Comparative analysis of superparamagnetic and ferromagnetic resonance in Co/Al_2O_3 nanocomposite films

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Magnetic resonance in ferromagnetic (FM) and superparamagnetic (SPM) nanocomposite (NC) systems can be analyzed in the framework of phenomenological Landau-Lifshitz (LL) theory taking into account various magnetization damping mechanisms and perturbations with peculiar temperature dependence [1-3].

Magnetic NC containing Co in the form of nanoparticles (NPs) were grown on policore substrates using two-crucible electron beam facility. This technology allows to obtain Co_X/Al_2O_3 samples with various Co content X = (16 - 41) at. % covering both FM and SPM films. The experimental studies of the temperature dependence of the resonance peak width (RPW) in FM and SPM nanocomposites were performed in the temperature range T=(3÷270) K with the Bruker spectrometer operating at 9.4 GHz. The pronounced increase of the RPW was observed at low temperatures indicating strong damping of magnetization precession. Figure presents the comparison of theoretical predictions for the correlation between the resonant field, the RPW and our experimental data. In the case of SPM film the RPW changes can be explained by the LL model (modification c), whereas for FM film the behavior of the discussed dependence is in conflict with all regimes proposed in theoretical calculations [1].

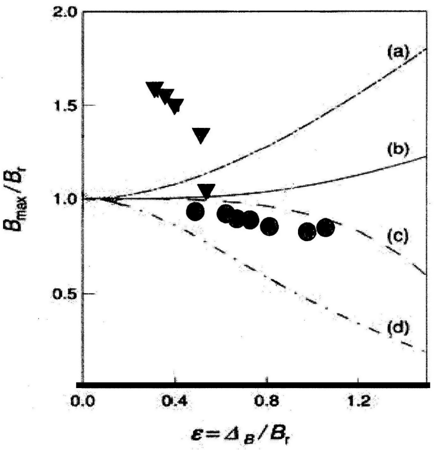

Fig. Lines a-d – LL theory with modifications [1]. Experiment: ▼ - FMR, Co41%; ● – SPR, Co16%. B_{max} - resonant field, B_r = 3.39 kOe - the field corresponding to g = 2, Δ_B - the half-width at half maximum of the resonance peak.

The observed damping was analyzed taking into account the complicated structure of NPs interface, the volume of which is 2.5 - 4 times larger than the one of Co core. This gives a rise to internal disturbing magnetic fields that violate the resonance conditions.

The possible sources of precession perturbations are the following: (1) an antiferromagnetic layer CoO; (2) an ensemble of magnetic oxygen vacancies on the interface $CoO\text{-}Al_2O_3$ [4]; (3) an ensemble of Co single atoms or their small clusters in the Al_2O_3 matrix. Therefore nontrivial changes of magnetization damping in SPR and FMR films probably is due to the conflict between ferromagnetic Co NPs and magnetic state of their shells.

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