A SURVEY OF THE MAGNETIZATION REVERSAL FOR CoCr FILMS AND
SOME PARTICULATE RECORDING MEDIA

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Abstract: In addition to previous research on the magnetisation reversal for sputtered CoCr films, two particulate perpendicular recording media, namely Ba-ferrite and Alumite have been measured. For comparison an isotropic Ba-ferrite sample and an in-plane γFe₂O₃ magnetic tape have also been evaluated. Only a few properties are compared which have been determined from the field- and angle-dependent VSM measurements. It was discovered for high Hc/IH CoCr films and the orientated Ba-ferrite media, in which the perpendicular anisotropy mainly results from crystalline anisotropy, that the magnetisation reversal is mainly controlled by a Co-type of incoherent rotation. On the other hand, for a magnetic tape having a high longitudinal orientation ratio, the magnetisation reversal is determined by the curling-type of incoherent rotation. The isotropic Ba ferrite media exhibit rather good in-plane characteristics. For Alumite (an array of Fe needles) it was found that the measured reduced coercivity vs. reduced diameter fit very well with the theoretical curling mode. But if the applied field deviates from the film normal, the magnetisation reversal can be interpreted from the superposition of Co-type of incoherent rotation and a contribution from the demagnetising field and dipole-dipole field.

INTRODUCTION.

In order to fully appreciate the latent potentialities of the characteristics of high density recording for CoCr films having perpendicular anisotropy, it is essential to investigate whether the magnetization is switched by rotation reversal or domain-wall motion. Although the controversy about the magnetization reversal mechanism has gone on for a long time, at present the published experimental data show that none of the classical models can be directly used to explain the angular dependence of the coercivity and remanent coercivity for CoCr films. In an attempt to clarify this problem, an enormous number of papers have been published based on experimental data from "microscopical" domain-observations, "macroscopical" VSM-loop measurements and computational modelling. In this paper a start is made to compare VSM measurements from different media having a perpendicular anisotropy and various microstructures and morphologies. Special attention is paid to the dependences of angle and amplitude of the applied field during measurement of the VSM-hysteresis loops. This is because it is a more realistic situation in recording processes; namely a media passing the head experiences fields that vary both in magnitude and direction. It is generally believed that the morphology for CoCr with high coercivity consists of columnar grains separated by an enriched Cr boundary. In order to compare the similarities and differences between sputtered CoCr films and other particulate recording media in this paper we shall concentrate our attention on investigating the relation between the magnetization reversal and the angular dependence of the magnetic parameters for perpendicular Ba-ferrite and Alumite media. For comparison an isotropic Ba-ferrite sample and in-plane γFe₂O₃ magnetic tape have also been measured. It is generally agreed that the smallest magnetic particles in the particulate media mainly consist of single-domain particles with an organic binder. It can be said that research on the nature of magnetic processes for particulate media will contribute to a better understanding of the magnetic behaviour in certain CoCr samples.

SAMPLE PROPERTIES

The most relevant data obtained from VSM and Torque measurements are summarized in Table 1. The maximum applied field is 800 kA/m. The CoCr films were RF sputtered. Sample #1 and #2 were made by Dr. Maeda (NTT Japan) having a so-called homogenous and fully segregated microstructure respectively [1]. The isotropic Ba-ferrite medium (#3) was punched from a commercial flexible magnetic disk. The related experimental data for a perpendicularly oriented Ba-ferrite medium (#4) are quoted from [2]. The two Alumite samples (#6,7) were supplied by Yamaha Japan. The longitudinally orientated sample was made from a commercial γFe₂O₃ tape. The CoCr samples #8,9 were made by Hitachi Japan with and without a Ge seed layer by a roll-coating process. The definitions of some parameters used are as follows:

1. The angle (θ) is defined as the angle between the applied field (Ha) and the easy axis of the recording media.
2. The coercivity Hc(0) along the easy axis is the measured value at θ = 0.
3. The squareness ratio Rs (θ) = Mr(θ)/Ms (uncorrected

<table>
<thead>
<tr>
<th>Table 1. Properties of the samples used.</th>
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<td>no samples</td>
<td>thickness (μm)</td>
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<tr>
<td>1 CoCr</td>
<td>2.4</td>
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<td>2</td>
<td>2.39</td>
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<tr>
<td>3 Ba-ferrite</td>
<td>96.7</td>
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<tr>
<td>4</td>
<td>12.1</td>
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<tr>
<td>5 γFe₂O₃</td>
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<tr>
<td>6 Alumite</td>
<td>2.19</td>
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<td>7</td>
<td>1.16</td>
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<tr>
<td>8</td>
<td>1.12</td>
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<tr>
<td>9 CoCr</td>
<td>2.41</td>
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for the demagnetization field). This reflects the ratio of the remanence to the saturation magnetization under a certain direction (θ).

4. The relative orientation ratio OR(θ) = Rs(θ)/Rs(θ) is the relative ratio of the squareness ratio value in the easy direction of the magnetization to that at other angles of Ha. The larger OR(θ), the better the magnetic orientation.

5. The parameters denoted by an index ⊥ or || are respectively normal or in-plane to the sample surface.

ABOUT CoCr FILMS

Sputtered CoCr films have been extensively evaluated by measuring the hysteresis loop [5-8] and observing the surface domain structure [9-12]. The following has been concluded from the related measured and calculated results:

1. Without seed layers the CoCr films are composed of an initial layer with a varying orientation of the magnetization from a random to an obviously in-plane orientation and the succeeding growth of a perpendicular anisotropic "top layer" [13-15]. The existence of Cr segregated columnar boundaries has been proposed [16]. Recently TEM observation of CoCr films by combining selective chemical etching with a successive ion-beam milling discovered the existence of a so-called "segregated CP structure", i.e. besides the non-magnetic layer at the grain boundaries, the bright stripes of Co-rich ferromagnetic phase, which are separated by a Cr-rich non-magnetic phase, also exist in each column [1]. The CP-structure will cause the size of the smallest ferromagnetic region to be much smaller than those of the columns in the CoCr films. Therefore, this Cr-rich layer will greatly decrease the exchange interaction between the magnetic regions. It was found [13-17] that the degree of segregation strongly depends on the Cr content and deposition condition. Therefore, a variety of CoCr films with different microstructures from a homogeneously continuous media to fully segregated ones can be prepared if the preparation conditions are appropriately controlled. In view of the above facts, it is reasonable to infer that both domain-wall motions (a continuous behaviour) and rotational reversal (a particle behaviour, i.e. no exchange through the non-ferromagnetic region) can possibly exist together in CoCr films. There is a continuous transition between the two models, depending on the composition and deposition conditions.

2. The method, which differentiates magnetization reversal in CoCr films according to their Hc∥/Hk values [9], is an efficient measure. As the Hc∥/Hk value increases from about 0.02 (low coercivity films) to about 0.1 (high coercivity films) the domain configuration will gradually change from a long stripe domain to a more or less a dot-like domain structure [9]. The experimental data show that with increasing Hc∥/Hk, the orientation direction of the magnetization gradually changes from in-plane (ORL = 0.7) to perpendicular (ORL = 3.9). Regarding the angular dependence of Hc, Hcr and the normalized demagnetizing factor, the magnetic behaviour for low Hc∥/Hk films is rather similar to that for isotropic media, while high Hc∥/Hk CoCr films exhibit a typical perpendicularly anisotropic one.

3. The magnetization reversal mechanism for a practical CoCr film is complicated by the contribution from both incoherent rotation with perpendicular orientation of the magnetization (top layer) and domain-wall motion with either in-plane or random orientation of the magnetization (initial layer). This results in the magnetization reversal mechanism strongly depending on the magnitude and direction of the applied field, because in general the coercivity of the initial layer is smaller than that of the top layer. In the low field range, the magnetization reversal is controlled by in-plane domain-wall motion, which is mainly contributed by the initial layer. The response of the CoCr films can be qualitatively interpreted as the superposition of the response of each layer to the applied field. In the range of the low field, the demagnetizing field exerts a tremendous influence on the magnetic behaviour of CoCr films, especially in the vicinity of the film normal direction. As was expected, the properties of the perpendicular orientation for CoCr films can be greatly improved by previously introducing some special seed layers on the substrate almost without an initial layer.

The seed-layered samples show excellent crystalline orientation (smaller Δθ50) and a higher orientation ratio (ORL) of the magnetization along the film normal than the samples with an initial layer, i.e. without a seed layer.

4. It was discovered [7,18] that for low Hc∥/Hk films the distribution of hysteresis loss vs. applied field curves exhibits a double peak characteristic. The high peak of this curve corresponds to the stripe-domain nucleation, while the field where the hysteresis loss just becomes zero corresponds to the dot-like domain nucleation field. However, for high Hc∥/Hk films this distribution curve exhibits a monotonically decreasing form with a single peak.

5. The magnetization reversal for low Hc∥/Hk (or partly Cr segregated) CoCr films can be considered as the superposition of the domain motion with perpendicular and in-plane orientation of the magnetization. As a temporary expedient, it was assumed [7,8] that the height of the high field peak on the distribution curve of hysteresis loss represents the proportion of domain-wall motion with perpendicular orientation as a whole, because the height of ΔWh vs. applied field at Hk reflects a relative change in the amount of the magnetization switched at that field. Under this assumption, the angular dependence of the proportion function P(θ) of the domain-wall motion with perpendicular orientation to the in-plane one can be experimentally determined by the field dependence of the distribution of the hysteresis loss on the angle [7,8]. In the case of high Hc∥/Hk (or fully segregated) CoCr films, it could be the superposition of a Co-type of perpendicularly incoherent rotational reversal with in-plane domain-wall motion. Based on the above models, it was experimentally confirmed that the measured angular dependence of the coercivity is consistent with the calculated one [7,8].
ANGULAR AND FIELD DEPENDENCE VSM MEASUREMENTS.

Sputtered CoCr films.

As mentioned above the magnetization reversal for a CoCr film can be considered as the superposition of a Cos-type incoherent rotation with the perpendicular orientation of the magnetization and the in-plane domain-wall motion, which mainly results from the initial layer. The angular dependence of the coercivity can be calculated [7,8] by:

\[
\frac{H_c(\theta)}{H_{cL}} = \cos(\theta)^4 p(\theta) + (H_c/H_{cL})^2 (1 - \alpha \cos^2 \theta)^{1/2} (1 - p(\theta))
\]  

(1)

where \( \alpha \) is an adjustable parameter. For most CoCr films we have evaluated \( \alpha \) at about 0.8, while \( p(\theta) \) represents the measured angular proportion function of incoherent rotation with perpendicular orientation of the magnetization to in-plane domain-wall motion. It is seen in Fig.1 that the calculated curve is almost identical to the measured one if \( H_{cL}/H_c \) is taken as 0.2. However, there is a rather large discrepancy between the measured and calculated curves if the magnetization reversal is assumed to be the superposition of an S-W type of coherent rotation with perpendicular orientation of the magnetization and in-plane domain-wall motion.

The angular dependence of remanent coercivity \( H_{cr} \) for a fully segregated CoCr film and the critical field of rotational reversal for a single-domain particle with an uniaxial anisotropy, which are drawn with solid and dashed lines respectively, are shown in Fig. 2. It was unexpectedly found that there is a strikingly similar change tendency between them both. When \( \theta = 45^\circ \) both the \( H_{cr} \) for a fully segregated film and the critical field for a single-domain particle are minimum. This means that the remanent coercivity starts exhibiting

![Graph](image)

**FIG.2.** The measured and theoretically angular dependences of the remanent coercivity for a fully segregated CoCr film (#2) and a single-domain particle with uniaxial anisotropy.

![Graph](image)

**FIG.1.** The relation between the measured and calculated angular dependence of the coercivity for a fully segregated CoCr film (#2).

more or less typical behaviour for a single-domain particle if the CoCr film possesses a typical columnar and fully segregated microstructure, but there still is a large difference in quantity between both curves. For comparison two CoCr films (#8,9) with and without a seed layer are studied. These films can also be considered respectively as a combination of a perpendicular and an in-plane anisotropic layer and a more or less single perpendicular layer. The influence of the seed layer can be clearly seen from the OR(90) value (see table 1). The rather large discrepancy between the measured and theoretical curves in Fig.2 suggests that even if CoCr
is completely segregated it does not exhibit a typical behaviour for single-domain particle (pure S-W mode),
because there is always a magnetostatic interaction
between the particles. Undoubtedly, this interaction
will exert an influence on the magnetic behaviour.
Therefore we have studied Alumite. The Alumite
is composed of an array of circular iron cylinders
separated by nonferromagnetic material. In view of
this similarity of the morphology of both, Alumite
media are thought to be an ideal model material [4]
for exploring the magnetization reversal, because the
size and distance between the Fe needles are well
defined and can be independently changed within
strict limits.

Alumite media (perpendicular particle array).
A widely used theory for an infinitely elongated
single-domain particle without any interaction between
the particles has been investigated. Typical angular
dependence of the reduced coercivity as function
of the reduced diameter curves can be found in [19-22].
In realistic magnetic media, however, magnetostatic
interaction between the particles is inevitable.
Precisely because of this, at present most of the
theory about the magnetization reversal cannot be
directly used to illustrate the magnetic behaviour
for most of magnetic recording media. In view of
the unique microstructure, Alumite is used as a model
material [3, 18]. There is only a magnetostatic
interaction between these iron cylinders. It has been
shown from the radius dependence of the coercivity,
that the reversal mechanism in Alumite is the curling
mode for an applied field perpendicular to the sample
surface [3, 18]. If the applied field deviates from
the film normal the magnetic behaviour will no longer obey
the curling mode. This is due to the presence
of magnetic charge inside the Fe needles resulting from
the interaction between them. The magnetic behaviour
of Alumite is subject to the local demagnetizing field
of the iron single-domain cylinder and macroscopic
demagnetizing field for the whole sample, which are
attributed to the inevitable outcome of the
interaction between iron single-domain needles. The
angular dependence of the coercivity for Alumite is
plotted in Fig. 3. The formula used [18] for the
calculated graph is:

\[
\frac{H_{c\theta}}{H_{c\perp}} = a \cdot \cos \theta + (1-a) f(\theta)
\]

(2)

where \( f(\theta) \) is the reduced coercivity calculated by the
curling mode with \( S = d/dz \). The proportion of Cos-type
of incoherent perpendicular rotation is given by \( a \). In
Fig. 3 it can be seen that for high coercivity Alumite
samples \( s=3 \) the measured curve basically follows the
calculated curve in the range of \( \theta = 0-60^\circ \) if \( a \) is taken
as 0.83. The discrepancy between the calculated and
the measured curve is that an obvious “elbow” in the
calculated one appears at about 70^\circ. Therefore we have
proposed another calculation model [18]. The presence
of magnetic charge (if the applied field deviates from
the film normal) must result in mutually magnetic
attraction between the needles along the sample plain.
This attraction will change the characteristic of the
demagnetizing field. If the angular dependence of the
demagnetizing field is assumed to obey the \( \sin^2 \theta \) law
[6] formula (2) can be changed into:

\[
\frac{H_{c\theta}}{H_{c\perp}} = a \cdot \cos \theta + (1-a)\sin^2 \theta
\]

(3)

The calculation for \( a = 0.75 \) is also shown in Fig.3
for #7. Now the calculated curve fits the measured one
well except in the range 80-90°. Formula (3) can also be
used for low coercivity Alumite media [18] where the
calculated curve (see circles in Fig. 3) is almost
consistent with the measured one, and \( a = 0.67 \).

Perpendicular oriented Ba-ferrite media.
It was known that the preferred direction of the
crystalline and shape anisotropy for a platelet-like
Ba fine particle (sub-tenth micro) are parallel and
normal to its c-axis (i.e. the platelet normal
respectively). In the absence of non-interaction
between the particles, the apparent coercivity is
given by: \( H_c = H_K - NMs. \) This means that both the
crystalline anisotropy (2Kms/Ms) and shape anisotropy
(NMs) contribute to \( H_c \) and the coercivity includes two
opposing components. The related experimental data
have confirmed that the particle shape and diameter
dependence of the coercivity for Ba ferrite particles
can be explained by the coherent rotation model in a
dilute state and the magnetization reversal inside a
Ba ferrite particle is nearly coherent [23-25].
The angular dependence of the coercivity \( H_c/H_{c\theta} \),
orientation ratio (OR\( \theta \)) and hysteresis loss (Wh/Wh
\) with respect to the applied field for Ba ferrite media
#3 are also measured [26]. It can be seen from this
that the parameters are almost independent of the
angle and their values almost approach 1 if the
applied field is larger than 3xHc (\( \approx \)240 kA/m). The
results listed in table 1 also show that both \( H_{c\theta}/H_{c\perp} \)
and OR(90) are very close to 1. Therefore, this
specimen can be considered as a magnetically isotropic
media.
The remanent coercivity \( H_{r\theta} \), in contrast with \( H_c \), is
affected by the medium-shape demagnetizing factor.
From the measured \( Hc/Hr\theta \) vs 0 curve we know that the
corrected one follows the 1/Cos (90-0) which can be
used to describe an incoherent rotation [27]. This
Ba-ferrite sample is mainly controlled by such a mode

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and the magnetic behaviour is strongly influenced by the shape-demagnetizing field. Comparing this with perpendicularly oriented Ba ferrite media (#4), the $H_C/H_{CL}$ value is much larger than that for an isotropic Ba ferrite media. The angular dependence of $H_C$ ($H_{a} = 800 \text{ kA/m}$) on perpendicularly oriented Ba ferrite media is shown in Fig.4.

A fanning model was proposed [2] to explain the magnetization reversal mechanism. According to this model, the angular dependence of the coercivity strongly depends on the ratio of a crystalline anisotropy field ($H_K$) to a dipole-dipole interaction field ($H_M$). As shown in Fig.4, in the range of 0 to 60° the measured $H_C/H_{CL}$ vs. $\theta$ curve is in good agreement with the calculated one based on the fanning model if $\beta$ is taken as 2, where $\beta$ is the ratio of the crystalline anisotropy ($H_K$) to the dipole-dipole interaction field ($H_M$). However, in the range of 60 to 90° the change tendency is quite different from that of the fanning model. The relatively large discrepancy between the measured and theoretical values in the range of 60 to 90° suggests that it is necessary to seek another model to interpret this phenomenon. Fortunately, it was previously discovered [5,6] that the Cos type of incoherent rotation for CoCr films is a relatively better fit with the measured curves of the coercivity than other mathematical models, if the influence of the in-plane magnetization component is considered. In view of these facts, the magnetization reversal is assumed to be the superposition of the Cos type of incoherent rotation with the perpendicular easy axis and a constant component, which represents an isotropic component of the magnetization, because this Ba-ferrite media can be considered as an incompletely oriented one. Based on the above assumption, the coercivity as function of the angle can be calculated by formula:

$$H_C(\theta)/H_{CL} = (1-p)*\cos + p$$  \hspace{1cm} (5)

where $p$ is the proportionality constant for the isotropic component of the magnetization as a whole. As shown in Fig.4, the calculated curve is consistent with the measured one. Similarly, it was proved [5,6] that for most of the CoCr films used the angular dependence of the remanent coercivity follows the formula:

$$H_{CR}/H_{CR1} = (1-p)^{(1-\alpha\sin^2\theta)}^{-1/2} + p.$$  \hspace{1cm} (6)

According to the same principle, with $p = 0.38$ two calculated $H_{CR}/H_{CR1}$ vs. $\theta$ curves are shown in Fig.5 for $\alpha$ taken as 0.7 and 0.8. It is clearly seen from the figure that the calculated curve for $\alpha = 0.7$ is in good agreement with the measured one. On the contrary, the calculated curve based on the fanning model (quoted from [2]) exhibits quite a different change tendency.

In-plane particulate tape

Coated magnetic tape of $\gamma Fe_2O_3$ is another type of particulate recording media, which has been extensively used as a longitudinal recording media. It has a rather high longitudinal orientation ratio and its angular dependence of OR is always the same when

FIG.4. Calculated and measured angular dependence of the coercivity for a perpendicularly oriented Ba ferrite film (#4).

FIG.5. The angular dependence of the remanent coercivity for a perpendicularly oriented Ba ferrite film (#4).
Ha > 72 kA/m (=3Hc). As the applied field decreases, the orientation ratio rapidly increases up to Ha = 23.2 kA/m (=Hc). The Hc/Hcr vs. θ curves for γ Fe3O4 magnetic tape are plotted against Ha in Fig. 6. As seen from this figure the effect of the applied field on the angular dependence of the coercivity is quite remarkable. At different Ha for each Hc/Hcr vs. θ curve there is a critical angle θcr below which the Hc/Hcr increases with increasing angle, but above this angle the Hc/Hcr drastically decreases still with increasing angle. With decreasing Ha, this critical angle will gradually move towards a smaller value. However, the form of Hc/Hcr will become a monotonically decreasing curve with increasing angle if Ha = 23.2 kA/m (=Hc). It was known [18] that curling applies only to infinitely long non-interaction cylindrical particles with uniaxial shape anisotropy. This means that for such a particulate media the crystalline anisotropy should be much smaller than the shape anisotropy. Fortunately, a high quality tape, in which the acicular γ Fe3O4 powder has a high aspect ratio, can basically satisfy the above conditions. Based on the curling model, the calculated angular dependences of the coercivity are plotted against different S values defined as R/Rc, (S=3, 2.2 and 1.7) in Fig. 6. There is a striking consistence between the measured angular dependences of the coercivity for Ha = 800, 72 and 23.2 kA/m and the calculated ones for S = 3, 2.2 and 1.7 respectively [29]. Due to the corresponding relation between the applied field and parameter S, it can be inferred that the S value decreases with decreasing applied field. It was known that the parameter S can be described as the formula KM for a specific magnetic tape, where K is a proportionality constant, if the exchange constant is thought to be invariable for this kind of tape. Therefore, with changing applied field, the change in the magnetization of magnetic tape can be considered as the main reason for the change in the position of the critical angle. The angular dependence of the remanent coercivity Hcr/Hcrs (Ha = 800 kA/m) was also measured. Comparing this with the angular dependence of the coercivity Hc/Hcr (Ha = 800 kA/m), it is unexpectedly found that both curves exhibit almost the same change pattern and the positions of their critical angles appear to be the same, viz. 70°. From these facts it will be reasonable to infer that the characteristics of the coercivity are determined by a controlled nucleation mechanism. It was known [30] that with a decreasing applied field, the coercivity will be more and more dependent on the magnetizing field and thus presumably is associated with incomplete saturation, i.e. with pinning residual or “nuclei”. Of course, as the magnetized field increases, the measured nucleation (unpinning) field will increase.

DISCUSSION

Based on the above analysis and experimental data, it can be concluded that the magnetization reversal mechanism is closely correlated with the origin of the uniaxial anisotropy, microstructure, the degree of the orientation of the magnetization and the related inhomogeneities. For both perpendicularly oriented Ba-ferrite media and high Hc3/Hk CoCr films, in which the origin of the perpendicular anisotropy is mainly determined by the crystalline anisotropy, the magnetization reversal is controlled by a Cos-type of incoherent rotation. Due to their different mirostructures, the magnetization reversal for high coercivity CoCr films can be considered as the superposition of a Cos-type of incoherent rotation with perpendicular orientation and in-plane domain-wall motion. It was experimentally proved [6,8] that these CoCr films consist of a “top layer” with perpendicular anisotropy and “initial layer” with different orientation of the magnetization from a random to a rather good in-plane orientation, depending on various deposition conditions. On the other hand, the magnetization reversal for perpendicularly oriented Ba ferrite media can be seen as the superposition of a Cos-type of incoherent rotation with perpendicular anisotropy and an isotropic component of the magnetization, because these media consist of a mixture of the organic binder and Ba ferrite platelets with a quite different degree of orientation of the magnetization, depending on the magnetic orienting technology. However, for a magnetic tape having a high longitudinal orientation ratio, in
which the in-plane anisotropy mainly results from the shape anisotropy, the magnetization reversal is controlled by the curling type of incoherent rotation.

CONCLUSIONS

1. As the $H_{c1}/HK$ values increase, the orientation direction of the magnetization for CoCr films gradually changes from the in-plane direction to the perpendicular one. In the meantime, the magnetic behavior of CoCr films gradually changes from a rather isotropic to a typical perpendicular anisotropic media and the domain configuration changes from a long stripe-domain to a more or less dot-like domain structure. There is a continuous transition between domain-wall motion and rotation reversal, depending on the composition and deposition conditions.

2. The magnetization reversal for low coercivity CoCr films can be considered as the superposition of domain-wall motion with perpendicular orientation and in-plane orientation.

3. With regard to both high coercivity CoCr films and perpendicularly oriented Ba ferrite media, in which the origin of perpendicular anisotropy is attributed to the crystalline anisotropy, the magnetization reversal is mainly controlled by a Cos type of incoherent rotation. Due to the different microstructure, the magnetization reversal for high coercivity CoCr films can be thought to be the superposition of a Cos-type of incoherent rotation with perpendicular orientation and in-plane domain-wall motion. The remanent coercivity will exhibit more or less typical behavior for single-domain particles if the CoCr films possess a typical columnar and a fully segregated microstructure.

4. For Alumite media the magnetic behaviors will no longer obey the curling mode if the applied field deviates from the film normal. This is due to the presence of magnetic charge at the side of the iron cylinders, which results from the interaction between them. The reversal can be interpreted from the viewpoint of the superposition of Cos-type incoherent rotation with perpendicular orientation and the magnetization reversal controlled by the demagnetizing field and dipole-dipole field.

5. The magnetization reversal for perpendicularly oriented Ba media is assumed as the superposition of a Cos type of incoherent rotation with perpendicular anisotropy and an isotropic component of the magnetization, which depends on the degree of the perpendicular orientation of the magnetization. However, the magnetic behavior for isotropic Ba ferrite media is rather favorable for longitudinal recording applications.

6. The magnetization reversal for a high longitudinally oriented $\gamma$ Fe$_2$O$_3$ magnetic tape is governed by the curling type of incoherent rotation. The coercivity is mainly governed by "controlled nucleation mechanism" [30].

7. The coercivity along the film planes for thin films having perpendicular anisotropy depends not only on the initial layer but also on the interaction between the basic magnetic units.

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