TEMPERATURE DEPENDENCE OF A TWOFOLD MAGNETIC BEHAVIOUR OF A NANOSCOPIC METAL/SILICON HYBRID SYSTEM – A COMPARISON BETWEEN Ni/Si AND Co/Si

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The investigated hybrid nanocomposite consists of a porous silicon template with electrochemically embedded Ni or Co nanostructures and offers magnetic characteristics which can be tailored by the electrochemical process parameters [1]. The magnetic behaviour of the nanocomposite strongly differs from the magnetic properties of the according bulk materials and is not only a consequence of nanostructuring of the semiconductor and the metals, respectively but also of their special combination within the nanoscopic silicon/metal hybrid system.
A twofold magnetic behaviour can be observed, a first one due to the spinmagnetism at magnetic fields below the saturation magnetization of the deposited metals and a second non-saturating term at higher fields above the saturation magnetization.
Tailored magnetic properties as coercivities, squareness and magnetic anisotropy can be achieved by tuning the process parameters during fabrication. The coercivities strongly depend on the geometry of the deposited metal structures, whereas the shape can be modified between spheres, ellipsoids and wires. The maximum elongation of the metal structures is a few microns and the diameter corresponds to the pore-diameter of the templates which can be varied between 30 nm and 100 nm leading to needle-like structures with an aspect ratio of about 100.
The temperature dependence of the coercivity of the Ni-filled samples shows an exponential decay with increasing temperature (4.2 K up to 300 K) whereas the curve progression of the coercivities of Co-filled samples shows a non-monotonous decrease within the same temperature interval. Between 4.2 K and 100 K the values differ less than 10% and at higher temperatures between 100 K and 250 K the coercivity drops of about half the value.
At high magnetic fields (> 1 T up to 7 T) above the saturation magnetization of the deposited metal the nanocomposites offer a non-saturating term additionally to the ferromagnetic spinmagnetism. In case of Ni deposited within the pores this term shows a paramagnetic characteristic and follows exactly the Curie-Weiss law (Fig. 1), whereas for Co/porous silicon samples the temperature dependent magnetization shows some deviations from the Curie Weiss law. Also in the high field region a difference in the temperature dependence between Ni and Co can be observed whereas the non-saturating term does not depend on the geometry of the embedded nanostructures in contrast to the ferromagnetic behaviour at lower fields.
Applications of the hybrid system can not only be found in magnetic sensor technology but the fabricated system is also a promising candidate to detect spin injection from a ferromagnetic metal into silicon. The investigated composite material merges semiconducting and ferromagnetic properties on one level and represents a kind of “ferromagnetic semiconductor” deployable at room temperature.

References:

[1] P. Granitzer, K. Rumpf, P. Pölt, A. Reichmann, H. Krenn, Physica E **38** (2007) 205.

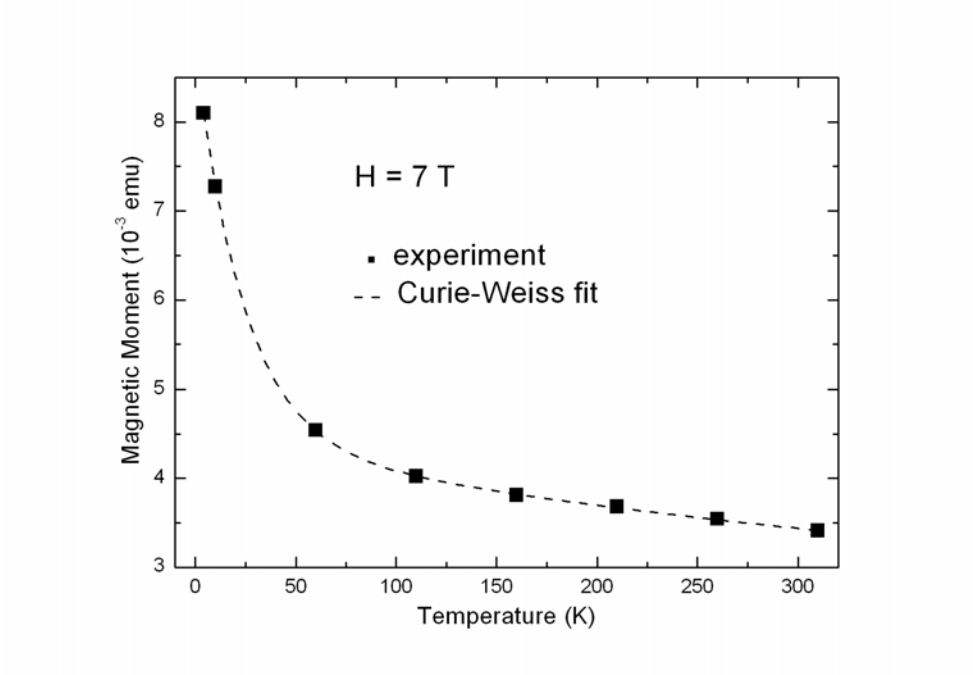

Figure 1: Temperature dependence of a Ni-filled porous silicon sample measured at a magnetic field of 7 T. The decreasing magnetic moment follows exactly the Curie Weiss law.