Arrays of exchange coupled magnetic nanostructures for permanent nanomagnets

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The purpose of this work is to fabricate nanostructured silicon with two different materials of embedded magnetic nanostructures to exploit the magnetic properties of both metals and gain control of the exchange coupling between the two metals especially with respect to their volume ratio. Furthermore a variation of the structure size and the proximity of the metal deposits modify the exchange coupling and thus the energy product.

Two different templates, porous silicon (PSi) and porous silicon nanotubes (SiNTs) are utilized to achieve such nanocomposites. The morphology (pore diameter, tube diameter) of the two systems is comparable. In the case of the utilization of PSi templates a mesoporous morphology with average pore diameters of 50 nm are used and these oriented and separated pores are filled with two different metals, namely as a first attempt Ni and Co. The two metals are deposited alternatingly by electrodeposition. A further approach is the chemical growth of Co nanoparticles within SiNTs [1] and the additional deposition of a Ni layer on the outer surface of the tubes which is shown in figure 1. Since the silicon wall of the tubes offers a porous structure the Co particles, which are localized near the pore surface on the wall of a given nanotube, can touch the Ni layer. An alternative structure involves the deposition of an additional Si layer (after the growth of Co particles inside the tubes) as a spacer before the Ni deposition.

In the presented work the dependence of the magnetic properties of a nanostructured silicon/bi-metal nanocomposite on the volume ratio of the metals, on the proximity of the nanostructures and also on the size of the metal deposits has been figured out. If the distance between the deposited bi-metal structures is small enough magnetic exchange coupling between them is present which could be observed. By tuning the bi-metal deposition an optimized energy product is achieved which gives rise to self-assembled nanocomposite systems containing permanent nanomagnets and arrays of them, respectively for on-chip applications.

[1] X. Huang, R. Gonzalez-Rodriguez, R. Rich, Z. Gryczynski, J.L. Coffer, *Chem. Commun*. 49, 5760 (2013).

Figure 1. Silicon nanotubes with chemically grown Co particles inside and a Ni layer covering the outside of the tubes.