Interparticle magnetic correlations in assemblies of Fe_3O_4 nanoparticles

Karine CHESNEL - Brigham Young University, USA

Magnetic nanoparticles (NPs) provide an ideal support for developing a wide range of nanotechnologies and biomedical applications, such as drug-delivery, gene delivery, hyperthermia, or contrast agents for MRI.[1] Magnetite (Fe_3O_4) NPs are good candidates for these applications due to their non-toxicity and long-life in the bloodstream. To optimize these applications, it is crucial to well control the magnetic response of individual NP when manipulating a collection of them via a magnetic field. In particular, it is useful to identify any interparticle magnetic correlations that may cause the magnetic response to deviate from superparamagnetism, induce superferromagnetism and magnetic hysteresis. To that end, we have studied the magnetic response of 5 – 100 nm Fe_3O_4 NPs and its dependence on NP size, using magnetometry [2] and spin muon resonance [3]. However, this information remains macroscopic or spatially averaged. Here we show how nanoscale spatial information on inter-particle magnetic correlations can be obtained via x-ray resonant magnetic scattering (XRMS) [4]. By tuning the energy of the x-rays to resonant edges of Fe and comparing opposite polarization helicities, we have extracted information about the local inter-particle magnetic orders within NP assemblies of various sizes.[5] We fitted the XRMS data using a model based on chains of NPs.[6] The data fitting shows ferromagnetic ordering when an external magnetic field is applied, and the emergence of antiferromagnetic ordering, competing with magnetic randomness, when the field is brought back near the coercive point (zero net magnetization). We studied how these correlations depend on particle size and found an enhancement of magnetic couplings and antiferromagnetic orders for bigger particles. [7]