Antimony Nanowire Networks*

M. F. Wagner[1,2], *S. Müller*[1], *C. Trautmann*[1,2], *and M. E. Toimil-Molares*† [1]
[1]GSI, Darmstadt, Germany; [2]TU Darmstadt, Germany

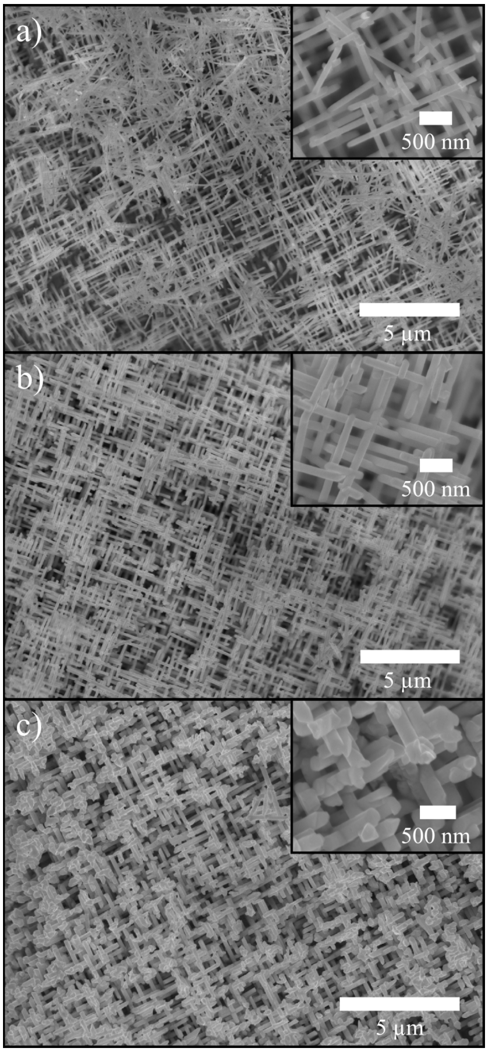

Figure 1: SEM images of Sb nanowire networks electrodeposited in etched ion-track membranes. Membranes with channels oriented under different angles were obtained by irradiating PC foils under four different beam incidence ($4 \times 5 \cdot 10^8$ ions/cm^2) followed by track etching to a mean wire diameter of a) 80, b) 130, and c) 220 nm.

Theoretical calculations predict an enhanced thermoelectric (TE) performance for materials that are confined in one dimension such as nanowires [1]. Sb as bulk material is p-type and Sb nanowire (NW) arrays could be employed for example as p-type element in nanostructured Peltier elements or thermocouples. However, bulk Sb and NWs made of Sb (as well as other TE materials, e. g., Bi and Bi_2Te_3) are very brittle and prone to break. The mechanical instability exhibited by arrays of parallel TE NWs constitutes thus a challenge towards their implementation in TE devices.

Here, we present the synthesis of 3D Sb nanowire networks (NWNWs). By ion-track technology and electrodeposition, we adjust integration density and NW diameter independently to provide mechanically stable and self-supporting structures of interconnected Sb NWs.

To create templates suitable for the electrochemical deposition of NWNWs, polymer foils were irradiated sequentially four times at the UNILAC facility with ~ 2 GeV Au ions under an angle of 45°. After each irradiation step, the foils were rotated by 90° about the surface normal [3]. Thus, after etching the tracks for 5, 7.5, and 10 min with 6 mol/l NaOH solution at 50 °C, networks of interconnected nanochannels were obtained. During etching, the mean diameter increased by (29 ± 3) nm/min [4]. These channels were then filled by electrodeposition from an Sb electrolyte based on hydrochloric acid and Sb(III)-chloride [5].

Homogeneous Sb NWNWs were grown at a temperature of 40 °C, applying pulsed deposition with an on-potential of -265 mV vs. a saturated calomel electrode (SCE) for 20 ms and an off-potential of -100 mV vs. SCE for 100 ms. After the deposition, the polymer template was removed with dichloromethane and the remaining NWNWs were investigated by scanning electron microscopy (SEM) [4].

Figure 1 shows SEM images of NWNWs with mean wire diameters of about a) 80, b) 130, and c) 220 nm with a fixed fluence of $4 \times 5 \cdot 10^8$ ions/cm^2 in all cases. The fluence of ions during the irradiation steps determines the integration density. With increasing etching time (i. e., increasing wire diameter), the interconnectivity is increased leading to more stable NWNWs.

In conclusion, we have shown that mechanically stable Sb NWNWs can be created by electrodeposition in etched ion-track membranes by adjusting NW diameter and track density. These results are promising for the device integration of quasi-1D materials. Thermoelectric transport properties and the crystalline structure of these networks will be further investigated.

References

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† M.E.ToimilMolares@gsi.de