Functionalised Nanotubes by Wetting of Porous Templates

M. Steinhart[1,2], Z. Jia[3], A. K. Schaper[3], R.B. Wehrspohn[1], U. Gösele[1], J.H.Wendorff[2]

1 Max-Planck-Institute of Microstructure Physics, Weinberg 2, D-06120 Halle, Germany

2 Institute of Physical Chemistry, Philipps-University, Hans-Meerwein-Strasse, D-35032 Marburg, Germany

3 Center of Materials Science, Philipps-University, Hans-Meerwein-Strasse, D-35032 Marburg, Germany

Nanotubes have attracted increasing interest during the last decade and may be used as building blocks for miniaturized devices (1-3). However, the preparation of tailored nanotubes is still a challenge in materials science. Wetting of ordered porous templates by melts or solutions containing polymeric components is a universal method to prepare nanotubes (4) and can easily be modified to customize their properties. Any polymer, polymer mixture or composite, which is processible in the liquid state, can be formed to nanotubes. A mesoscopic film of adsorbed polymers covers the pore walls rapidly if a porous matrix exhibiting a high surface energy is brought into contact with the wetting liquid. This will happen even in the case of mixtures containing inorganic compounds or in the case of polymeric liquids loaded with nanoparticles. Solidification of the wetting liquid at this stage results in the preservation of nanotubes with a wall thickness of the order of 10 nm. Their size depends on the size of the template pores. We used either porous alumina or macroporous silicon. Currently, diameters ranging from some tens of nm up to a few microns and lengths up to 100 µm are accessible.

The wetting approach extends the range of materials that can be formed to nanotubes. For instance, we prepared nanotubes from polytetrafluoroethylene with ultra-high molecular weight. Moreover, wetting of porous templates allows the generation of a fine structure in the nanometer range within the nanotube walls. Hence, nanotubes with a high specific interface or surface area are accessible. At first, multi-component nanotubes are formed by wetting of templates with the corresponding mixtures. Subsequently, decomposition into co-existing phases is induced to generate a fine phase morphology within the tube walls. Finally, the composite nanotubes are annealed to allow controlled ripening of the phase structure. Depending on the selected components, their concentrations and the ripening stage, nanotubes with characteristic wall morphologies are obtained. Selective removal of one component yields residual nanotubes with a specific nano-roughness and a controllable porosity.

We demonstrate this exemplarily by means of structured palladium (Pd) nanotubes since Pd nanoparticles are of considerable interest for catalysis, sensor technology and hydrogen storage. They were prepared by wetting of porous templates with a mixture consisting of a Pd precursor (palladium(II)acetate) and a sacrificial polymer (polylactide). We obtained polycrystalline Pd nanotubes with a adjustable crystallite size and porosity (figure 1).

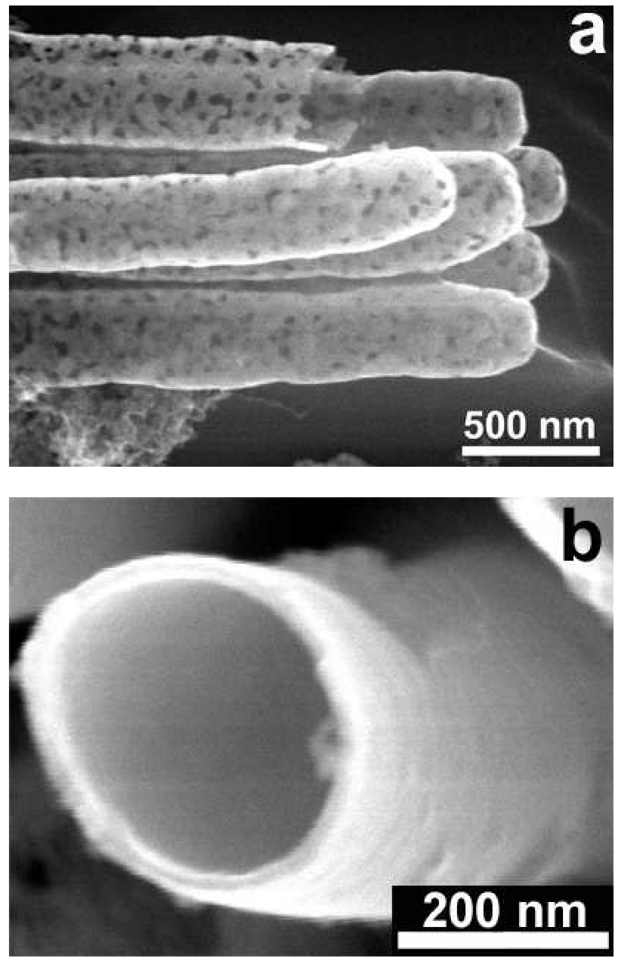

Figure 1: scanning electron micrographs of Pd nanotubes obtained by wetting of porous templates: (a) Pd nanotubes with structured pore walls. (b) cross-section of an individual Pd nanotube.

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