Co-O Evaporated Films for Magnetic Recording Media

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Abstract—The coercivity of Co-O obliquely deposited films formed directly on the polymer substrate increases with increasing thickness up to around 40 nm, and decreases over 50 nm. A CoO underlayer makes the coercivity and the uniaxial magnetic anisotropy of the films high owing to an improvement of c-axis orientation of hcp Co. The morphological texture of the under layer is considered to promote the c-axis orientation of the films. The Co-O films are endowed with resolution potential high enough to attain Gbit/inch² order of areal recording density. The comparison between the Co-O film and hard disk media in the recording properties shows that the Co-O tape has much higher reproduced voltage than the disk for magnetoresistive (MR) reproduction use.

I. INTRODUCTION

Co-O evaporated films are now on the market as thin film magnetic recording tapes for digital VCR (DVC) and some streamers. Having high reproduced voltage and low noise, the films have attained recording density of 300M-400 Mbit/inch². In order to improve high density recording performance, it is necessary to make the film thickness thinner. However, as film thickness becomes thin, magnetic properties deteriorate. CoO underlayers are effective to improve magnetic properties in thin thickness region [1].

This paper presents the relation between thickness and magnetic properties, the effect of underlayers and recording characteristics compared with hard disks.

II. MEDIA PREPARATION

Tape media were prepared by using a web-coater type continuous vacuum deposition system. Co atoms were deposited in an oxygen atmosphere to form Co-O films and CoO underlayers on a polyethylane terephthalate film. The minimum incident angle to the substrate was 60°, where the incident angle is defined as the angle between incident vapor beam direction and the film normal of the substrate.

III. MAGNETIC PROPERTIES AND MICROSTRUCTURE OF Co-O FILMS

Closed circles in Fig.1 show the thickness dependence of the coercivity H_c of Co-O films with the saturation magnetization M_s of 600 kA/m, where H_c was measured in transport direction of the substrate. H_c increases with increasing the thickness up to 40 nm, and decreases in the region

Fig.1. Co-O film thickness dependence of H_c .

over 50 nm.

Closed circles in Fig.2 show the thickness dependence of the magnetic anisotropy energy K_u determined by $\beta + 45^\circ$ torque analysis method [2]. K_u increases with increasing the thickness. This is because of the improvement of c-axis orientation in the direction of grain growth with increasing the thickness.

Magnetocrystalline anisotropy field of grains

Fig.2. Co-O film thickness dependence of K_u .

Fig.3. A cross sectional TEM image (a), electron diffraction patterns in in-plane (b) and cross section (c) of a Co-O film with a CoO underlayer.

$H_{k\text{grain}}$ was independent on the thickness. Hence, $H_{c,av}/H_{k\text{grain}}$, which is considered as an index of magnetic isolation of grains [3], shows the same tendency as the thickness dependence of H_c , where $H_{c,av}$ is an average value of H_c measured in transport direction and width direction of the substrate. The thickness dependence of $H_{c,av}/H_{k\text{grain}}$ and the change of K_u suggest the following. The Co-O films have low H_c when the thickness is below 30 nm, since the anisotropy energy is low and the magnetic separation among grains is not enough. H_c of the films becomes the highest around the thickness of 40 nm, because the magnetic anisotropy energy is high and the magnetic

Fig.4. SEM images of a CoO underlayer (a) and an Al_2O_3 underlayer (b).

separation is promoted. When the thickness is over 50 nm, H_c becomes low, because the magnetic separation is not enough in spite of high anisotropy energy.

IV. IMPROVEMENT OF MAGNETIC PROPERTIES USING UNDERLAYERS

We investigated underlayers to make H_c of the Co-O films high in the thin thickness region. Open circles in Fig.1 show the thickness dependence of H_c of the Co-O films with the CoO underlayers. H_c of the films with the underlayers increases drastically in thin thickness region compared with the films without ones.

Open circles in Fig.2 show the thickness dependence of K_u of the Co-O films with the CoO underlayers. The films with the underlayers have higher K_u than those without ones. Difference of K_u between the films with and without underlayers is especially notable in thin thickness region.

Figure 3 shows a cross sectional transmission electron microscope (TEM) image (a), an electron diffraction pattern in in-plane (b) and cross section (c) of a Co-O film with a CoO underlayer. The in-plane diffraction pattern shows that the c-axis of the hcp Co preferentially grows in transport direction of the substrate. On the other hand, the preferential orientation was not observed in in-plane for the Co-O films without the CoO underlayers. The c-axis of the hcp Co also preferentially grows in the growing direction of columnar grains in cross section, and the c-axis orientation is more remarkable than that of the Co-O films without the CoO underlayers.

Figure 4 shows scanning electron microscope (SEM) images of a 30 nm thick CoO underlayer (a) and a 40 nm thick Al_2O_3 underlayer (b), where the latter had no effect like the former. In the CoO

Fig.5. Recording characteristics of a Co-O tape and hard disks.

underlayer, highly isolated grains are arranged uniformly, whose diameter is about 10 nm. In the Al_2O_3 , the grains of 20-30 nm diameter combine each other and grain boundary is unclear.

From the surface pictures shown in Fig.4, the following is considered as a role of the CoO underlayers which promotes the c-axis orientation of the Co-O films. Atoms for the magnetic layer deposited obliquely on the substrate are accumulated almost vertically on the convex surface of CoO grains. Since vertically deposited Co films have a tendency such that the c-axis orients in the incident beam direction, the c-axis of the obliquely deposited Co-O films are apt to orient in oblique direction. Moreover, the self-shadowing effect is more remarkable for the Co-O films formed obliquely on the CoO underlayers, resulting in the promoted separation among the grains.

V. RECORDING CHARACTERISTICS

A read/write experiment of tapes was carried out by using a drum tester, while that of hard disks were done by using a spin stand.

The Co-O films showed reproduced voltage recognizable up to 600 kFRPI, and superior recording resolution over the recording density of 400 kFRPI. However, for helical scan type magnetic tape recording appliances, progress to

high density recording becomes slow, because of issues of head tracking and difficulty of using MR heads.

Figure 5 shows a comparison of recording characteristics between a Co-O tape and some hard disks. The Co-O tape has $B_r \cdot t$ of 772 $\text{G} \cdot \mu\text{m}$ and H_c of 120 kA/m, where B_r is residual magnetic flux density and t is thickness of magnetic layer. The hard disk for inductive heads has a Co-Ni-Cr magnetic layer whose $B_r \cdot t$ is 270 $\text{G} \cdot \mu\text{m}$ and H_c is 130 kA/m. The hard disk for MR heads has a Co-Cr-Pt magnetic layer whose $B_r \cdot t$ is 130 $\text{G} \cdot \mu\text{m}$ and H_c is 130 kA/m. The measurements of the tape and the disks were performed with the same Metal-In-Gap (MIG) ring-type head under the condition of contact recording, where gap length was 0.16 μm and track width was 6 μm .

In Fig.5, it is found that the Co-O tape has the highest reproduced voltage and the disk for MR heads has the lowest one. The reproduced voltage at low recording density is almost proportional to $B_r \cdot t$. The low reproduced voltage of the disk for MR heads is complemented by using MR heads in hard disk drives. As for the noise, precise estimation has not been performed yet, because of the low head sensitivity. SN ratios are hence not judged from this measurement. It is clear that guide to design magnetic layers for disks is considerably different from that for tapes.

VI. CONCLUSIONS

The results are as follows.

- (1) H_c of the films formed directly on the polymer substrate is low at thin thickness region such as 20 nm, having maximum value around thickness of 40 nm, and becomes low over 50 nm.
- (2) The CoO underlayers have the remarkable effect which makes H_c of the Co-O films high in the film thickness region under about several tens nm. This is considered to be owing to the morphology of the CoO underlayers which consist of isolated grains with diameter of about 10 nm.
- (3) The Co-O tapes have much higher reproduced voltage than the disks for MR heads.

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