Semiconducting/ferromagnetic nanocomposites investigated with respect to their temperature dependence and magnetic interactions

P. Granitzer[1], K. Rumpf[1], R. Gonzalez-Rodriguez[2], J. Coffer[3]
[1] *Institute of Physics, University of Graz, Universitaetsplatz 5, 8010 Graz, Austria*
[2] *Department of Physics, University of North Texas, USA*
[3] *Department of Chemistry, Texas Christian University, Fort Worth, USA*
petra.granitzer@uni-graz.at

Low dimensional structures of semiconducting and magnetic materials, respectively, are employed in various realms to create new nanoscopic systems with novel physical properties. Therefore nanostructured silicon, which is formed in a self-organizing process, can be used as versatile host material for magnetic materials, especially a quasi-regular arrangement of the pores / tubes leads to specific magnetic properties occurring from magnetic interactions between the metal-deposits.
The main scope of this work is the investigation of magnetic interactions between metal deposits embedded within the pores or tubes. In this respect composite systems consisting of porous silicon (PSi) and silicon nanotubes (SiNTs) with deposited Ni, Co, NiCo and Fe_3O_4 structures are discussed. Ni, Co and NiCo which are electrochemically deposited within the pores can be adjusted in their size, geometry and distribution by modifying the deposition parameters. Fe_3O_4 nanoparticles are previously synthesized and then infiltrated within the nanostructured silicon materials.
Magnetic interactions between metal deposits can be controlled on the one hand by the morphology of the PSi (distance between the pores) or SiNTs (wall thickness) and on the other hand by the distribution, size and shape of the deposited metal structures. To get a clear knowledge about the magnetic interactions single hysteresis curves are not sufficient and thus first order reversal curves (FORC) are performed at various temperatures [1].
The investigation of the temperature-dependency of the magnetization of the different nanocomposite systems is a further subject of this work. Temperature dependent magnetization measurements of composite systems are appropriate to determine if the specimens are ferro- or superparamagnetic, which is an inherent property of isolated particles below a certain critical size. Metal silicide formation during annealing weakens the ferromagnetic behavior. In the case of magnetite nanoparticles (NPs) in general the annealing process modifies their structural and magnetic phase due to oxidation which leads to different magnetic characteristics. High-temperature measurements are performed under Ar gas which prevents oxidation of the samples. To figure out the Curie temperature (T_C) of the composites the magnetic response of the systems is recorded dependent on the temperature in a range between 80 and 1273 K. T_C is determined for the various composite systems and compared with the ones of the corresponding bulk materials which shows that systems with embedded nanostructures in the range of a few hundred micrometers offer lower T_C and such with small nanoparticles much higher T_C than the corresponding bulk materials. This observed behavior can be interpreted by some structural changes due to the annealing. The lower T_C for the samples with elongated metal structures is driven by the fact that the deposits are not essentially single domain.

References

[1] P. Granitzer, K. Rumpf, R. Gonzalez-Rodriguez, J. Coffer, Nano Select, doi.org/10.1002/nano.202300166.