Experimental report

18/02/2019

Proposal: 5-54-193 **Council:** 4/2015

Title: Dipolar coupling in arrays of magnetic nanoparticles, studied using time-of-flight polarized GISANS

Research area: Physics

This proposal is a new proposal

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Samples: iron oxide mesocrystals

Instrument	Requested days	Allocated days	From	To
D33	4	3	06/11/2015	09/11/2015

Abstract:

We propose a time-of-flight polarized GISANS study on mesocrystals of iron oxide nanoparticles in order to elucidate the magnetic dipolar interactions in orientationally aligned nanoparticles.

The long range ordered mesocrystals under study consist of monodisperse maghemite nanocubes with edge lengths of 9.3 nm and 11.1 nm. First polarized GISANS test measurements carried out at D33 reveal a large amount of reflections that are resolution-limited in their FWHM.
With the proposed experiment we will exploit the time-of-flight mode at D33 in order to access the depth resolution of GISANS without variation of the incident angle and at the same time increase the Q resolution onf the experiment.
As a result, we expect to gain insight into the dipolar coupling in long range ordered arrangements of orientationally aligned nanoparticles. This study will be a valuable asset to our ongoing TISANE studies towards the directionally resolved magnetization relaxation in maghemite nanocubes.

Dipolar coupling in arrays of magnetic nanoparticles, studied using time-of-flight polarized GISANS

The physical properties of nanosized magnetic objects are intensely investigated for both technological and scientific reasons [1,2]. Magnetic interparticle interactions may influence the magnetic properties and are thus relevant for technological applications. For example, the progress towards higher density magnetic data storage requires increasingly smaller magnetic entities and a small distance between differently magnetized magnetic objects. In order to retain the magnetization state in the required relaxation time and temperature range, a large magnetic anisotropy of the small magnetic objects and a low interaction of the neighboring objects are important.

We have carried out polarized GISANS experiments for two different mesocrystal samples consisting of maghemite nanocubes with edge lengths of 9.3 nm and 11.1 nm. Scans were performed for both samples during zero field cooling and field cooling in a saturating field of 1.5 T. After sample cooling to 10 K, the polarized beam was measured in both cases during application of a saturating field and subsequently in remanence with a 10 mT guide field. Additionally, magnetic field dependent measurements have been performed for the sample of 9.3 nm nanocubes at room temperature.

Time-of-flight mode measurements carried out initially during by SANSPOL measurements with a calibration sample did not show any improvement in resolution. Therefore, all polarized GISANS measurements were performed using a monochromatic beam with a wavelength of 6 Å, Furthermore, an aperture of 6x1 mm^2, a sample-detector distance of 2.5 m and a collimation length of 5.3 m was chosen.

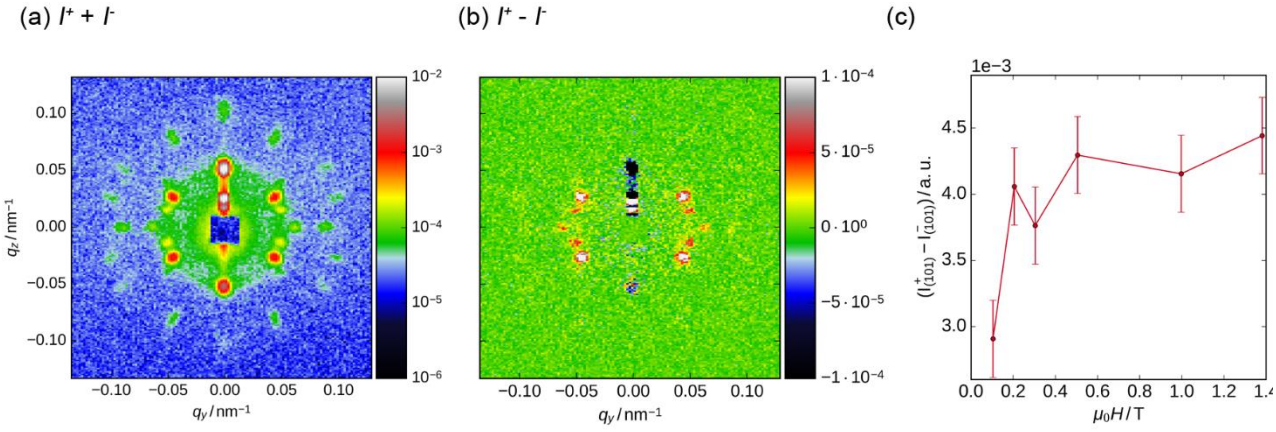

Fig. 1: Polarized GISANS from mesocrystal of 9.3 nm nanocubes in saturating field showing the (a) sum and (b) contrast of both channels and (c) their dependence of the magnetic field.

First qualitative evaluations of the obtained scans were obtained by observing the behavior of the (101) reflection. In the magnetic field dependent measurements at room temperature, an increase and saturation of the magnetic contrast is observed in I^+ - I^- (Fig. 1c), corresponding to the full alignment of all nanoparticle magnetic moment in direction of the magnetic field.

Furthermore, remanent contrast is obtained after field cooling and zero field cooling (Fig. 2). Here, the magnitude of the remanent magnitude differs slightly for the different cooling conditions after normalizing the data to their respective monitor values. Detailed analysis of the obtained magnetic contrast in terms of the DWBA theory using the BornAgain software package is necessary for more quantitative statements and work towards a detailed analysis is ongoing.

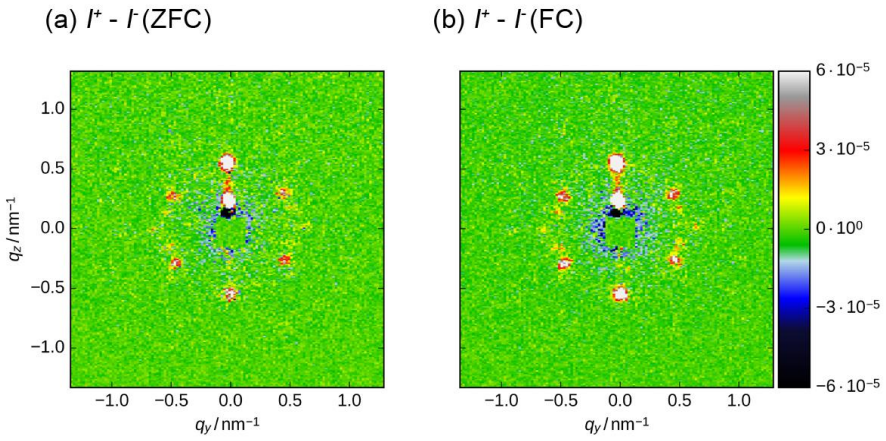

Fig. 2: Remanent contrast for mesocrystal of 9.3 nm nanocubes obtained after (a) zero field cooling and (b) field cooling.

References:

[1] S. Bader, *Rev. Mod. Phys.* **78**, 1 (2006)
[2] M. McHenry, D. Laughlin, *Acta Mater.* **48**, 223 (2000).