Features of dispersion of dimensional and magnetic parameters in spinel ferrite nanoparticles

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Magnetic nanoparticles (MNPs) have been used in many important technological applications such as ultra-high density magnetic recording and data storage, highly sensitive magnetic sensors, permanent magnets and various biomedical applications, which are of a great interest nowadays. Here, we suggest the ways to account for the dispersion of size and magnetic parameters, and adequately predict the behavior of MNP ensembles under various conditions.

AFe_2O_4 (A = Ni, Zn, Co) MNPs were synthesized by precipitation from non-aqueous solutions. Unfortunately, the synthesized NMPs do not have a uniform size distribution, and this may significantly affect their widespread use, since obtaining monodispersed nanoparticles requires an additional step, which increases production cost. Thus, it is of a paramount importance to develop a relatively simple approach to predict the behavior of such MNPs under different external factors.

Formulas used for approximation:

$$M(H,T) = c\int_0^\infty \mu L\left(\frac{\mu H}{kT}\right) f(\mu \mid \mu_0, \sigma)\, d\mu$$

$$f(v \mid v_0, \sigma_v)\, dv = \frac{\mu}{M_S} f(\mu \mid \mu_0, \sigma)\, d\mu$$

where μ – a magnetic moment of a particle; μ_0 – a magnetic moment average; σ – a magnetic moment dispersion; k – the Boltzmann constant; T – temperature; f – a log-normal distribution; L – the Langevin function.

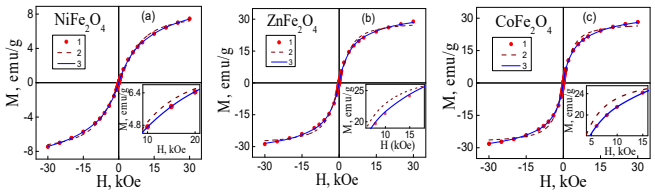

Fig. 1. Magnetization curves M(H) for nanopowders $NiFe_2O_4$ (a), $ZnFe_2O_4$ (b) and $CoFe_2O_4$ (c). 1 - experimental data, 2 - Langevin function fit in the monodisperse approximation, 3 - Langevin function fit weighted by the magnetic moments distribution function. The insets show enlarged graphs in the regions of strong magnetic fields.

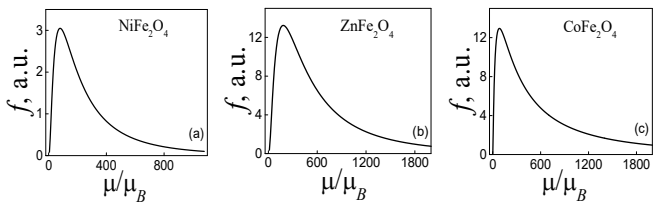

Fig. 2. Magnetic moments distribution function for $NiFe_2O_4$ (a), $ZnFe_2O_4$ (b) and $CoFe_2O_4$ (c) nanopowders, derived from the fitting of M(H) curves presented in Fig. 1.

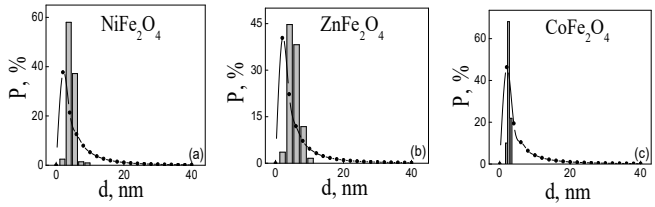

Fig. 3. Size distribution function for nanopowders $NiFe_2O_4$ (a), $ZnFe_2O_4$ (b) i $CoFe_2O_4$ (c). Histogram - nanoparticle size distribution obtained using TEM; solid curve with points - size distribution function obtained from the analysis of magnetic properties of nanopowders.

Conclusions

It is shown that the size distribution function obtained from the magnetic characteristics makes it possible to adequately describe the behavior of an ensemble of nanoparticles containing weakly magnetic or nonmagnetic shells. As concluded, the proposed approach is effective for analyzing the dispersion of the dimensional and magnetic parameters of nanoparticle ensembles and for predicting their behavior under the influence of electro-magnetic fields.