Numerical Micromagnetic Simulation of Fe-Pt Nanoparticles with Multiple Easy Axes

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Abstract

We have carried out numerical 3D finite element micromagnetic simulations to study the influence of the demagnetizing field, the distribution of easy axes and the particle size on the coercivity of FePt nanoparticles.

Key words: FePt, nanoparticles, micromagnetics, anisotropy
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1. Introduction

High density magnetic storage media require tight control of the grain size, grain size distribution, chemical composition, and microstructure to ensure the thermal stability of the bits and keep the media noise low. However, as the areal density increases, the grain size and the magnetic switching volume decreases. In order to maintain the stability materials with higher uniaxial anisotropy than the common CoCrPt alloys are required. FePt thin films and self assembled nanoparticles [1] are promising candidates for high density magnetic storage media. Their magnetocrystalline anisotropy is 50–100 times larger than in CoPtCr media alloys which may allow areal densities in the Tbit/in^2 regime [2].

2. Finite Element Model

The geometry of our FePt nanoparticles is modeled after HREM images by Bian et al. [3]. We have split our particle into six parts of equal volume (cf. Fig. 1). In each part the magnetocrystalline anisotropy axis is uniform, but we have varied direction of the axes in the different parts. The material parameters have been taken from [2], which give $J_\mathrm{s} = 1.43$ T, $A_\mathrm{exch} = 1.0 \times 10^{-11}$ J/m, $K_\mathrm{ani} = 7.7\,\mathrm{MJ/m^3}$, $H_\mathrm{ani} = 10769\,\mathrm{kA/m}$ ($\hat{=}13.5\,\mathrm{T}$), $l_\mathrm{exch} = 1.2$ nm.

3. Stoner-Wohlfarth Behavior

First we have carried out simulations of a particle with a single magnetocrystalline anisotropy axis parallel to the z-axis and a diameter of 60 nm. As expected we find the behavior of a typical Stoner-Wohlfarth particle. Then we have included the demagnetizing field in the simulation and found only a very small influence on the nucleation field, which is reduced by less than 5 %. This is due to the dominating role of the anisotropy, which gives rise to an anisotropy field of more than 13 T. In comparison the demagnetizing field in a par-

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Table 1
Coercivity as a function of the easy axis distribution: The first, second, and third number of a triplet in the first column indicates in how many of the six parts of the finite element model the easy axes are parallel to the z-, x-, and y-axis, respectively. In the (2:2:2(a)) configuration there are three pairs of neighboring parts with equal anisotropy axes, whereas in the (2:2:2(b)) (cf. Fig. 1) configuration each pair of neighboring parts has perpendicular easy axes.

$x:y:z$	H_c (kA/m)
5:1:0	3330
4:2:0	3140
4:1:1	3310
3:3:0	3630
3:2:1	3420
2:2:2(a)	3430
2:2:2(b)	2040

ticle with perfectly homogeneous magnetization varies from 0.4 to 0.9 T within the particle.

4. Multiple Easy Axes

Then we have studied the influence of a distribution of easy axes within the particle. As described above, we have varied the easy axis in the six parts of our model and calculated the coercivity for an external field applied parallel to the z-axis. The results are summarized in Tab. 1. The left column indicates, how many of the six parts of our model have their easy axis parallel to the z-, y-, and x-axes, respectively. The results show, that the coercivity is decreased by a factor of three as compared to the nucleation field. However, the different distributions of easy axes show no significant influence on the coercivity. This behavior indicates, that the 90° domain wall at the interface between two misaligned parts of the particle determines the coercivity. Thus, already a single misaligned part is sufficient to reduce the coercivity by a factor of three.

Finally, we have reduced the size of the particles and studied their coercivity. The shape and aspect ratio remained the same, the model has just been rescaled to the desired size. The exchange length of FePt is about 1 nm and the resulting domain wall width about 3 nm. As a result, the properties of very small particles are modified due to the increasing importance of the exchange interactions. The results of our simulations are summarized in Fig. 1. We have used the (2:2:2(b)) distribution of easy axes, where each pair of neighboring parts in our model has perpendicular easy axes (cf. Fig. 1).

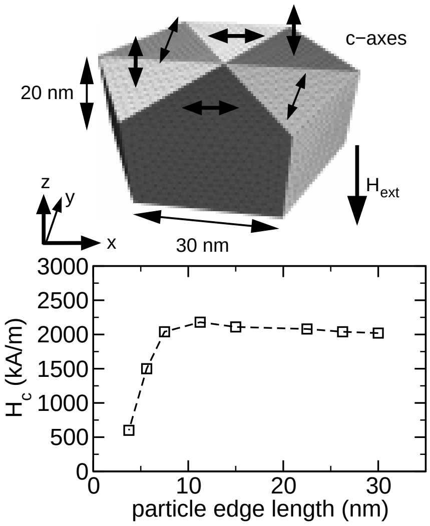

Fig. 1. Coercivity as a function of the edge length of the nanoparticle. The easy axis distribution is shown in the top figure for the (2:2:2(b)) distribution, where all neighboring pairs have perpendicular easy axes.

For this distribution we find a further reduced coercivity of 2040 kA/m, which drops to 600 kA/m if the particle size is reduced to 3.75 nm.

5. Conclusions

Shima et al. [1] have measured coercivities of up to 40 kOe (3200 kA/m) for FePt thin films with strongly faceted islands, which agree well with our simulations. In very small FePt nanoparticles of approximately 20 nm diameter Bian et al. [3] have found regions with different easy axes and measured coercivities of 4.4 kOe (350 kA/m). Our simulations have shown a similar reduction in coercivity depending on the particle size and distribution of easy axes.

References

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