Experimental Report

15/01/2014

Proposal: **9-10-1319** **Council:** 10/2012

Title: SANS Measurements on Antiferromagnetic Manganese Oxide Nanoparticles

This proposal is a new proposal

Research Area: Physics

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Samples: MnO nanoparticles in D2O

Instrument	Req. Days	All. Days	From	To
D33	2	2	03/06/2013	05/06/2013

Abstract:

Fundamental research on magnetic nanostructures is an important part of today's scientific effort in information technology and other fields of current activity. The goal is to reach growing bit density in data storage, which continuously requires miniaturization. Our long term objective is the understanding of magnetic interparticle interactions of anisotropic and composite nanoparticles. The focus of our studies are composite nanoparticles of a ferromagnetic and an antiferromagnetic compound, Iron Platinum and Manganese Oxide, and the exhibited exchange bias in this kind of nanoparticle. Therefore the investigation of spin structure inside these particles is necessary. To achieve a better understanding on the interaction at the interface the determination of spin structure in each compund particle is inevitable. The aim of the proposed project is to determine the spatial magnetization distribution within antiferromagnetic manganese oxide nanoparticles and the required method is therefore SANS.

SANS Measurements on Antiferromagnetic Manganese Oxide Nanoparticles

Miniaturization is the goal of information technology and data storage. This can be obtained by using magnetic nanoparticles as a new material for data storage media. The smaller size of nanoparticles compared to conventional magnetic domains could increase the data density on such media. The requirement for an application in this field is a high magnetic anisotropy which impedes magnetization reversal. The increased surface-volume ratio results in an enhanced magnetic anisotropy in nanoparticles compared to the bulk material [1].
Together with our collaborators from the Chemistry Department of the University of Mainz (Prof. Tremel) we follow an approach, where FePt nanoparticles (in the atomically unordered phase) are magnetically stabilized by an antiferromagnetic nanoparticle grown epitaxially to the FePt particle [2]. Our long term project is to understand the spin structure and magnetization density of the combined particles and in detail the structure at the interface between antiferromagnetic and ferromagnetic particle. To determine the contribution of the interaction at the interface to the magnetization density a detailed investigation of the subunits is inevitable.

Previous polarized SANS experiments on ferromagnetic iron oxide nanoparticles revealed a constant magnetization in the particle core, which decreases towards the nanoparticle surface [3]. The magnetization decrease can be attributed to surface spin canting. A similar result is expected for the ferromagnetic iron platinum particles. For the antiferromagnetic manganese oxide nanoparticles, an enhanced magnetization at the particle surface as compared to the antiferromagnetic core is expected due to non-compensated spins caused by surface spin disorder.

In this study SANS experiments with polarized neutrons on dispersions of manganese oxide (MnO) nanoparticles and iron platinum (FePt) nanoparticles were performed. Aim of the study was the determination of the magnetic form factor and thus the spatial magnetization distribution within each of these nanoparticles, in order to investigate in future SANS experiments the magnetic form factor of the combined particles to a nanodimer and to determine the contribution of the interaction. The MnO nanoparticles are of size 19 nm and the FePt nanoparticles are of size 5nm, both samples have a lognormal size distribution in the order of 7-10%. Both samples were diluted in deuterated toluene and measured with polarized neutrons in SANS geometry at the instrument D33. To determine the magnetic form factor a field of 6T which saturates the samples magnetization was applied perpendicular to the neutron beam and both polarization measurements were compared to observe a difference. The measurements were performed at different temperatures below the Curie-temperature of iron platinum and below the neel-temperature of manganese oxide.

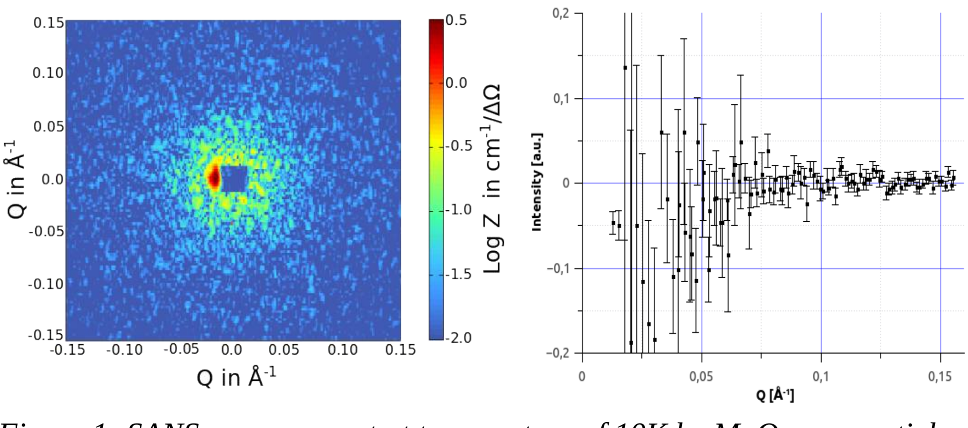

Figure 1: SANS measurement at temperature of 10K by MnO nanoparticles with a diameter of 19 nm. Left: I(+)-I(-) scattering pattern measured at an applied an field of 6T. The isotropic scattering shows no magnetic scattering contribution. Right: Integrated intensity within an opening angle of 10° perpendicular to the applied field.

Figure 1 shows the data obtained from the manganese oxide nanoparticles. As no difference between both intensities is visible we conclude that the sample does not exhibit magnetic scattering contribution even in low temperature and in saturating field. From this data the spatial magnetization distribution within the nanoparticles can not be extracted.

For the iron platinum particles one can detect a slight difference in the two intensities which is much clearer to see in the 2D pattern of the I(+)-I(-) measurement, see figure 2 left. The plot of the subtraction of both measurements shows an oscillating curve, see figure 2 right. This curve revelas information on the spatial magnetization distribution and in the next steps of analizing the data several magnetic form factors will be fitted to the it. This will give information about the alignment of spins insight these particles and near the surface.

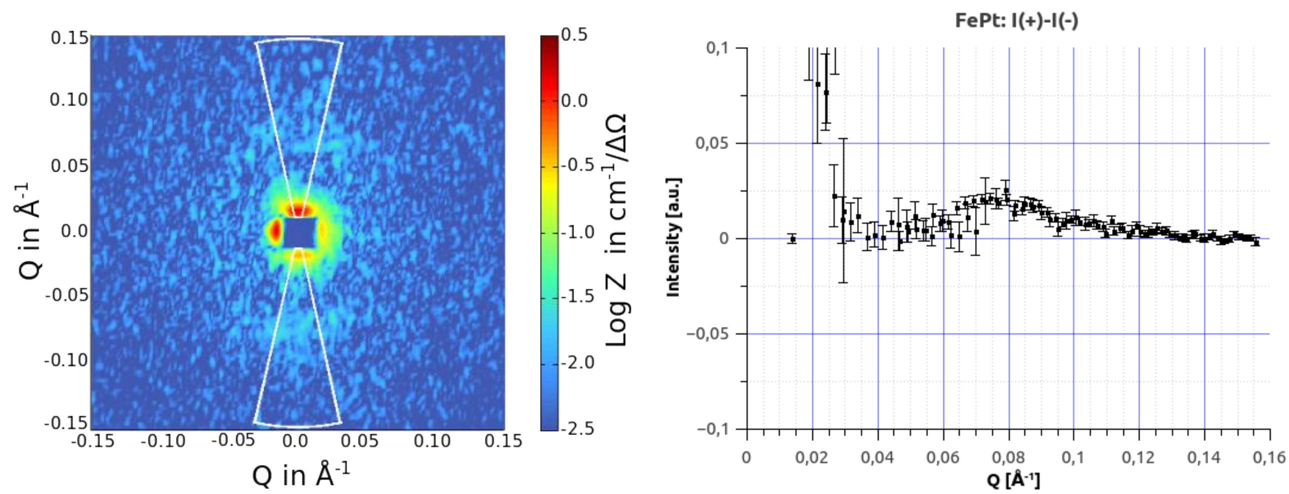

Figure 2: SANS at 10K by FePt nanoparticles with a diameter of 5 nm. Left: I(+)-I(-) scattering pattern with anisotropic contribution in the marked regions perpendicular to the direction of the field. Right: Integrated intensity of the left picture. One can clearly see the oscilation of the curve.

In future experiments SANS measurements of the combined particles should be performed and compared to these results. The comparison of magnetic contributions of the single nanoparticles and the nanodimers will give information about the influence of the antiferromagnetic manganese oxide subunit to the ferromagnetic iron platinum subunit. The change in the magnetic form factor should be obtained to describe the influence of the interaction at the interface on the magnetic behavior of the nanodimers.

[1] S. Rusponi et al., Nat. Mat. 2, 546 (2003).
[2] T. D. Schladt, T. Graf, W. Tremel, Chem. Mater. 21, 3183 (2009).
[3] S. Disch et al., New J. Phys. 14, 013025 (2012).