20p-F4-7

Energy Dissipation of Superparamagnetic Suspensions in Term of Nonlinear AC Magnetization

Tokyo Inst. of Tech.[1], ○Suko Bagus Trisnanto[1], Yoshitaka Kitamoto[1]

E-mail: kitamoto.y.aa@m.titech.ac.jp

The mathematical approach of nonlinear magnetic response of superparamagnetic system in the presence of thermal agitation is often associated with Langevin function which deals with the ratio of Zeeman energy to thermal energy in defining overall magnetization. Based on this concept, many prospective biomedical applications of magnetic nanoparticles have been developed, e.g. magnetic particle imaging[1)] and magnetic hyperthermia[2)], by utilizing sinusoidal magnetic field to induce magnetization responses of the particles. In these cases, a few amount of external field energy is dissipated during relaxation processes in which its value corresponds to the imaginary part of magnetic susceptibility.

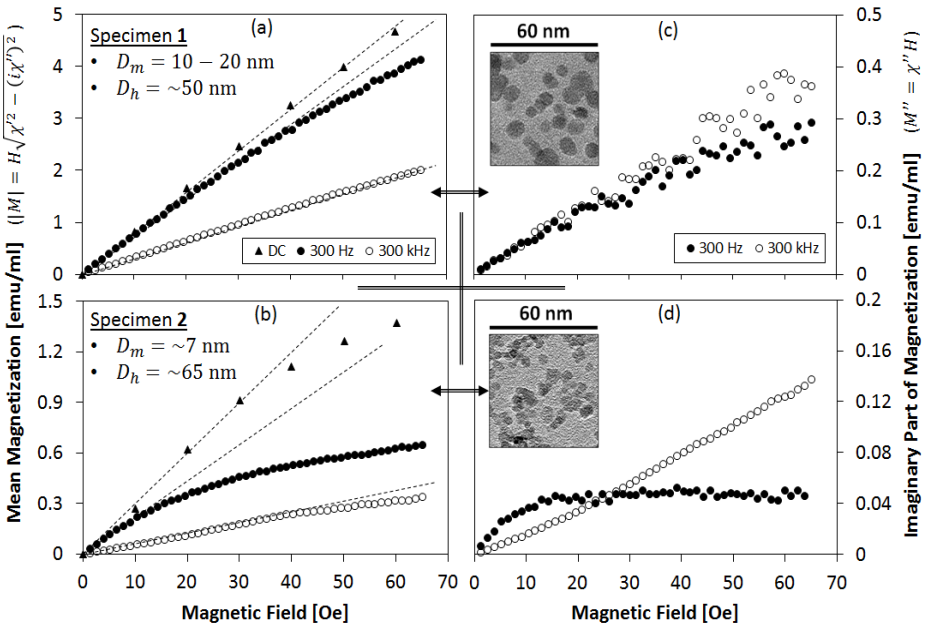

Fig. 1 Magnetic responses of iron oxides nanoparticles suspensions

In order to evaluate energy dissipation of superparamagnetic suspensions, we investigated the AC magnetization response of magnetic suspensions containing iron oxides nanoparticles with different average particle size, by measuring complex magnetic susceptibility at 300 Hz and 300 kHz. Then, we calculated the mean magnetization, $|M| = H\sqrt{(\chi')^2 - (i\chi'')^2}$, from the results obtained under applied fields up to 65 Oe (rms), to confirm nonlinear AC magnetization as shown in Fig. 1(a-b). Considering that only imaginary part of magnetization contributes in energy loss, we found that there is field strength dependence of the dissipated energy. The imaginary part of magnetization shows a linear response at 300 kHz according to Fig. 1(c-d). But, as we confirmed in Fig. 1(d), it saturates at low frequency-high fields in which a high degree of nonlinearity of magnetic response was found. This correlates with the relaxation dynamics of the particles causing such saturation of rotational motions. The reduction of energy dissipation due to nonlinear response of AC magnetization, furthermore, implicitly decreases the hyperthermic efficiency.

References: 1). S. Biederer *et al*, J. Phys. D: Appl. Phys. **42**, 205007 (2009)

2). G. Vallejo-Fernandez *et al*, J. Phys. D: Appl. Phys. **46**, 312001 (2013)