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Dependency of etched film thickness on the magnetic and structural properties of air-annealed FePt thin films

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1. Introduction

Of late, studies on Fe-Pt alloys are still continued for an advancement of high density magnetic recording media. This is due to the fact that ordered FePt phase with equi-atomic composition has a high magnetocrystalline anisotropy(ku) of $6.6 \sim 10 \times 10^7$ erg/cm^3, thus giving a large coercive value as a result[1-2].

Recently we reported that transformation rate of air-annealed Fe-Pt films were higher than that of vacuum-annealed samples. However, the reason for the rapid transformation are still ambiguous.

In this article, magnetic properties of air-annealed Fe-Pt alloy thin films with various composition were compared with those of samples annealed in a high vacuum better than 10^{-6} Torr. Also air-annealed films were ion-milled in order to investigate the origin of rapid transition rate as well as to understand magnetic properties of air-annealed Fe-Pt thin films with 30-50 at.% Pt contents.

2. Experimental procedure

120 nm thick Fe-Pt thin films with 12~68 at.% Pt content were sputtered on both corning 7059 glass and Si wafer with natural oxide on the surface. Subsequently, the films were annealed in the air and in a high vacuum for 30~60 min.

The magnetic properties of these films were measured in the direction parallel to the film plane by VSM under a maximum field of 16 kOe. Chemical composition of the films were analyzed by EPMA. For the structural analysis, XRD and HRTEM was also used. The films were ion-milled by reactive ion beam etching (RIBE) system with etching rate of around 5 nm/sec.

3. Results and discussion

Open circles and triangles of Fig.1 shows the variation of coercivity of Fe-Pt thin films with various Pt content annealed at 400 and 350°C under a high vacuum better than 10^{-6} torr, respectively. In Fig. 1 it could be seen that order-disorder transition temperature is as low as 400°C. However, the transition temperature of Fe-Pt films could be reduced to a temperature lower than 350°C when annealed in the air as shown in solid squares of Fig 1. Also a coercivity as high as 6 kOe could be obtained in the air-annealed Fe-Pt films with Pt content less than 50 at.% Pt.

In order to clarify the acceleration mechanism of order-disorder transition, cross section of the film annealed at 350°C in the air was observed by TEM. The thickness and grain size of the as-deposited film was 120 nm and smaller than 10 nm, respectively. It was revealed that annealed film consisted of two layers of 60 nm crystalline Fe-O layer and 100 nm ordered Fe-Pt layer in the cross sectional TEM analysis. More important fact was that the Fe-Pt metallic layer consisted of 20 nm upper layer and 80 nm lower layer. The upper layer showed a smaller grain size of 5 nm while the lower layer showed a larger grain size of 30 nm. It seems that Fe-O layer was formed by the migration of oxygen atoms to the Fe-O/Fe-Pt interface because light elements could migrate more easily. These migrated oxygen atoms would penetrate to the grain boundary as revealed in the EDS analysis. This Fe-O phase in the grain boundary seemed to inhibit the growth of the ordered Fe-Pt grain. Less oxygen was detected in the lower layer, thus yielding larger grains than the upper layer.

RIBE system was used for more detailed analysis of magnetic properties. When film was etched to the thickness of 60 nm, magnetic properties such as coercivity and magnetization at 15 kOe were hardly changed as shown in Fig. 2. It could be seen that the Fe-O layer probably have α-Fe_2O_3 structure.

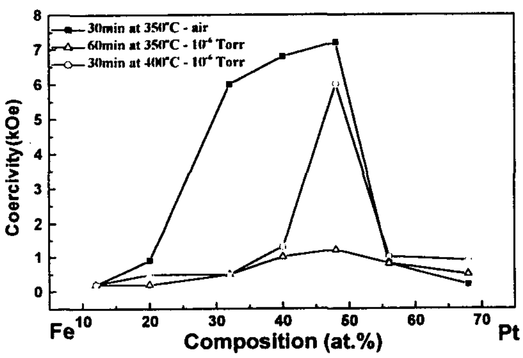

Fig. 1 the coercivity values dependent of composition change on air-annealed(solid) and high vacuum-annealed(open) FePt films

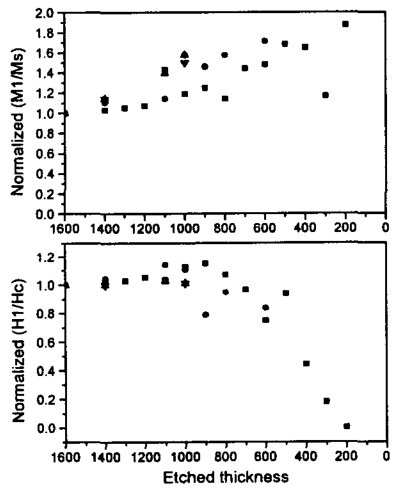

Fig. 2 the coercivity and magnetization dependent of etched thickness of FePt films

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