DISTRIBUTION OF HYSTERESIS LOSS IN SPUTTERED CoCr FILMS

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Abstract. – The distribution of the hysteresis loss (ΔW_h) for films with a high $H_{c\perp}/H_k$ ratio shows a monotonically decreasing behaviour with applied field (H_a) while medium and low $H_{c\perp}/H_k$ exhibit a double peak characteristic. The high field peak agrees with H_{cw} as determined from domain observations. By changing the direction of H_a from perpendicular to an in-plane direction, the ΔW_h to the in-plane orientation of M is shown.

1. Introduction

Several experimental methods have been published in order to understand the magnetization process in sputtered CoCr films for perpendicular recording. The domain behaviour has been studied by magneto-optical Kerr effect [1-3], Bitter powder method [4] and colloid SEM method [5, 6]. The VSM hysteresis loop was studied [7, 9] by means of the initial slope as a function of the angle between the easy axis and applied field (H_a) [10] and also with the aid of the dependence of the magnitude of H_a [11, 12]. It has been shown [13] that the normalized hysteresis loss as a function of the orientation of H_a can be used as a criterium to

determine the reversal mechanism in CoCr. We have discussed this by introducing the distribution of the hysteresis loss (ΔW_h) as a function of H_a in the VSM loop [14] by:

$$\Delta W_h = \int_{H_{a1}}^{H_{a2}} d(M_1 - M_2) dH/W_h \quad (1)$$

Here M_1 and M_2 represent the magnetization of the descending and ascending curves of the VSM loop for a maximum $H_a = 800$ kA/m.

2. Experimental

The relevant properties of the analysed RF magnetron sputtered films are given in table I. The samples

Table I. – Magnetic properties of CoCr films.

No #	Sample	M_s kA/m	h nm	$H_{c\perp}$ kA/m	$H_{c\perp}/H_k$	H_n kA/m	H_{cw} kA/m	H_2 kA/m
1	0203 - 1	402	520	8	1.5	320	260	256
2	0218 - 6	426	650	32	5.5	368	212 - 272	256
3	0218 - 8	434	700	60	8.9	448	~ 188	—
4	0204 - 2	410	1 230	8	1.4	352	312	296
5	0211 - 2	441	760	10	1.7	364	236	250
6	0203 - 8	423	700	18	3.2	352	272	265
7	0218 - 2	413	1 220	46	7.5	395	248 - 300	245

Fig. 1.

Fig. 1. – The behaviour of ΔW_h vs. H_a for a low $H_{c\perp}/H_k$ film (# 1) at four different orientations of H_a with respect to the film.

Fig. 2.

Fig. 2. – The behaviour of ΔW_h vs. H_a for low, medium and high $H_{c\perp}/H_k$ films for H_a perpendicular (0°) and in-plane (90°).

are typical representatives of our classification scheme low, medium and high coercivity ($H_{c\perp}/H_k$) [2]. In the figures 1 and 2 measured data from such samples are given with $H_{c\perp}/H_k$ values of 1.5, 5.5 and 8.9 % respectively. From the hysteresis loop we can indicate several characteristic fields such as the nucleation field H_n , which is determined as the field where the first reversed domain is nucleated. This field is experimentally determined by the linear extrapolation of the measured domain density to one domain per square unit area [1, 2]. Another important field is the domain wall coercivity (H_{cw}) which is estimated where the stripe-out of the nuclei occurs.

3. Low $H_{c\perp}/H_k$ films

The domain photographs are obtained by Kerr microscopy and shown in figure 1 in their relation to ΔW_h vs. H_a for a low coercivity sample (# 1) at a direction perpendicular (0°) to the film plane. Coming from saturation the first nucleated domains are observed at an applied field of about 300 kA/m. It is nearly impossible to observe smaller domains because of the limited resolution of the method used [1]. A H_{cw} value is determined at the H_a where the first nuclei have been striped-out. From the data it can be seen that a double peak behaviour appears at a lower field H_3 and at a higher field H_2 . Another field (H_1) can be determined at $\Delta W_h = 0$. In figure 1 it can be seen that the peak behaviour changes as the direction of the applied fields varies from perpendicular (0°) to in-plane (90°). In that case H_2 will gradually move to a higher field while the low field peak is independent of the direction of the field. The amplitude of H_2 decreases gradually while H_3 increases. The latter is related to the in-plane magnetization component of the CoCr layer and is observed for all orientations of H_a . In the case of high $H_{c\perp}/H_k$ this peak will become more and more pronounced as H_a is applied at an angle $> 20^\circ$ [14]. All our magnetron sputtered films show the initial-layer effect by the typical jump at zero field in the in-plane hysteresis loop [12]. The orientation of the magnetization of such a layer increases with a decreasing $H_{c\perp}/H_k$ ratio [13]. It can be seen in figure 1 that a strong relationship exists between the H_{cw} (determined from the Kerr photo's) and the value of the high field peak (H_2) determined from the ΔW_h vs. H_a curve. The data of the films with other properties are presented in table I.

4. Comparison low, medium and high $H_{c\perp}/H_k$ films

In figure 2 ΔW_h vs. H_a is shown for low (# 1), medium (# 2) and high (# 3) $H_{c\perp}/H_k$ films for the perpendicular (black symbols) and in-plane direction (open symbols) of the field applied. For the perpendicular direction the high $H_{c\perp}/H_k$ film shows a decreasing behaviour and low field peak is not observed. If H_a is applied in the plane of the films the low field peak is

present for all samples studied. The high field peak is not observed for the high $H_{c\perp}/H_k$ films but clearly seen for low coercivity samples if H_a is applied perpendicular to the sample. The height of the peak at $H_a \sim 0$ is larger for low than for high $H_{c\perp}/H_k$ films. The medium $H_{c\perp}/H_k$ samples show an intermediate behaviour.

The influence of the in-plane orientation of the magnetization is shown by changing the direction of H_a from perpendicular to an in-plane direction. It is shown (Fig. 1) that for low $H_{c\perp}/H_k$ samples the in-plane component is present for all orientations of H_a . It can be concluded from this that the reversal has been considered as the superposition of the domain-wall motion both perpendicular and in-plane orientation of the magnetization (see also [11, 12, 14]).

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