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, \( H_{cr} \). Along the hard direction the squareness is approximately one-half that along the easy axis and \( H_{cr} \) 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\(^1\) to \(^2\). Accommodation (also called reptation \(^3\)) 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 \(^3\) to \(^7\). 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 \( M = M_s + M_0 \exp(-S t) \), 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 CrO\(_2\) \(^11\), \( S \) has the largest magnitude for a negative field closer to the remanent coercive field (\( H_{cr} \)) 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 \( \mu \)m. The ME tape has curved Co grains formed at an angle to the substrate and a thickness of about 0.2 \( \mu \)m. 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 \( H_{cr} \). 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 cannot be seen from Figs. 1 and 2 that \( H_{cr} \) 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, \( H_{cr} \), was then determined. The values of \( M_{rx} \) and \( H_{cr} \) 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, (2) both tapes have directions in which \( M_{ry} \) and \( M_{rx} \) 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
Fig. 1. Magnetization remanences, $M_x$ and $M_y$ (left axis) and coercive field (right axis) as a function of orientation of the MP tape.

Fig. 2. Magnetization remanences, $M_x$ and $M_y$ (left axis) and coercive field (right axis) as a function of orientation of the ME tape.

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 $\gamma$Fe$_2$O$_3$ particles. However, for the ME tape in the hard direction, where there is also a distinct difference between the
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REFERENCES