Synthesis of Cu-Ni core-shell nanowires by a two-step etching and electrodeposition

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In recent years, one-dimensional nanostructures such as nanowires and nanotubes have inspired extensive research efforts because of their potential applications in physics, chemistry, materials science, and many other fields [1]. In this work, nanocables with a core-shell structure are synthesized consisting of a Cu core that is surrounded by a Ni layer. According to theoretical calculations [2,3], such nanostructures are expected to display interesting physical properties as a function of size, crystal structure, and thickness of the core and shell layer. We describe an approach to fabricate core-shell nanocables by two-step etching in combination with electrochemical deposition. Polycarbonate (PC) foils were first irradiated with swift heavy ions (fluence ~ 5 x 10⁸ ions/cm²) and subsequently exposed to UV light on each side of the foils for 2 h in order to enhance the track-etching rate. The ion tracks in the foils were etched in a 5 M NaOH solution at 50 °C for 3 minutes leading to cylindrical channels with diameters 80-90 nm. In the following step, Cu was electrochemically deposited in the channels in a two-electrode arrangement at constant applied cell voltage of U = -0.27 V. A thin Au layer sputtered on one side of the PC template and a copper cone, served as cathode and anode, respectively. The electrolyte consisted of 75 g/l CuSO₄·5H₂O and 30 g/l H₂SO₄. After that, the membrane with embedded Cu nanowires was immersed once more in a 5 M NaOH solution at 50 °C to form an annular tube around each Cu nanowire. Finally, Ni was potentiostatically deposited in the annular free space between the template and the Cu wire, applying U = -1.5 V with a nickel cone as anode and using an electrolyte of 250 g/l NiSO₄·6H₂O, 50 g/l NiCl₂·6H₂O and 30 g/l H₂BO₃.

For characterization, the PC template was dissolved in dichloromethane, and the morphology of the Cu nanowires and Ni/Cu nanocables was investigated by scanning electron microscopy (SEM) (JSM 7401F, JEOL). Figure 1(a) displays the Cu nanowires with cylindrical shape, smooth surface and uniform diameter (d ~ 80 nm). After the second etching step and subsequent deposition of Ni, the diameter of the structures is significantly increased to about ~ 200 nm (Fig. 1(b)), demonstrating that Ni shell has been successfully grown onto the Cu nanowires. The Ni/Cu nanocables display a not so homogeneous diameter contour and a relatively rough surface. Further investigations are underway to clarify if the roughness is due to contour inhomogeneities formed during the second etching step or during the Ni deposition process. Figure 2 shows the cross section of a single nanocable analysed by energy dispersive x-ray analysis (EDX). The elemental map reveals a Cu-rich core (red) and a Ni-rich shell (blue) as expected. EDX compositional line profiles are displayed in Fig. 2(b).

![Figure 1: SEM images of Cu nanowires (diameter 80 nm) before (a) and after (b) deposition of a Ni shell. The diameter of the Ni/Cu nanocables is 200 nm.](image)

![Figure 2: Elemental composition of single Ni/Cu nanocable analysed by EDX (a), composition mapping (b) line profiles of wire cross section with Cu-rich (red) and Ni-rich (blue) regions.](image)

In conclusion, a multi-step process is demonstrated to synthesize nanocables with a Cu core surrounded by a Ni shell. The fabrication involves standard electrodeposition of Cu nanowires followed by a second chemical etching process. The tube region formed around the Cu wires is subsequently electrochemically filled resulting in a Ni shell. The existence and elemental composition of the core-shell structure is confirmed by EDX.

References