Control of the shape and size of soft magnetic nanoparticles with three-dimensional vortex structure

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1. Introduction

Magnetic nanoparticles currently are of interest for their bio applications, which include magnetic resonance imaging, targeted drug delivery, cell separation, immunoassay, and hyperthermic treatment of malignant cells [1-4]. Magnetic nanoparticles' unique properties can be achieved by means of the control of their shape, size and distribution. However, such nanoparticles' intrinsically low saturation magnetization values, which require relatively high magnetic fields, makes their use in clinical settings highly problematic. A new type of magnetic material, therefore, is required. Soft magnetic nanoparticles of high saturation magnetization but negligible interaction represent one possible alternative in this regard.

2. Experimental method

In the present study, we have synthesized spherical shaped, homogeneous $Ni_{80}Fe_{20}$ nanoparticles with controlledsizeusingpolyolprocess. The Ni - Fe NPs were synthesized by reduction from Fe and Ni precursors dissolved in propylene glycol (PG) at an optimized pH and temperature. In this method, PG was used as polyol solvent. Even though it is known that the solvents itself have little reduction ability but it change into propanol during heating and at designed temperature, metal salts can be reduced in the redox reaction by the modified solvent.

$$2CH_3CHOH\text{-}CH_2OH+M(OH)_2 \rightarrow CH_3COCOCH_3+2H_2O+M^0 \cdots\cdots (1)$$

In the reaction process, disproportion of iron hydroxide required since polyols are too weak to reduce Fe ions whereas Ni reduction occurred easily because of thermodynamic preference. However, disproportionation of ferrous hydroxide happens in reaction according to equation 2 and Fe particles produced even though iron is too electropositive to be reduced by polyols.

$$4Fe(OH)_2 \rightarrow Fe + Fe_3O_4+4H_2O \cdots\cdots (2)$$

The synthesized magnetic nanoparticles were then characterized by XRD, TEM and FESEM to study the phase purity, shape, size and structural assemblies. As permalloy nanoparticles are highly magnetic and tend to be agglomerated easily, it is therefore, dispersed in water, followed by sonication for long time before sample preparation for TEM and FESEM measurement. Partially dispersed solution was then loaded by drop-casting on TEM grid and Si wafer, kept on a rare earth magnet and dried at room temperature. Next, the micromagnetic simulation was carried out using FEMME (version 5.0.8) to study the intermediate assemblies of the magnetic nanoparticles in terms of the magnetic interaction energy.

3. Result and Conclusion

In this presentation we report the successful synthesis of monodisperse 100 – 300 nm diameter permalloy (Py) nanoparticles of a unique spin configuration (i.e. vortex state). In the present study, the distributions of synthesized Py nanoparticles on a silicon (Si) wafer were investigated. Some specific trends were found on combination of permalloy particles depending on the number of assembled particles. Our statistical analysis revealed a clear order of priority among a rich variety of geometrical configurations of the primary vortex-state particles. These results will provide valuable insights into the interplay between nanoparticles' distributions and magnetic interaction in the unique three-dimensional vortex state.

4. References

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