

## THE DEPENDENCE OF THE MICROSTRUCTURE AND MAGNETIC PROPERTIES OF CoNiCr/Cr THIN FILMS ON THE SUBSTRATE TEMPERATURE

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**Abstract** - Thin CoNiCr/Cr films were deposited on Corning 7059 glass substrate by rf diode sputtering. The CoNiCr layer thickness was fixed at 40 nm; the Cr layer thickness,  $d_{Cr}$ , ranged between 60 and 400 nm. At  $d_{Cr} = 170$  nm, when the substrate temperature before deposition  $T_s$  was set below 100 °C, both the Cr underlayer and the CoNiCr layer were more or less randomly oriented. When specimens were deposited at  $T_s \geq 200$  °C, the Cr layer was strongly {100} textured and the CoNiCr layer was strongly  $\{2\bar{1}10\}$  textured. The CoNiCr  $\{2\bar{1}10\}$  texture is epitaxially favored by the Cr {100} texture. With increasing  $d_{Cr}$ , the Cr {110} texture increased and the CoNiCr  $\{2\bar{1}10\}$  texture decreased. The grain size increased with  $T_s$  and  $d_{Cr}$ . In-plane coercivity,  $H_c$ , initially increased with  $T_s$  to peak at  $T_s = 200$  °C. As  $T_s$  was increased further from 200 to 260 °C,  $H_c$  decreased. The squareness and saturation magnetization were not sensitive to  $T_s$ .

### INTRODUCTION

Sputtered CoNiCr/Cr thin films have been considered as good candidates for longitudinal recording media because of the large values of in-plane coercivity  $H_c$ , saturation magnetization  $M_s$  and squareness  $S$  [1]. The magnetic properties and the structure of CoNiCr/Cr thin films have been studied extensively [1-4]. The magnetic properties of CoNiCr/Cr thin films have been found to be closely related to the crystallographic texture and to the grain size of the CoNiCr layer, which in turn depend on the crystal texture and the grain size of the Cr underlayer [2-4]. In this paper, we present the results of our investigation on the effects of *substrate pre-heating* on the crystal texture and grain size of CoNiCr/Cr/glass specimens. The correlation between the magnetic properties and the structure is discussed.

### EXPERIMENTAL PROCEDURE

Bilayer CoNiCr/Cr thin films were deposited on Corning 7059 glass substrates by rf diode sputtering in a L-H Z400 system employing a Co-30%Ni-7.5%Cr (at.%) alloy target and a Cr target. The base pressure in the deposition chamber was about  $5 \times 10^{-7}$  Torr. The argon pressure was set at 10 mTorr. Both the CoNiCr and the Cr layers were deposited at 10 nm/min. The CoNiCr layer thickness was fixed at 40 nm. The Cr layer thickness ranged between 60 and 400 nm. Before deposition the substrates were pre-heated by an electrical substrate heater to different temperatures.  $T_s$ , the substrate temperature before deposition, was measured by sticking *Tempilable*<sup>®</sup> temperature monitors on the substrate surface. *Tempilables*<sup>®</sup> (Tempel Division of Big Three Industries, S. Plainfield, NJ 07080) are a series of self-adhering "phase-change" or "fusible" indicators. An irreversible color change from black to white occurs at a particular temperature when a crystalline solid turns to liquid. The magnetic properties were measured by vibrating sample magnetometer (VSM). The crystallographic texture was measured by x-ray diffraction using Cu radiation. The microstructure was examined by transmission electron microscopy (TEM).

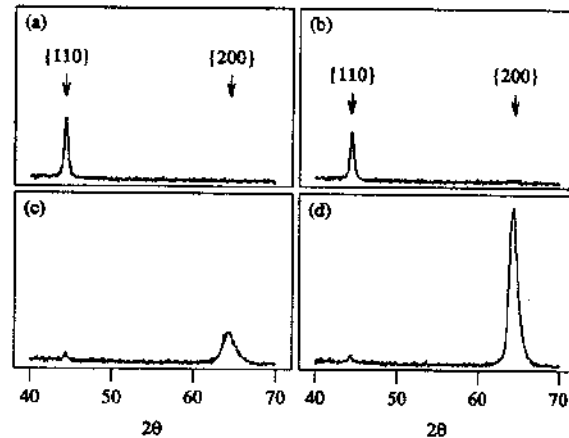


Figure 1. X-ray diffraction spectra of (170 nm) Cr/glass samples deposited at (a)  $T_s = 45$  °C, (b)  $T_s = 105$  °C, (c)  $T_s = 200$  °C and (d)  $T_s = 260$  °C.

### RESULTS AND DISCUSSION

The crystal texture of the Cr underlayer varied with the substrate temperature,  $T_s$ . X-ray diffraction spectra of (170 nm) Cr/glass specimens deposited at different  $T_s$  values are shown in Fig. 1. For  $T_s \leq 105$  °C, only the Cr {110} peak was observed. However, for  $T_s \geq 200$  °C, the {110} peak was weak and the {200} peak became dominant. The intensity of the {110} peak,  $I(110)$ , for  $T_s = 45$  °C was much smaller than the intensity of the {200} peak,  $I(200)$ , for  $T_s = 260$  °C. We conclude that at a film thickness of 170 nm, Cr films prepared at  $T_s \leq 105$  °C are nearly randomly oriented; for  $T_s \geq 200$  °C, the Cr films are strongly {100} textured [5]. The crystal texture of the Cr film also varied with the film thickness,  $d_{Cr}$ . The x-ray diffraction spectra of Cr/glass specimens deposited at  $T_s = 200$  and 260 °C with different  $d_{Cr}$  values are shown in Fig. 2. At a fixed  $T_s$  value,  $I(110)$  increased dramatically when  $d_{Cr}$  was increased from 170 nm to 400 nm, while  $I(200)$  changed little. The favoring of the {110} texture at larger  $d_{Cr}$  values is probably due to the fact that {110} planes have the smallest surface energy in the bcc Cr structure. The {100} texture observed for small  $d_{Cr}$  ( $\leq 170$  nm) films deposited at high  $T_s$  value ( $\geq 200$  °C) is probably due to the nature of the Corning 7059 glass substrate/Cr metal interface [5].

The crystal texture of the CoNiCr layer also varied with  $T_s$  and  $d_{Cr}$ . The x-ray diffraction spectra of (40 nm) CoNiCr/(170 nm) Cr/glass specimens deposited at different  $T_s$  values are shown in Fig. 3. For  $T_s \leq 105$  °C, only one peak at the position of the overlapping Cr {110} and the CoNiCr {0002} peaks was observed [6]. Thus we cannot tell whether the CoNiCr film is {0001} textured or randomly oriented. However, since the intensity of this peak is small, it seems that the CoNiCr layer is probably randomly oriented. For  $T_s \geq 200$  °C, a strong CoNiCr  $\{2\bar{1}10\}$  peak was observed accompanying the strong Cr {200} peak; this indicated that the CoNiCr layer was strongly  $\{2\bar{1}10\}$  textured. The x-ray diffraction spectra of bilayer

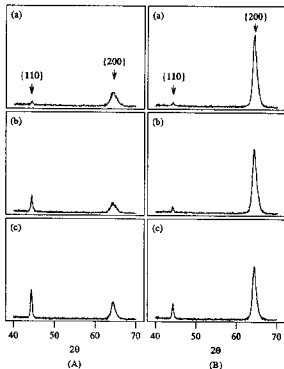


Figure 2. X-ray diffraction spectra of (a)  $d_{Cr} = 170$  nm, (b)  $d_{Cr} = 250$  nm and (c)  $d_{Cr} = 400$  nm Cr/glass samples deposited at (A)  $T_s = 200$  °C and (B)  $T_s = 260$  °C.

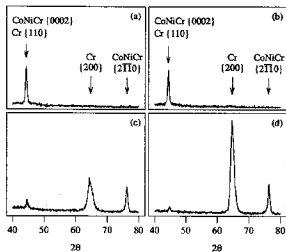


Figure 3. X-ray diffraction spectra of (40 nm) CoNiCr/(170 nm) Cr/glass samples deposited at (a)  $T_s = 45$  °C, (b)  $T_s = 105$  °C, (c)  $T_s = 200$  °C and (d)  $T_s = 260$  °C.

(40 nm) CoNiCr/Cr/glass specimens deposited at  $T_s = 200$  and 260 °C with different  $d_{Cr}$  values are shown in Fig. 4. It is interesting to compare these spectra with the spectra of single layer Cr/glass specimens shown in Fig. 2. From Fig. 2 we see that as  $d_{Cr}$  increases, the Cr {110} texture increases. In Fig. 4 we can see that at fixed  $T_s$  value, when  $d_{Cr}$  was increased from 170 nm to 400 nm, the CoNiCr {2110} peak intensity decreased dramatically. Both Fig. 3 and Fig. 4 indicate that the CoNiCr {2110} peak is strong only when the Cr {200} peak is strong. Therefore we conclude that CoNiCr {2110}

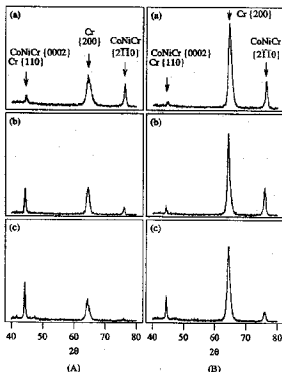


Figure 4. X-ray diffraction spectra of (40 nm) CoNiCr/Cr/glass samples with (a)  $d_{Cr} = 170$  nm, (b)  $d_{Cr} = 250$  nm and (c)  $d_{Cr} = 400$  nm; (A)  $T_s = 200$  °C and (B)  $T_s = 260$  °C.

texture is epitaxially favored by Cr {100} texture [7]. This conclusion is consistent with our earlier microdiffraction results [4].

In Figs. 5a and 5b we show the bright field TEM images of (40 nm) CoNiCr/(400 nm) Cr/glass samples deposited at  $T_s = 105$  and 260 °C, respectively. The grain size increased significantly with increasing  $T_s$ . For  $T_s = 105$  °C, the grain size was about 30 nm. At  $T_s = 260$  °C, the grain size was about 50 nm.

The in-plane coercivity,  $H_c$ , depends both on  $d_{Cr}$  and on  $T_s$ . The  $H_c$  of (40 nm) CoNiCr/Cr/glass specimens with different  $d_{Cr}$  is plotted against  $T_s$  in Fig. 6. Specimens with larger  $d_{Cr}$  have higher  $H_c$  values. At fixed  $d_{Cr}$ ,  $H_c$  initially increased with  $T_s$  up to 200 °C. As  $T_s$  was increased further from 200 °C to 260 °C,  $H_c$  decreased. The changes in  $H_c$  with  $d_{Cr}$  and  $T_s$  are associated with both changes in grain size and crystallographic texture. The grain size increases with both  $d_{Cr}$  and  $T_s$ . The inter-granular magnetic coupling could be reduced with an increase in grain size and the coercivity would increase [8-10]. The decrease in  $H_c$  as  $T_s$  was increased from 200 to 260 °C might be due to oxidation of the Cr underlayer [2,4]. Larger  $T_s$  values favor CoNiCr {2110} texture in which the c-axes of the grains lie in the film plane. We have found the CoNiCr {2110} texture to decrease with increasing  $d_{Cr}$ . It is generally believed that larger  $H_c$  values are associated with the increased presence of crystallite easy axes in the film plane. However, it is not clear from Fig. 6 whether a higher  $H_c$  value is associated with increased CoNiCr {2110} texture. The effects on  $H_c$  of grain size and crystallographic texture cannot be separated. The squareness and saturation magnetization were not sensitive to  $d_{Cr}$  and  $T_s$ .

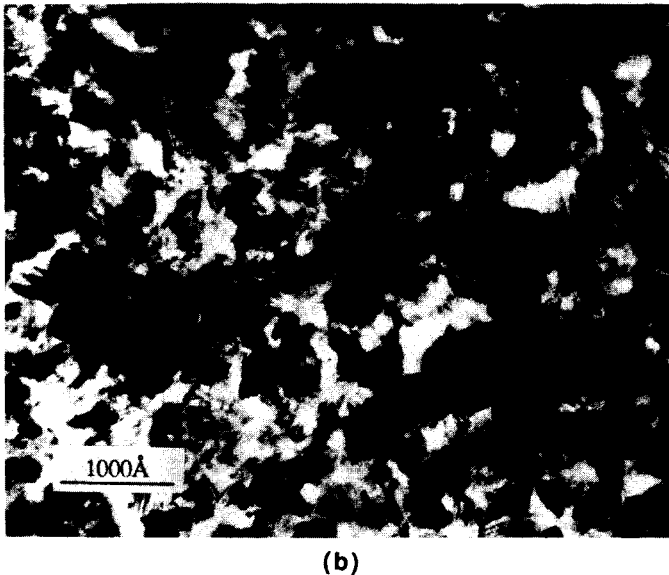
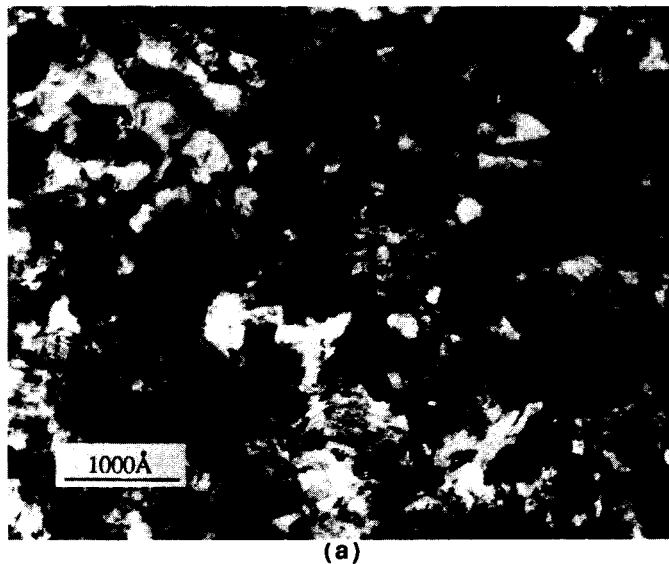


Figure 5. TEM bright field images of (40 nm) CoNiCr/(400 nm) Cr/glass samples deposited at (a)  $T_s = 105$  °C and (b)  $T_s = 260$  °C.

### CONCLUSIONS

The microstructure and magnetic properties of CoNiCr/Cr/glass specimens were studied. For specimens deposited at  $T_s \leq 105$  °C, only a peak at the position of the overlapping CoNiCr {0002} and Cr {110} peaks was observed in the x-ray diffraction spectra. Both the Cr layer and the CoNiCr layer are probably more or less randomly oriented. When  $T_s$  was increased (by substrate pre-heating), the Cr {100} texture increased; the CoNiCr  $\{2\bar{1}10\}$  texture also increased due to epitaxial growth. At fixed  $T_s$  values, with increasing  $d_{Cr}$ , the Cr {110} texture increased and the CoNiCr  $\{2\bar{1}10\}$  texture decreased. The CoNiCr grain size increased with increasing  $T_s$  and  $d_{Cr}$ . In-plane coercivity,  $H_c$ , increased with  $T_s$  initially to peak at  $T_s = 200$  °C. As  $T_s$  was increased further to 260 °C,  $H_c$  decreased. The changes in  $H_c$  are probably associated with changes in grain size. The effect of the CoNiCr  $\{2\bar{1}10\}$  texture on  $H_c$  is not clear from the  $H_c$  vs.  $T_s$  relation.

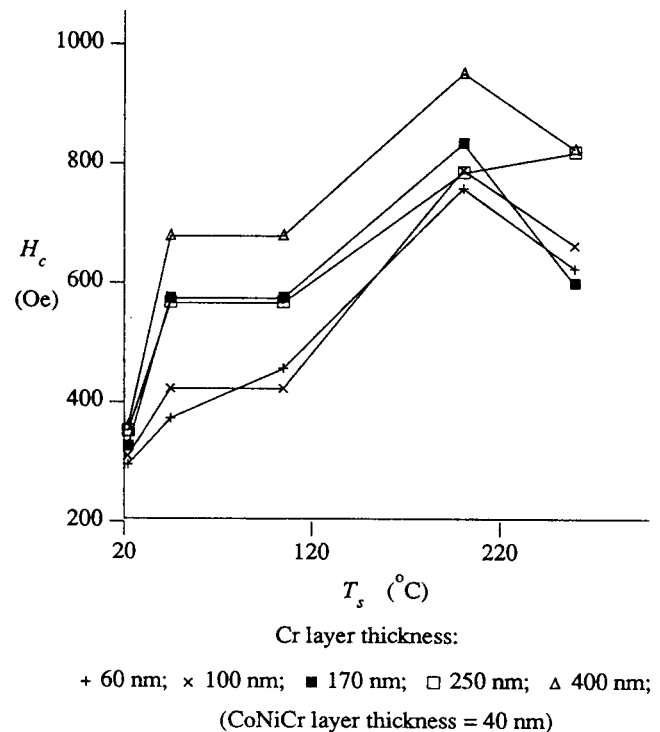


Figure 6.  $H_c$  vs.  $T_s$  for CoNiCr/Cr/glass samples with various Cr underlayer thicknesses.

### ACKNOWLEDGEMENT

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### FOOTNOTE

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