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Magnetic Core-Shell Morphology of Structurally Uniform Magnetite Nanoparticles

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Magnetic nanoscale structures are intriguing, in part, because of the exotic properties that emerge compared with bulk. The reduction of magnetic moment per atom in magnetite with decreasing nanoparticle size, for example, has been hypothesized to originate from surface disordering to anisotropy-induced radial canting, which are difficult to distinguish using conventional magnetometry. Small-angle neutron scattering (SANS) is ideal for probing structure, both chemical and magnetic, from nm to microns across an ensemble of particles. Adding polarization analysis (PASANS) of the neutron spin orientation before and after interaction with the scattering particles allows the magnetic structure to be separated into its vector components. Application of this novel technique to 9 nm magnetite nanoparticles closed-packed into face-centered crystallites with order of a micron revealed that at nominal saturation the missing magnetic moments unexpectedly interacted to form well-ordered shells 1.0 to 1.5 nm thick canted perpendicular to their ferrimagnetic cores between 160 to 320 K [1]. These shells additionally displayed intra-particle "cross-talk", selecting a common orientation over clusters of tens of nanoparticles. However, the shells disappeared when the external field was removed and interparticle magnetic interactions were negligible (300 K), confirming their magnetic origin. This work has been carried out in collaboration with Ryan Booth, Julie Borchers, Wangchun Chen, Liv Dedon, Thomas Gentile, Charles Hogg, Yumi Ijiri, Mark Laver, Sara Majetich, James Rhyne, and Shannon Watson.

[1] K.L. Krycka *et al.*, Phys. Rev. Lett. 104, 207203 (2010)