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Induced Magnetic Anisotropy of Sputtered FeN Films Due to Substrate Tilting

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FeN thin films were deposited by RF-reactive diode sputtering to investigate magnetic characteristics variation due to substrate tilt during the film deposition, and their magnetic properties were measured by VSM, SEM and AFM. When the substrate tilt pivot edges were parallel to the applied field, the magnetic anisotropy was increased. When the substrate tilt pivot edges were perpendicular to the applied field, the easy magnetization axis became the hard magnetization axis, and the hard axis became the easy axis as the tilt angles were increased. The reason is believed to be due to the fact that the tilt induced shape magnetic anisotropy became larger than the field induced magnetic anisotropy by DC magnetic field as the crystal grains are enlongated along the substrate tilt pivot edges due to "oblique incidence anisotropy" commonly found in eveporated thin films.

I. Introduction

The magnetic properties of FeN thin films can be controlled by the composition and microstructure of the thin films[1]. They have good corrosion resistance and abrasion resistance. Furthermore, FeN films have high saturation magnetization(about 20 KG), low coercivity (below 0.5 Oe), high operating frequency (about 200 MHz), high magnetic flux density (about 20 KG), and high permeability (μ > 4000)[2]. Therefore, they are expected to be used as thin film head materials for high density recording.

Up to now, results have been reported for the films, which were deposited by RF diode sputtering[3], facing target sputtering[4], plasma evaporation[5], and ion beam deposition[6]. However, when FeN thin film head devices are fabricated, there exists increase of coercivity. The reason is due to the fact that the magnetic anisotropies of devices are changed with the tilt of substrates[7,8,9,10,11].

In this paper, RF diode sputtered FeN films are fabricated by tilting substrates during the film deposition, and their magnetic anisotropies are analyzed by vibrating sample magnetometer (VSM), scanning electron microscope (SEM) and atomic force microscope (AFM).

II. Experimental procedure

The films were deposited onto Corning glass 7059 substrates using Perkin-Elmer 2400 8L RF-diode sputtering system (8 ″ targets). The base pressure was below 4.0×10^{-7} Torr and RF power was 800 Watt. The flow ratio of N_2 and Ar was 6.6 : 100, and gas pressure was 3 mTorr. The deposition time was 25 min. each. A DC magnetic field of 45 Oe was applied by holding S_mCo_5 magnets around the substrate table to induce the magnetic anisotropy.

In order to compare the magnetic anisotropy due to substrate tilt with the magnetic anisotropy due to DC magnetic field applied, the substrate tilt angles were varied by 0°, 15°, 30°, and 45°. As shown in Fig. 1, the substrates where tilted so that the substrate tilt pivot edges are (a) parall or (b) perpendicular to the applied DC magnetic field by $SmCo_5$ magnet.

The film thickness was determined by Tencor alpha-step profilometer.

The easy and hard axis coercivities and the saturation magnetization were measured by a VSM. The film microstructure were analyzed by SEM, and AFM.

III. Experimental results and discussion

Fig. 2 shows the change of thickness of the films with substrate tilt angles. As the tilt angle was increased, the thickness was decreased. When the tilt angle was 0°, the deposition rate was 243 Å/min. When the tilt angle was increased to 45°, the deposition rate was decreased to 178 Å/min.

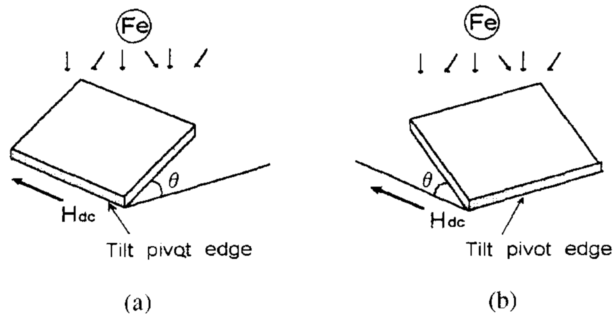

Fig. 1. Substrate tilting during film deposition. Substrate tilt pivot edges are (a) parallel to H_{dc} (b) perpendicular to Hdc.

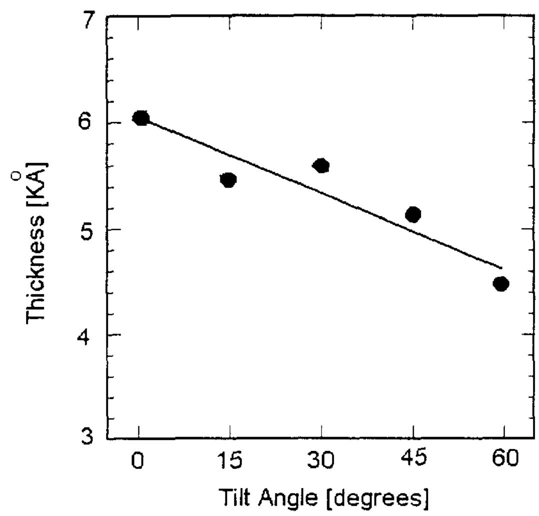

Fig. 2. Variation of thickness with tilt angles. The deposition time was 25 min. each.

When the substrate pivot edges were parallel to the applied field (H_{dc}), the easy axis coercivity was increased, and the hard axis hysteresis loops showed the increase of the anisotropy as the tilt angle was increased, which is shown in Fig. 3. The tilt induced anisotropy direction is parallel to the field induced anisotropy and the anisotropies are added, which results in the increase of the anisotropy in the hard axis hysteresis loops. The increase of easy axis coercivity is also due to this increase of tilt induced anisotropy.

Fig. 4 shows that the tilt induced anisotropy is perpendicular to the Hdc induced anisotropy when the substrate tilt pivot edge is perpendicular to the applied DC field. The easy axis becomes the hard axis and vice versa when the tilt angle is increased, because the tilt induced anisotropy becomes larger than the field induced anisotropy.

Fig. 5 shows the SEM micrographs of a film which is deposited with 45° of tilt angle and with the pivot edge perpendicular to H_{dc}. Fig. 5 (a) is the micrograph of the side perpendicular to the pivot edge and Fig. 5 (b) is the micrograph of the pivot edge. In Fig. 5 (a), we can see the long, narrow, sloped columnar growth of grains, while in

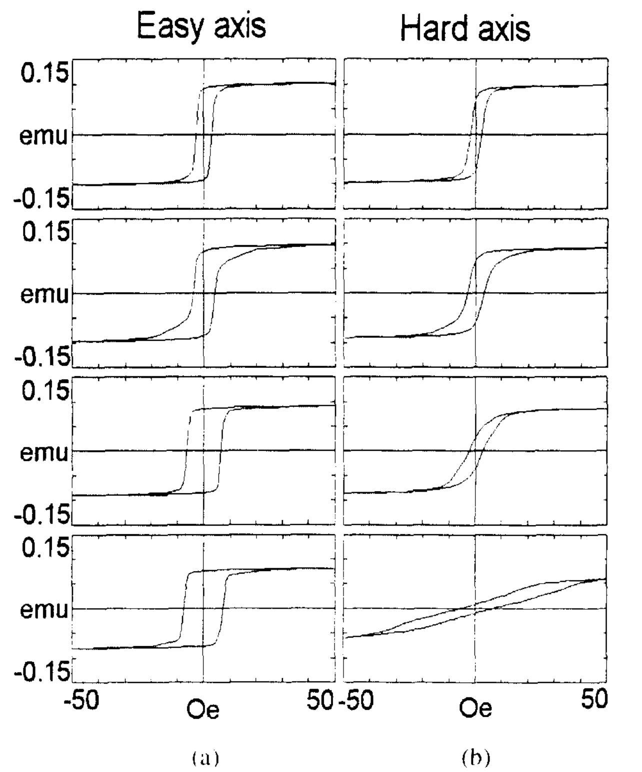

Fig. 3. Hysteresis loops for FeN films measured (a) parallel to (b) perpendicular to H_{dc}. The substrate tilt pivot edges were parallel to the applied field during the deposition.

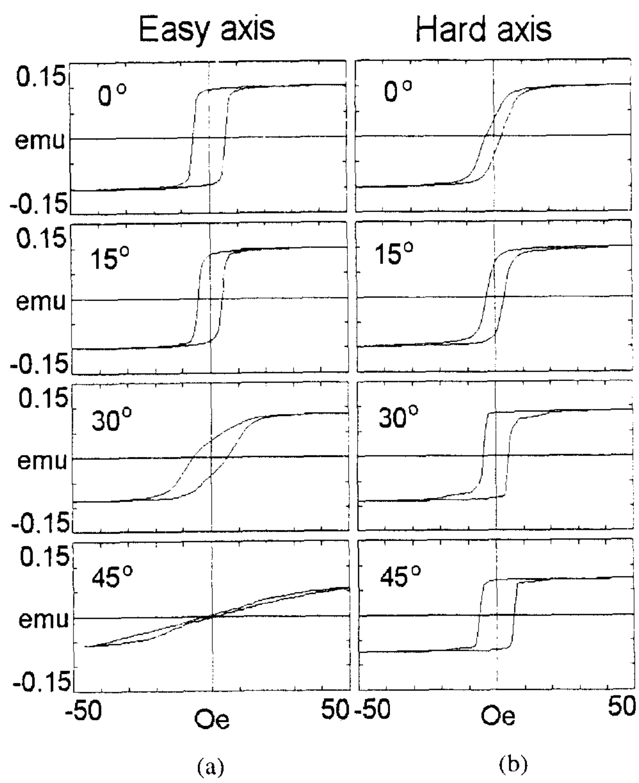

Fig. 4. Hysteresis loops for measured (a) parallel to (b) perpendicular to H_{dc}. The substrate tilt pivot edges were perpendicular to the applied field during the deposition.

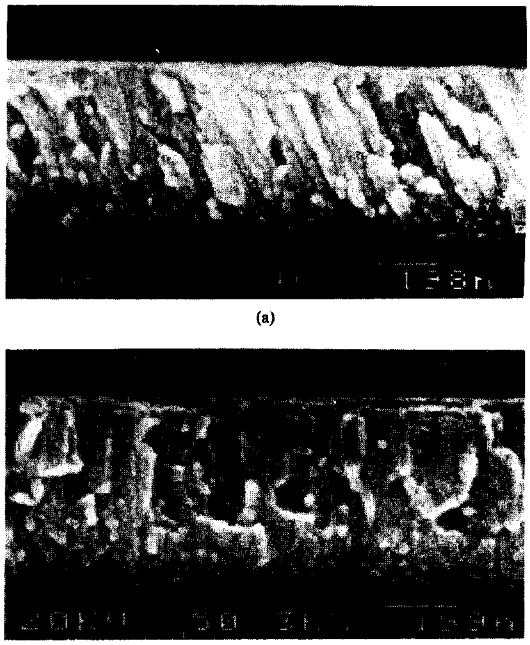

Fig. 5. SEM micrographs showing (a) the side of the film perpendicular to the pivot edge and (b) the pivot edge.

Fig. 5 (b), we see broader column width. These show that the grain shapes are longer in the direction of pivot edge than perpendicular to the edge. The sloping angle of the grain columns was about 22° which is about 50 % of the substrate sloping angle.

Fig. 6 (a) shows the AFM picture of the film with no

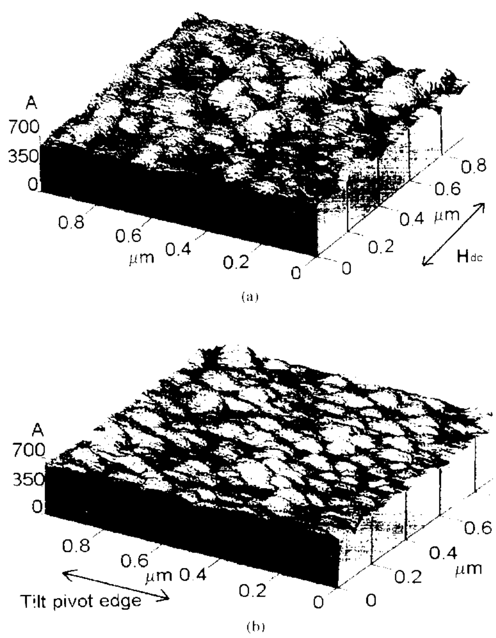

Fig. 6. AFM surface topographs of the films with (a) no substrate tilt and (b) substrate tilt of 45°. The substrate tilt pivot edge was perpendicular to the applied field during the deposition.

substrate tilt. Fig. 6 (b) shows the AFM picture when the substrate tilt pivot edge was parallel to H_{dc} and the tilt angle was 45°. Fig. 6 (a) shows the round grain shape, while Fig. 6 (b) shows the long extended grain shape along the tilt pivot edge. As shown in Fig. 4, when substrate tilt pivot edge is perpendicular to H_{dc}, the hysteresis loops of hard axis and easy axis are interchanged as the tilt angle is increased. This is thought to be due to the fact that the shape anisotropy of the enlongated grains is larger than field induced anisotropy.

IV. Conclusion

FeN thin films were deposited by varying substrate tilt angles. A DC magnetic field (H_{dc}) was applied during thin film deposition, and the substrate tilt pivot edges were parallel or perpendicular to H_{dc}. As the substrate tilt angle was increased, the film thickness became thinner and induced magnetic anisotropy increased. As the tilt angle was increased, the shape anisotropy from enlongated grains along the direction of the substrate pivot edge became larger than the field induced anisotropy. Therefore, the shape of the easy axis and hard axis hysteresis loops are changed.

Acknowledgment

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References

[1] T. K. Kim and M. Takahashi, Appl. Phys. Lett. **20**, 492 (1972).

[2] S. Wang, M. H. Kryder and D. J. Roger, IEEE Trans. Magn., **MAG-28**, 2418 (1992).

[3] C. Chang, J. M. Siverstcn, IEEE Trans. Magn., **MAG-23**, 3636 (1987).

[4] A. Morisaka and M. Naoe, J. Appl. Phys., **63(8)**, 3230 (1988).

[5] T. Tanaka and E. Fujita, J. Magn. Soc. Japan, **14**, 256 (1990).

[6] D. S. Rickerby, J. Vac. Sci. Technol., **A4(6)**, 2809 (1986).

[7] R. E. Jones, Jr., J. Williams, L. Spector, C-J. Lin, S. Wang, S. Pichai and B. M. Clemens, IEEE Trans. Magn., **MAG-31**, 3817 (1995).

[8] J. Honda, S. Kumagai, Y. Ikeda and M. Hayakawa, **ICF 6**, Japan, 560 (1992).

[9] J. Honda, Y. Ikeda and M. Hayakawa, **ICF 6**, Japan, 928 (1992).

[10] K. Umeda, E. Kita and A. Tasaki, IEEE Trans. Magn., **MAG-22**, 591 (1986).

[11] R. E. Jones, Jr., IDEMA Conference, 111 (1996).