Synthesis of nanogaps between smooth and porous nanowires

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By interaction of metallic nanowires (NW) with electromagnetic radiation of appropriate wavelength, resonant surface charge density oscillations, called surface plasmons, can be excited. These oscillations are responsible for a large electromagnetic field enhancement in the NW near-field, which makes these wires suitable as functional elements in devices for e.g. highly sensitive detection of molecules using surface enhanced infrared spectroscopy[1] and Raman spectroscopy[2,3], and selectively killing of cancer cells by photothermal therapy [4,5].

The even stronger field enhancements achieved by plasmon coupling at nanogaps between narrowly spaced nanostructures [6,7,8] have recently been, experimentally and theoretically, a subject of increasing scientific interest. However, controllable fabrication of nanogaps between well-defined nanostructures continues being an experimental challenge.

Here, we report the synthesis of closely spaced smooth and porous nanowires by electrochemical deposition in etched ion-track membranes. Polycarbonate foils were irradiated at the GSI linear accelerator UNILAC with heavy ions accelerated to an energy of 11.1 MeV/u. The irradiated foils were track-etched with a 6 mol/l sodium hydroxide solution at 50° C to produce cylindrical pores randomly distributed in the foils. Au/Ag/Au nanowires were grown by pulsed-deposition using a single-electrolyte containing both silver and gold cyanide ions.

Figure 1 shows a scanning electron microscopy (SEM) image of two multisegment nanowires. Segments with higher concentration of gold appear brighter than the ones with higher silver content.

To selectively etch out the silver of the segmented nanowires, the nanostructures were treated with nitric acid. This results in the formation of nanogaps with sizes down to about 8 nm as shown in Figure 2. In addition, composition and concentration of the electrolyte, and pulse parameters determined the Au and Ag content of the segments, and thus the morphology of the wires after dissolution of the Ag. Using different concentrations of $KAg(CN)_2$ in the electrolyte, smooth segments enclosing the gap (Figure 2) as well as very porous segments (Figure 3) were obtained.

In conclusion, segmented silver gold nanowires and small nanogaps down to 8 nm were created. Furthermore, the morphology of the segments enclosing the gap can be varied by adjusting the deposition parameters. Plasmon resonance measurements on these structures are under way.

References

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Figures

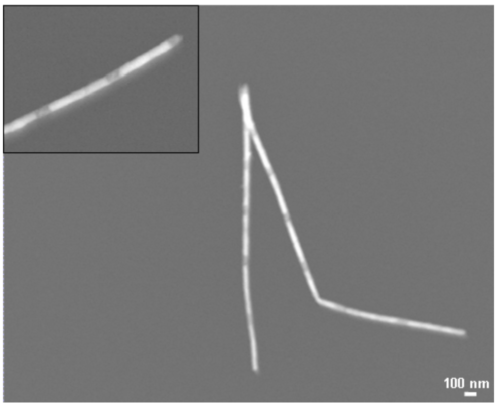

Figure 1: SEM image of two nanowires displaying the gold and silver segments. The inset shows a zoom in at higher magnification.

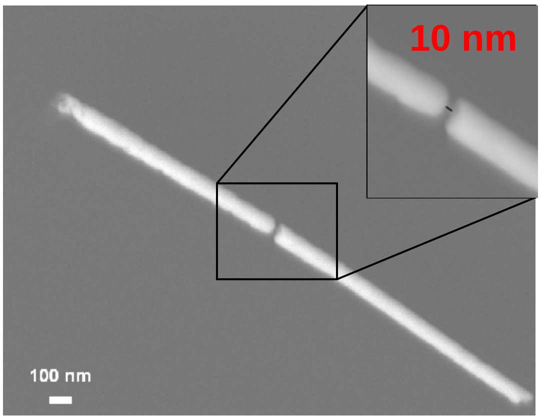

Figure 2: 10 nm gap between two smooth Au nanowires. The inset shows the gap at higher magnification.

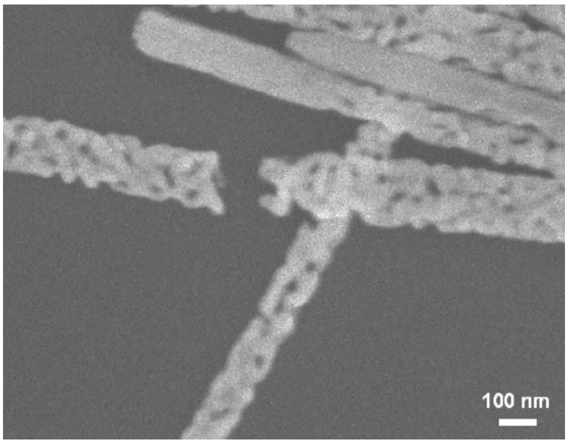

Figure 3: Porous nanowires enclosing a nanogap