Temperature dependence of coercivity in Co-based longitudinal thin-film recording media

Tao Pan,[a] Geoffrey W. D. Spratt, Li Tang, Li-Lien Lee, Yongchang Feng, and David E. Laughlin
Data Storage Systems Center, Carnegie Mellon University, Pittsburgh, Pennsylvania 15213

The coercivity of Co-based (CoCrTa and CoCrPt), disk media was found to depend on temperature. The thinner the film, the smaller the switching unit ($K_u V$), and the larger $dH_c/H_c\, dT$. $dH_c/H_c dT$ for CoCrTa (400 Å) on different underlayers or intermediate layers is generally larger than that of CoCrPt (400 Å) on different underlayers or intermediate layers. The temperature dependence of coercivity in Co-based disk media is caused by the temperature dependence of crystalline anisotropy of Co and small switching unit of the media. [S0021-8979(97)35308-0]

I. INTRODUCTION

As the recording areal density approaches 10 Gbits in.^{2}, thermal effects on disk media becomes of major concern in longitudinal recording technology.[1] Previous work has focused on the moment decay in a dibit.[1] This article focuses on another aspect of the thermal effect of disk media: the temperature dependence of coercivity of Co-based disk media. The time dependence of coercivity for particulate tape media has been of interest for many years.[2] Recently, it was found that metal evaporated tape media (CoNiO and Co–CoO) exhibit a large temperature dependence of coercivity.[3] In this article we investigate the temperature dependence of coercivity for state-of-the-art Co-based disk media.

II. EXPERIMENT

The fabrication of the disk media used in this article has been previously documented.[4–6] The temperature dependence of coercivity for these media was measured using a DMS-1660 dual VSM/torque magnetometer. The time dependence of coercivity of the media was measured[3] using a Micromag 2900 alternating gradient magnetometer (AGM). The coercivity was measured across six decades in time.

III. EXPERIMENTAL RESULTS

A. Temperature dependence of coercivity in CoCrTa media

The temperature dependence of coercivity for four samples of $Co_{80}Cr_{18}Ta_2$/Cr (1000 Å), made under the same deposition conditions but of CoCrTa thickness ranging from 100 to 800 Å, is shown in Fig. 1. Their switching volumes, listed in Table I, were obtained by measuring the time dependence of coercivity.[3] The grain size of each film, shown in Figs. 2(a)–2(d), qualitatively can be seen to increase with film thickness but is difficult to quantitatively characterize. The temperature dependence of coercivity and $K_u V/k_B T$ of fixed thickness CoCrTa (400 Å) with different underlayers or intermediate layers or bias voltages are listed in Table II. The temperature dependences of coercivity for CoCrTa media deposited at different bias voltages (samples F and G) are approximately the same, so the bias voltage does not appear to have an effect on the temperature dependence of coercivity. Since increasing bias voltage results in a Ta-enriched medium,[7] the results indicate that the composition of Ta does not play an important role in determining the temperature dependence of coercivity for these media. The values of $dH_c/H_c\, dT$ are between 0.29%/°C and 0.39%/°C. Although sample G was observed to have a smaller and more uniform Cr grain size compared to the rest of the samples,[5] no significant difference between its $dH_c/H_c\, dT$ and that of the rest of the samples was found. This might be caused by an enhanced K_u due to the possible better lattice matching between the CoCrTa $(10\bar{1}1)$ and 10 nm Cr (110)/NiAl (90 nm). When the deposition order Cr (10 nm)/NiAl (90 nm) was reversed into NiAl (10 nm)/Cr (90 nm), the lattice matching between the Co and NiAl (10 nm)/Cr (90 nm) was worse than that between Co and Cr (10 nm)/NiAl (90 nm). Therefore, it is possible that the relatively severe temperature dependence of coercivity for sample H is due to the weak K_u of this sample. It appears that the CoCrTa film thickness has a much more severe effect on $dH_c/H_c\, dT$ of the medium than the underlayer or intermediate layer structure.

The temperature dependence of coercivity of CoCrTa (400 Å) with different thickness Cr, shown in Fig. 3, is approximately the same when the Cr thickness is over 100 nm. Cr underlayer thickness has a smaller effect on the tempera-

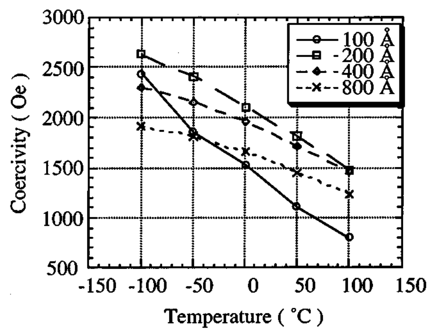

FIG. 1. H_c vs temperature for different thicknesses of CoCrTa/Cr (100 nm).

[a]Present address: IBM, 5600 Cottle Rd., San Jose, CA 95193.

TABLE I. Comparison of the switching volumes and $dH_c/H_c\ dT$ of four different thickness CoCrTa media.

Medium	K_uV/k_BT	$dH_c/H_c\ dT$ (%/°C)	Sample
CoCrTa (100 Å)/Cr (1000 Å)	80	0.65	A
CoCrTa (200 Å)/Cr (1000 Å)	127	0.34	B
CoCrTa (400 Å)/Cr (1000 Å)	169	0.29	C
CoCrTa(800 Å)/Cr (1000 Å)	260	0.29	D

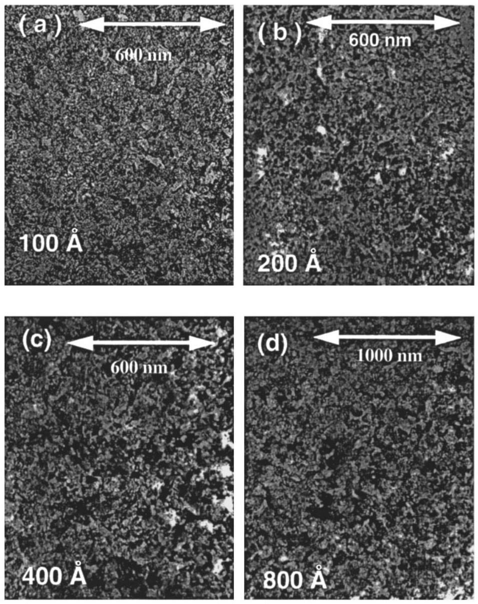

FIG. 2. Bright field images different thicknesses of CoCrTa/Cr (1000 Å).

TABLE II. Switching volumes and $dH_c/H_c\ dT$ for CoCrTa (400 Å) with different underlayers and different bias voltages.

Bias voltage (V)	Underlayer	K_uV/k_BT	$dH_c/H_c\ dT$ (%/°C)	Sample
−200	Cr (100 nm)	212	0.31	E
0	Cr(10 nm)/NiAl (90 nm)	219	0.32	F
−200	Cr (10 nm)/NiAl (90 nm)	229	0.33	G
−200	NiAl (10 nm) Cr (90 nm)	218	0.38	H
−200	NiAl (125 nm)	253	0.29	I
−200	NiAl (100 nm)	226	0.35	J

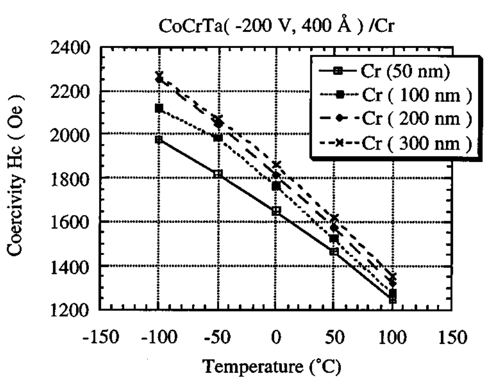

FIG. 3. H_c vs T for CoCrTa with different thicknesses of the Cr underlayer.

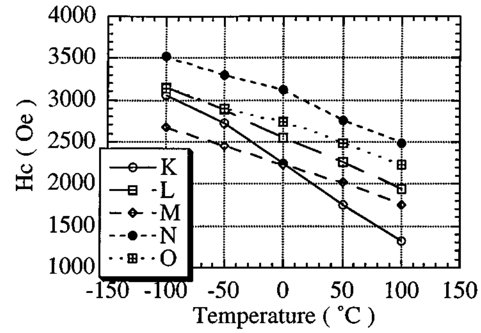

FIG. 4. H_c vs T for different thicknesses of CoCrPt/Cr (1000 Å, −200 V).

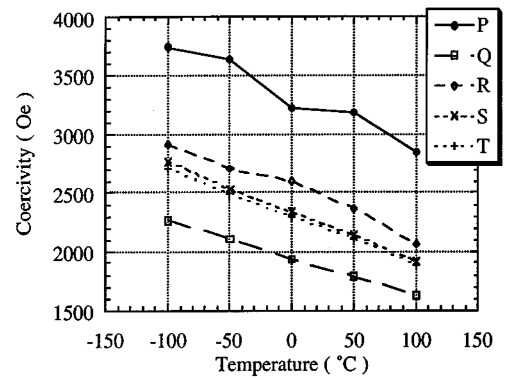

FIG. 5. H_c vs T for CoCrPt for different underlayers or intermediate layers.

TABLE III. Switching volumes and $dH_c/H_c\ dT$ of different thickness CoCrPt media.

Medium	K_uV/k_BT	$dH_c/H_c\ dT$ (%/°C)	Sample
CoCrPt (100 Å)/Cr (1000 Å)	89	0.50	K
CoCrPt (200 Å)/Cr (1000 Å)	210	0.27	L
CoCrPt (400 Å)/Cr (1000 Å)	317	0.23	M
CoCrPt (600 Å)/Cr (1000 Å)	404	0.23	N
CoCrPt (800 Å)/Cr (1000 Å)	408	0.21	O

TABLE IV. Switching volume and $dH_c/H_c\ dT$ for CoCrPt with different underlayers.

Underlayer	K_uV/k_BT	$dH_c/H_c\ dT$ (%/°C)	Sample
Cr (25 Å)/Nial (100 nm)	450	0.12	P
Cr (100 nm)	270	0.20	Q
NiAl (25 Å)/Cr (100 nm)	287	0.17	R
Cr (100 nm) 260 °C heating	356	0.19	S
NiAl (100 nm)	290	0.20	T

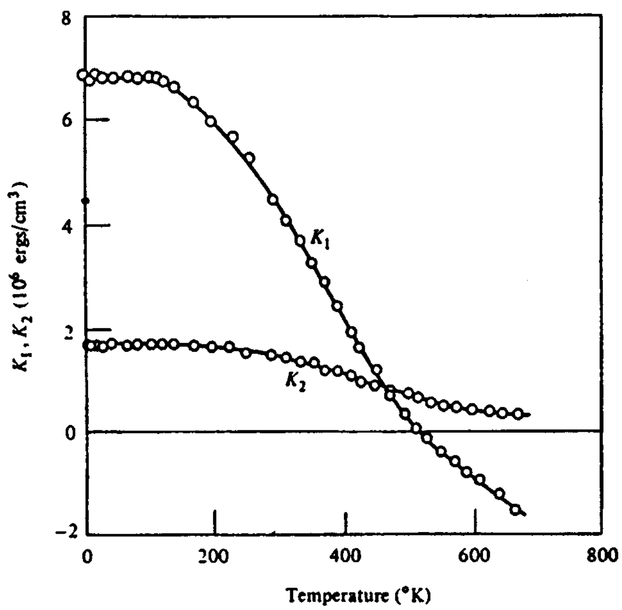

FIG. 6. Variation of anisotropy constant of Co with temperature.

ture dependence of coercivity than does the CoCrTa thickness.

B. Temperature dependence of coercivity in CoCrPt media

Another important Co-based disk medium is CoCrPt. The temperature dependence of coercivity for the five different thickness of $Co_{72}Cr_{10}Pt_{18}$/Cr(1000 Å) is shown in Fig. 4. Their switching volumes and $dH_c/H_c\ dT$ are listed in Table III. $dH_c/H_c\ dT$ increases and K_uV/k_BT gets smaller as the film becomes thinner, which is in agreement with the trend observed previously.

The switching volumes and $dH_c/H_c\ dT$ for CoCrPt (400 Å), deposited at a bias voltage of −100 V with different underlayers, are listed in Table IV. In general, the temperature dependence of coercivity for CoCrPt is less severe than CoCrTa, because CoCrPt has a higher anisotropy[8] and larger grain size[9] than CoCrTa. CoCrPt (400 Å)/Cr (25 Å)/NiAl (100 nm) medium[6] has the highest coercivity among the other CoCrPt media, which probably indicates that it has the highest anisotropy for all the CoCrPt on different underlayers and intermediate layers, shown in Fig. 5. This might be the explanation for the low $dH_c/H_c\ dT$ for CoCrPt (400 Å)/Cr (25 Å)/NiAl (100 nm). Furthermore, all the coercivities of CoCrPt and CoCrTa show linear dependence on temperature except CoCrPt (400 Å)/Cr (25 Å)/NiAl (100 nm), which is not yet fully understood.

IV. DISCUSSION AND CONCLUSIONS

The crystalline anisotropy of cobalt is known to depend on temperature, as shown in Fig. 6. $dK_u/K_u\ dT$ of cobalt is about −1.0%/ °C at room temperature.[10] Therefore, it is conceivable that the temperature dependence of K_u can cause the temperature dependence of coercivity. In addition, small K_uV/k_BT can also cause the temperature dependence of coercivity.

The thinner the film, the smaller the switching unit K_uV, and the larger $dH_c/H_c\ dT$. As the Co-alloy disk film gets thicker, in addition to a larger switching volume, K_u can also increase. $dH_c/H_c\ dT$ for CoCrTa (400 Å) on different underlayers or intermediate layers is generally larger than that of CoCrPt (400 Å) on different underlayers or intermediate layers. This temperature dependence of coercivity in Co-based disk media might be an issue for high linear density recording.

ACKNOWLEDGMENTS

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