Arrays of FePt loaded nanostructured silicon offering high energy product

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In the framework of this presentation silicon nanotubes (SiNTs) and porous silicon (PSi), with deposited hard magnetic FePt nanoparticles (NPs) are used as platform to create nanomagnetic arrays. FePt-loaded composite materials have potential in high-performance magnets and as rare earth magnet alternatives and therefore their magnetic characteristics are investigated. Depending on the size face-centered cubic (fcc) FePt particles generally show a superparamagnetic or soft magnetic behavior. In contrast face-centered tetragonal (fct) FePt particles offer high uniaxial magnetocrystalline anisotropy with hard magnetic behavior. Thus the purpose is to fabricate hard magnetic FePt particles within nanostructured silicon. Co nanoparticles (NPs) are grown inside the same nanostructured silicon templates as a comparison.
The formation process of FePt nanocrystals within SiNTs and PSi is carried out by a multistep process. The used solution contains H_2PtCl_6 $6H_2O$ and $Fe(NO_3)_3$ $9H_2O$, wherat the Fe:Pt ratio has been varied from 1:1, 3:1 to 6:1. In the case of SiNts as template material the average FePt particle size is 5 (± 2) nm and in the case of PSi as template the particle size is 9 (± 4) nm. Co NPs are grown within these two template materials also in applying a solution method, containing $CoCl_2$ $6H_2O$.
The magnetic response of the different systems is measured with a vibrating sample magnetometer (VSM) in recording the magnetization versus the applied magnetic field. The hysteresis curves show characteristics which are tuneable by varying the geometry and size of the deposited metal structures. Not only dipolar coupling between magnetic particles within the pores and between adjacent pores plays a crucial role, but also exchange coupling between bi-metal nanostructures is of importance and favorable to influence the performance of magnetic hard/soft nanostructures. To escape the superparamagnetic limit single domain particles which are thermally and magnetically stable are beneficial. Measurements of magnetization versus temperature are performed in a range between 5 K and 300 K which also confirm the ferromagnetic behavior of the samples. Samples with different ratios between Fe and Pt (Fe:Pt = 1:1, 3:1, 6:1) vary in their coercivity in the range of 5% for both types of matrices, SiNTs and PSi. The magnetic investigations show moreover that the coercivities of FePt-NP loaded PSi are about twice as high as the coecivities of SiNTs loaded with FePt NPs [1]. Comparison of the FePt loaded samples with Co NPs loaded ones, shows in both sample types a significant increase of the coercivity for FePt. In the case of Co-deposition the utilization of PSi as template also offers higher coercivities compared to SiNTs as template. These results show that for the investigated composite systems, the ones consisting of PSi and FePt offer the highest energy product.

References

[1] K. Rumpf, P. Granitzer, R. Gonzalez-Rodriguez, J. Coffer, ECS Trans., 113 (2024), 11.