Experiment title:
Structure and Dynamics of Roodlike Colloids in Dependence on External Magnetic Fields

Experiment number:
SC2315

Beamline:
ID02

Date of experiment:
from: 21.9.2007 to: 24.9.2007

Date of report:
16.2.2009

Shifts:
9

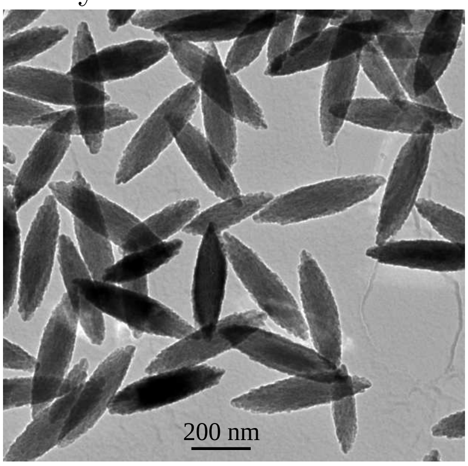
Local contact(s):
Dr. Michael Sztucki

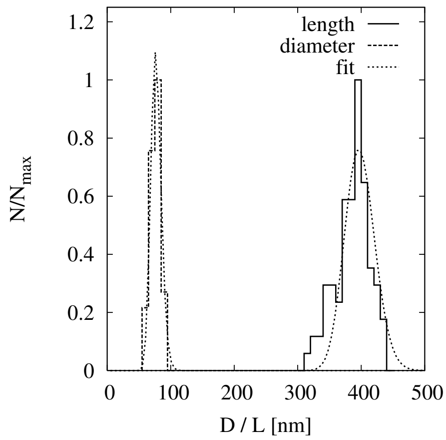
Received at ESRF:

Names and affiliations of applicants (* indicates experimentalists):
Joachim Wagner, Christian Märkert,
Physical Chemistry, Saarland University, Saarbrücken, Germany

Report:

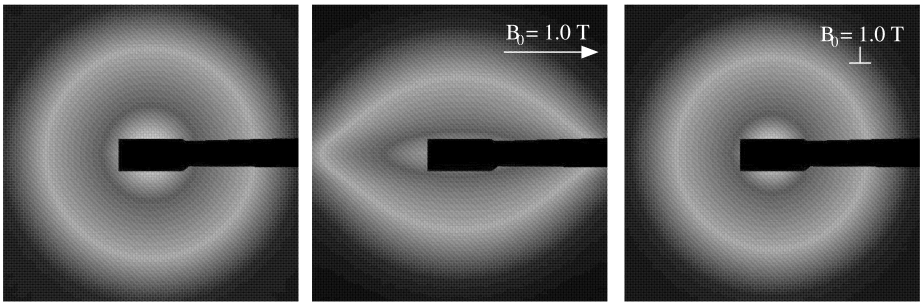
In the presence of phosphate anions regioselectively covering planes parallel to the hexagonal axis of hematite (α-Fe_2O_3) colloidal, spindle shaped iron oxide particles can be grown. The aspect ratio of the particles can be tuned by the concentration of the surface active phosphate anions.



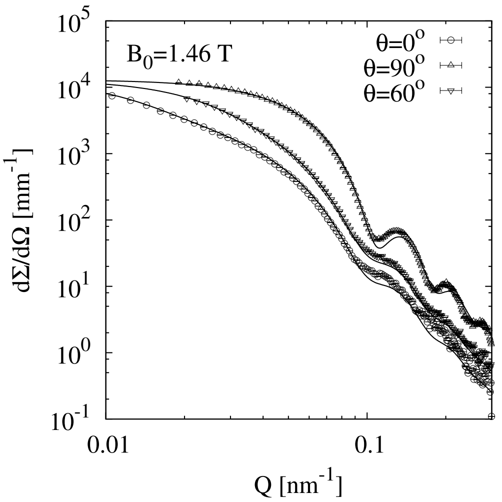


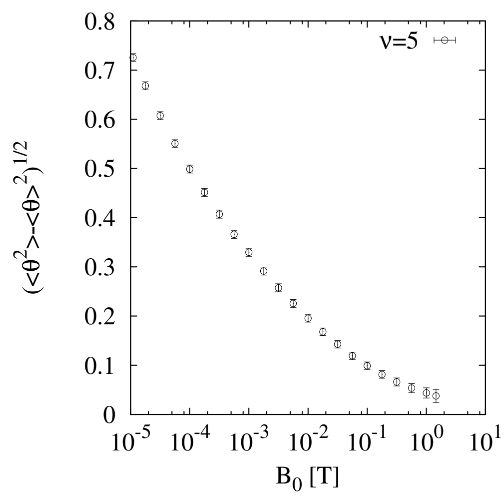
The shape as well as the narrow size distribution is visible from the TEMicrograph. These particles are despite of their comparatively large volume bearing a small magnetic moment in the order of $10^3\,\mu_B$. However, due to the anisotropy of the magnetic susceptibility tensor ($\Delta\chi = \chi_{\|} - \chi_{\perp} < 0$), these particles can be aligned in external fields with the long axis perpendicular to the field direction.

The small angle X-ray scattering of dilute suspensions consisting of hematite particles with volume fractions of $\phi \approx 10^{-3}$ and different aspect ratios is investigated in dependence on the flux density and the direction of external magnetic fields. The magnetic field is applied using the sample environment of ID02 equipped with permanent magnets. The data are collected using 12 keV photons at a single detector distance of $d = 10\,\mathrm{m}$ at ID02. In the following a typical snapshot is displayed without external field and with fields of $B_0 = 1.0\,\mathrm{T}$ applied perpendicular to the primary beam and parallel to the primary beam (i.e. perpendicular to the plane of detection).



In the middle picture clearly the orientation of the long particle axis perpendicular to the field can be seen, whereas at the right hand side, the circular symmetric shape results from an ensemble of particles aligned perpendicular to the primary beam ($\theta = \pi/2$) , with the long axis however statistically aligned in this plane ($0 < \phi < 2\pi$). The scattered intensity can be described by spindle-shaped particles with constant aspect ratio, underlaying a Schulz-Flory size distribution, whereby the angle θ denotes $\angle(\mathbf{B_0}, \mathbf{Q})$. Here, the best parameters are $\sigma = 80 \pm 1\,\mathrm{nm}$ for the short diameter, $\nu = 5.0 \pm 0.2$ for the aspect ratio and $Z = 64 \pm 1$ for the Schulz exponential parameter corresponding to a polydispersity $p = 0.124 \pm 0.001$. Increasing the flux density, the width of the orientational distribution function decreases, as visible by the the variance $(\langle\theta^2\rangle - \langle\theta\rangle^2)^{1/2}$.





Even flux densities in the range of some millitesla are sufficient to induce a significant alignment of the particles with large aspect ratio. With decreasing aspect ratio and particle volume, the angular variance increases at constant flux density.