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EFFECTS OF Pt AND Cr ADDITION ON MAGNETIC PROPERTIES IN Co-Cr-P-Pt MAGNETIC THIN FILMS

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Abstract—We studied the effects of Pt and Cr addition in a new Co-Cr-P-Pt alloy system with the coercivity higher than 2000 Oe even when they were deposited without substrate heating and bias voltage. The coercivity of the films increased from 1000 to 2000 Oe or higher by addition of 12 at.%Pt. The variation of the anisotropy field with increasing Pt content was similar to that of the coercivity. This indicate that the increase of the coercivity might be associated with increase of the anisotropy field with Pt addition. With the addition of Cr, the coercivity of the films increased up to 8 at.%Cr and the coercive squareness of the films decreased. The angular variation of coercivity deviated at a lower angle from domain wall motion mode as the Cr content increases. From these result, it is believed that the grain isolation of the films is enhanced with the addition of Cr.

I. INTRODUCTION

Developments of high coercivity media at very thin thickness are essential for ultra high density recording. We have reported Co-Cr-P-Pt thin films with coercivities higher than 2600 Oe at a thickness of 180 Å (M_r·t value of 0.9 memu/cm^2) even when they were deposited without substrate heating and bias voltage[1], and our previous work showed phosphorus was an effective element for the enhancement of grain isolation and the reduction of out-of-plane orientation[2]. In this paper, we discussed the effects of the Pt and Cr addition on the magnetic properties in Co-Cr-P-Pt thin films.

II. EXPERIMENTAL PROCEDURE

Samples were prepared by using dc magnetron sputtering on circumferentially textured Ni-P/Al substrates and non-textured glasses. The composition of films was varied by changing the number of Co_4P_3, Pt and Cr chips placed on a Co-7 at.%Cr target or pure Co target. Sputtering conditions are listed in table I.

Table I. Sputtering conditions

Target	Cr(99.9 %) Co-7 at.%Cr + Co_4P_3, Pt, Cr chips Co(99.9 %) 〃
Substrate	textured Ni-P/Al-Mg Corning 2948 glass
Background pressure	less than 5 × 10^{-7} torr
Sputter pressure	10 mtorr (99.999 % Ar)
Ar flow rate	50 SCCM
Sputter Power	Cr underlayer : 460 W magnetic layer : 300 W
Substrate temperature	room temperature
Film thickness	Cr underlayer : 1000 Å magnetic layer : 500 Å

The composition of magnetic layers were determined by wavelength dispersive spectroscopy. The magnetic properties were measured by a vibrating sample magnetometer. The anisotropy of films were studied by a torque magnetometer using the films sputtered on textured Ni-P/Al substrates. The crystalline structures were analysed by XRD using the films sputtered on glass substrates.

III. RESULTS AND DISCUSSION

A. Effects of Pt

Fig. 1 shows the coercivity of $CoCr_{3-4}P_{11-14}Pt_x$ films with varying Pt content. The coercivity of the films increased from 1000 Oe to 2000 Oe or higher by addition of 12 at.%Pt. When Pt content exceeded 12 at.%, the coercivity of the films decreased. Fig. 2 and 3 show the variation of the squareness and coercive squareness of $CoCr_{3-4}P_{11-14}Pt_x$ films with varying Pt content. The squareness and the coercive squareness of the films increased up to 12 at.%Pt and kept nearly constant with the addition of Pt. The magnetic properties of films deposited on the glass substrates behaved very similarly to those of films deposited on Ni-P/Al substrates. In order to investigate the effect of Pt on the coercivity of the films, the

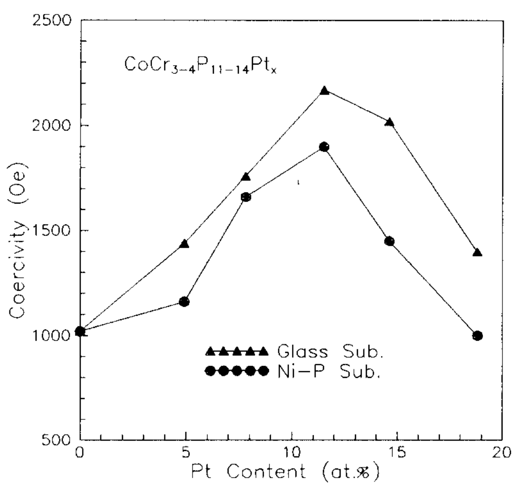

Fig. 1 Variation of coercivity with Pt content

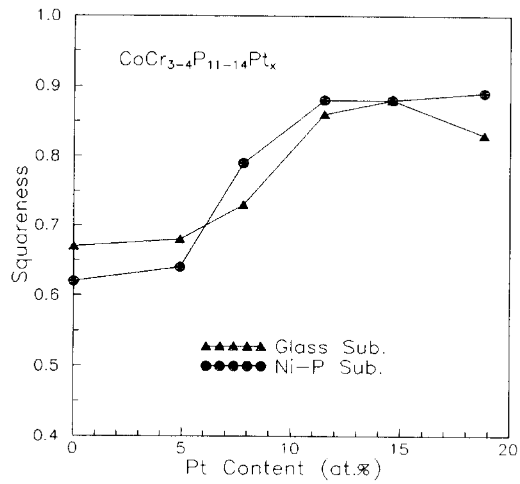

Fig. 2 Variation of squareness with Pt content

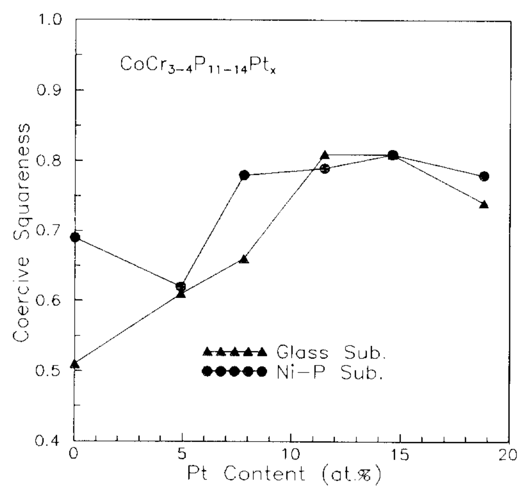

Fig. 3 Variation of coercive squareness with Pt content

preferred orientation of the films and the variation of anisotropy field with the addition of Pt was studied.

X-ray diffraction patterns of $CoCr_{3-4}P_{11-14}Pt_x$ films are shown in Fig. 4. The change of the preferred orientation of the films is not clear because the X-ray diffraction peak position of Co (0002) and $(10\bar{1}1)$ overlaps with that of Cr (110). We attempted to deconvolve the Co $(10\bar{1}0)$, (0002),

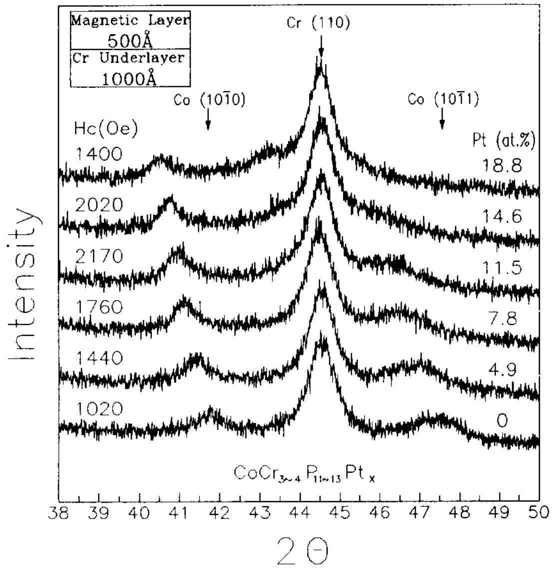

Fig. 4 Variation of XRD spectra with Pt content

(10$\bar{1}$1) peaks and Cr (110) peak by Lorentzian curve fitting. Relative intensities of Co (10$\bar{1}$0), (0002) and (10$\bar{1}$1) peaks of the films were represented by "orientation coefficients[3]":

$$TC_{hkl} = \frac{\left(\frac{I_{hkl}}{I_{r,hkl}}\right)}{\frac{1}{n}\Sigma\left(\frac{I_{hkl}}{I_{r,hkl}}\right)} \quad (1)$$

where TC_{hkl} represents orientation coefficient of (hkl), I_{hkl} and $I_{r,hkl}$ represent the intensity of (hkl) of specimen and powder, respectively, and n represents the number of peaks. It is frequently reported that enhancement of in-plane preferred orientation of easy axis results in the increase of coercivity. But our result(table II), in-plane preferred orientation was not improved by the addition of Pt, therefore, it is thought that the increase of coercivity is not due to the enhancement of in-plane preferred orientation.

The anisotropy of the films was also studied.

Table II. Variation of orientation coefficient of $CoCr_{3\text{-}4}P_{11\text{-}14}Pt_x$ films with Pt content.

Pt Content	Orientation Coefficient		
(at.%)	(10$\bar{1}$0)	(0002)	(10$\bar{1}$1)
0.0	2.47	-	0.47
4.9	2.43	0.12	0.45
7.8	2.09	0.46	0.45
11.5	2.03	0.57	0.41
14.6	1.82	0.77	0.42
18.8	1.76	0.96	0.29

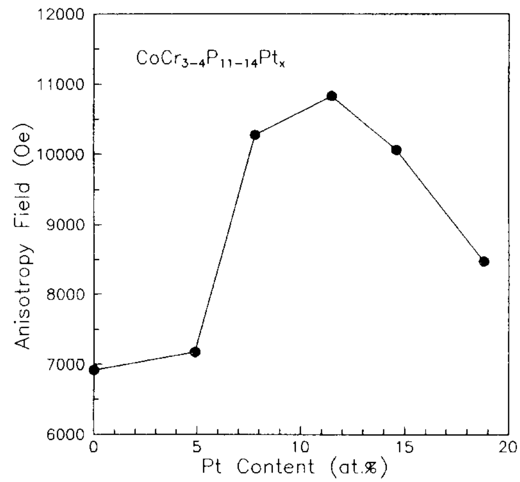

Fig. 5 Variation of anisotropy field with Pt content

Fig. 5 shows the variation of the anisotropy field of films with varying Pt contents. The anisotropy field of films was obtained by dividing the peak-to-peak torque(determined by extrapolation to infinite field[4]) by saturation moment of the sample(measured by VSM). The variation of the anisotropy field of the films behaved very similarly to that of the coercivity. This implies that increase of the coercivity of the films with the addition of Pt is directly related to the increase of the anisotropy field.

B. Effects of Cr

Fig. 6 shows the variation of the coercivity of

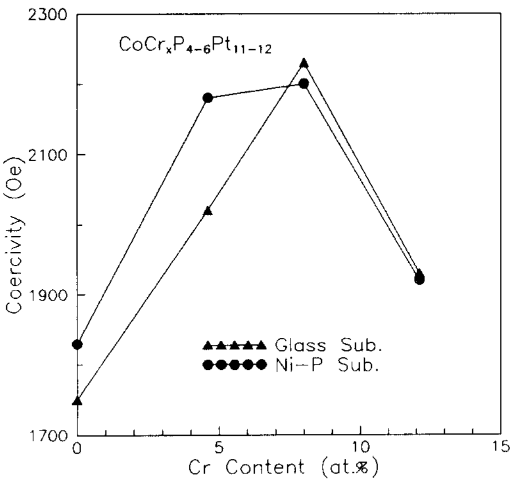

Fig. 6 Variation of coercivity with Cr content

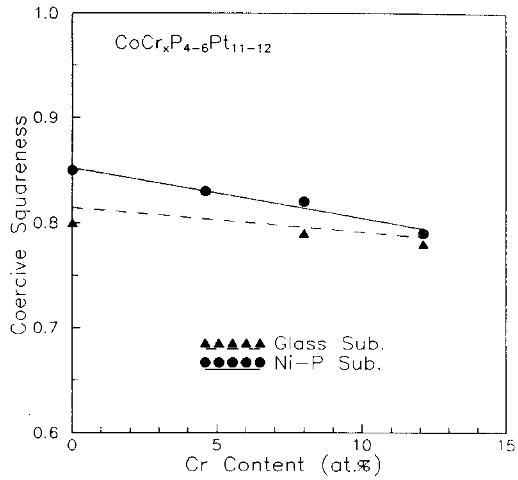

Fig. 8 Variation of coercive squareness with Cr content

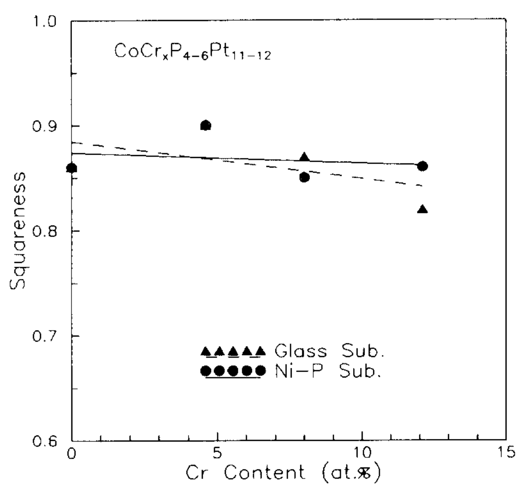

Fig. 7 Variation of squareness with Cr content

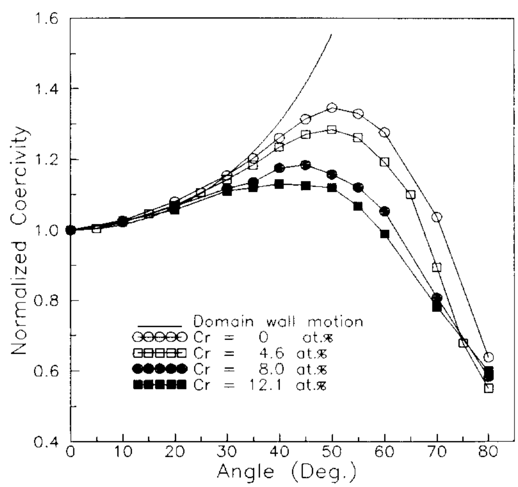

Fig. 9 Angular variation of coercivity with varying Cr content

CoCr$_x$P$_{4-6}$Pt$_{11-12}$ films with varying Cr content. The coercivity of films increased from 1800 Oe to 2200 Oe by addition of 8 at.%Cr. The squareness and the coercive squareness slightly decreased with increasing Cr content, as shown in Fig. 7 and 8. The decrease of coercive squareness of films may be associated with enhancement of grain isolation by the addition of Cr.

Fig. 9 shows the angular variation of coercivity with varying Cr content. With the addition of Cr, the angular variation of coercivity deviates at a lower angle from domain wall motion mode as the Cr content increases. This indicates other magnetization reversal mechanisms may take over as the Cr content increases in the films. The change of magnetization reversal mechanism is associated with grain isolation[5]. The result of the angular variation of coercivity also coincides with the decrease of coercive squareness with Cr addition. This can be associated with the enhancement of grain isolation with Cr addition.

IV. CONCLUSIONS

(1) The coercivity of the films increased from 1000 to 2000 Oe or higher by addition of 12 at.%Pt. This might be associated with the increase of the anisotropy field with Pt addition.

(2) With the addition of Cr, the coercivity of the films increased up to 8 at.%Cr and the coercive squareness of the films decreased. The angular variation of coercivity deviates at a lower angle from domain wall motion mode as the Cr content increases. This can be associated with the enhancement of grain isolation with Cr addition.

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