Synthesis, self-assembly, and magnetic properties of FePt-Au Nanoparticles

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Introduction


- These materials meet many of the requirements for ultra-high density media, including small grain size, narrow size distribution, weak interactions, and high K.

- Phase transition occurs at high annealing temperature (~600°C). Lowering the ordering temperature is a key issue for L1\textsubscript{0} FePt nanoparticles.
Structural Transition of FePt Nanoparticles

Disordered with cubic anisotropy

Ordered with uniaxial anisotropy

annealing

fcc-like structure
Only Fundamental Peaks (111), (200), ...

XRD

fct-like structure
Fundamental & Superstructural Peaks (111), (200), (002), ...; (001), (110), ...

Fe atom  Pt atom

K_u: ~10^7 erg/cc

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FePtAu Synthesis

\[
\text{Pt(acac)}_2 (0.5 \text{ mmol}) + \text{ Au acetate (0.05-0.3 mmol)} \\
+ 1,2\text{-hexanediol (2 mmol)} + \text{ phenyl ether (20 mL)} \\
\downarrow \text{(heat to 80°C under nitrogen)} \\
\text{Add Fe(CO)}_5 (1 \text{ mmol}) + \text{ oleic acid (0.5 mmol)} \\
+ \text{ oleylamine (0.5 mmol)} \\
\downarrow \text{(reflux at 260°C for 30 min)} \\
\text{Particle Dispersion} \\
\downarrow \text{(add 40 mL ethanol)} \\
\text{Isolate Particles by Centrifuging}
\]
Purification of FePtAu Particles

1. Disperse particles in hexane
2. Add ethanol to precipitate the particles
3. Centrifuge and discard mother liquor
4. Disperse particles in hexane
5. Add ethanol to precipitate the particles
6. Centrifuge and discard mother liquor

Yield about 100 to 200 mg of particles
TEM images and XRD patterns of as-made FePtAu nanoparticles

Bilayers

Trilayers
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• As-made FePt-Au nanoparticles shows fcc structure, indicating chemical disordered.

• FePt-Au nanoparticles with diameter ~ 3.5 nm self-assembled into hexagonal array.

• The fundamental peaks shifts to the lower angle with increasing Au, suggesting the lattice was expanded after introducing Au.
Phase transition and magnetic properties of FePt-Au nanoparticles upon annealing
• The phase transition was revealed by the evolution of superlattice peaks (indicated by dotted lines), the splitting of (200) and (002) peaks and the shift of (111) peak.

• Upon annealing, Ag was phase separating from the particles.

• Coercivity increase with annealing temperature.
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Coercivity of FePt, FePtAg, FePtAu Nanoparticles

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Dynamical coercivity & KV/kT

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\[ V_{sw} = C \frac{kT}{M_s H_0}, \quad C = \left( \frac{KV}{kT} \right)_{\text{meas}} \]

assumes \( H_0 \approx \frac{1}{2} H_k = \frac{K}{M_s} \)

\[ M_s = 1100 \text{ G} \]

\[ \bar{d} = 2 \star \sqrt[3]{\frac{3}{4\pi}} V_{sw} \approx 9 - 12 \text{ nm} \]

\[ d \approx 3.5 \text{ nm (TEM)} \]
Summary

• Self-assembled FePt-Au nanoparticles of diameter ~ 3.5 nm were synthesized and annealed at different temperatures.

• Compared with FePt and FePtAg nanoparticles, $H_C$ was significantly enhanced with addition of Au. The ordering temperature was reduced more than 150$^\circ$C. The possible mechanism is due to the defects and lattice strain introduced by the Au and the subsequent segregation of the Au upon annealing, activating the nucleation of the ordered phase.

• Dynamical coercivity measurements reveals the average switching volume is larger than the particle’s volume.