Superferromagnetoresistors

Vladimir Kondratyev

Joint Institute for Nuclear Research, Dubna, Russia

The strong ferromagnetic nanoparticles are analysed within the band structure based shell model [1] accounting for discrete quantum levels of conducting electrons. As is demonstrated such an approach allows to describe the observed superparamagnetic features of these nanocrystals. Assemblies of such superparamagnets incorporated into nonmagnetic insulator, semiconductor or metallic substrates are shown to display ferromagnetic coupling resulting in a superferromagnetic ordering at sufficiently dense packing. Properties of such metamaterials are investigated by making use of the randomly jumping interacting moments model accounting for quantum fluctuations induced by the discrete electronic levels and disorder. Employing the mean-field treatment for such superparamagnetic assemblies we obtain the magnetic state equation indicating conditions for an unstable behaviour. Respectively, magnetic spinodal regions and critical points occur on the magnetic phase diagram of such ensembles. The respective magnetodynamics exhibit jerky deportment expressed as erratic stochastic jumps in magnetic induction curves. At the critical points magnetodynamics display the features of self-organized criticality. Analyses of magnetic noise correlations are proposed as model-independent analytical tools employed in order to specify,

quantify and analyse magnetic structure and origin of superferromagnetism. We discuss some results for a sensor mode application of superferromagnetic reactivity associated with spatially local external fields, e.g., a detection of magnetic particles. Transport of electric charge carriers between superparamagnetic particles is considered as tunneling and the Landau level state dynamics. The tunneling magnetoresistance is predicted to grow up noticeably with decreasing nanomagnet size. The giant magnetoresistance is determined by ratio of respective time of flight and relaxation and can be significant at room temperatures. Favorable designs of superferromagnetic systems for sensor implications are revealed.

[1] V.N. Kondratyev, and V.A. Osipov, Nanomanufacturing. 3, 263 (2023).