Effects of Cr Intermediate Layers on CoCrPt Thin Film Media on NiAl Underlayers

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***Abstract*—Sputter-deposited NiAl underlayers can induce better in-plane c-axis textures in the overlying CoCrPt films and have a smaller grain size than Cr underlayers. However, it is found that the CoCrPt/NiAl films on glass substrates have lower coercivity values than the CoCrPt/Cr films. A scheme which inserts a Cr intermediate layer, about 2.5nm thick, between the CoCrPt and NiAl layers is found to greatly improve the in-plane magnetic properties of the CoCrPt/NiAl films. The existing $(10\bar{1}0)$ texture of the CoCrPt/NiAl films is enhanced by the Cr intermediate layer. Coercivity as high as 4500 Oe can be achieved. This increase is attributed to the change in interface structure.**

I. INTRODUCTION

It is well known that the in-plane magnetic properties of Co alloy thin films are strongly dependent upon their crystallographic texture and microstructure which in turn are greatly influenced by their underlayers. Underlayers have been used mainly for two purposes [1]. First, the underlayer produces a Co alloy film with a preferred crystalline orientation by epitaxy. Second, the grain size and degree of segregation within the Co alloy film can be controlled by its underlayer. Underlayers which improve the c-axis orientation of the HCP phase of the magnetic layer in the plane of the film are believed to be more suitable for longitudinal recording. Therefore, efforts have been made [2], [3] to improve the crystallographic texture of the Co alloy thin films by either choosing appropriate underlayers or by fine tuning the deposition process parameters. However, texture improvement alone may not translate directly to enhancement of the magnetic properties since grain isolation [4], [5], element segregation [6], interfacial chemistry [7], and other microstructural factors also play important roles [8].

The authors previously have shown that because NiAl and Cr have similar crystal structures and lattice constants the NiAl films can be used as underlayers for CoCrTa [9]. It was found that sputter deposited NiAl films have smaller grain sizes than similarly deposited Cr films and the NiAl underlayers tend to induce better $(10\bar{1}0)$ textured Co alloy films. Despite these virtues, however, the Hc values of the CoCrTa/NiAl were found to be lower than that of the CoCrTa/Cr unless the NiAl underlayers were thick.

In this paper we report on a way to keep the benefits, i.e., small grain size and good in-plane c-axis texture, derived from the NiAl underlayer intact and to improve upon the resulting magnetic properties. We accomplish this by inserting a thin layer of material, called the intermediate layer, between the Co magnetic layer and its NiAl underlayer. When the intermediate layer is thin and has a crystal structure closely resembling either the magnetic layer or the underlayer, it will be less likely to disrupt the existing epitaxial relation or to increase the size of the Co grains. However, the magnetic properties can be changed due to the modifications in surface induced anisotropy, chemistry, interlayer diffusion and interface structure.

The intermediate layer material chosen for this study is Cr because it has a crystal structure similar to the NiAl underlayer. A CoCrPt alloy is used for the magnetic layer. The CoCrPt alloy is one of the best candidates for future high density longitudinal recording media because high coercivities can be easily obtained. The use of Pt has been shown by others to be important in attaining high coercivities [10]. The coercivity of CoCrPt alloys increases in proportion to the Pt content until about 40 at% [11]. However, Pt enlarges the lattice constants of Co alloys. The lattice mismatch between CoCrPt and its Cr underlayer becomes too large to allow good epitaxy as the Pt content increases. Therefore it is difficult to achieve a good in-plane c-axis texture in the CoCrPt/Cr film unless an alloying element is added to the Cr to enlarge its lattice [2] or an HCP intermediate layer is introduced [12]. NiAl has never been used as an underlayer for the CoCrPt alloy. When NiAl is used as an underlayer for the Co alloy it tends to have a lattice match between the (112) NiAl texture and the $(10\bar{1}0)$ texture of Co [9]. This is a much better lattice match than the commonly observed lattice match between the $(11\bar{2}0)$ or $(10\bar{1}1)$ texture of Co and its Cr underlayer. The $(112)/(10\bar{1}0)$ epitaxy will be less disturbed by the lattice expansion of the Co. Therefore NiAl can serve as a better underlayer for inducing crystallographic texture.

The aims of this study are 1) to find out if the NiAl underlayer can give CoCrPt film a crystallographic texture which favors longitudinal recording, and 2) to evaluate the effects of the Cr intermediate layer.

II. EXPERIMENTAL

Thin films of CoCrPt/NiAl with and without intermediate layers were RF sputter deposited onto 1 square inch smooth glass substrates without preheating. CoCr alloy target with bonded Pt chips was used. Other details of the sputtering conditions were described elsewhere. [9] CoCrPt/Cr films were also prepared for comparison purposes. All CoCrPt layers were 40nm thick and sputtered with a -100V substrate bias unless stated otherwise. The Cr and NiAl films were

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deposited without bias. The deposition rates of the CoCrPt, NiAl and Cr were 13.3, 13.1 and 12.8 nm/min respectively. X-ray diffractometry with a Cu K_α radiation was used to characterize films' texture. The CoCrPt films sputtered with a -100V substrate bias were found by energy dispersive x-ray spectroscopy (EDX) to have a composition of Co-10 at%Cr-18 at%Pt. The in-plane magnetic properties of the thin films were measured by a vibrating sample magnetometer (VSM).

III. Results and Discussion

Table I lists the in-plane magnetic properties of a 40nm thick CoCrPt film on Cr, NiAl underlayer and NiAl underlayer with a 2.5nm thick Cr intermediate layer where the underlayers are 100nm thick. The coercivity and squareness values show a dramatic increase due to the presence of the Cr intermediate layer. The change in Mrt is less significant.

Fig. 1 shows the x-ray diffraction spectra of the films listed in Table I. The Co(0002) peak (at 43.1°) shows up in the CoCrPt/Cr film but not in the CoCrPt/NiAl film which is a telltale sign of the better c-axis orientation texture of the CoCrPt/NiAl. In addition, the later film has a visible $(10\bar{1}0)$ Co peak which is another indication of a better in plane c-axis orientation textured film. As expected, the Cr intermediate layer does not corrupt the texture of the CoCrPt/NiAl film; on the contrary, the $Co(10\bar{1}0)$ peak becomes stronger indicating an even better in-plane Co alloy texture. This is consistent with the higher coercive squareness value of the film with a Cr intermediate layer, see Table 1. CoCrPt/NiAl films with Cr intermediate layer thickness ranging from 0.5nm to 100nm were also made. Their x-ray detected textures were very similar and their coercivities stayed high at about 3250 to 3700 Oe. This is indicative that the epitaxial relation between NiAl and CoCrPt is easy to maintain through the Cr intermediate layer even when the Cr layer is relatively thick.

We have also modified the interface of the CoCrPt/Cr films with thin intermediate layers of NiAl. These films showed no changes in CoCrPt's texture but ~18% drop in coercivity.

Table II shows the magnetic property measurements of a series of 40nmCoCrPt/100nmNiAl films with periodically alternating Cr and NiAl intermediate layers. Higher Hc, S and S* are always observed whenever Cr is in contact with the CoCrPt film. Figure 2 plots the x-ray diffraction spectra of the samples in Table 2. A consistent trend is observed which shows that specimens with Cr intermediate layers touching the CoCrPt have stronger $(10\bar{1}0)$ peaks. It is known [13] that the atom relaxation at the NiAl free surface enriches surface Al concentration. This may deteriorate the epitaxy between

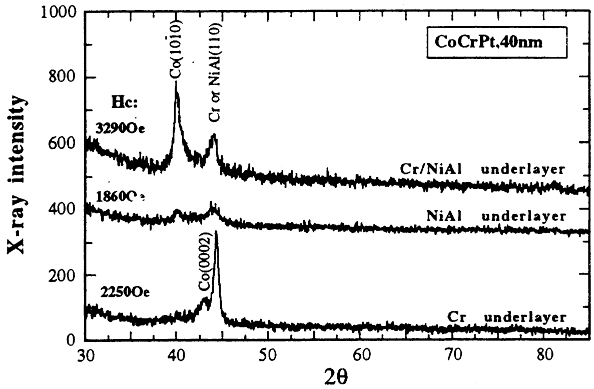

Figure 1. X-ray diffraction spectra of CoCrPt/Cr and CoCrPt/NiAl with and without a 2.5nm Cr intermediate layer.

the CoCrPt and NiAl. The inserted Cr intermediate layer improves this situation and hence allows epitaxial growth.

Figures 3 and 4 show the effects of the Cr intermediate layers on the coercivity of the CoCrPt/NiAl films with various underlayers and CoCrPt layer thicknesses. The CoCrPt/NiAl films with Cr intermediate layers always have the highest coercivity except when the underlayer is thinner than 40nm. However, because NiAl has a smaller grain size than Cr, the higher Hc values of the CoCrPt/Cr films (when underlayers are thin) are possibly due to their larger grain sizes. Figure 5 compares the coercivity of films deposited at different substrate bias voltage. It also shows that the Hc for the CoCrPt/NiAl with a Cr intermediate layer is the greatest for all bias conditions. Because bias sputtering changes both the film composition and microstructure this suggests that the CoCrPt/NiAl film with a Cr intermediate layer always has the highest coercivity among a wide range of composition and microstructure of the CoCrPt. A coercivity as high as 4500 Oe was reached for the film sputtered with -175V substrate bias.

IV. Conclusions

Sputter-deposited NiAl films provide good epitaxial underlayers for the longitudinal recording CoCrPt films but less than ideal in-plane magnetic properties. A Cr intermediate

TABLE I

MAGNETIC PROPERTIES OF CoCrPt FILMS ON DIFFERENT UNDERLAYERS

Underlayer	Hc(Oe)	S(Mr/Ms)	S*	SFD	Mrt(memu/cm^2)
Cr	2250	0.86	0.85	0.18	1.34
NiAl	1850	0.84	0.88	0.16	1.36
Cr/NiAl	3290	0.90	0.95	0.062	1.34

TABLE II

MAGNETIC PROPERTIES OF CoCrPt/NiAl FILMS WITH MULTIPLE INTERMEDIATE LAYERS

Specimen▾	Hc(Oe)	S(Mr/Ms)	S*	SFD	Mrt(memu/cm^2)
A	3290	0.90	0.95	0.062	1.34
B	2330	0.87	0.93	0.088	1.42
C	3210	0.90	0.95	0.058	1.37
D	2420	0.89	0.93	0.083	1.46
E	3560	0.91	0.95	0.059	1.34

▾Specimen's intermediate layer structure:
A: 2.5nmCr
B: 2.5nmNiAl/2.5nmCr
C: 2.5nmCr/2.5nmNiAl/2.5nmCr
D: 2.5nmNiAl/2.5nmCr/2.5nmNiAl/2.5nmCr
E: 2.5nmCr/2.5nmNiAl/2.5nmCr/2.5nmNiAl/2.5nmCr

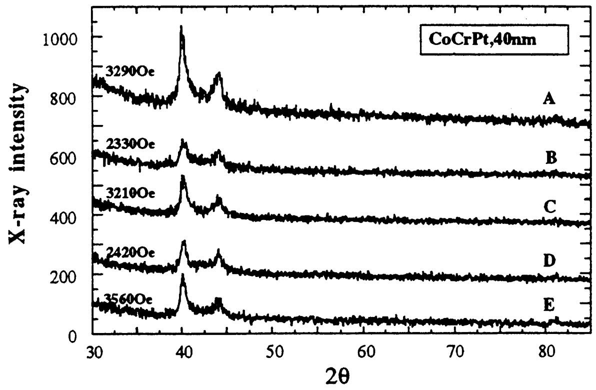

Figure 2. X-ray diffraction spectra of the films listed in Table 2.

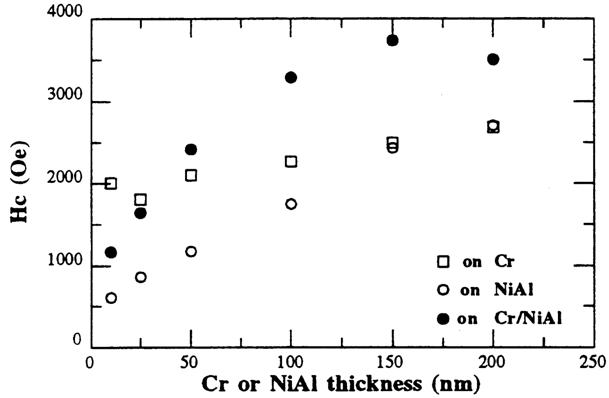

Figure 3. Coercivity vs. underlayer thickness of a 40nm thick CoCrPt film deposited on Cr, NiAl or Cr/NiAl underlayer.

layer dramatically improves the magnetic properties of the CoCrPt/NiAl thin film through texture enhancement and possibly Cr interdiffusion. This study shows that modification of the structure and chemistry of the interface between the Co layer and its underlayer is important for the magnetic properties.

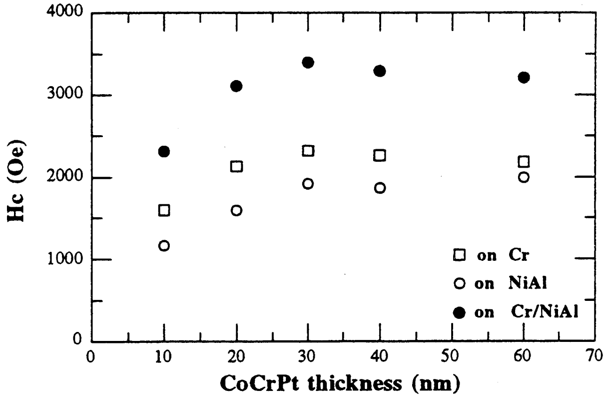

Figure 4. Coercivity of a CoCrPt film on Cr or Cr/NiAl underlayer vs. thickness of the CoCrPt film. All underlayer thicknesses are 100nm.

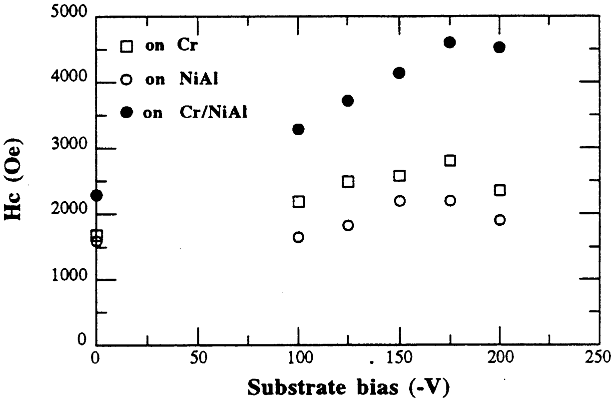

Figure 5. Coercivity of a 40nm thick CoCrPt film on Cr, NiAl or Cr/NiAl underlayer vs. substrate bias voltage during the deposition of CoCrPt. All underlayers are 100nm thick.

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