MAR06-2005-006930

Abstract for an Invited Paper
for the MAR06 Meeting of
the American Physical Society

Vortex State in Sub-100 nm Magnetic Nanodots.

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Magnetism of nanostructured magnets, which size is comparable to or smaller than ferromagnetic domain size, offers a great potential for new physics. Detailed knowledge of magnetization reversal and possible magnetic configurations in magnetic nanostructures is essential for high-density magnetic memory. Many theoretical and experimental studies are focused on a magnetic vortex which in addition to a circular in-plane configuration of spins has a core, - the region with out-of-plane magnetization. We present a quantitative study of the magnetic vortex state and the vortex core in sub-100 nm magnetic dots. Arrays of single-layer and bilayer nanodots covering over 1 cm^2 are fabricated using self-assembled nanopores in anodized alumina. This method allows good control over the dot size and periodicity. Magnetization measurements performed using SQUID, VSM, and MOKE indicate a transition from a vortex to a single domain state for the Fe dots. This transition is studied as a function of the magnetic field and dots size. Micromagnetic and Monte Carlo simulations confirm the experimental observations. Thermal activation and exchange bias strongly affect the vortex nucleation field and have a much weaker effect on the vortex annihilation field. Direct imaging of magnetic moments in sub-100 nm dots is extremely difficult and has not been reported yet. Polarized grazing incidence small angle neutron scattering measurements allow dot imaging in reciprocal space. Quantitative analysis of such measurements performed on 65 nm Fe dots yields the vortex core size of $\sim$ 15 nm, in good agreement with the 14 nm obtained from the simulations.

This work is done in collaboration with Chang-Peng Li, Zhi-Pan Li, S. Roy, S. K. Sinha, (UCSD), Xavier Batlle (U. Barcelona), R. K. Dumas, Kai Liu, (UC Davis), S. Park, R. Pynn, M. R. Fitzsimmons (LANL), J. Mejia Lopez (Pontificia U. Catolica de Chile), D. Altbir, (U. de Santiago de Chile), A. H. Romero (Cinvestav-Unidad Queretaro), and Ivan K. Schuller (UCSD) and supported by AFOSR, US DOE, NSF, UC-CLE, Spanish MECD, Catalan DURSI, FONDECYT, Millennium Initiative, and Conacyt Mexico.