to substrate distance of 6 cm, the rf input power of 300 watt, and Ar pressure of 1~5 mTorr. The film thickness was measured by using a stylus-type surface profiler. The film composition was determined by electron probe microanalysis (EPMA) and the microstructure was observed by x-ray diffraction with Cu K_α radiation. The magnetic properties were measured by using a vibrating sample magnetometer (VSM) at a maximum magnetic field of 15 kOe. Annealing was carried out for 1 hr in a high vacuum (below 5×10^{-6} Torr) at various temperatures ranging 100~450℃.

3. Results and discussion

Two main type of residual stress are considered to exist in the present Sm-Fe-B thin films. One is intrinsic compressive stress, the formation of which is related to the sputtering process itself. The other is tensile stress, which results from the difference in the thermal expansion coefficients of the substrate and thin film [2]. In the as-deposited state, a compressive stress is more dominant than the tensile stress in Sm-Fe-B thin films, since total measured residual stress, which is the sum of the two stress components of compression and tension, is large compressive. Magnetoelastic interactions indicate that compressive stress enhances in-plane anisotropy in thin films with negative magnetostriction. The results indicate that the compressive stress is more easily removed by annealing than the tensile stress. The absolute value of stress decreases with increasing annealing temperature, and reachs zero at an annealing temperature of 370℃. At high annealing temperature, the type of stress becomes even tensile. Then, the anisotropy type transforms from in-plane into well-developed out-of-plane anisotropy.

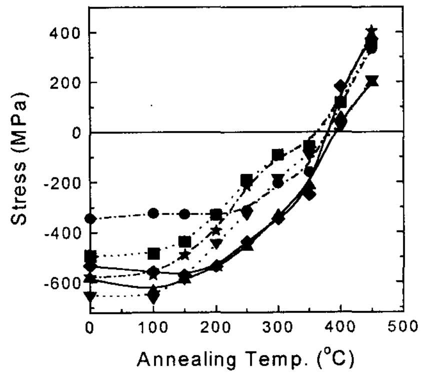

Fig. 1. The annealing temperature dependence of residual stress at the composition $Sm_{15.1}Fe_{84.1}B_{0.8}$ thin films.

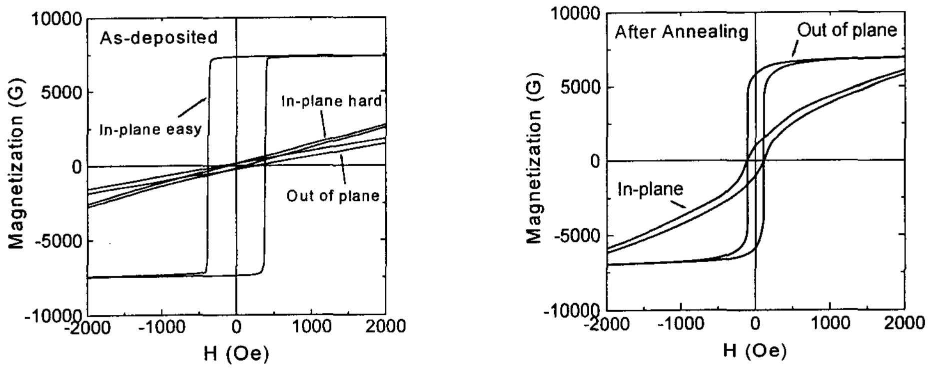

Fig. 2. The M-H hysteresis loops of a $Sm_{24.7}Fe_{74.6}B_{0.7}$ thin film in the as-deposited state and annealing at 450℃.

4. References

[1] S. H. Lim, Y. S. Choi, S. H. Han, H. J. Kim, S. Moon, H. K. Kang, M. H. Oh, and C. H. Ahn, Proc. of the Fifth Inter. Symp. on Magn. Mater, Processes and Devices (Edited by L. T. Romankiw, S. Krongelb, C. H. Ahn) Electrochemical Society Proc. Vol. 98-28, pp. 327-341

[2] F. Schatz, M. Hirscher, M. Schnell, G. Flik and H. Kronmuller, J. Appl. Phys., vol.76, pp. 5380-5382, 1994.