Structural and Magnetic Investigations on FePt Nanoparticles

J. Biskupek[1], Z. Zhang[1,3], and U. Kaiser[1],
U. Wiedwald[2], L. Han[2], B. Kuerbanjiang[2], and P. Ziemann[2]

1. Central Facility of Electron Microscopy, Ulm University, D-89081 Ulm.
2. Institute of Solid State Physics, Ulm University, D-89081 Ulm
3. Erich Schmid Institute of Materials Science, Austrian Academy of Sciences, 8700, Leoben

Johannes.Biskupek@uni-ulm.de
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Magnetic nanoparticles and thin films exhibiting a large magnetic anisotropy energy density (MAE) have attracted enormous attention over the last years due to their potential use in magnetic data storage or sensing applications. FePt alloy nanoparticles and films have a huge MAE in the chemically ordered $L1_0$ phase. This ordered phase is typically obtained by annealing the as-prepared chemically disordered fcc FePt nanoparticles at temperatures above 600°C. Besides standard colloidal approaches [1], such fcc FePt nanoparticles can be fabricated by a micellar technique resulting in regular arrays on various substrates [2,3]. This approach offers the advantage that the interparticle distance can be tuned between 20-100 nm. Due to the larger separation particle agglomeration can be avoided during the annealing induced transformation into the $L1_0$ phase. Moreover, the particles are magnetostatically decoupled.

We investigated the formation of the $L1_0$ phase for 2-10 nm FePt particles as a function of the annealing temperature and time on Si/SiO_x substrates. Hysteresis loops at T = 15K reveal strongly enhanced coercive field after an annealing step at 700°C for 30 min compared to the as-prepared particles. The effective MAE is found to be $1\text{-}2\times10^6$ J/m^3 using simple Stoner-Wohlfarth modeling that is a factor of 3-5 smaller than the FePt bulk MAE.

In order to correlate the magnetic properties to the structure of the particles we performed transmission electron microscopy (TEM) investigations of FePt particles on both, Si/SiOx and MgO(001) substrates. Basically, the lowered MAE could originate from defective crystal structures, imperfect ordering of Fe- and Pt-planes (chemical ordering parameter), and/or inhomogeneous segregation of Fe/Pt within the particles.

The applied TEM methods included conventional TEM (bright-field, dark-field, electron diffraction), spherical aberration corrected high resolution imaging and scanning TEM (Z-contrast). It was found that most particles contain defects such as stacking faults and multiple twins (Figure 1). Calculated TEM images based on various models of FePt nanoparticles (Figure 2) were generated and compared to experimental images especially to analyze and to determine the chemical ordering parameter of the $L1_0$ phase, crystal structure and defects.

[1] C. Antoniak et al., Phys. Rev. Lett. 97, 117201 (2006)
[2] A. Ethirajan et al., Adv. Mater. 19, 406 (2007)
[3] U. Wiedwald et al., Appl. Phys. Lett. 90, 062508 (2007)
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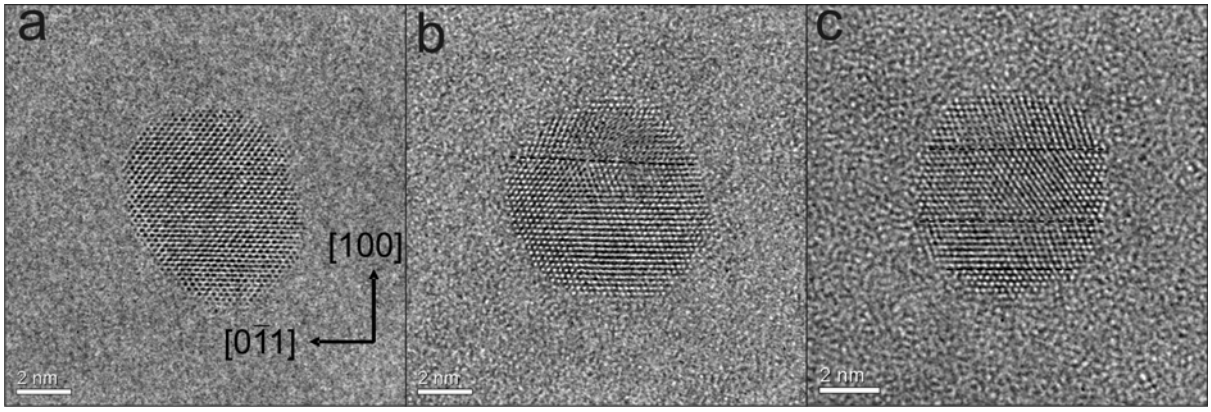

Figure 1. C_S-corrected HRTEM images of FePt nanoparticles (<011> viewing direction) of silicon oxide substrate. (a) FePt with no stacking faults and twins along [100]. (b,c) examples of nanoparticles with stacking faults and multiple twins that are responsible for lowered MAE.

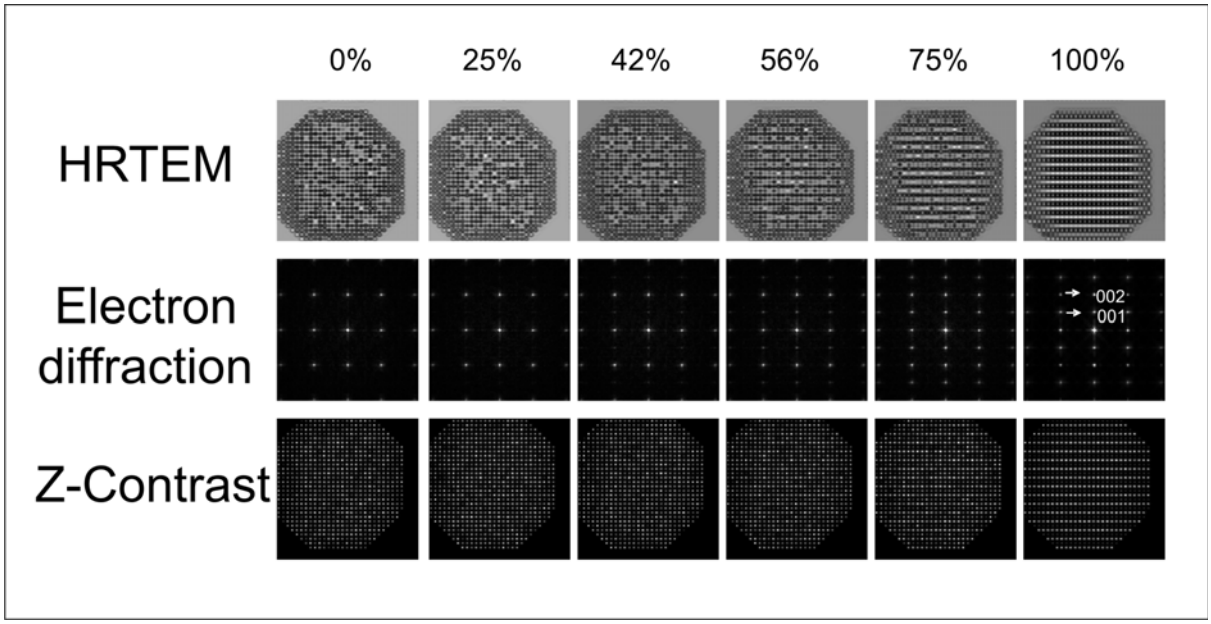

Figure 2. Image calculations of FePt nanoparticles with varying order parameter. The figure show the HRTEM, electron diffraction pattern and Z-contrast images and the effect of ordering parameter to the image contrast. Note that the 001 reflection (in electron diffraction) appears with the increasing of order parameters.

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