

Improvement of preferred orientation of NiAl/CrMn underlayers deposited on prebaked tape substrates

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It was observed that the coercivity of CoCrPt films deposited on a polyimide tape was much lower than the coercivity deposited on a rigid glass substrate under identical conditions. X-ray diffraction showed that the desirable (112) and (110) texture of the NiAl/CrMn underlayers on the tape substrate was severely degraded during the deposition process. This resulted in the destruction of (10.0) growth texture of CoCrPt films and a significant reduction of magnetic coercivity. However, degassing of the tape substrate under vacuum before deposition significantly enhanced the magnetic properties. The coercivity of the film reached 170 kA/m which is near that achieved on a glass substrate. Auger analysis also revealed that oxygen was present in the NiAl/CrMn underlayers deposited without degassing the tape substrate. © 2002 American Institute of Physics.

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INTRODUCTION

Sputtered tape media, using materials similar to those that are so successful in rigid-disk media, constitute a possibility for future high density tape recording media. Concerns over thermal damage to fragile polymer substrates and poor texture on those substrates have hindered pursuit of this solution to tape media. It has been reported that using a higher sputtering pressure and no substrate heating can solve the problem of substrate stress or deformation.¹ However, low coercivity on polymeric substrates remains a challenge for application of high recording density tape media. In this study, we have addressed the enhancement of the magnetic properties of CoCrPt films by maintaining preferred orientation of NiAl/CrMn on a flexible substrate. As will be seen later, the process examined here is relatively complex (four layers) and is likely to be expensive to commercialize. Future work will address this. In this study, we concentrate on how to develop good texture on polymer using established method.

EXPERIMENT

Films of $\text{Co}_{59}\text{Cr}_{15}\text{Pt}_{26}$ were rf sputter deposited on 1 cm×5 cm polyimide tape (kapton) of 30 μm thickness. A mechanically robust (thick) and thermally robust polymer was chosen for this initial study. In the future, thinner coupons of PEN and PET will be examined. A $\text{Co}_{86}\text{Cr}_{12}\text{Ta}_2$ interlayer and NiAl/Cr₉₂Mn₈ underlayers were deposited on the tape prior to depositing the CoCrPt layer. Silicon adhesive was used to attach the tape to a rigid Si substrate. A CoCr alloy target with bonded Pt chips was used for the magnetic film preparation. The base pressure in the chamber was about 5×10^{-7} Torr and the Ar sputtering pressure was

fixed at 10 mTorr. Deposition was performed at about 2.3 W/cm² sputtering power density. All CoCrPt films were 35 nm thick unless stated otherwise. The thicknesses of the CoCrTa intermediate layer and NiAl/CrMn underlayers were fixed at 4–5 nm and 100 nm/30 nm, respectively. Magnetic properties of the samples were measured by alternating gradient magnetometer (AGM). Structural characteristics were studied with an x-ray diffractometer (Philips X'pert Pro with an x-ray lens) using Cu K_α radiation. A scanning auger multiprobe system (Perkin-Elmer PHI 600) operating at 3 kV was used for Auger analysis in the samples.

RESULTS AND DISCUSSION

The CoCrPt films were deposited on a polyimide tape with a CoCrTa interlayer and NiAl/CrMn underlayers without intentional substrate heating. NiAl/CrMn underlayers were used in order to induce a smaller grain size and to better promote epitaxial growth of the hcp structure without substrate heating.² Films on a glass substrate were prepared as a reference sample in order to compare with the films directly deposited on the tape substrate.

As shown in Fig. 1, it was found that the coercivity (60 kA/m) of films deposited on the polyimide tape was much lower than the coercivity (200 kA/m) deposited on a glass substrate under identical conditions. The significant reduction of coercivity occurred even for films deposited on the region of rigid carrier substrate adjacent to the kapton. This suggests that gas contamination originating from the tape substrate on the adhesive is the cause of a drastic reduction of the coercivity of the films. It does not appear that the degradation can be attributed to degassing from the adhesive. Films were deposited with all adhesives eliminated in order to minimize the source of contamination. Nearly the same magnetic properties as those on a glass could be obtained only when the degassing was performed.

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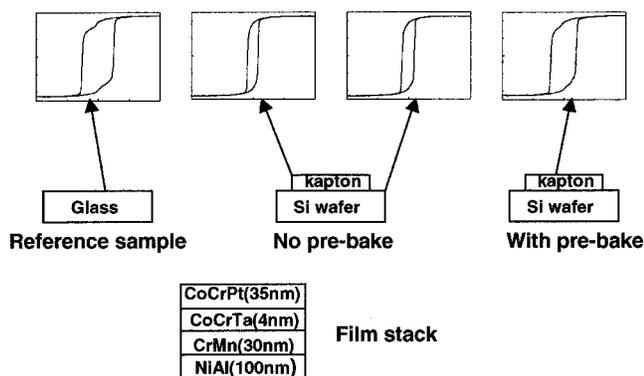


FIG. 1. Structure of the stack studied in this work. The significant reduction of coercivity was observed even for films deposited on the region of rigid carrier substrate adjacent to the kapton.

This conclusion is also supported by the fact that significant improvement of coercivity was seen in films deposited on a tape when the tape is degassed before deposition. When the tape substrate was pre-baked for degassing at 120–130 °C and then cooled under vacuum before deposition, the coercivity increased up to 170 kA/m which is near that achieved on glass. Moreover, we note that the pressure of the chamber increased by more than one order of magnitude (1×10^{-5} Torr) during the prebaking of the tape substrate. In contrast, the pressure was maintained at nearly the initial base pressure of 5×10^{-7} Torr during the prebaking of a glass substrate to the same temperature. The degassing of the tape substrate was sustained until the initial base pressure was established again, which took about 30 min.

As shown in Fig. 2, it was found from x-ray diffraction (XRD) that the desirable (112) and (110) texture of NiAl/CrMn underlayers on the tape substrate was severely degraded during the deposition process, unless the degassing of the tape substrate was performed. This resulted in the destruction of (10.0) growth texture of the subsequently deposited CoCrPt films and a significant reduction of magnetic coercivity.

The measured magnetic properties of all samples are listed in Table I. It can be seen that the magnetic properties with the prebaking treatment are comparable to those ob-

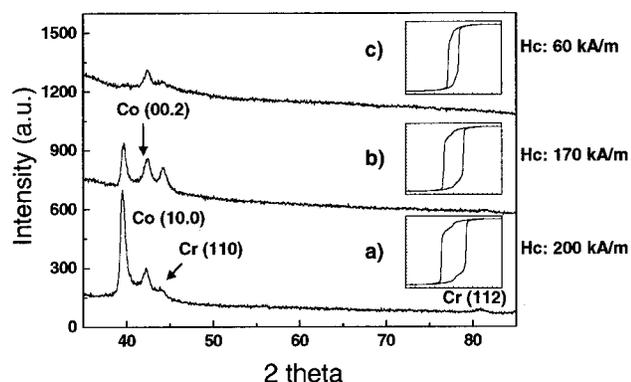


FIG. 2. XRD spectra of the NiAl/CrMn/CoCrTa/CoCrPt films on (a) a glass, (b) a tape after prebaking under vacuum, and (c) a tape without prebaking.

TABLE I. In-plane magnetic properties of NiAl/CrMn/CoCrTa/CoCrPt films on a glass, a tape after prebaking under vacuum, and a tape without prebaking.

Sample	On glass	On kapton	
		With prebake	Without prebake
H_c (kA/m)	199	163	59
M_s (kA/m)	537	636	791
M_{r1} (mA)	17.1	19.8	21.4
S	0.81	0.80	0.69
S^*	0.95	0.89	0.75
$\Delta M/M_r$ peak	0.58	0.48	0.20

tained on glass. The slight difference of the magnetic properties may be attributed to the influence of a different substrate which may result in change of the crystal grain size distribution and the surface morphology of the films.³ One puzzling result for which we have no explanation is that the M_s values of films on polymer substrates and particularly nonbaked substrates are higher. Based on the level of contamination discussed later, this trend is the opposite of what was expected. The S^* behavior is consistent with that of the $\Delta M/M_r$ peak. However, it shows the sample deposited on a polymer substrate without degassing has a smaller $\Delta M/M_r$ peak suggesting the grains weaker exchange coupling. In the prebaked and reference samples some double hysteresis loops are observed. This may be due to coexistence of fcc and hcp Co phase at this high Pt content as suggested by the presence of a (200) ring in the transmission electron microscopy (TEM) diffraction pattern. Differences of grains in shape were also observed from TEM plan-view images of the samples with no prebake and with prebake. The sample with no prebake showed distinct separation between the grains, while the grains of the other sample appear completely dense. It is worth noting the sample having clear physical separation shows a smaller $\Delta M/M_r$ peak. This may be attributed to sputter deposition under poor vacuum conditions due to the presence of oxygen, which destroyed the underlayer texture as seen by XRD.

Consistent with the XRD results, Auger analysis revealed the presence of oxygen contamination during sputtering. Two samples were prepared and Auger depth profiles were taken of each. The samples were deposited with prebaking under vacuum and without prebaking, respectively. Auger depth profiles were obtained by measuring the Auger spectrum after every 15 s of Ar sputter etching in the Auger chamber. Figure 3 shows that oxygen was trapped in the film deposited without prebaking treatment while there is no measurable trace of oxygen in the film deposited after prebaking. A closer examination revealed that the oxygen entrapment primarily occurred during the NiAl/CrMn underlayers deposition process. The substrate temperature was estimated using temp labels during deposition. It was found that the sputtering gives rise to an increase of substrate temperature up to 130 °C. Due to this heating, it is hypothesized that the contaminants adsorbed in the polymer substrate are emitted during deposition. It is believed that water vapor is the oxygen carrying contaminant that is emitted.

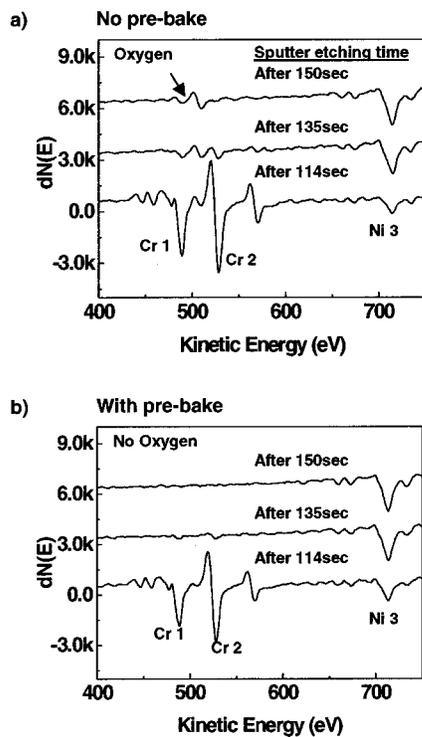


FIG. 3. Auger depth profiles of NiAl/CrMn/CoCrTa/CoCrPt films for sample (a) deposited without prebaking and for sample (b) deposited after prebaking under vacuum. Oxygen appears in sample (a), while there is no trace of oxygen in sample (b).

To explain this, a separate sputtering system was instrumented with a residual gas analyzer (RGA) to evaluate the contamination during sputtering. Using the RGA, we were not able to detect any definitive change in sputtering environment, but this may be due to different amount of substrate heating in the different system during sputtering. It was observed, however, that water was exhausted from the tape

substrate when the substrate was explicitly heated for degassing as Iwasaki *et al.* presented.⁴ This strongly suggests that water vapor can be a significant source of oxygen contamination which can degrade magnetic film properties. It is known that some polymers can absorb significant amounts of water in the atmosphere. The coefficient of hygroscopic expansion of a polyimide tape is about 13.0×10^{-6} (/ % RH), which indicates a significant change in length as it takes up water upon an increase in the ambient relative humidity.⁵

CONCLUSIONS

Magnetic media on polymer substrates having a coercivity of 170 kA/m were obtained by applying NiAl/CrMn underlayers during CoCrPt deposition with a thin CoCrTa intermediate layer. Degassing from the tape substrate was essential to achieve comparable magnetic properties to those obtained on a rigid glass substrate. The existence of oxygen contaminants in the films was confirmed with Auger analysis and was seen to degrade the growth texture of the NiAl/CrMn underlayers. Accordingly, this resulted in the destruction of (10.0) growth texture of CoCrPt films and a significant reduction of coercivity.

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- ¹J. Veldeman, H. Jia, and M. Burgelman, *IEEE Trans. Magn.* **36**, 2351 (2000).
- ²L.-L. Lee, D. E. Laughlin, and D. N. Lambeth, *IEEE Trans. Magn.* **30**, 3951 (1994).
- ³F. Kirino, N. Inaba, M. Futamoto, N. Koiso, and T. Maro, *IEEE Trans. Magn.* **36**, 2348 (2000).
- ⁴S. Iwasaki, K. Ouchi, K. Saiki, and M. Kimura, *IEEE Trans. Magn.* **22**, 1158 (1986).
- ⁵B. L. Weick and B. Bhushan, *IEEE Trans. Magn.* **32**, 3319 (1996).