ASIAN – EROUPE PHYSICS SUMMIT (ASEPS)

MONTE CARLO STUDY OF COLLECTIVE BEHAVIOR OF MAGNETIC NANOPARTICLE SYSTEMS

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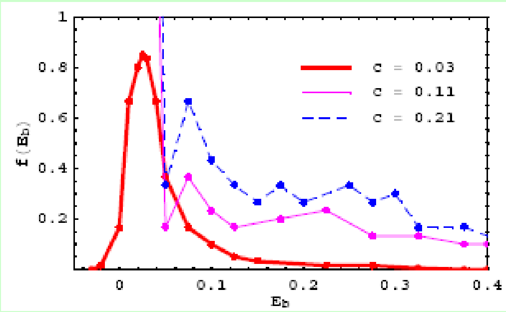
Energy of Magnetic Nanoparticle Sytems

$$E^{(i)} = -K_u V_i \left(\frac{\boldsymbol{\mu}_i . \mathbf{n}_i}{|\boldsymbol{\mu}_i|}\right)^2 - \boldsymbol{\mu}_i \mathbf{H} + g\sum_{j\neq i}^{N}\left(\frac{\boldsymbol{\mu}_i.\boldsymbol{\mu}_j}{r_{ij}^3} - 3\frac{(\boldsymbol{\mu}_i.\mathbf{r}_{ij})(\boldsymbol{\mu}_j.\mathbf{r}_{ij})}{r_{ij}^5}\right)$$

The first term in Eq.3 is the anisotropy energy, n_i is the direction of the anisotropy axis, $|n_i| = 1$. The second term is the Zeeman energy, H is the external field. The last time is the dipolar energy between two particles i and j separated by r_{ij}, and constant $g = \mu_0/4\pi$.

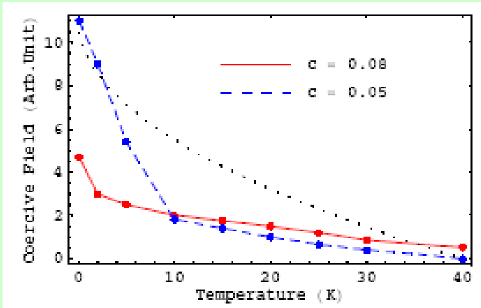
Barrier Distribution



In the dilute sample, the barrier distribution responds to the size distribution, namely log-normal distribution, however, with increasing the concentration, the barrier distribution shifts to the large-energy and the relation disappears and the distribution peaks appears at the lower energy and the high energy tails become longer.

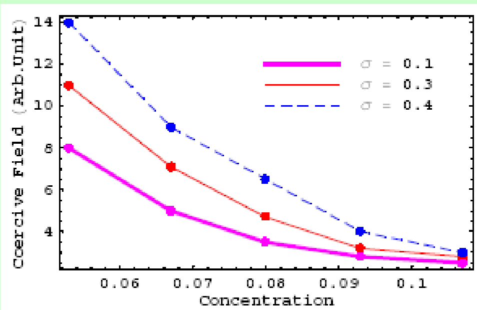
This result has an importance significant to show the role of the size distribution and the dipolar interaction. The size distribution plays dominant role in the non-interacting sample, and with increasing the concentration it is replaced by the dipolar interaction.

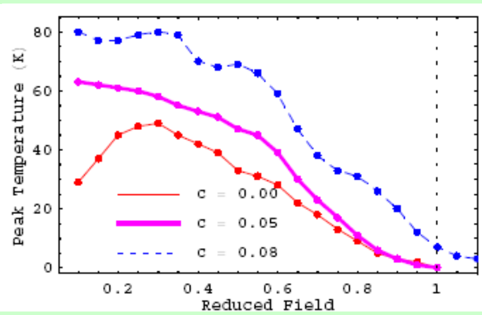
Temperature Dependence of Coercive Field



At the low temperature, the coercive fields completely separate, and as saw in Fig.2a, the coercive field decreases along with the increase of the concentration, however, at the certain temperature, about 10 K in our case, the coercive field starts to increase. This temperature is called the glass translation, T_g, or super-ferromagnetic (SFM) translation temperature, T_c. It is worth commenting that the temperature dependence of coercive field does not follow the classical theoretical prediction, $H_c \sim 1 - (T/T_B)^{1/2}$, as represented by dot line. The temperature T_g (T_c) raises as the dipolar interaction is strong, and it can exceed the blocking temperature if the sample is very dense

Collective Behavior At The Low and The High Temperature





The dipolar energy is minimal as the moments parallel together. Therefore, the rotation of a moment can excite the rotation of another. The dipolar interaction deduces the decrease of the coercive field below the translation temperature T_g (or T_c) and the increase of blocking temperature. The field dependence of the peak temperature changes from the bell-like shape to the plateau-like shape as the interacting strength increases. Under the influence of the dipolar interaction, the magnetic nanoparticle system has properties responding to spin glass material at the low temperature and to the multi-domain wall material at the high temperature, however, with the greater properties.