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Effect of Substrate Thickness on the Magnetic properties and Magnetostriction of Amorphous Tb-Fe Thin Films

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비정질 Tb-Fe계 합금박막의 자기적 특성과 자기변형에 미치는 기판 두께의 영향

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1. Introduction

Thin films of giant magnetostrictive R-Fe (R: rare earth elements) based alloys, which exhibit a large magnetostriction at a low magnetic field, were recently developed, and they were shown to be suitable for Si-based microdevice applications [1]. The deflections observed in microactuators coated with Sm-Fe thin films were in a satisfactory level but this is not the case in Tb-Fe thin films, the deflections being much smaller than those expected from standard samples with the same microstructure and composition [2]. From more recent preliminary experimental results, it was observed that amorphous Tb-Fe thin films coated onto Si-based microdevices possess much higher coercivity than those coated onto standard Si substrates. The reason for this large difference may be considered as the thermal effect during sputtering causing structural relaxation or even crystallization. In order to minimize the heat affect, substrates are in contact with a water-cooled substrate holder. This then, however, does not give a desired result, possibly due to an inefficient heat flow at the substrate/substrate holder interface. It is considered that large heat capacity of Si substrate may contribute to dissipating heat flow from deposited atoms. The microfabricated substrate is much thinner than the standard one and hence the heat capacity of the former is much smaller than the latter. Therefore it is explained that the degree of thermal effect for a thin substrate is much greater than that for a thick one. The motivation of this study is to find the reason for the large discrepancy in the magnetic properties by examining the effects of substrate thickness on the magnetic properties of amorphous Tb-Fe thin films.

2. Experiments

Thin films were coated onto Si and glass substrates by rf magnetron sputtering. A composite target consisting of an Fe disc and Tb chips was used. The substrates thicknesses and deposited film area were varied widely from 50 to 525 ㎛ and from 4 to 160 mm^2, respectively. 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 ~ 400 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.

3. Results and discussion

The coercivity and M_r/M_{15} rapidly increase with decreasing substrate thickness at around 50 ㎛ thick substrate. The substrate values of 200 and 525 ㎛ indicates that the slightly change of magnetic properties according to increasing with input power and sputtering time which enhance the heat affect (see Fig. 1). At the any sputtering condition, this may be because, when the substrate thickness is higher, the heat can be dissipated more effectively due to a larger heat capacity, and smaller structural relaxation or more effective suppression of crystalline phases can be obtained. Even though all samples still remain amorphorized, it is considered that the more structural relaxation which can be characterized by a parameter such as the structural correlation length occurred in the thin films coated onto a thin substrate. From these results, it can be expected that the value of magnetostriction for the 200 or 525 ㎛ thick substrates is superior to that for 50 ㎛. That for 50 ㎛ thick one is abated by increasing structural correlation length as a function of coercivity. In the case of the thin films of 200 ㎛ thick substrate with good softness (below 40 Oe) and in-plane anisotropy due to effective dissipation of heat flow, a magnetostriction of 203 ppm at 100 Oe was obtained (see Fig. 2). The same results was obtained from 365 ㎛ thick substrate.

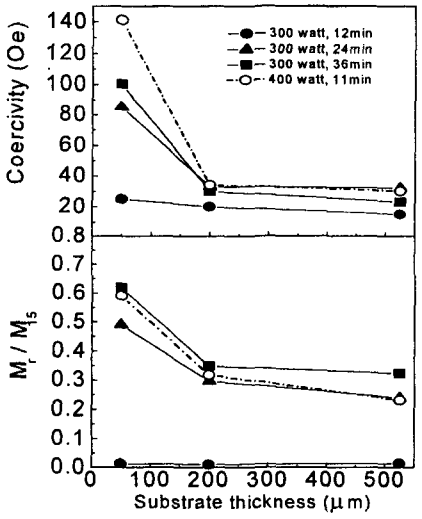

Figure 1. Magnetic properties as a function of Si substrate thickness for Tb-Fe thin films

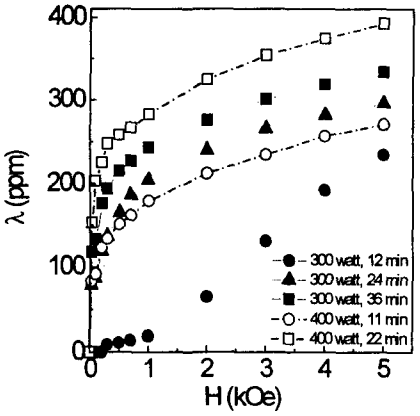

Figure 2. The λ-H plots for 200 μm thick Si substrate coated with Tb-Fe thin films.

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] S. H. Lim, Y. S. Choi, S. H. Han, H. J. Kim, J. W. Choi and C. H. Ahn, IEEE Trans. Magn., 34 (4): 2041-2044 (1998)