OVERVIEW:

The Hall effect is an important characteristic of some semiconductors that develop a transverse voltage that is typically linearly proportional to the applied magnetic fields [1]. By using this property in a differential Hall element magnetometer, the coercive and remnant fields of materials can be measured by inserting the sample and magnetometer device into a static, high magnetic field region provided by a superconducting solenoid with a room temperature bore. The goal of the present work was to determine the signal to noise ratio in order to provide a figure of merit for using this system for the characterization of magnetic nanoparticles.

EXPERIMENTAL SETUP AND METHOD:

The Hall elements, model HG-166A [2], were chosen for the magnetometer because of their high sensitivity (2 V per T) and their low cost. The method employs two Hall elements in a differential schematic, where the sample is localized next to one of the Hall elements [Fig. 1]. Ideally, the voltage being measured arises exclusively from the presence of the sample.

The Differential Hall Element Magnetometer (DHEM) is fixed at the end of a PVC probe that is designed to enter the superconducting magnet at centimeter intervals [Fig. 2]. Twisted pairs of copper wire (40 AWG) connect the DHEM to a workbench where the electronics are located. A LabVIEW program was written that regulates the DC voltage in order to maintain a constant current of 5 mA. Simultaneously, the program stores the Hall voltage measured at each interval.

DATA AND RESULTS:

The DHEM was inserted and removed through the magnet without a sample to provide a background noise plot that would be subtracted from subsequent data analysis [Fig. 3]. The mass of the sample was reduced until the coercive field would no longer be detectable, which provides a figure of merit for how much of a material is needed to effectively employ the DHEM. A commercial SQUID magnetometer was used to provide an alternative measurement for the purpose of comparing them to those obtained by the DHEM [Fig. 6].

Fig. 7: Hysteresis plots (from remnant magnetization to saturation, then immediately back to remnant for time purposes) for descending sample mass.

The measured coercive field values [Fig. 7] fall within 10%, except for the 240mg sample which is within 18% (not pictured) of the SQUID’s analysis. A slope arises at approximately 750 mT that is attributed to unknown reasons, though presumably due to the non-linear growth seen in the background noise plot. Conversion from millivolts to emu G was accomplished by matching the remnant magnetization values from the DHEM and SQUID and calculating a ratio, which in turn was 1 mV ≈ 0.256 emu G.

CONCLUSIONS AND FUTURE WORK:

The use of a DHEM to measure the coercive fields of materials is a time and cost efficient substitute to using the SQUID. After considering the uncertainties created by the: irregular background noise (ideally should be linear), error between identical measurements, and offset voltage; a minimum magnetization of ≈ 2 emu G is necessary for precision results due to the sensitivity of the DHEM.

Future endeavors would entail construction of a new light weight probe and incorporating a stepper motor for interval readings. A simple change to LabVIEW would allow an automatic data acquisition without manual interference. Also, exploration into minimizing background noise (experiment with different Hall elements) and the cause of the extraneous slope would help to increase accuracy and precision. In order to increase the figure of merit, more sensitive units would be required.

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