High Aspect Ratio Nanotubes fabricated by Ion-Track Technology and Atomic Layer Deposition *

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Nanotubes and nanochannels embedded in solid state membranes are of high relevance in many different fields including nanofluidics, catalysis, health care, or solar energy harvesting. On the way to novel industrial applications, systematic basic studies on these nanostructures as well as development of suitable fabrication techniques to precisely tailor their dimensions and surface properties are required. For synthesis of cylindrical nanochannels anodic alumina and polymer membranes are frequently used.

In this study, we fabricated nanotubes of alumina (Al_2O_3), titania (TiO_2) and silicon dioxide (SiO_2) by combining the ion-track technology and atomic layer deposition (ALD). As template we used 30-μm thick polycarbonate foils, which were irradiated at the UNILAC with 2 GeV heavy ions and a fluence of 10^9 ions/cm^2. Subsequent chemical etching transforms each ion track into a cylindrical nanochannel [1]. Depending on the etching time, cylindrical nanochannels with a diameter between 55 and 400 nm and respective aspect ratios between 545 and 75 were fabricated. The etched membranes were coated by ALD with Al_2O_3, TiO_2 and SiO_2.

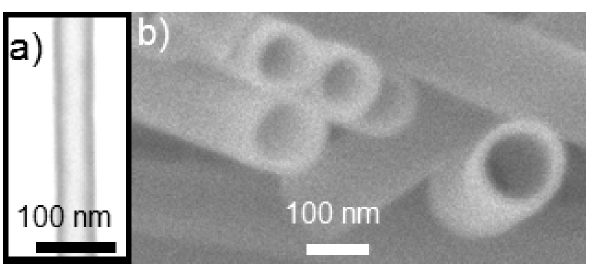

Figure 1: a) STEM image of a single SiO_2 nanotube with an aspect ratio of 545 and a wall thickness of 10 nm. b) SEM image of TiO_2 nanotubes with an aspect ratio of 207 and a wall thickness of 15 nm.

To study the successful coating along the complete length of the nanochannels the polycarbonate template is dissolved by wet-chemical methods. The resulting nanotubes are visualised by scanning electron microscopy (SEM) and scanning transmission electron microscopy (STEM) in SEM. Figure 1 displays representative images of SiO_2 (a) and TiO_2 (b) nanotubes.

Coated and uncoated samples were further investigated by small angle X-ray scattering (SAXS). Deduced nanochannel radii as a function of etching time are displayed in Figure 2. As expected the channel radii increase linearly with increasing etching time. The values of the coated channels are shifted by 10 nm to smaller radii, in complete agreement with the nominal coating thickness of the ALD process. The SAXS scattering pattern of the coated membranes show the same high-quality ondulations indicating highly conformal ALD coating.

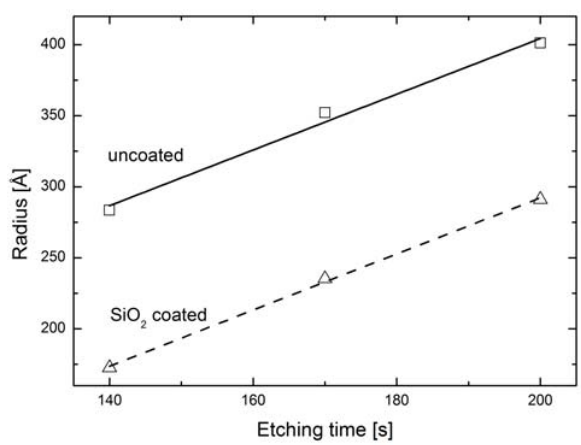

Figure 2: Nanochannel radius deduced from SAXS before (□) and after (△) ALD deposition of 10-nm SiO_2. Uncertainties are smaller than symbols.

In conclusion, these first results show the fabrication of inorganic nanotubes in ion-track etched polycarbonate membranes with aspect ratios above 500. The successful surface modification process creates new opportunities in the precise reduction of pore sizes for filtration or purification applications.

References

[1] M. E. Toimil-Molares, Beilstein J. Nanotechnol. 3 (2012) 860

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