Aftereffect and Accommodation Anisotropy in Metal-Particle and Metal-Evaporated Recording Media

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Abstract -Aftereffect and accommodation are measured in metal recording media using either evaporated cobalt (ME) or particulate iron (MP) as the magnetic material. These materials are highly anisotropic and measurements have been made parallel to the plane of the media both along the easy direction and along the hard direction. Along the easy direction, the loops are square and there is only a small difference between the coercive field, H_c , and the remanent coercive field, H_{ci} . Along the hard direction the squareness is approximately one-half that along the easy axis and H_{ci} is shifted considerably from H_c .

I. INTRODUCTION

Aftereffect is a time drift in the magnetization occurring after the magnetic field has been rapidly switched and is due to thermal activation over an energy barrier [1-2]. Accommodation (also called reptation [1]) is the drift of a minor loop that occurs when the minor loop is repeatedly cycled and is due to changes in the interaction field that occur during the cycling and has been modeled using physically realistic Preisach-based scalar accommodation models [3-7]. Both effects are important considerations in high-density recording media. As previously discussed [8,9], broad distributions in the switching fields, and/or in the interaction fields, can cause the aftereffect to follow a log(time) behavior and accommodation to follow a log(number of cycles) behavior. In particular, the magnetization decay for the aftereffect rate can be expressed in terms of a decay rate S , where the magnetization, M , is given by $M = M_0 + SM_s \ln(t)$, where M_s is the saturation magnetization. In this form S is dimensionless and will be given as a percent.

When the magnetic field is rapidly switched, the magnitude of the aftereffect will depend on the initial and final magnetic field. Of greatest interest is the value of S measured when the field is switched from a positive value, high enough to saturate the magnetization, to a negative field. It has been often stated that S has its greatest value for negative fields near the coercive field. However, for the case of a recording media utilizing

$\gamma\text{Fe}_2\text{O}_3$ particles [10] and for one using CrO₂ [11], S has the largest magnitude for a negative field closer to the remanent coercive field (H_{ci}) rather than to the coercive field (H_c). This was also true for the magnitude of the accommodation [10]. Here we measure aftereffect and accommodation in two commercially produced recording media, fabricated using evaporated cobalt (ME) or particulate iron (MP) as the magnetic material. As fabricated, these materials are highly anisotropic. The MP tape has a layer of fine, elongated, iron metal and thickness of about 2 μm . The ME tape has curved Co grains formed at an angle to the substrate and a thickness of about 0.2 μm . We have measured the aftereffect parallel to the plane of the media both along the easy direction and along the hard direction. Along the easy direction, the loops are square and there is only a small difference between H_c and H_{ci} . Along the hard direction the squareness is approximately one-half that along the easy axis and the remanent coercive fields is shifted considerably from the coercive field.

We find that, as for the previous results for $\gamma\text{Fe}_2\text{O}_3$ material, the maximum aftereffect decay rate for the MP tape occurs when the field is switched to a value near the remanent coercive field. However for the ME tape, the maximum aftereffect decay rate occurs near the coercive field rather than near the remanent coercive field. Further, in contrast with the MP tape, the remanent coercivity in the hard direction of the ME tape is less than that in the easy direction.

II. EXPERIMENTAL

Anisotropy measurements are displayed in Figs. 1 and 2. To obtain these data, an angle was set and then a field large enough to saturate the material was applied. The field was then reduced to zero and the remanent magnetizations parallel to the applied field, M_{rx} , and perpendicular to the applied field, M_{ry} , were measured. A value for the coercive field, H_c , was then determined. The values of M_{rx} and H_c are a maximum in the easy direction and a minimum in the hard direction. The value of M_{ry} is zero in both the easy and hard directions. It can be seen from Figs 1 and 2 that (1) both tapes are highly anisotropic, (2) the moment per unit area of the ME is about one-tenth that of the MP tape, (3) both tapes have directions in which M_{rx} and M_{ry} are of equal magnitudes, and (4) the ME tape has a greater reduction in coercive field in the hard direction than does the MP tape. The sample shape was circular, hence the observed anisotropy is due to the

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Fig. 1. Magnetization remanences, M_{rx} and M_{ry} (left axis) and coercive field (right axis) as a function of orientation of the MP tape.

Fig. 2. Magnetization remanences, M_{rx} and M_{ry} (left axis) and coercive field (right axis) as a function of orientation of the ME tape.

microstructure of the tape.

Hysteresis loops in the easy and hard directions for the MP tape are shown in Fig. 3, and for the ME tape in Fig. 4. For the MP tape the squareness of the loop along the easy direction is about 0.8, and along the hard direction about 0.4. The squareness of the ME tape is slightly greater in the easy direction, and slightly less in the hard direction.

The remanent loops taken at negative fields are plotted, along with portions of the hysteresis loops, in Figs. 5 and 6. The remanent loop magnetization (shown on the y-axes in Figs. 5 and 6) is obtained by first saturating the sample in the positive direction, then changing to the field indicated on the x-axes, then relaxing the field to zero and measuring the resultant magnetization. The remanent coercive field, H_{ci} , is that field for which the magnetization becomes zero at zero field. For the MP tape material we have, along the easy axis, $H_c = -140$ mT and $H_{ci} = -150$ mT, and along the hard direction we find $H_c = -110$ mT and $H_{ci} = -180$ mT. For the ME tape along the easy axis, $H_c = -115$ mT and $H_{ci} = -125$ mT, and along the hard direction $H_c = -70$ mT and $H_{ci} = -97$ mT. An interesting difference between the two materials is that, for the MP tape, H_{ci} is larger in the hard direction, whereas, for the ME tape, it is larger in the easy direction.

Fig. 3. Hysteresis loops in the easy and hard directions (in plane) for the MP tape.

Fig. 4. Hysteresis loops in the easy and hard directions (in plane) for the ME tape.

The aftereffect decay rates in the easy and hard directions for the MP tape are shown in Fig. 7, and for the ME tape in Fig. 8. The decay rates are determined by first saturating the material with a positive field, H_1 , then rapidly switching to a negative field, H_2 , (plotted along the x axes in Figs 7 and 8), and then measuring the magnetization as a function of time. The value of M/M_s , where M_s is the saturation magnetization, is then plotted vs. the natural logarithm of time. This plot is a straight line and its slope, S , is termed the decay rate. Determined in this way, S is dimensionless and is plotted as a percent. S is a function of H_2 , the direction of H (both H_1 and H_2 were always in the same direction for these measurements).

III. DISCUSSION

For both materials, there is little difference between H_c and H_{ci} along the easy axis (see Figs. 7 and 8). Along the easy axes, S is largest for values of H_2 approximately equal to H_c and H_{ci} . For the MP tape in the hard direction, where there is a large difference between H_c and H_{ci} , the largest S value occurs nearest H_{ci} . This behavior is the same as that observed previously [10] for a recording medium fabricated with $\gamma\text{Fe}_2\text{O}_3$ particles. However, for the ME tape in the hard direction, where there is also a distinct difference between the

Fig. 5 Remanence loops (RL) and portions of the hysteresis loops (HL) in the easy and hard directions for the MP tape.

Fig. 6. Remanence loops (RL) and portions of the hysteresis loops (HL) in the easy and hard directions for the ME tape.

values of H_c and H_{ci} , the maximum in the decay rate occurs near H_c rather than near H_{ci} .

The S values in the easy direction for the MP material are a factor of 3 larger than those found previously [10] for the $\gamma\text{Fe}_2\text{O}_3$ medium. For the ME tape the maximum magnitudes of S are about 30 % greater than found in the MP tape. However, in contrast with the MP tape, the remanent coercivity in the hard direction of the ME tape is less than that in the easy direction.

The accommodation behavior of the MP tape (see Fig. 8) is qualitatively similar to that found previously [10] for a $\gamma\text{Fe}_2\text{O}_3$ recording medium. The largest accommodation and aftereffect occur for values of H_2 near the remanent coercive field. The accommodation observed in the ME tape appears to be qualitatively different than in the MP tape, in that the maximum accommodation and aftereffect are less than the remanent coercive field. In fact, the accommodation for the ME tape appears largest for H_2 less than the coercive field. The origin of these differences is not clear at this time. Theoretical explanations are current under development.

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Fig. 7. Aftereffect decay rates for the MP tape in the easy and hard directions as a function of the field applied after first saturating with a positive field. Arrows mark the location of the coercive, H_c , and remanent coercive, H_{ci} , fields.

Fig. 8. Accommodation rates for the MP tape. After saturation at H_1 and field change to H_- , the loop is cycled between H_- and H_+ .

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