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Magnetization Reversal in AFC Media

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***Abstract*—In this paper, we report on a study of magnetization reversal processes in antiferromagnetically coupled media. We describe the reversal in terms of the reversible and irreversible susceptibility that has been measured for the CoCrPtB system of fixed-recording layer thickness and variable-stabilization layer thickness. We find that very thin stabilization layers do not couple strongly to the recording layer, and that for Mrt greater than 0.11 memu/cm^2, some of the change in magnetization becomes irreversible.**

***Index Terms*—Antiferromagnetic coupled, irreversible susceptibility, reversible susceptibility, SFD.**

I. Introduction

RECENT advances in high-density longitudinal thin-film recording have centered around the use of multilayer structures where the recording layer has its magnetic behavior stabilized by the incorporation of a thin magnetic layer separated by approximately 8 Å of Ruthenium [1], [2]. Such a structure is, in essence, a synthetic antiferromagnet and has been described as both synthetic antiferromagnet (SAF) insert media and antiferromagnetically coupled (AFC). The behavior of antiferromagnetically coupled magnetic structures has been studied extensively in systems such as copper cobalt multilayers which exhibit the well-known giant magnetoresistance (GMR) effect [3]. However, for the case of the electrical behavior there was no real requirement for a full understanding of the reversal processes ongoing in both layers. For the use of such structures as stabilized recording media, it is essential that a complete understanding of the magnetization reversal processes be available so that model predictions of the recording performance can be made.

The reversal in both layers in such a structure is complex. Each layer will have its own inherent switching field distribution (SFD) arising from a grain size distribution, anisotropy dispersion, etc. Given that the two magnetic layers in AFC media are generally of different thicknesses a distinct SFD is expected to be present in each layer. However, the AF coupling between the layers gives rise to a further complication in that the exact magnitude of the total effective applied field acting on a grain is not known. It is often the case that the effect of the exchange coupling between the layers is considered only in terms of the effect of the bottom layer acting on the top layer, but in reality, the exchange interaction works both ways, and the reversal in each layer is affected by the other. In this paper, we report on a study of the origins of hysteresis in such structures. We have undertaken our study by determining both the reversible and irreversible components of the magnetization for both layers. Samples have been evaluated where the thickness of the stabilization layer is varied between an Mrt value of 0.05–0.30 memu/cm^2. For all of the structures examined, the thickness of the upper layer was kept constant with an Mrt value of 0.3 memu/cm^2. A fixed interlayer of 8 Å of Ruthenium was used in all samples. Further details of the reversal process in the context of the recording performance have been reported elsewhere [4].

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II. Experiments

Experiments have been performed on a set of antiferromagnetically coupled magnetic recording media. The structure of the samples was underlayer/interlayer/CoCrPtB (Mrt varied)/Ru(8 Å)/CoCrPtB (Mrt fixed) on isotropic alloy substrates. The underlayer structure is proprietary. The thickness of the recording CoCrPtB layer was fixed at 0.3 memu/cm^2, while the thickness of the stabilization CoCrPtB layer varied from 0.05 memu/cm^2 to 0.17 memu/cm^2 in steps of 0.02 memu/cm^2, and from 0.2 memu/cm^2 to 0.3 memu/cm^2 in steps of 0.05 memu/cm^2.

An alternating gradient force magnetometer (AGFM)[1] was used to characterize the samples. The software of the AGFM has been modified in order to measure the reversible susceptibility as a function of the applied field. In the modified program, a large field was first applied to saturate the samples; then the field was reduced to a certain value, and the magnetic moment M_1 of the samples was measured. The field was then increased by a small amount of 20 Oe and the moment M_2 recorded. The reversible susceptibility at this field is equal to $(M_2 - M_1)/20$. Two such measurements were performed for each sample over different field ranges. One was from 2 to -2 kOe to resolve the sharp peak in reversible susceptibility around zero field. The other was from 6 to -6 kOe to obtain the reversible susceptibility around the loop. The total susceptibility was obtained by differentiating the hysteresis loops of the samples, which were taken at field steps of about 20 Oe. The irreversible susceptibility was obtained from the dc demagnetization remanence curves, which were again taken with a field step of about 20 Oe.

III. Results and Discussion

Figs. 1–4 show sets of data for four of the samples in the series we have examined. These are the samples where the stabilization layer has an Mrt value of 0.05 (Fig. 1), 0.11 (Fig. 2), 0.17 (Fig. 3), and 0.30 (Fig. 4). In each figure, we show the hysteresis loop and the dc demagnetizing (DCD) remanence curve in part

[1]The AGFM is a commercial product of the Princeton Measurements Systems Corporation, Princeton, NJ, model M2900.

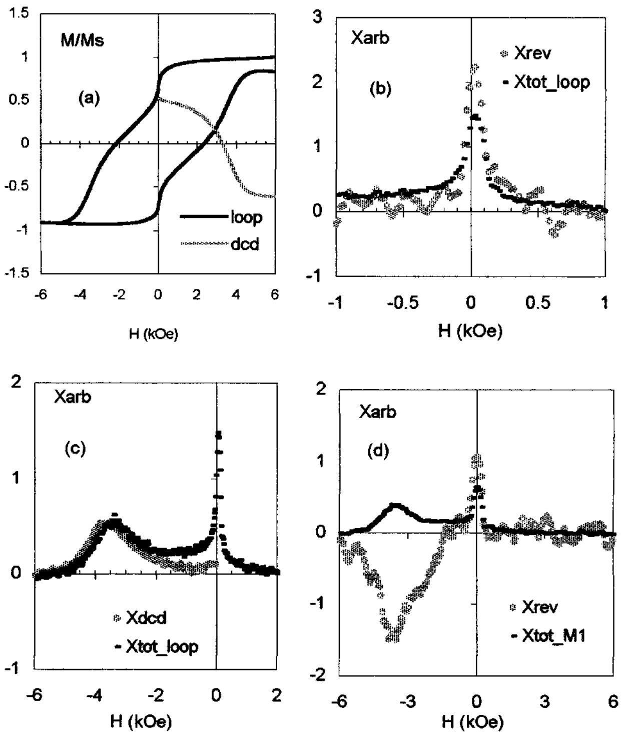

Fig. 1. Reversal for the sample with a stabilization layer of $Mrt = 0.05$.

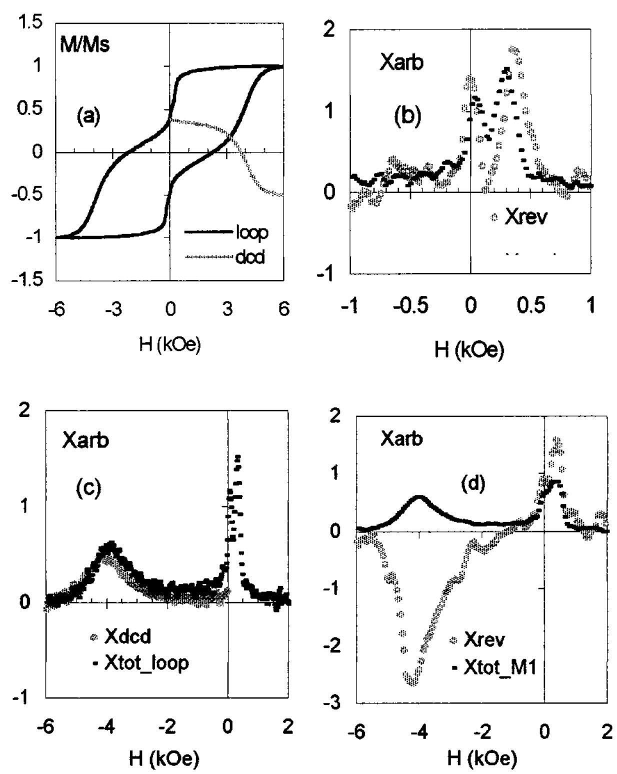

Fig. 2. Reversal for the sample with a stabilization layer of $Mrt = 0.11$.

(a), and the total susceptibility obtained by differentiating the loop and the reversible susceptibility in part (b). It should be noted that the failure of some of the loops to close is due to temperature drift in the piezo electric of the AGFM, which occurs over the relatively long times taken for these measurements. Part (c) of each figure again shows both the total susceptibility de-

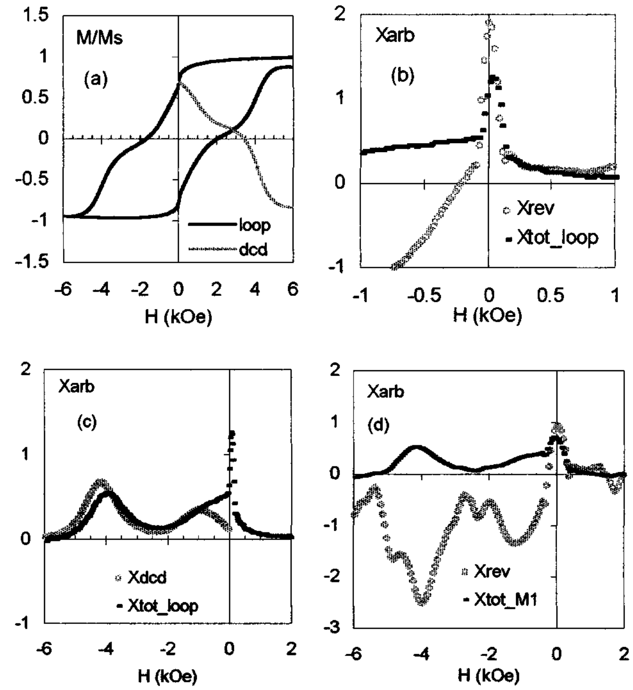

Fig. 3. Reversal for the sample with a stabilization layer of $Mrt = 0.17$.

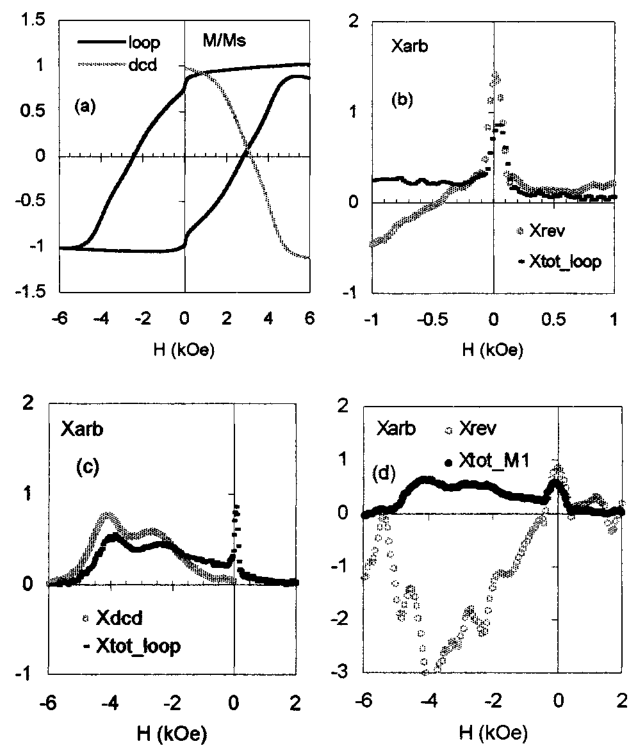

Fig. 4. Reversal for the sample with a stabilization layer of $Mrt = 0.30$.

termined from the hysteresis loop and the irreversible susceptibility determined from the differential of the DCD curve. Part (d) shows the total susceptibility but also the reversible susceptibility over a wider field range so as to encompass the switching region of the recording layer.

From the data in all figures, it is apparent that there is a significant component of reversible magnetization that switches around zero field in all cases. This component in the magnetization derives from the NiP smoothing layer that has been applied to the alloy substrate. The data in part (a) of Figs. 1–4 indicate that all the media show the expected hysteretic behavior with the classical stepped loop. For sample 1 ($Mrt = 0.05$) there does not appear to be a significant component of reversible magnetization in positive fields or near zero field as determined from the small recoil field. The only significant component of reversible magnetization appears to be that which occurs at around the coercivity as seen in Fig. 1(d). We have found that this apparently anomalous negative susceptibility is due to a time-dependent effect in the recording layer that occurs during the 20 Oe field excursion. Hence this is an artefact in the data and it appears through the whole set of the samples as shown in part (d) of Figs. 1–4.

However, Fig. 1(c) shows a significant deviation between the total susceptibility and the irreversible susceptibility at fields between zero and about 1000 Oe, indicating that significant reversible magnetization is occurring at this point. Therefore, in this instance, we believe that the reversal of the stabilization layer is to a large extent, being masked by the reversal of the NiP layer. This implies that the stabilization layer is in essence fully superparamagnetic around zero field but also that there appears to be little antiferromagnetic coupling between the recording layer and the stabilization layer that would force the stabilization layer to reverse in positive field.

The interpretation of the results for sample 1 are confirmed by the data in Fig. 2 for the sample with $Mrt = 0.11$. Here, the AFC has clearly become well established and in addition to the hysteresis loop showing a marked reversal in positive field there also appears a large peak in the reversible component of magnetization at a field of about $+300$ Oe.

Fig. 3 show the data for the sample with $Mrt = 0.17$. From the data for the hysteresis loop and the total susceptibility, it is now apparent that the large reversible component in the magnetization at around zero field or even in positive field has now been removed and consideration of the data in Fig. 3(c) shows that the reversal of the stabilization layer has become partially irreversible due to the double peak in the data obtained from the DCD curve. This gives rise to a double peak in the reversible susceptibility as shown in Fig. 3(d), which occurs at fields mirroring those at which there are peaks in the irreversible magnetization shown in Fig. 3(c). This indicates that the effect of both layers on each other is now to cause some irreversible behavior in the switching region.

Similiar behavior, but of a more extreme nature, is shown in Fig. 4, where the recording layer and the stabilization layer now have nominally the same value of Mrt. Here, despite the fact that the two layers are identical, there appears to be multimodal switching with a double peak in the irreversible susceptibility shown by the data in Fig. 4(c). This gives rise inevitably to a very broad multimodal peak in the reversible component of magnetization shown in Fig. 4(d), and clearly, very complex behavior is now occurring. We believe that the fact that the two layers do not reverse at identical fields may be due to differences in the SFD arising from variations in the degree of epitaxy between the stabilization layer, which is grown on top of a normal underlayer structure, and the recording layer, which is grown on top of the ruthenium layer. Clearly, there are indications here that careful control of the epitaxy is required to ensure that the recording layer switches at the expected field.

A further facet of the data for this system is the second minimum in the reversible component of the magnetization developing at fields greater than 6 kOe [Fig. 4(d)]. Due to the strong AFC any removal of the applied field will result in the reversal of one or other of the layers during minor field excursions. From our data we cannot distinguish which of the layers is switching back when the applied field is reversed.

In addition to the data displayed in Figs. 1–4, we have examined an additional six samples where the value of Mrt for the stabilization layer was varied to intermediate values between those shown in the figures. All data follow the same trends as those described above. Assuming that the optimum recording properties would be obtained when the stabilization layer is able to rotate relatively freely without irreversible changes, then our data shows that it should be possible from such measurements to select optimum structures for application in these areas. That being the case, it would appear that for this system at least the sample with a Mrt value of the stabilization layer of 0.11 would appear to give optimum properties since the stabilization layer appears to rotate freely in positive field [Fig. 2(b)] without showing any significant irreversible behavior [Fig. 2(c)]. For all samples with a higher value of Mrt, some element of irreversible behavior appears [e.g., Fig. 3(c)]. In each layer, there is an SFD. The fact that the irreversible component in the stabilization layer for samples 3 and 4 switches at a relatively modest field indicates there is a possibility that some irreversible change continues into the switching field region of the recording layer and may cause undesirable irreversible switches in the recording layer. The significant irreversible susceptibility in the stabilization layer [Fig. 3(c)] will give rise to time dependence effects in the stabilization layer itself, which will limit the switching speed of the structure as a whole. Measurements of magnetic viscosity made on such systems will exhibit complex effects. A further study of magnetic viscosity effects will be reported upon separately.

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