MAGNETIC BEHAVIOR OF SiO₂ OPALS WITH EMBEDDED Fe AND Ni NANO PARTICLES
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Using the Stöber method, silica spheres were obtained and arranged in an fcc lattice. Fe⁰ has been introduced into void spaces of the artificial opals by means of the reduction of FeSO₄ with NaBH₄. Magnetization curves of the as synthesized Fe⁰ nanoparticles and of the artificial opals with Fe⁰ nanoparticles were measured by using the vibrating sample magnetometry (VSM) technique with an applied magnetic field oriented along the [111] direction. In order to interpret the hysteresis cycles of magnetization, the homogenization theory developed in [1] to model the system of fcc arranged SiO₂ spheres with embedded Fe⁰ nanoparticles together with an effective media model, namely Maxwell-Garnett formula, which describes the interstitial region of the opal, consisting in a mixture of air and Fe⁰ have been applied. Such homogenization theory provides explicit formulas for all the components of the permittivity and permeability tensors of a magnetodielectric photonic crystal in terms of the parameters of the inclusions (Fe⁰-air mixture) and the host material (SiO₂ spheres) in the quasistatic limit. On the basis of these theoretical models, we have elaborated a computing program to calculate the effective permittivity and permeability of the SiO₂ opals with Fe nanoinclusions of different shape. Using the effective permeability, depending on the applied magnetic field, curves of magnetization vs magnetic field are straightforwardly calculated. The theory reproduces the general features of measured magnetization curves; nonetheless, remarkable features of the experimental curves of the system remain to be properly described, giving rise to a more profound analysis of both, the sample and the theoretical model. In particular, the strong dependence of hysteresis loops on the Fe filling fraction, which was experimentally observed, is numerically confirmed by using an appropriate magnetic-field dependent permeability for Fe nanoparticles.

Keywords: Magnetic, Nanoparticles, Composites

References:

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