

## Order-Disorder Phase Conversion of FePt Nanoparticles for Ultrahigh-Density Magnetic Recording

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Increasing the storage density of magnetic recording media necessitates the development of new materials. Monolayers of monodisperse ferromagnetic nanoparticles (NPs) can potentially extend the density limit into the Tbit/in<sup>2</sup> range [1]. NP monolayers are envisioned as future bit-patterned magnetic recording media, where the storage density limit depends on the NP size. While smaller NP sizes increase the storage density, the reduced magnetocrystalline anisotropy energy of smaller NPs makes their moments more susceptible to ambient thermal energy-induced fluctuations (superparamagnetism), which prevents information storage. As a material's magnetocrystalline anisotropy constant ( $K$ ) increases, the size at which the transition occurs between ferromagnetism and superparamagnetism decreases. Therefore, materials with high  $K$ , such as the intermetallic L1<sub>0</sub> phase of FePt with  $K$  of  $7 \times 10^7$  erg/cm<sup>3</sup> [2] corresponding to a critical diameter for magnetic recording of approximately 4 nm are attractive candidates for future ultrahigh-density magnetic recording.

Ligand-stabilized FePt NPs synthesized by wet-chemical methods are of particular interest, because they can be obtained with highly monodisperse size distributions, and the ligands facilitate self-assembly into ordered monolayers. As-synthesized, ligand-stabilized FePt NPs have disordered (A1) structures, whose magnetic properties are not useful for information storage. Annealing is required to convert the NPs into the L1<sub>0</sub> phase but also induces coalescence and sintering between NPs. Depositing the NP monolayers on thermally-robust SiN membranes and then coating them with a thin layer of Al<sub>2</sub>O<sub>3</sub> by atomic layer deposition overcomes this limitation.

The products of thermally-annealed monolayers of FePt NPs were analyzed using a JEOL 2010F microscope for high-angle annular dark-field scanning transmission electron microscopy (HAADF STEM) imaging of individual NPs. HAADF STEM reveals that as-synthesized A1 FePt NPs, depending on their composition, converted to the L1<sub>0</sub> or L1<sub>2</sub> intermetallic phase after annealing. HAADF STEM imaging also gives insight into the order-disorder phase conversion process and allowed qualitative determination of the ordering, which was imperfect (long range order parameter,  $S < 1$ ) and varied between individual NPs. Segregation of Pt to the NPs' surfaces and a Gaussian-like distribution of NP compositions resulted in mixed-phase NPs, where regions of L1<sub>0</sub> and L1<sub>2</sub> coexist. These compositional limitations and surface effects inhibit formation of perfectly-ordered ( $S=1$ ) intermetallic NPs [3].

### References

- [1] S. Sun et al., *Science* 287 (2000) 1989-1992.

- [2] K. Inomata et al., *J. Appl. Phys.* 64 (1988) 2537-2540.
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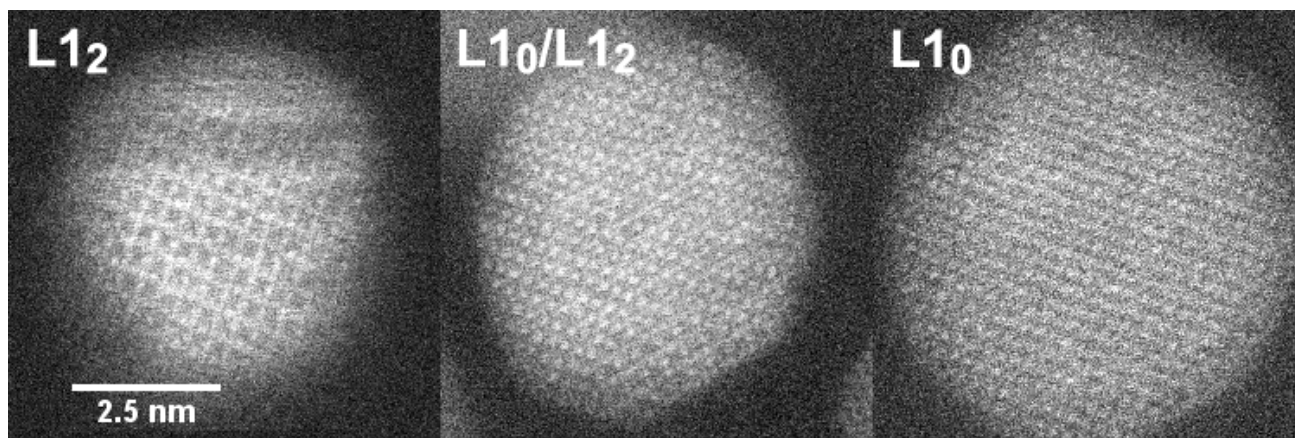


FIG. 1. HAADF STEM images of three intermetallic FePt nanoparticles with L1<sub>2</sub>, L1<sub>0</sub>, or mixed structures.