INFLUENCE OF ANNEALING CONDITION ON THE STRUCTURE AND MAGNETIC PROPERTIES OF NdFeB THIN FILMS

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Abstract: Influence of annealing condition on the structure and magnetic properties of NdFeB magnetic thin films has been investigated. The results have shown that NdFeB films, which were prepared at cooling substrate (Ts = 30°C), have soft magnetic properties (Hc = 50Oe). After crystallization by annealing at 700°C for 20 min in Ar gas with different rate of temperature (300°C/min and 60°C/min), hard magnetic properties of the films have been observed. However, structure and magnetic properties of the films with higher rate of annealing condition (300°C/min) were better. On the other hand, perpendicular anisotropy properties of the films have been observed.

1. Introduction

Application of hard magnetic films in MicroElectroMechnical System (MEMS) has been studied recently. These devices are prepared from relatively thick films (1 ÷ 5μm) and high energy product of the rare earth magnets promises smaller device size. The largest market for hard magnetic film is in the magnetic data storage on computer hard disk. In order to exceed densities of 100Gbit/in^2, materials with a higher unaxial magnetic anisotropy are interested. The high perpendicular magnetic anisotropy of $Nd_2Fe_{14}B$ thin films (4.6 10^7erg/cm^3) presents the additional possibility of parking bits closer together using perpendicular recording [1,2].

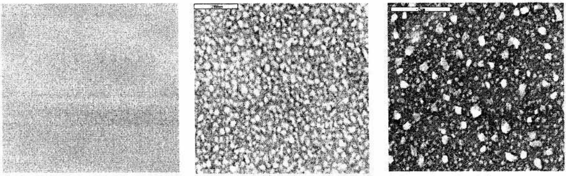
There are many technical parameters (for example elemental components, sputtered power, substrate temperature, annealing condition ...) strongly influence on the structure and magnetic properties of NdFeB thin films. In this paper, influence of annealing condition was studied.

2. Experiment

NdFeB films were sputtered onto Si (100, 111) wafer at nominal room temperature. The sputter gas pressure was 5 10^{-3} mbar for all layers in the film structure. A 20 nm Mo buffer layer and protective layer were used for all NdFeB thin films. A target was ingot NdFeB alloy with composition of $Nd_{30}Fe_{61}B_9$. The film composition was determined by EDX. The film thickness was set to approximately 200 nm. After depositing, the samples were annealed at 700°C for 20 min under heating rate of 60°C/min and 300°C/min in the applied field of 0,7T. Magnetic properties of the films were evaluated by vibrating sample magnetometer. The surface image of the films was observed by SEM and AFM.

3. Results and discussion

Influence of heating rate on microstructure and magnetic properties of the films has been studied. Fig. 1 shows SEM images of NdFeB thin films as deposited (a) and after annealed (b, c). It shows that the surface of deposited film were smoothly. However, after annealed at 700^{0}C for 20 min with different heating rates, the crystal particles were clearly observed. For the films with higher heating rate (300^{0}C/min), most of the crystal particles are the same size of 100 nm (fig.1 b). Contrarily, for the lower heating rate films (60^{0}C/min,), the grain size is different each other, some of them were over 300 nm diameter (fig. 1c).



a) As deposit *b) Heating rate of 3000C / min* *c) Heating rate of 600C / min*

Fig.1. SEM images of NdFeB films as deposit (a), after annealed at 700^{0}C for 20 min (b, c)

AFM image of the film after annealed at 700^{0}C for 20 min with heating rate of 300^{0}C/min was showed in fig 2. It corresponds to the SEM image in fig 1b.

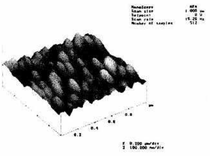
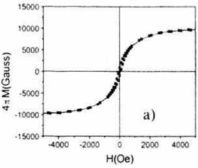
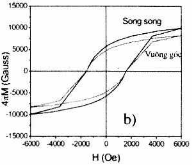


Fig.2. AFM image of the film after annealed at 7000C for 20 min with heating rate of 3000C/min

Magnetic properties of NdFeB films have been investigated by vibration sample magnetometer. Fig. 3 shows hysteric loop of deposited film (a), after annealed at 700^{0}C for 20 min with different heating rate (b, c). It shows that as deposited film were soft magnetic films (Hc=50 Oe). After annealed, hard magnetic property has been observed, coercivity of the film is the same in both directions (perpendicular and parallel to the film): $Hc// = Hc\perp = 1650$ Oe and $Hc// = Hc\perp = 900$Oe for the sample of 300^{0}C/min and 60^{0}C/min heating rate, respectively.

In this study, samples were first annealed at 700^{0}C for 20 min with heating rate of 300^{0}C/min and second annealed at 500^{0}C for 10 min then cooling to room temperature in applied field (H_A) of 0.7T. The applied fields were both perpendicular ($H_{A\perp}$) and parallel ($H_{A//}$) directions to the films. The results of Hc and Mr were showed in tab. 1





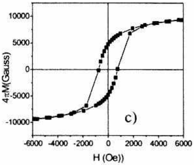


Fig.3. Hysteric loops of deposited film (a), after annealed at 700°C for 20 min with different heating rates (b,300°C/min; c,60°C/min).

Tab 1. Values of Hc and Mr of the films with and without field cooling

	H_A=0 T	$H_{A\perp}$=0,7T	$H_{A//}$=0,7T
Hc//	1650 Oe	1320 Oe	1690 Oe
Hc⊥	1650 Oe	1760 Oe	1580 Oe
Mr//	6200 Gauss	5800 Gauss	6600 Gauss
Mr⊥	5300 Gauss	5700 Gauss	4900 Gauss

Tab. 1 shows that the sample of perpendicular applied field ($H_{A\perp}$); perpendicular coercivity Hc⊥ was increased and parallel coercivity Hc// was decreased. For the sample of parallel applied field $H_{A//}$; Hc⊥was decreased and Hc// was increased. Remanent magnetization (Mr) was the same effective as coercivity.

4. Conclusion

For the NdFeB films with high heating rate (300°C/min), the grains are absolutely the same size of 100nm. That cause good magnetic properties Hc=1650Oe and Mr = 6200Gauss.

The coercivity and remanent magnetization of the films, which were cooled in applied field, show that are increased following the direction of the applied field.

References

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