

## CoCrTa Intermediate Layers on NiAl Underlayers for CoCrPt Longitudinal Thin Film Magnetic Media

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**Abstract** — A CoCrTa intermediate layer was added between a CoCrPt recording layer and a NiAl underlayer. CoCrPt (10 $\bar{1}$ 0) texture improves and the in-plane coercivity increases using this medium structure. The effects of substrate bias on film texture and coercivity were studied. Pt concentration and lattice constant for CoCrPt were also characterized as functions of the bias voltage.

**Index Terms** — Co, lattice match, NiAl, substrate bias.

### I. INTRODUCTION

Underlayers have significant influence on both the texture and microstructure of Co-alloy thin films, which are key factors in determining their magnetic properties and recording performance. The currently most widely-used underlayer, Cr, can induce in-plane Co textures through lattice matching epitaxial growth [1]. CoCrPt alloys are one of the best candidates for high density media [2]. However, Pt enlarges the Co lattice and the mismatch between the CoCrPt and Cr lattices can become too large to induce good epitaxial growth as the Pt content increases. One solution to this problem has been to increase the bcc lattice constant of Cr by adding V [2], Ti [3], or Mo [4] into it. Another solution is to first grow a lattice matched hcp template on the underlayer, upon which a Co-alloy with a larger hcp lattice can then grow. CoCrTa and Co intermediate layers have been inserted between the Cr and a high Pt content CoCrPt layer and better in-plane texture and a higher coercivity were obtained [5].

NiAl, which has the B2 crystal structure and a lattice constant very similar to Cr, was found to be an excellent alternative underlayer material [6]. Sputter-deposited NiAl thin films have finer grains than similarly deposited Cr films and tend to induce better (10 $\bar{1}$ 0) textured Co-alloy films. It was also found that Cr intermediate layers greatly improved the magnetic properties of CoCrPt on NiAl underlayers [7].

In this paper, we apply this hcp intermediate template concept to the media when NiAl underlayers are used. The influence of the CoCrTa intermediate layer, deposited on a NiAl underlayer, upon the texture and magnetic properties of CoCrPt, is investigated as a function of the intermediate layer thickness and processing conditions.

### II. EXPERIMENTAL

CoCrPt/NiAl thin films with and without CoCrTa intermediate layers were deposited onto glass substrates without substrate heating by RF diode sputtering. The Ar sputtering pressure was 10 mTorr and the base pressure was about  $5 \times 10^{-7}$  Torr. All CoCrPt layers and NiAl underlayers

were 30 nm and 100 nm thick, respectively, and were deposited with  $-100$  V and  $0$  V substrate bias, respectively, unless stated otherwise. The CoCrTa intermediate layers were sputtered with  $-170$  V or without substrate bias. The deposition rates of the CoCrPt, NiAl, and Cr were about 10, 13, and 12 nm/min respectively.

The in-plane magnetic properties of the samples were measured using a vibrating-sample magnetometer (VSM) with a maximum applied field of 10 kOe. Film textures were examined by an x-ray diffractometer using Cu-K $\alpha$  radiation. The compositions of the CoCrPt and CoCrTa films were determined by energy dispersive x-ray spectroscopy (EDX).

### III. RESULTS AND DISCUSSION

Fig. 1 shows the x-ray diffraction spectra of samples with various thicknesses of the CoCrTa intermediate layer. Compared to the sample with no intermediate layer, the film with as little as 1 nm CoCrTa layer exhibits a stronger CoCrPt (10 $\bar{1}$ 0) peak. Furthermore, no visible increase in this peak is obtained by increasing the intermediate layer thickness. Hence, only a very thin CoCrTa intermediate template is needed to promote better in-plane-textured CoCrPt. For the sample with a 20nm CoCrTa intermediate layer, the CoCrTa (10 $\bar{1}$ 0) peak also appears, but is located at a higher angle than the CoCrPt peak, indicating a smaller lattice constant. From a higher resolution x-ray diffraction scan of these two peaks, the lattice constant,  $a$ , was calculated to be 2.59 Å for the CoCrPt and 2.53 Å for the CoCrTa films, while the bulk value reported for pure Co is 2.505 Å [8]. The compositions measured by EDX are Co-6at%Cr-16at%Pt and Co-10at%Cr-2at%Ta. Assuming that their  $c/a$  ratios are very close to pure Co, the lattices of the CoCrPt and CoCrTa films expanded by about 3% and 1%, respectively, compared to pure Co. It has been shown that a Co (10 $\bar{1}$ 0) plane matches almost perfectly with a NiAl (112) plane in both directions [10] and while the weak intensity (112) reflection is not

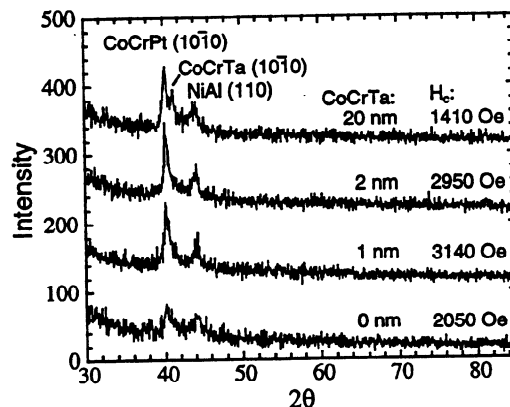


Fig. 1 X-ray diffraction spectra for CoCrPt(30 nm)/CoCrTa(x nm)/NiAl(100 nm) films.

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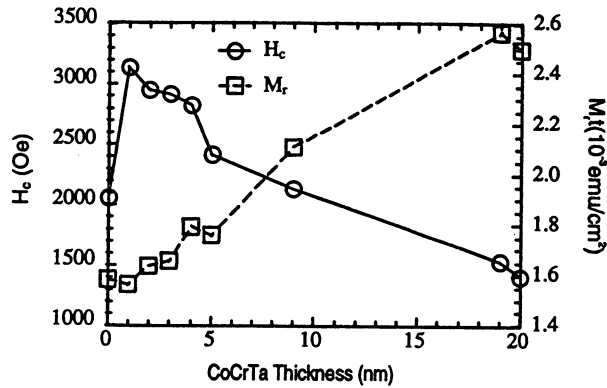


Fig. 2  $H_c$  and  $M_t$  vs. CoCrTa intermediate layer thickness for CoCrPt(30 nm)/CoCrTa(x nm)/NiAl(100 nm) films.

clearly visible in Fig. 1, some (112) texture is anticipated. Thus the mismatch between the NiAl and the CoCrPt is 3% while it is only 1% between the NiAl and the CoCrTa. Therefore, this smaller lattice mismatch may still induce a (10 $\bar{1}$ 0) textured CoCrTa which provides the hcp template for the growth of (10 $\bar{1}$ 0) textured CoCrPt. On the other hand, the 3% mismatch is apparently too large for a good epitaxial growth of CoCrPt directly on NiAl.

The coercivity and  $M_t$  vs. CoCrTa intermediate layer thickness are shown in Fig. 2. The  $H_c$  increases by about 1000 Oe as the CoCrTa thickness increases from 0 to 1 nm, which is believed mainly due to the improvement of the CoCrPt (10 $\bar{1}$ 0) texture. As with the x-ray diffraction data, a further increase of the intermediate layer thickness does not improve the CoCrPt properties. A decrease in  $H_c$  is observed because the CoCrTa layer, which would normally have a lower coercivity than CoCrPt, represents a larger fraction of the total magnetic film thickness. Since the overall magnetic film thickness is increasing, so does the  $M_t$ .

Fig. 3 shows the x-ray diffraction data and coercivities for samples with an increasingly thick NiAl underlayer, a 2 nm CoCrTa intermediate layer and a 30 nm thick CoCrPt layer. As the NiAl (112) peak evolves from invisible to visible for thicker NiAl layers, the CoCrPt (10 $\bar{1}$ 0) texture improves and  $H_c$  increases. While it might be tempting to think that the CoCrPt (10 $\bar{1}$ 0) texture is caused by the NiAl (110) texture, it is observed that this (110) peak is independent of the NiAl thickness as the coincident Co (0002) peak decreases.  $H_c$  is instead directly correlated with the underlayer thickness and

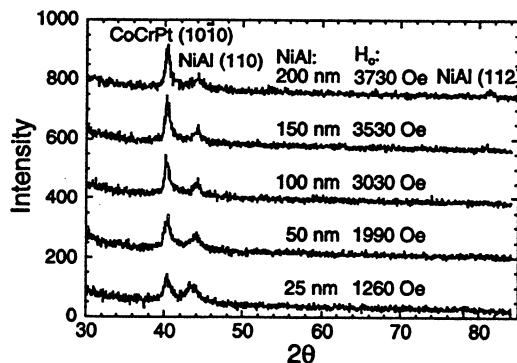


Fig. 3 X-ray diffraction spectra and  $H_c$  of CoCrPt/CoCrTa/NiAl films.

the NiAl (112) texture evolution. Further, it should be noted that for a random polycrystalline NiAl film the ratio of the intensity of the (110) to (112) peak is about 5:1 [8].

Fig. 4 shows  $H_c$  of 30 nm CoCrPt deposited with various substrate bias voltages on CoCrTa(2 nm)/NiAl(100 nm). The coercivity increases as the substrate bias increases. When the high bias voltage was combined with the thick NiAl underlayer, such as a -200 V bias and a 200 nm thick underlayer, coercivities as high as 4700 Oe were obtained. The lattice constant,  $a$ , calculated from the x-ray diffraction data and the Pt concentration, measured by EDX, for CoCrPt films, are plotted vs. substrate bias in Fig. 5 (a). There is a threshold bias voltage of about 50 V, after which the lattice constant and the Pt content both increase. This threshold implies that there is a minimum Ar ion energy required before Co atoms are preferentially removed from the film to increase the Pt concentration. Supposedly Cr is removed at about the same rate as Co, however the low Cr content of the alloy made this unobservable. The lattice constant varies linearly from the pure Co value through the higher Pt content values, as shown in Fig. 5 (b).

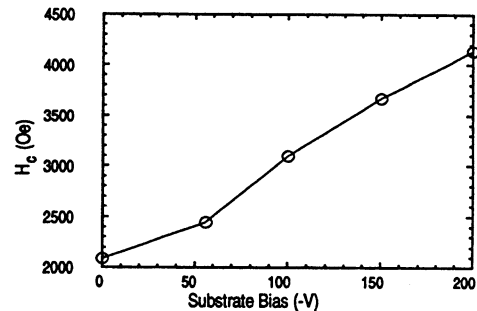


Fig. 4  $H_c$  vs. substrate bias for CoCrPt/CoCrTa/NiAl films. Bias voltages were applied during CoCrPt deposition. CoCrTa and NiAl were deposited without bias.

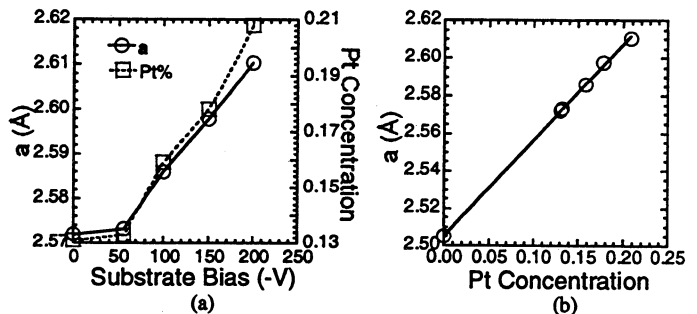


Fig. 5. (a) Lattice constant and Pt concentration vs. substrate bias and (b) lattice constant vs. Pt concentration for CoCrPt films.

The CoCrTa intermediate layers for all the preceding samples were deposited with no substrate bias. The magnetic properties of samples prepared with bias and unbiased sputtered intermediate layers are compared in Fig. 6. In both cases,  $H_c$  increases as the CoCrTa thickness increases from 0 to 1 nm and then decreases as the thickness of CoCrTa keeps increasing. The samples with thin intermediate layers (< 4 nm) deposited with no bias have higher  $H_c$  than the ones deposited with bias. One possible explanation for this behavior is that a bias-sputtered CoCrTa film has more Ta in it, just as there is more Pt in the bias-sputtered CoCrPt film,

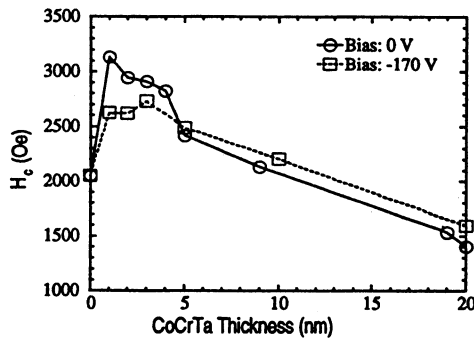


Fig. 6  $H_c$  vs. bias and unbiased deposited CoCrTa intermediate layer thickness for CoCrPt(30 nm)/CoCrTa(x nm)/NiAl(100 nm) films.

and thus the film has a larger lattice constant [10] causing a larger mismatch with NiAl. Another possible explanation is that the Ar ion bombardment caused by applying a bias during the initial stage of Co-alloy deposition on the NiAl underlayer may have some degrading effects such as damaging the NiAl interface or causing interfacial mixing of the Co-alloy with the underlayer. To further understand the effect of the substrate bias, the deposition of CoCrPt was split into two phases, an unbiased deposition followed by a normal -100V-bias-deposition, while the total CoCrPt thickness was maintained constant at 30 nm. No CoCrTa intermediate layer was added between the CoCrPt and NiAl layers.  $H_c$  and  $M_t$  vs. the ratio of the unbiased CoCrPt layer thickness to the total CoCrPt thickness,  $T_{unbias}/T_{total}$ , are shown in Fig. 7.  $H_c$  increases by 540 Oe when the initial layer of an unbiased-deposited CoCrPt is introduced and then decreases with increasing percentage of the unbiased-sputtered material in the CoCrPt layer. Fig. 8 shows the x-ray diffraction spectra for samples with various  $T_{unbias}/T_{total}$ . All the CoCrPt (10 $\bar{1}$ 0) peaks have almost the same intensity indicating no significant difference of CoCrPt crystalline texture. Therefore, even though a lower Pt concentration and thus a smaller lattice constant result when no bias is used, the initial increase in  $H_c$  cannot be explained by a better lattice match. This suggests that the prevention of the degrading effect due to the substrate bias during the formation of the Co-alloy/NiAl interface may be the explanation.

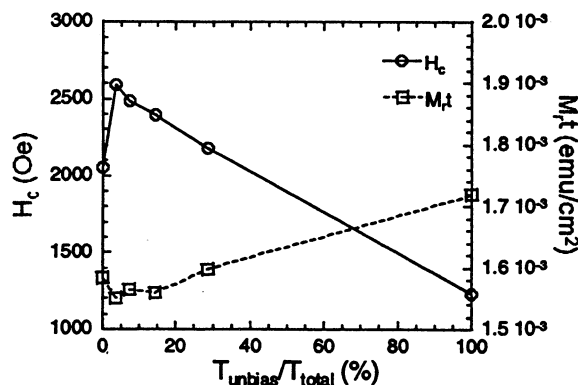


Fig. 7  $H_c$  and  $M_t$  vs.  $T_{unbias}/T_{total}$  for CoCrPt(30 nm)/NiAl(100 nm) films.

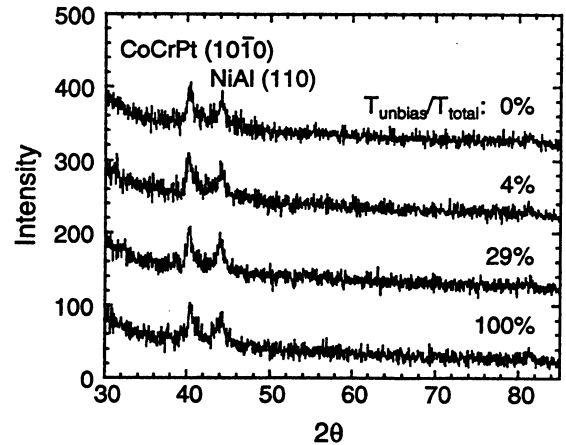


Fig. 8 X-ray diffraction spectra of CoCrPt(30 nm)/NiAl(100 nm) films with various  $T_{unbias}/T_{total}$ .

#### IV. CONCLUSIONS

Since the CoCrTa atomic spacing matches well to the NiAl lattice, CoCrTa forms a (10 $\bar{1}$ 0) textured hcp template on a NiAl underlayer. This improves the subsequently deposited CoCrPt film texture (10 $\bar{1}$ 0). The addition of a thin CoCrTa layer on a NiAl underlayer increases the coercivity of the CoCrPt film. Applying substrate bias during the initial stage of Co-alloy growth on NiAl underlayers has some degrading effects and lowers the coercivity. This study also shows that the Pt concentration in CoCrPt increases when deposited with higher substrate bias and its lattice constant increases linearly with the Pt content.

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