Magnetization Measurements of Multi-Layer Thin Films of Fe\textsubscript{3}O\textsubscript{4} Nanocrystals

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Introduction

Investigations of coupling effects within ensembles of magnetic nanocrystals have been among the most widely pursued areas within magnetics of nanosystems. One of the model materials systems for these studies has been iron oxide (Fe\textsubscript{3}O\textsubscript{4}, magnetite) nanocrystals, as they exhibit an interesting array of magnetic collective properties. These characteristics arise as a result of the competition among dipole-dipole interactions, magnetic exchange interactions, and single particle anisotropies in Fe\textsubscript{3}O\textsubscript{4} nanocrystal assemblies. [1]. Furthermore, these dipole-dipole and exchange interactions affect the metal-insulator transition of Fe\textsubscript{3}O\textsubscript{4} and the transport of spin-polarized electrons between nanocrystals. [2] To study the influence of packing on the coupling between these magnetic nanocrystals, we measured the magnetic moment for Fe\textsubscript{3}O\textsubscript{4} nanocrystal powders and for tightly-packed, multi-layered Fe\textsubscript{3}O\textsubscript{4} nanocrystal thin films, made through electrophoretic deposition.

Experimental

Magnetization measurements as functions of temperature for 13.5 nm Fe\textsubscript{3}O\textsubscript{4} nanocrystal powders and multi-layer thin films were conducted at the National High Magnetic Field Lab with a Quantum Design 16-Tesla Physical Property Measurement System (PPMS). Key experiments included the zero-field-cooled and field-cooled magnetic moment measurements as functions of temperature, and magnetic moment vs. applied field measurements on both organically functionalized iron oxide nanocrystal powders and multi-layer nanocrystalline thin films deposited onto silicon.

Results and Discussion

The zero-field cooled (ZFC) and field-cooled (FC) measurements of the 13.5 nm Fe\textsubscript{3}O\textsubscript{4} nanocrystal powder are displayed in Fig. 1. These results confirm the metal-insulator transition in Fe\textsubscript{3}O\textsubscript{4} nanocrystals, evidenced by a sharp increase in the magnetization of the sample as the temperature increases from 25 K through 120 K. Fig. 2 presents the ZFC and FC data of thin film of 13.5 nm Fe\textsubscript{3}O\textsubscript{4} nanocrystals. The absence of the metal-insulator transition in Fig. 2 is the most significant difference between the powder and thin film samples. These results suggests that the nanocrystals, when casts into tightly packed thin films via electrophoretic deposition, may exhibit strong coupling phenomena compared to their powder form.

Conclusions

The magnetic measurements of 13.5 nm Fe\textsubscript{3}O\textsubscript{4} nanocrystal powders and thin films indicate significant differences in their respective magnetization responses. Such insight on coupling phenomena among iron oxide nanocrystal assemblies may lead new applications of magnetic nanocrystals in device applications.

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References