High-frequency response of superferromagnetic metal-dielectric nanocomposites

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Dynamical magnetic response of superferromagnetic dispersions of metallic nanoparticles in dielectric matrices is studied for the microwave range of the driving magnetic field, using micromagnetic simulations. The attention is focused on layers of several nanocomposites of potential application as core materials in microinductors and transformers, (on chip power converters have to operate in a high-frequency range due to the high spatial confinement) [1], [2]. The nanocomposites offer reduction of the eddy-current losses due to a high resistivity at a relatively-high permeability and lack of intra-particle domain structure. Strong magnetic response is achievable via excitation of FMR or the oscillatory motion of domain walls depending on the orientation of the driving in-the-plane field relative to the easy axis, (the transverse or longitudinal field, respectively). We simulate idealized nanocomposites by assuming the nanoparticles to be identical and homogeneously dispersed. The material parameters are extracted from data, based on the random magnetic anisotropy (RMA) model. For example composites of the nanoparticles of Co or $Fe_{65}Co_{35}$ dispersed in Al_2O_3, SiO_2 or MgF_2 are tested with regard to the limit efficiency of the response in terms of the high permeability and low hysteretic losses of power. In paticular, we discuss the dependence of the response (magnetization) amplitude on the nanoparticle concentration and frequency limitations on the stability of the domain structure. Beyond FMR and the domain-wall assisted dynamics, we simulate the response to the rotating in-the-plane field, which drives a precession (almost in-the-plane rotation) of the magnetization below a threshold frequency and above a threshold-field value. Such an excitation mode is related to the highest possible amplitude of the magnetization oscillations at lowered hysteretic loss compared to the linear-field-excited modes. Moreover, the rotational mode is not accompanied by the domain-wall motion, thus, by the excess losses.

References:

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