THE INTERIOR INTERFACES OF A SEMICONDUCTOR/METAL NANOCOMPOSITE AND THEIR INFLUENCE ON ITS PHYSICAL PROPERTIES

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A semiconductor/metal hybrid system with silicon as base material is fabricated in two steps by electrochemical methods. First the silicon substrate is anodized in an aqueous hydrofluoric acid solution to achieve a nanostructured porous medium offering oriented pores perpendicular to the surface arranged in a quasi regular pattern. Second the deposition of ferromagnetic metals during a subsequent galvanic process is used to embed metal nanostructures within the pores of the silicon matrix. The achieved nanoscopic hybrid system consists of a quasi-regular 3-dimensional arrangement of metal nanostructures embedded within the pores of the silicon matrix. The used metals are Ni, Co, Fe, Cu and their alloys.
The physical properties (e.g. magnetic, optical) of nanostructured semiconductors or metals change drastically compared to their bulk materials. The investigated system combines both, nanostructured silicon and nanostructured metal. In such a hybrid system the interface between metal and silicon nanostructures is of interest in correlation with the properties of the material and can be influenced by different fabrication conditions.
If the matrices are aged in ambient air before filling with a metal the porous silicon template offers a native SiO_x layer due to the oxidation of the hydrogen terminated surface of the pore-walls. Using as-etched samples for deposition of the metal into the pores leads to the formation of a more complex interface during the cathodic deposition procedure which is observed by FTIR-spectroscopy. The correspondingly occurring absorption peaks can be attributed to O-Si-H modes (2250 cm^{-1}), Si-OH bending modes (1635 cm^{-1}) and SiO_3 (1368 cm^{-1}) which is shown in Fig.1. Investigations by electron microscopy (SEM, TEM) also show the presence of SiO_x-species along the pores.
Magnetic characterizations of Ni-filled porous silicon samples carried out by SQUID-magnetometry do not show an exchange bias effect [1] which indicates that the embedded Ni-nanostructures are not covered by an oxide layer and the oxygen observed by EDX-spectroscopy can be attributed to SiO_x. In contrast Co-filled samples show a small exchange bias effect.
The fabricated nanocomposites are versatile systems which are applicable in magnetic sensor technology, as magnetooptical devices, in nanobiology due to the biodegradability of porous silicon (drug delivery, targeting of magnetic particles) and as a great advantage these materials are integrable in today’s microtechnology. Furthermore the formation of a defined oxygen-layer covering the surface of the pores could act as tunnel-barrier to perform spin-injection experiments to detect spin-polarized electrons.

References:

[1] J. Nogues, J. Sort, V. Langlais, V. Skumryev, S. Surinach, J. S. Munoz, M. D. Baro, Physics Reports **422** (2005) 65-117.

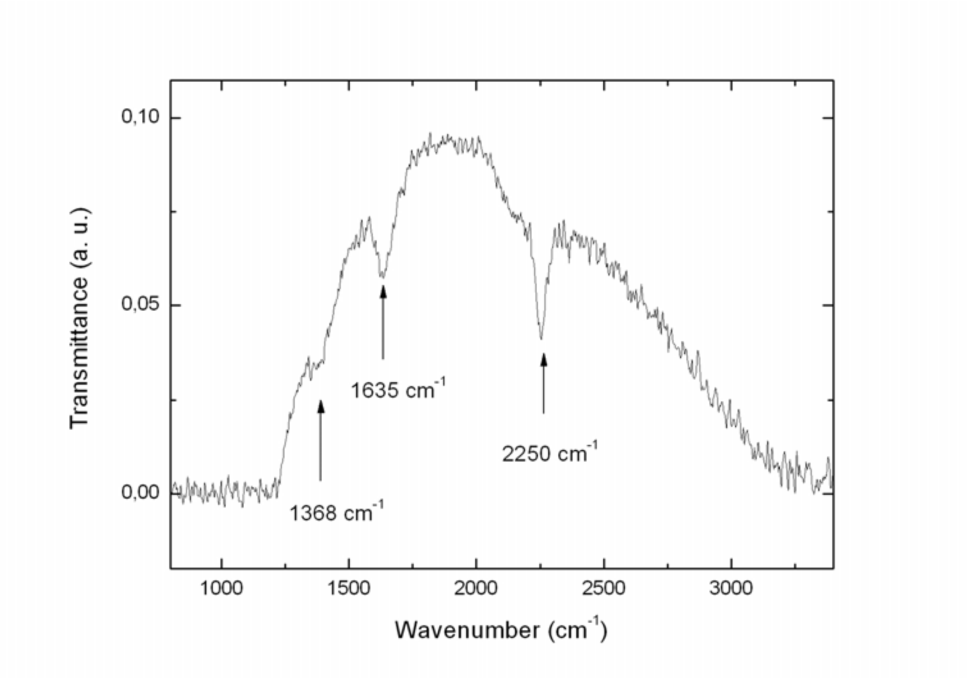

Figure 1: FTIR transmission spectrum of a Ni-filled porous silicon sample showing absorption peaks around 1368 cm^{-1} (SiO_3), 1635 cm^{-1} (Si-OH) and 2250 cm^{-1} (O-Si-H).