Z-STEM Imaging of Chemical Ordering in FePt Magnetic Nanoparticles

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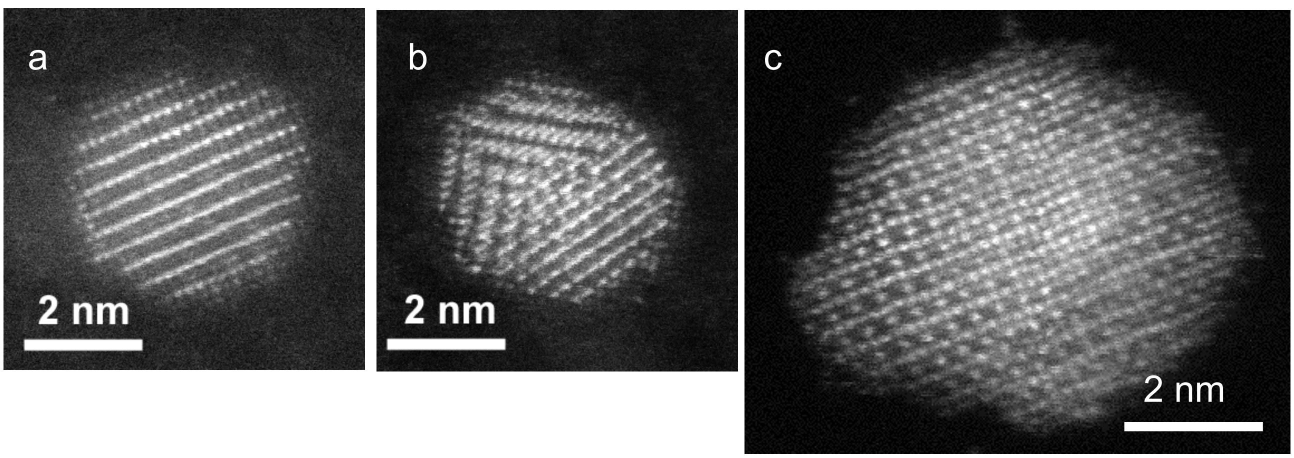
Scientific challenge: Monodispersed FePt nanoparticles (3-10 nm) produced by chemical synthesis have great potential for future magnetic storage media. The FCC as-synthesized FePt nanoparticles require annealing to chemically order into the tetragonal $L1_0$ structure where FePt exhibits exceptional magnetic properties with bulk uniaxial-magnetocrystalline anisotropy (Ku) greater than 10^7 ergs/cm^3 and nanoparticle coercivity that can exceed 22 kOe. Understanding the $L1_0$-ordering phase transformation is critical for using these FePt nanoparticles as engineered magnetic nanostructures, but X-ray diffraction (XRD) is not sensitive to the initial stages of ordering and provides no information concerning the nucleation and growth mechanism of the ordered structure. HAADF-STEM, is being used to investigate the development of $L1_0$ order in FePt nanoparticles, both ex-situ and in-situ.



Accomplishment: FePt nanoparticles of 3.8 nm average diameter were dispersed on an ultrathin carbon support film and characterized after annealing for 30 minutes at 600°C in a H_2-N_2 reducing environment. STEM imaging was performed at 200 kV with a probe-corrected JEOL 2200FS-AC. Ex-situ annealed FePt nanoparticles, as shown in the figure (a,b), have completely ordered structures, exhibit faceting on (110), (100), and (010), and sometimes have internal interfaces such as anti-phase domain boundaries (APBs). The onset of the ordering transformation was revealed by in-situ heating experiments of particles with a mean diameter of 5.2 nm using a Protochips MEMS-based heating system. The development of superlattice structures at the surfaces of the particles was observed following in-situ annealing for short times at 500°C. However, subsequent observation at 400°C with continuous rastering of the probe over a particle resulted in additional substantial changes to particle shape, faceting, and ordered structure, including the unexpected development of Pt_3Fe-type $L1_2$ order (figure c). Subsequent measurements of individual nanoparticle composition by EDS in a Philips CM200-FEG revealed a wide range of compositions, but overall indicated the particles were Pt-enriched. The results clearly indicated the need for improved composition control during the chemical synthesis and the need to avoid potential beam-induced artifacts during in-situ experiments.

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