A Model for the Easy-Axis Alignment of Chemically Synthesized L$_{10}$ FePt Nanoparticles

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This project was funded by grant NSF MRSEC - DMR 0213985.

Abstract

- **Easy-axis orientation** of chemically synthesized L$_{10}$ FePt nanoparticles obtained by drying a dispersion in a magnetic field has been calculated.
- Degree of orientation depends on $\mu H/kT$ and $KV/kT$. ($\mu =$ particle moment, $K =$ anisotropy constant, $V =$ particle volume).
- **Exact analytical solution** obtained for $KV/kT > \mu H/kT$.
- **Monte-Carlo model** used to calculate the orientation for arbitrary values of $KV/kT$ and $\mu H/kT$.
- MC model gives good qualitative agreement with the measured field and angular dependence of orientation.
- Calculated orientation is higher than measured and is consistent with a reduced anisotropy constant due to particle aggregation during the drying process.

Theory

$$E = KV \sin^2 \phi - M_V H \cos \psi$$

Remanence $= m_o = \left\langle \cos \theta \right\rangle$

$$Z = \int_0^{2\pi} \int_0^\pi \left[ \sin \phi \sin \psi \cos \left(-a \sin^2 \phi + b \cos \psi \right) \right] d\phi d\psi,$$

$$a = \frac{KV}{kT}, \quad b = \frac{\mu H}{kT}.$$

**Strong coupling approximation (SCA)**, $KV/kT > \mu H/kT$:

$$\left\langle \cos \theta \right\rangle = 1 + \frac{1 - \cosh(b)}{b \sinh(b)},$$

**Intermediate to strong coupling approximation (ISCA)**, valid for $KV/kT > 3$ and $m_o > 0.6$

$$\left\langle \cos \theta \right\rangle = \frac{e^{-a} - 1}{a I(a)},$$

$$I(a) = \int_1^\infty \frac{\exp(ax^2)}{x} dx,$$ $L(b) = \text{Langevin}$ $fct$

Summary

- The orientation process for L$_{10}$ FePt nanoparticles has been calculated.
- Results are in qualitative agreement with experiment, but predict higher orientation than obtained experimentally.
- Results suggest that small FePt nanoparticles can be highly oriented in modest fields.

Calculated remanence using Monte-Carlo model and strong (SC) and intermediate to strong (ISCA) approximations for KV/kT = 10.

Measured hysteresis loops of aligned directly synthesized L$_{10}$ FePt nanoparticles [1].