Anomalous Hall effect magnetometry studies of magnetization processes of thin films.

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Abstract

The anomalous Hall effect (AHE) has been recognized as a useful tool for measuring the magnetic hysteresis M(H) loops of perpendicular magnetic recording media (PMRM), and has shown particular utility for characterizing double-layered PMRM since the loops for both the recording layer (RL) and soft under layer (SUL) may be measured simultaneously, a task not easily accomplished using conventional magnetometers because of the difficulty associated with extracting the properties of the RL and SUL individually.

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1. Introduction

The anomalous Hall effect (AHE) has been recognized as a useful tool for measuring the magnetic hysteresis M(H) loops of perpendicular magnetic recording media (PMRM), and has shown particular utility for characterizing double-layered PMRM since the loops for both the recording layer (RL) and soft under layer (SUL) may be measured simultaneously, a task not easily accomplished using conventional magnetometers because of the difficulty associated with extracting the properties of the RL and SUL individually. We have conducted a systematic study of the magnetic properties (hysteresis loops and Henkel plots) using both a Vibrating Sample Magnetometer (VSM) and an AHE magnetometer of a Co:Cr sample in an effort to correlate results and further develop the AHE technique.

2. Method

To fully investigate the details of the magnetic properties, processes, and interactions magnetic measurements other than just hysteresis loop measurements are required, such as DC demagnetization (DCD), isothermal remanent magnetization (IRM), Henkel plots, Curie point measurements, minor hysteresis loops and magnetic viscosity. We have measured major and minor hysteresis loops and Henkel plots for a Co:Cr thin film sample using both a Vibrating Sample Magnetometer (VSM) and an AHE magnetometer. To achieve maximum sensitivity from low conductivity samples, an AC current methodology was used. This technique also eliminates errors due to thermal EMF voltages. To eliminate residual resistance voltages from the Hall measurements, geometry averaging techniques commonly employed in conventional Hall effect measurements on semiconductors were used. In Hall effect measurements of semiconductors, field reversal is often used to eliminate resistance effects[3]. When a full

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hysteresis loop is measured, a modified form of field reversal must be used. The Hall voltage from positive fields on the descending curve are averaged with the Hall voltage at negative fields on the ascending curve. This method however is not suitable for measurements that only circumvent a portion of the hysteresis loop, such as DCD and IRM, and hence alternative methodologies are required. Geometric averaging, by measuring the hall voltage in two different directions, can be used to remove residual resistance values[3].

3. Results

Figure 1 shows results of major and minor hysteresis loop measurements for a Co:Cr thin film sample recorded using a VSM and AHE magnetometer. The data is normalized to 1. In the case of the AHE measurement the sample was measured using a van der Pauw configuration.

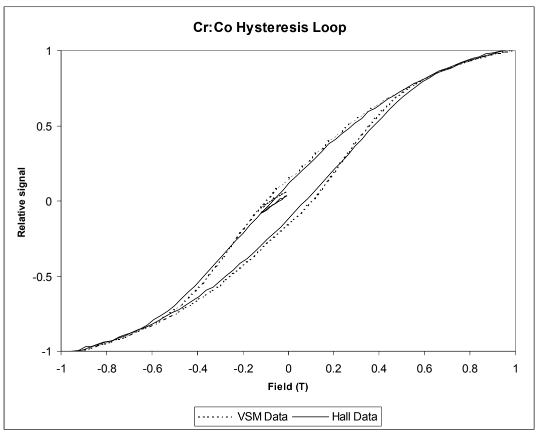

Figure 2 Hysteresis loop with minor loop for Cr:Co sample. Both VSM data and AHE data are shown. The data has been normalized to one.

At each field, the Hall voltage was measured across both diagonals and averaged. This removes the residual resistance from the measurements. Field reversal averaging was not used. The agreement between the two measurement methods is very good. The detail in the minor loop can be seen in both methods. This demonstrates that the geometrical averaging can be used in place of field averaging in an AHE magnetometer.

In addition DCD and IRM measurement were conducted with both the VSM and AHE. In these experiments only portions of the Hysteresis loop are traversed. Again geometric averaging was used to remove the residual resistivity for the AHE magnetometer. Figure 2 shows a Henkel plot of the IRM and DCD data. Again the data has been normalized to one. In each case the best fit line to the data and equation are presented on the figure. In each case the slope of the lines are very close to –2.

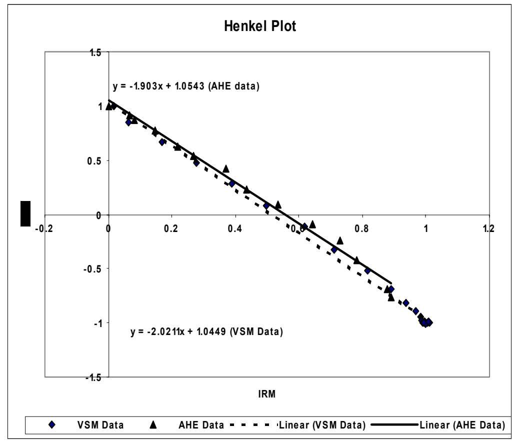

Figure 1 Henkel plot of Cr:Co sample taken on both VSM and AHE. The data is normalized to one.

4. Discussion

Anomalous Hall effect magnetometry can be used to study magnetization processes in thin film materials. AHE magnetometry can be used to study magnetic processes using measurements other than hysteresis loops, and the results correlate well with those obtained using conventional magnetometry methodologies (i.e., VSM).

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