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Growth of oblique sputtered Co and CoCrPt thin films for high-density tape recording

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Abstract

In this paper, we report the properties of Co/Cr and CoCrPt/CoCrMn thin films grown by oblique sputtering onto polymer substrates. It is observed that in both cases, the underlayers promote the formation of HCP-structure of the magnetic layers, which results in a high magnetic anisotropy of the films consequently, high coercivities of 200 and 300 kA/m are obtained in the 20 nm Co/180 nm Cr and 30 nm CoCrPt/50 nm CoCrMn films, respectively. However, in the case of Co/Cr film, Co grains are relatively large and elongated following the transverse direction while in the case of CoCrPt/CoCrMn film, a tiny columnar structure inclined toward the incident direction is observed. This fact results in a different magnetic behavior of these films.

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Keywords: Magnetic anisotropy; Magnetic recording media; Thin films; Sputtering

1. Introduction

In order to increase the density in tape recording, media with higher coercivity and lower magnetic thickness are needed. In addition, the decoupling between magnetic grains is desired in order to obtain a high signal-to-noise ratio (SNR). Oblique evaporation of Co and Co alloys onto a polymer substrate has been applied to produce media for high-density magnetic recording tape [1]. Beside evaporation, oblique sputtering is also proposed as a promising technology [2] because sputtering can offer a number of advantages such as possibility to obtain binary and ternary compounds as well as microstructural controllability. However, it is shown that Co and Co alloys directly sputtered onto polymer substrates possess only a moderate anisotropy which is originated from the shape anisotropy of the columns [2]. In previous work, we have shown that an introduction of a proper underlayer can rapidly increase the anisotropy of the films due to the promotion of the HCP structure [3]. In this paper, we compare the properties of obliquely sputtered Co/Cr and CoCrPt/CoCrMn films. The films were deposited by using DC magnetron onto a solid drum covered with 10 μm thick PET substrate. Prior to each deposition, the vacuum chamber was evacuated down to a base pressure (10^{-7} mbar). All the layers were sputtered with the same incident angle ($70 \pm 5^{\circ}$ with respect to the film normal),

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at room temperature, and at a fixed Ar pressure of 4×10^{-3} mbar. CoCrPt and CoCrMn layers were sputtered from composite targets with the composition of $Co_{68}Cr_{13}Pt_{19}$ and $Co_{67}Cr_{30}Mn_3$, respectively. At this concentration, the underlayer, CoCrMn film, is paramagnetic but still crystallizes in HCP structure providing a good lattice matching with CoCrPt layer [5]. The microstructural analyses were carried out using scanning electron microscopy (SEM) and transmission electron microscopy (TEM). The magnetic properties of the films were investigated using a vibrating sample magnetometer (VSM) and a torque magnetometer. Hysteresis loops were measured in the film plane along the longitudinal and the transverse directions (parallel and perpendicular to the incident plane, respectively).

2. Results and discussion

2.1. Microstructure

From X-ray diffraction patterns depicted in Fig. 1, we can observe that in the case of the Co/Cr film, there are two planes of HCP Co (1 0 .1) and (1 0 .0) presented. These two planes are known to grow epitaxially on Cr (1 1 0): Co (1 0 .1) with the *c*-axis orientation tilted out of the film plane whereas Co (1 0 .0) with the *c*-axis fully in plane. In the case of the CoCrPt/CoCrMn film, two diffraction peaks characteristic for (1 0 .1) and (0 0 .2) planes of the HCP structure are presented. The strong intensity of (0 0 .2) diffraction peak suggests that the *c*-axis is out of the film plane in the case of the CoCrPt/CoCrMn film.

Topography of the films is presented in Fig. 2. In the case of Co/Cr, Co grains are relatively large (around 60 nm) and elongated in the transverse direction. This elongation can be explained due to the epitaxial growth of Co on Cr, where the topography of Cr also exhibits an elongation following the transverse direction [4]. In the case of CoCrPt/CoCrMn, a different topography is observed. It is shown that the film consists of very fine grains with an average grain size of 10 nm. Moreover, no elongation in the transverse direction of the grains is observed (see Fig. 2). This fact indicates that the growth mechanism of CoCrPt on CoCrMn underlayer is different with that of Co on Cr underlayer. The alloyed films (CoCrPt and CoCrMn) probably have a lower atomic mobility, which in turn yields a smaller grain size compared to the case of single element films (Co and Cr).

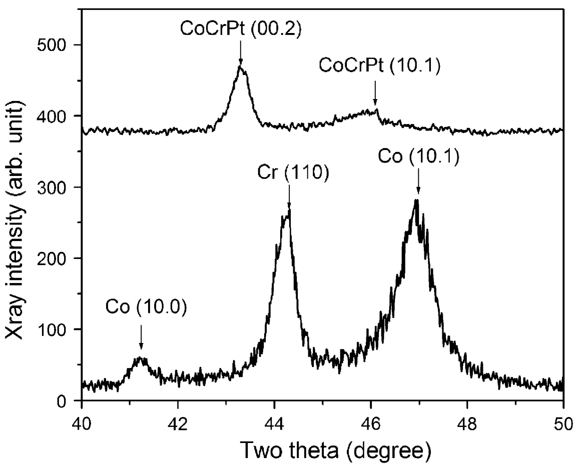

Fig. 1. X-ray diffraction pattern of the Co/Cr film (lower curve) and the CoCrPt/CoCrMn film (upper curve).

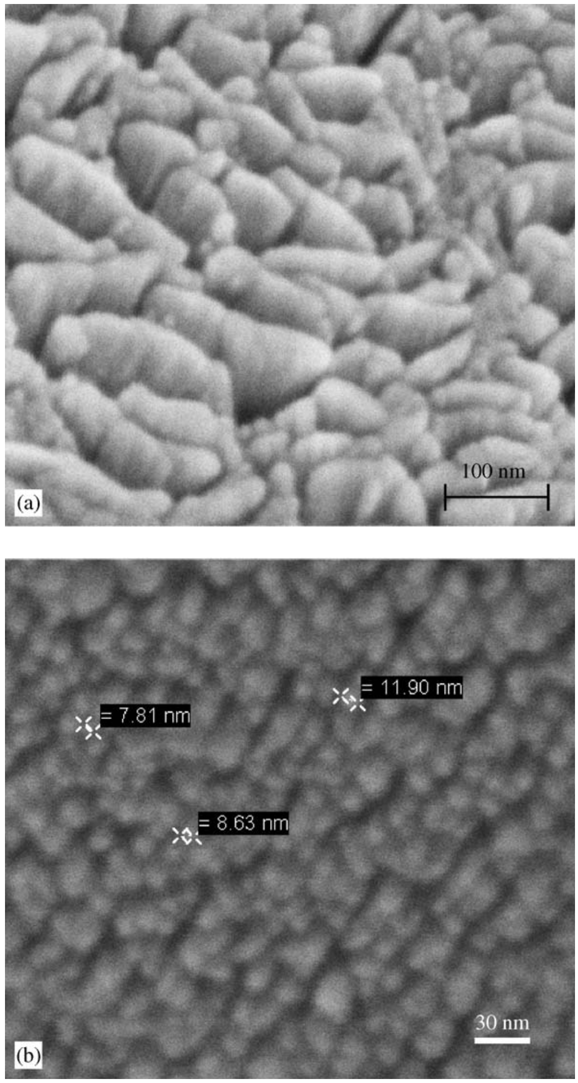

Fig. 2. SEM images of Co/Cr film (a) and CoCrPt/CoCrMn film (b). The incident direction is vertical.

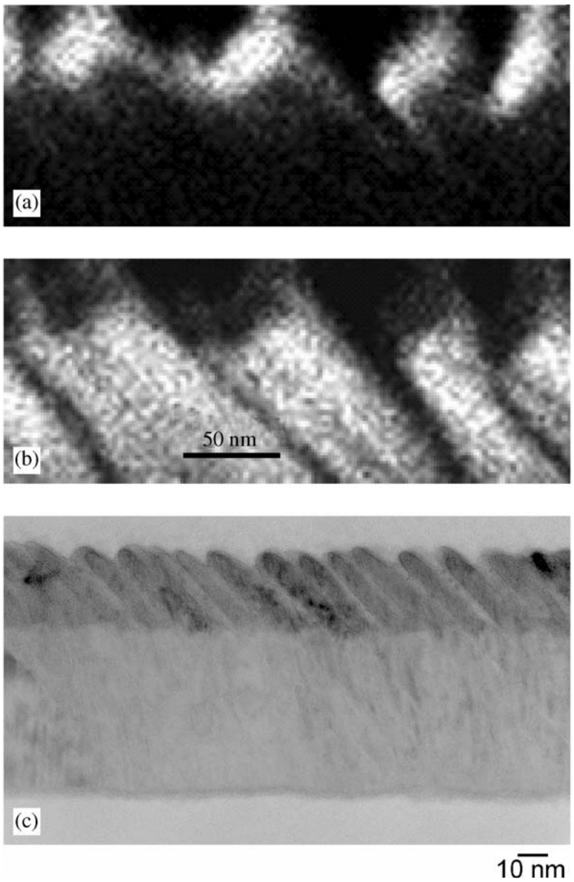

Fig. 3. EDS maps of Co (a) and Cr (b) of Co/Cr film and bright field image of CoCrPt/CoCrMn film (c).

Further investigations of microstructure have been carried out on the film cross-section using TEM analyses. Figs. 3a and b indicate the energy dispersive spectroscopy (EDS) maps of the Co/Cr film. These images reveal well-separated islands of Co with an average diameter of 50 nm grown on titled Cr columns. In addition, the orientation relationship between Co and Cr has been studied by taking high-resolution electron microscopy images in adjacent Co and Cr grains at different positions in the layer and subsequent fast Fourier transformations (FFT) of the images. At all positions the orientation relationship $[\bar{1}0\,.1]_{Co}$ parallel to $[1\,0\,0]_{Cr}$ and $[\bar{1}1\,.1]_{Co}$ parallel to $[0\,1\,1]_{Cr}$ was found. In the case of CoCrPt/CoCrMn, due to the nuclei of CoCrPt are very fine, the film exhibits very well-defined columnar structure with an average column diameter around 6 nm (Fig. 3c). The structure with narrow columns of the CoCrPt/CoCrMn film would be a marked advantage for tape media because the recording density is related to the width of magnetic columns.

2.2. Magnetic properties

Magnetic properties of Co/Cr and CoCrPt/CoCrMn films have been studied using a VSM and a torque magnetometer. For the case of Co/Cr film, the in-plane easy axis is in the transverse direction (see Fig. 4a). A high coercivity (H_c) of 200 kA/m and a high anisotropy field (H_a) of 600 kA/m were obtained. In the case of CoCrPt/CoCrMn film, however, the in-plane easy axis is in the longitudinal direction. It is clear that the film has a high anisotropy with high H_c of 290 kA/m and H_a of 900 kA/m. The value of H_c is double the value of commercial ME tape (135 kA/m) and also higher than that of advanced MP tape (200 kA/m). The difference of the magnetic behavior of these films can be explained by the difference in microstructure mentioned above. The elongated islands in the transverse direction of the Co/Cr film give rise to the orientation of magnetization in the transverse direction whereas the columnar structure inclined toward the incident direction of the CoCrPt/CoCrMn film results in an orientation in the longitudinal direction. In addition, the double switching observed in the hysteresis loops of CoCrPt/CoCrMn

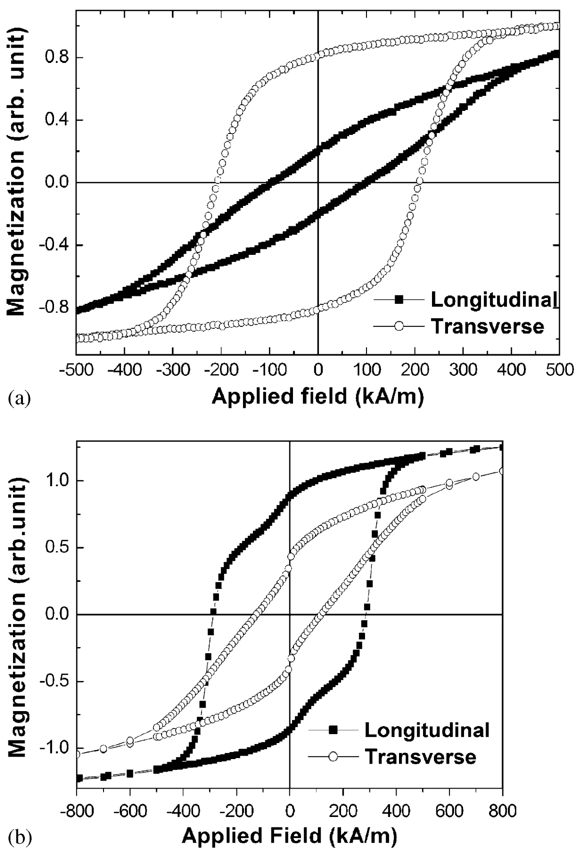

Fig. 4. Hysteresis loops measured in the film plane of Co/Cr film (a) and CoCrPt/CoCrMn film (b).

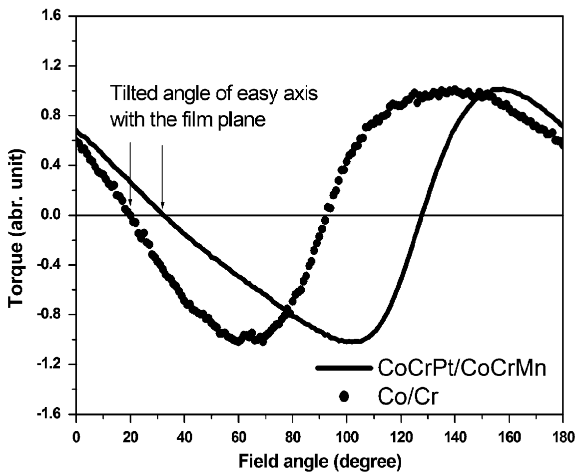

Fig. 5. Torque curves of Co/Cr and CoCrPt/CoCrMn film measured at 1350 kA/m from film plane to film normal.

film (see Fig. 4) can be explained by the existence of both (10.1) and (00.2) texture as indicated by XRD measurement. Primarily results show that a single switching can be obtained in these films by changing the sputtering conditions. From torque measurements, the tilted angle of the easy axis with respect to the film plane can also be determined. The tilted angle is higher for the case of CoCrPt/CoCrMn film due to the present of (00.2) texture out of the film plane (see Fig. 5).

In conclusion, both obliquely sputtered Co/Cr and CoCrPt/CoCrMn films are suitable for high density tape recording. Nevertheless, because of the very fine grain size, CoCrPt/CoCrMn films would be more suitable for further increase of recording density.

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