Physics

Electricity & Magnetism fields

Okayama University *Year* 2005

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MAGNETIC ANISOTROPIES OF OBLIQUELY EVAPORATED CO FILMS

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Introduction

In-plane large coercive forces are obtained by oblique magnetic anisotropies [1]. The evaporation technique is utilized for the production of the magnetic recording tapes such as Hi8ME and DVC tapes.

Magnetic anisotropy is usually determined by torque technique. However, it can be determined by ferromagnetic resonance (FMR). Although Kittel formula is useful to determine the anisotropy [2-4], the model is inadequate for the vertical plane of thin films because the magnetization direction differs from that of the static field. Therefore, we have used strict solutions [5-7]. In this paper, we study magnetic anisotropies of pure Co films.

Experimental

Co films with a thickness of 1000 Å were evaporated on glass substrate, which was kept at 150°C. Incident angle (η) was changed from 0° (normal) to 75°. Uniaxial tilt anisotropy field ($H_k=2K_u/M_s$) and in-plane anisotropy field were determined by Q-band ferromagnetic resonance (FMR). The resonance equations are similar to those in the previous paper [6,7]. The applied static field is rotated in the plane containing the evaporation-beam direction and the film normal (x-z plane) and the film plane (x-y plane). For fitting of the resonance fields, we used $\gamma/2\pi=3.1$ GHz/kOe. The in-plane magnetic properties are measured using vibrating sample magnetometer; the static fields are applied in the film plane.

Results and Discussion

The coercive force (H_c) is around 230 Oe at η=60° and decreases slightly with increasing η; H_c upturns at η>60° and reaches to 1650 Oe for the η=80°. The H_c value is larger than that obtained by Speliotis [1]. For η=60°, H_c along the parallel is slightly larger than that of perpendicular axis.

The remanence ratio (M_r/M_s) is 0.7 at η=0° and increases with increasing η. However, it shows small dip between η=45° and 60° for the parallel axis, indicating an easy axis along the perpendicular axis. At η=75° and 80°, M_r/M_s shows a large value of 0.95, indicating an large anisotropy along the parallel axis. The saturation magnetization (M_s) is 1400 G at η=0° and decreases with increased η; at η=0° Ms dropped to 450 G.

Fig. 1 shows the anisotropy field (H_k) and tilt angle (α) as a function of incident angle (η). The η=0° film have a perpendicular anisotropy field ($H_k=2K_u/M_s$) of 2.0 kOe. The tilt angle α increases slightly with increasing angle η. H_k decreases slightly with η and H_k shows negative value at η=45°. Although the film with η=45° is indicated to have another anisotropy along the perpendicular axis estimated from the M_r/M_s values, we analyzed by a uniaxial-anisotropy model. Since we used uniaxial model, the results shows an easy plane; H_k becomes negative. Meanwhile, Hk becomes large at η>60° and increases to 5 kOe and the α increases to 28° for the η=75° film. The large anisotropy field (H_k) of 5 kOe and tilt angle (α) of 25° were observed for the η=80° film. We could not obtained clear FMR signals for the η=80° film, because the film has large half width. We also estimate the the easy axis is not clearly fixed to a direction during the film growth.

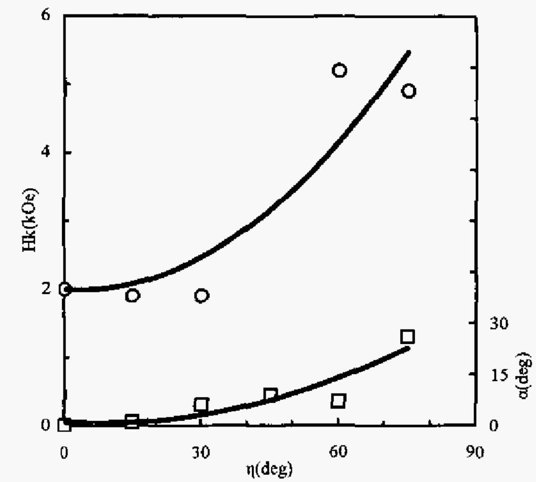

Fig. 1 Incidence angle (η) dependence of anisotropy field (H_k)[○] and tilt angle (α)[□].

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