

Anomalous magnetic anisotropy and effects of field cooling in a single 40 nm Fe_3O_4 nanoparticle

S. Maity,¹ U. Thuwal,¹ H. Courtois,² Clemens B. Winkelmann,² and A.K. Gupta¹

¹*Department of Physics, Indian Institute of Technology Kanpur, Kanpur 208016, India*

²*Univ. Grenoble Alpes, CNRS, Grenoble INP, Institut Néel, 38000 Grenoble, France*

Magnetization (\vec{m}) reversal in individual single magnetic nano-particles provides unambiguous information [1] which in bulk ensembles suffers from inter-particle interaction and averaging over particle size, shape, orientation, and defect configurations. A 40 nm size Fe_3O_4 nano-particle was placed on the weak link of a Nb μ -SQUID for optimal coupling. The M-H measurements of this ferrimagnetic particle at 2 K show single domain characteristics. A model is discussed to understand how different components of \vec{m} contribute to the magnetic flux through the SQUID loop. The experimentally determined angle dependent switching field is found to be close to that predicted by the generalised Stoner-Wohlfarth model, or the asteroid model, with a mixture of cubic and biaxial anisotropies [2].

Due to the mixed anisotropy the angle dependent switching field exhibits multiple crossings at certain angles. The particle also exhibits changes in anisotropy in different cooling runs from room temperature and after ambient exposure. Fe_3O_4 in bulk is known to exhibit a metal-insulator Verwey transition near 115 K with crystallographic change from an inverse spinel structure above 115 K and a monoclinic structure below it. Under this transition a slight change in c-axis lattice parameter can lead to a deformation and change in anisotropy. Our initial attempts to control the anisotropy-axes through field cooling failed with field-cooling from up to 200 K temperature and 1.6 T magnetic field. However, when it is cooled from above 375 K we see the anisotropy is cooling-field-direction dependent for cooling from above about 115 K. This is discussed in terms of water adsorbed on particle surface giving a surface strain which dominates the energetics over the field cooling leading to same distortion in every field cooling run from above 115 K despite presence of large fields. The field-cooling controlled anisotropy can have applications in nanotechnology and spintronics.

References:

[1] W. Wernsdorfer, "Classical and quantum magnetization reversal studies in nanometer-sized particles and clusters." Handbook of Advanced Magnetic Materials. Boston, MA: Springer US (2007), 77.

[2] . A. Thiaville, "Coherent rotation of magnetization in three dimensions: A geometrical approach." Physical Review B 61, 12221 (2000).