Chemically Synthesized FePt Nanoparticles


Chemically synthesized FePt nanoparticles have received considerable attention in recent years because of their potential for ultra-high density data storage. The synthesis originally described by Sun and co-workers yields monodisperse nanoparticles that have the A1 structure, are superparamagnetic, and can self-assemble into two and three-dimensional arrays. High-temperature annealing is required to transform the particles to the high-anisotropy L10 structure. We have been addressing several materials issues related to the phase transformation of these particles.

We have shown that additive metals (Au, Ag, Pd, Cr, Cu) can significantly affect the ordering temperature in three-dimensional arrays; however, they also affect particle sintering and grain growth. For a given metal additive, we have found that the onset of chemical ordering, grain growth, and coercivity enhancement all occur at a similar temperature. There is growing evidence of a size effect on chemical ordering. In order to address this issue, we have compared the effect of annealing temperature on order parameter and magnetic properties of arrays of 3 nm FePt and FePtAu particles and 6 nm FePt and FePtAu nanoparticles. The larger particles order more easily and the additive Au enhances the ordering for each size. In all cases, however, sintering occurs at high annealing temperatures, which complicates the size effect issue.

We have been developing ways of isolating nanoparticles in order to study chemical ordering in the absence of sintering. In one method, films consisting of FePt and Cu nanoparticles have been prepared and chemical ordering and magnetic properties have been studied as a function of FePt/Cu ratio and annealing temperature. In a second method, FePt nanoparticles have been encased in a silicate structure to inhibit sintering. Initial results show that these methods are effective in reducing sintering.

One of the most difficult problems has been to make L10 FePt nanoparticle films with oriented easy axes. Annealing in large magnetic fields has not been successful. We have succeeded by synthesizing FePt nanoparticles with partial chemical order. Using a high-temperature procedure, 8 nm FePt nanoparticles with Hc ~ 600 Oe were synthesized. The particles were dispersed in a commercial tape binder and oriented by drying in a magnetic field. A similar high temperature synthesis was used to make FePtAu nanoparticles with Hc ~ 5,000 Oe; however, these particles are difficult to disperse and align.

The order-disorder temperature for FePt nanoparticles has been modeled as a function of particle size. A lattice gas method was used with 1st, 2nd, and 3rd nearest neighbor interaction potentials. The interaction potentials were determined by first-principles calculations of a number of small atomic systems. The results show that the order-disorder temperature decreases with particle size. For 3.5 nm particles, the transition temperature is 1100 K, compared with 1510 K calculated for bulk FePt. We are also simulating the sintering process using multi-body, embedded atom potentials to conduct classical, molecular dynamics simulations of nanoparticles en vacuo and on idealized surfaces.