	Experiment title: Mineral liquid crystals in external magnetic fields	**Experiment number**: 26-02-345
Beamline: BM26B	**Date(s) of experiment**: From: 14-11-2006 To: 20-11-2006	**Date of report**: 30- 11 -2006
Shifts: 15	**Local contact(s)**: Kristina Kvashnina	
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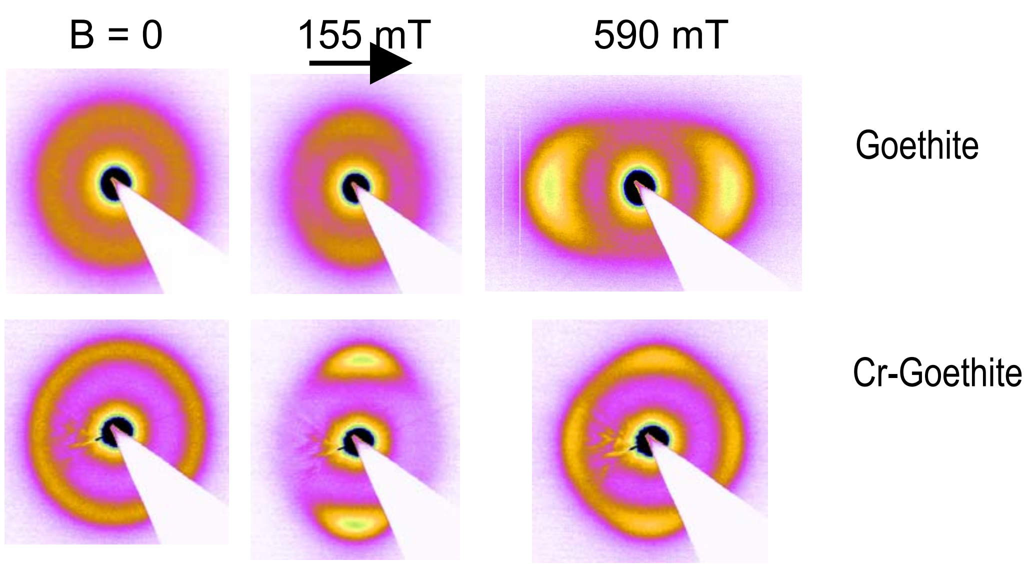
Report: (max. 2 pages)

It is known that Goethite particles show interesting magnetic properties [1]: they possess a considerable permanent magnetic moment along their long axis, presumably due to uncompensated spins within their anti-ferromagnetic crystal structure, combined with an induced moment with an easy axis along one of the shorter particle dimensions.

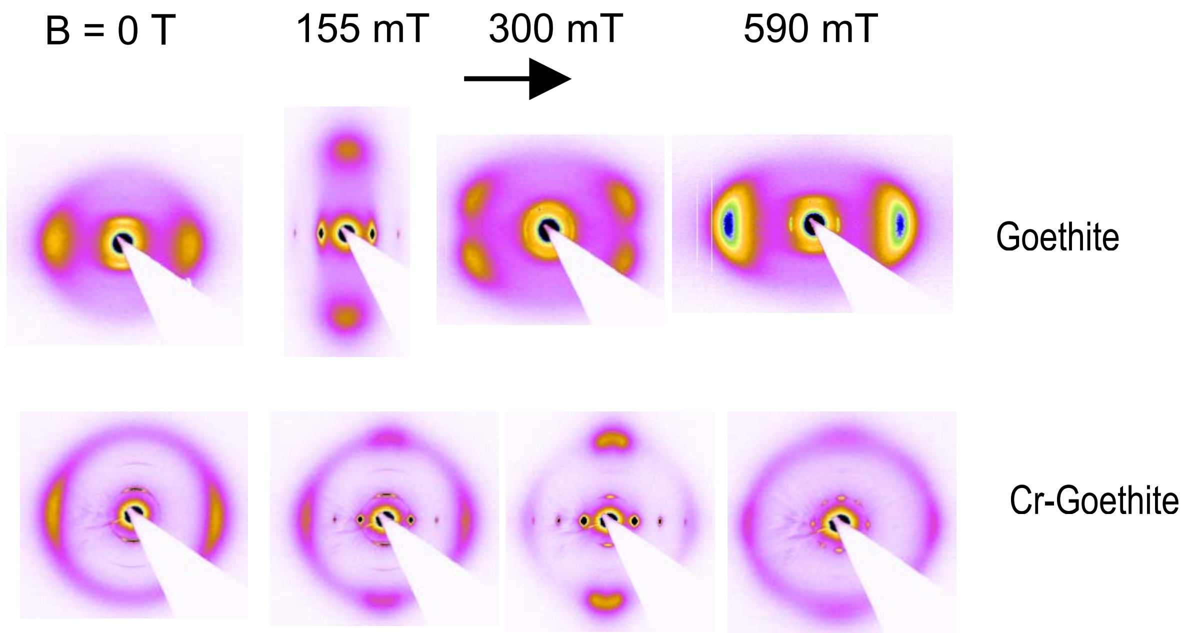
One of the main goals we hoped to achieve in this project was to find ways to tune these opposing types of magnetic behaviour by changing the relative importance of the permanent moment and the induced moment. Therefore, we replaced part of the Fe-atoms in normal Goethite (α-FeOOH) by Cr-atoms during the synthesis. Scanning Electron Microscopy (SEM) in combination with Energy Dispersive X-ray Analysis (EDX) indicated that the Cr-ions were really incorporated into the particles. In the present measurement session at DUBBLE we compared a system with 2.4 % Cr substituted for Fe with a pure Goethite system of similar dimensions (L x W x T) and similar relative polydispersity:
Goethite: L=220 nm (±17 %), W=62 nm (±29 %), T~20 nm
Cr-Goethite: L=214 nm (±25 %), W=62 nm (±25 %), T~25 nm
At low volume fractions we found the following magnetic response for these systems:



At B = 0 T both systems show an isotropic scattering pattern, which gradually transforms into an anisotropic (para-nematic) pattern, consistent with the long axes of the particles aligning along the field direction.

However, at B = 155 mT the Cr-doped Goethite is clearly much more highly ordered than Goethite itself. At higher fields, we see indications that the particles (start to) turn perpendicular to the field. At B = 590 mT this process seems to be virtually complete for the pure Goethite, whereas the Cr-Goethite is only starting to rotate.

At higher volume fractions we were able to identify a layer-like smectic phase in both of these systems. Here, we found the following scattering patterns:



The additional sharp small-angle reflections in these patterns correspond to the periodicity of the smectic layers, whereas the perpendicularly oriented, diffuse wider-angle peaks correspond to the liquid-like ordering within the layers. Also within the smectic phase it is clear that the particles (starting off from their accidentally perpendicular orientations) first turn their axes parallel to the field and only at higher fields turn perpendicular to the field. However, for Cr-Goethite at B = 300 mT the smectic phase is still virtually completely aligned along the field (and very well ordered, note the third order peak) whereas the rotation perpendicular to the field has only just started at B = 590 mT .

From these results we conclude that it is possible to vary the magnetic properties of Goethite particles considerably by substituting iron with chromium. In future, we intend to synthesize particles with various degrees of substitution and study the differences in magnetic behaviour, for which we will need a stronger magnetic field. We shall also try to find Cr-Goethite systems showing an additional nematic phase, which could to be compared with existing theory [2].

The figures presented above illustrate only a few examples of the results of this experiment. The study was performed for many samples of several types of nanoparticles, at different concentrations and field strengths. In addition, a study of the detailed profile of the focused direct beam and the stability of its position was performed using a high-resolution (about 1 micron) detector kindly provided by BM-05. Moreover, we took advantage of presence of Dr. W. Bras during the experiment. A preliminary test measurement was performed to investigate the influence of remaining sources of vibrations on the stability of the beam position on the detector. These vibrations remain the main factor that limits our resolution. The results of this test measurement are very important for our future efforts of pushing the limits of the microradian setup at DUBBLE.

Finally, we would like to thank K. Kvashnina, W. Bras, N. Vilayphiou and D. Detollenaere for excellent support.

[1] B.J. Lemaire, P. Davidson, J. Ferré, J.P. Jamet, P. Panine, I. Dozov, and J.P. Jolivet, Phys. Rev. Lett. **88**, 125507 (2002).
[2] H.H. Wensink, and G.J. Vroege, Phys. Rev. E **72**, 031708 (2005).