Sintering Behavior of Spin-Coated FePt and FePtAu Nanoparticle


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Motivation

- Chemically synthesized FePt nanoparticles have great potential for ultra-high density storage media.
- High chemical ordering can be obtained by furnace annealing; however, there is a strong correlation between the chemical ordering and the sintering process of FePt nanoparticles.
- Small angle neutron scattering (SANS) and small angle X-ray diffraction (SAXRD) are powerful methods to nondestructively characterize the position ordering of particle arrays. The chemical ordering and particle sintering behavior of spin-coated FePt and FePtAu nanoparticles have been investigated by using SANS, SAXRD, and magnetometry.

Experiment

- FePt and [FePt]95Au5 Nanoparticles were synthesized by thermal decomposition of Fe(CO)5 and reduction of Pt(acac)2 and gold acetate in Pheny ether.
- Particles were cast on to the Si wafers by spin-coating.
- Post-annealing was done in the tube furnace in Ar/H2 for 30 minutes.
- SANS measurements were performed on the 30 m NG3 SANS instrument at the National Institute of Standards and Technology (NIST) Center for Neutron Research.
- SAXRD measurements were performed in the reflection geometry with a Philips X’Pert Materials Research Diffractometer (X’Pert-MRD).
- Magnetic hysteresis curves and dynamic coercivity were measured on a Princeton Micromag 2900 alternating gradient magnetometer (AGM).

Intensity $I(q)$ extracted from SANS image of as-made FePt nanoparticles

- SANS scattering intensity exhibits a well-defined peak at $q=0.085$ Å$^{-1}$, indicating an in-plane coherence length $a \sim 7.3$ nm.
- SAXRD reflectivity measurements give a perpendicular coherence length $c = 12.0$ nm.
- The ratio of $c/a$ is about 1.64, indicating the as-made FePt nanoparticle array has the hexagonal close-packed superstructure.

Intensity $I(q)$ extracted from SANS images of FePt nanoparticles

- For FePt nanoparticles, the SANS peak is nearly fixed in position and broadens slightly with annealing temperature up to 300 °C. Further increase in the annealing temperature results in decomposition of the surfactants, and the SANS peak rapidly shifts to higher $q$ value, indicating shrinking and sintering of the FePt nanoparticle array.

SAXRD pattern of as-made FePt nanoparticles

- The intrinsic remanent coercivity, $H_{r0}$, and thermal stability factor, $KV/kT$, can be obtained by fitting with Sharrock’s formula. FePt nanoparticles have large $H_{r0}$ and $KV/kT$, indicating a large switching volume after annealing.

Summary

- The spin-coated FePt and FePtAu nanoparticles have a hexagonal close-packed ordered superstructure.
- The annealing process, which is needed to achieve hard magnetic properties, destroys the assemblies via agglomeration and sintering based on SANS and magnetic measurements.
- This effect is more pronounced for FePt nanoparticles than for FePtAu nanoparticles.