Chemical Ordering and Magnetic Properties of Silica Coated FePt Nanoparticles

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Motivation:

- Chemically synthesized FePt nanoparticles have potential for very large magnetic storage densities
- Arrays of nanoparticles coated with organic surfactants sinter during thermal annealing because of a breakdown of the surfactant.
- More robust coatings are needed to prevent sintering.
- Prevention of sintering will help to study the effect of intrinsic effects of particle size and metal additives on chemical ordering.

Synthesis of Silica Coated FePt Nanoparticles

- Nanoparticles prepared using standard FePt nanoparticle synthesis
- Particles are cleaned and tetramethyl ammonium hydroxide (TMAOH) added
- With TMAOH, particles are now dispersible in water, with minimal impact on particles’ physical or magnetic properties
- Particles added to solution containing tetraethyloorthosilicate (TEOS), encapsulating particles in a silica shell. Concentrations of .05mL and .5mL TEOS were used.
- Particles dispersed in isopropyl alcohol or tetrahydrofuran (THF). Samples then annealed at 700°C for 30min in an Ar/H2 atmosphere

TEM (non-annealed silicated FePt in THF)

- TEM clearly shows that silica coats the particles.
- Some particles are “clumped” together, which will allow sintering during annealing.

Coercivity vs. TEOS Concentration

- Coercivity, $H_C$, decreases with added TEOS mainly due to reduction in grain size.
- Intrinsic coercivity, $H_0$, slightly decreases with added TEOS.
- Smaller $H_0$ without silica due to sintering and incoherent reversal.

Anisotropy vs TEOS Concentration

- $K$ slightly decreases with increased TEOS due to better particle isolation.
- Smaller $K$ of uncoated particles due to limitations of Sharrock equation for highly sintered particles.

Thermal Stability versus TEOS Concentration

- Large decrease in $K$ due to reduction in particle volume.
- Silica coating reduces grain growth and increased TEOS allows more effective isolation of individual particles.

Dynamic Coercivity Analysis

Time dependent remanent coercivity measurements were analyzed using the Sharrock equation to determine the intrinsic switching field, $H_0$, magnetic anisotropy, $K$, thermal stability factor, $KV/kBT$, and the magnetic switching diameter, $d_{sw}$:

$$H_{sw}(t) = H_0 \left[ 1 - \frac{k_BT}{K} \ln(f(t)) \right]^{2/3}$$

$$H_0 = \frac{1}{2} H_A + \frac{K}{M}$$

$$V_{sw} = \frac{4}{3} \frac{d_{sw}^3}{2}$$

- Huge decrease in switching volume from after silica coating.
- Strong evidence that silica inhibits sintering.

Magnetic Switching Volume

- FePt nanoparticles can be effectively coated with a silica shell using TEOS. Silica shell survives annealing and is effective in inhibiting particle sintering. Grain isolation is improved by by using more TEOS in the preparation.
- Future work will focus on more effectively coating individual particles and controlling the shell thickness.
- FePt particle size will be changed and metal additives will be used to study effect of size and additives on chemical ordering in absence of sintering.

Conclusions and Future Work

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