孤立したマグネタイトナノ粒子の磁気特性評価

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Magnetic characterization of well-isolated magnetite nanoparticles

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Introduction

In recent year, method for synthesizing magnetic nanoparticles has made remarkable progress. However, the true magnetic characteristics of the nanoparticles such as magnetic anisotropy is yet to be revealed due to interactions between nanoparticles. As a consequence, the application-oriented design of magnetic nanoparticles has become difficult. Thus in this study, we have prepared ideal interaction-free magnetite nanoparticle system by coating magnetite particles with silica of enough shell thicknesses and measured their magnetic properties to clarify the true magnetic anisotropy of individual magnetite nanoparticles.

Experimental

First, magnetite particles with average diameters of 7.8 nm and 13.1 nm were synthesized. Then, these magnetite particles were coated with silica shell of thicknesses 20.8 and 28.9 nm, respectively. In the first-order reversal curve (FORC) diagrams (Fig. 1), we can find that interaction field disappears with coating. In other words, the magnetite nanoparticles are magnetically isolated by the silica-shell. This fact can be confirmed by the proportional relationship between isothermal remanent magnetization and DC demagnetization remanence.

Results and discussion

Using these well-isolated magnetite nanoparticles, the magnetic measurements yield intriguing information as follows: (A) Remanent magnetization from the magnetic saturation is just equal to a half of the saturation magnetization, and magnetization curves can be explained as the superimposition of Stoner-Wohlfarth hysteresis loops considering the switching field distribution derived from the remanence analysis. These results clearly indicates that uniaxial magnetic anisotropy is predominant in the individual magnetite nanoparticles in spite of the cubic symmetry of their crystal. (B) Blocking temperature distributions calculated from thermal decay curves of isothermal remanent magnetization at various applied fields show that the coercivity significantly varies even for the same size, although their mean value becomes higher when the size is smaller. These results indicate that the magnetic anisotropy is not only correlated with the surface/volume ratio, but also considerably affected by the other factors such as crystallinity, lattice strain, or particle shape. Further discussion will also be reported.

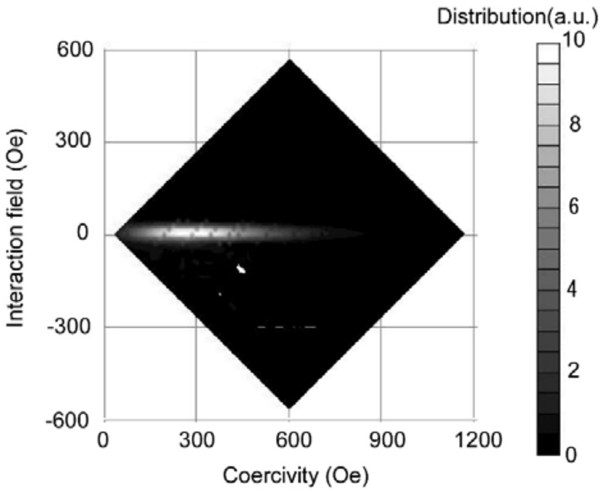

Fig. 1 FORC diagram for magnetite particles of 13.1 nm.