Ni electrodeposited within porous silicon – a self assembled nanomaterial

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The investigated nanocomposite system is composed of a porosified silicon wafer and embedded ferromagnetic nanostructures. Porous silicon achieved by anodization of a highly doped n-type silicon wafer offers oriented pores grown perpendicular to the surface and clearly separated from each other. Within the pores of the porous silicon matrix Ni-nanostructures are precipitated by a galvanic deposition process. The obtained hybrid system merges the electronic properties of silicon with the magnetic properties of the incorporated ferromagnetic metal. The porous silicon/metal nanocomposites are characterized by electron microscopy (SEM, TEM) and SQUID-magnetometry to figure out a correlation between the magnetic behaviour and the structural characteristics.

The characterization of the porous silicon template regarding the self-assebled pore-arrangement, porosity and pore-size as well as of the metal filled specimens with respect to the geometry and spatial distribution of the precipitated metal nanostructures is carried out by scanning electron microscopy (SEM). Figure 1a and 1b show a cross-sectional survey of the porous silicon layer exhibiting straight pores with an average diameter of 80 nm, grown perpendicular to the wafer surface and a plan-view image of the same template. Analysis of the top-view picture by image processing gives a porosity of about 60%. Precipitated metal nanostructures are investigated also by SEM in using the back scattered electrons to get element-sensitive information. Furthermore the nanocomposite is characterized by transmission electron microscopy (TEM) (figure 2) which allows to figure out additional information about the interfacial nature of the samples. Investigating the PS/metal interface by TEM one can say that the pore-walls of the PS-matrix are covered by an oxide layer of about 5 nm. The oxidation of the pores is formed after the anodization by aging in air. FTIR-spectroscopy also shows the presence of oxide in case of aged porous silicon. The deposited metal (Ni) structures are also covered by oxide which likely arises after the preparation of the membrane by focused ion beam. Magnetization measurements of Ni-filled samples do not show an exchange bias effect [1] which indicates that the nanostructures are not covered by an antiferromagnetic Ni-oxide.

These nanocomposites are formed during electrodeposition of Ni whereas specific metal precipitation can be reached by tuning the electrochemical parameters. This allows to fabricate samples with desired magnetic properties [2]. Coercivities, magnetic remanence and magnetic anisotropy strongly depend on the geometry of the precipitated nanostructures as well as on their spatial distribution within the porous layer. Both features can be adjusted quite accurate by varying the deposition current density and the frequency of the applied current. Due to the structural characterization of the samples a correlation between morphology and magnetic behaviour is gained.

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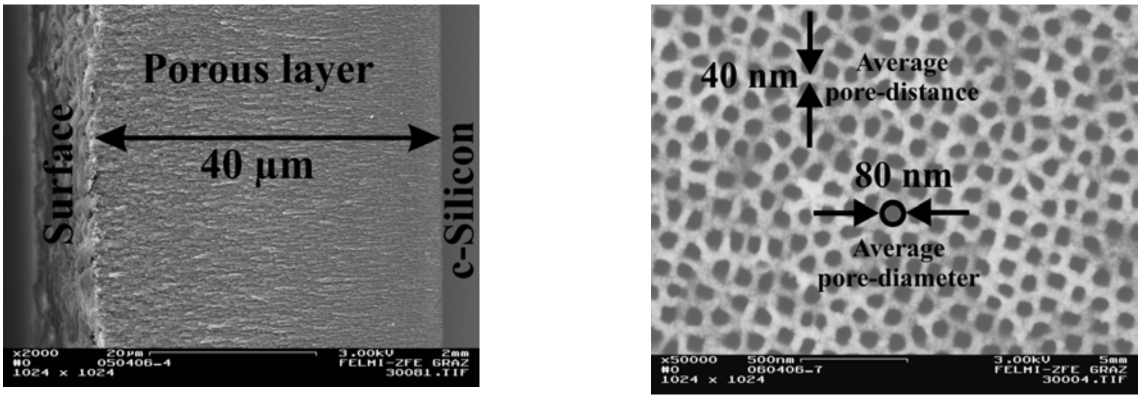

a) b)

Figure 1: a) Scanning electron micrograph of a cross-section of a porous silicon layer with a thickness of about 40 µm. b) Plan-view image of the same sample showing a quasi-regular pore arrangement with an average pore-diameter of 80 nm and a mean pore-distance of 40 nm.

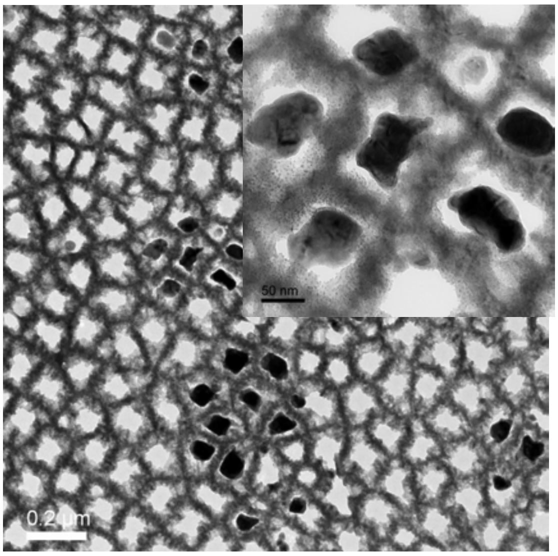

Figure 2: Zero-loss TEM image of a porous silicon sample with electrochemically deposited Ni. The dark spots are Ni-particles within the pores at the cutting plane. Empty pores can also contain Ni-particles but on a different level of the porous layer. The inset shows a zoomed area.

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