TOOLS FOR MANIPULATION AND CHARACTERIZATION OF NANOSTRUCTURES

Kristian Mølhave, Peter Bøggild
Dept. of Micro and Nanotechnology, Technical University of Denmark, Lyngby, Denmark
krm@mic.dtu.dk

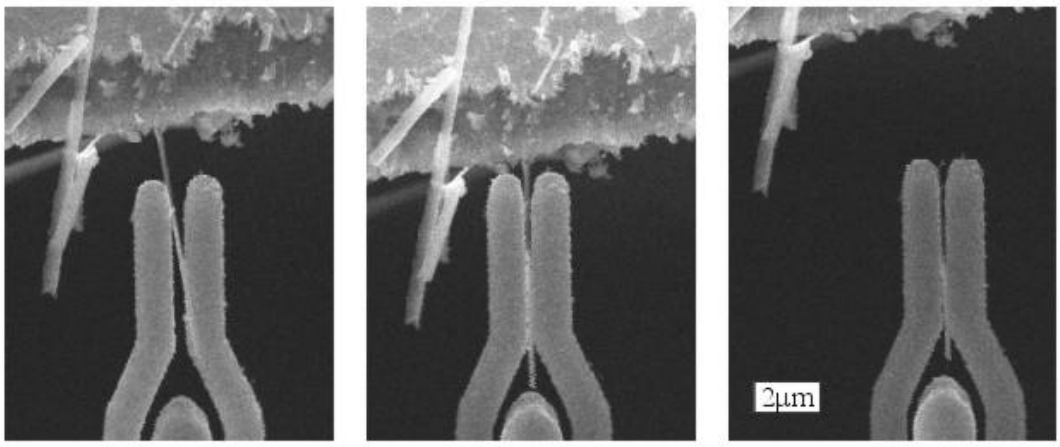
For construction and characterization of prototype devices with nanometer-scale parts, we have developed range of new tools for manipulation, assembly and characterization of three-dimensional structures with nanometer-scale components inside a scanning electron microscope (SEM). The system can also be used for preparing transmission electron microscopy (TEM) samples.

We have designed, fabricated, and characterized microfabricated grippers with electrostatic actuation, which were then successfully used for in-situ SEM pick-and-place manipulation of silicon nanowires (Fig. 1) [1]. For increased gripping force and control over the manipulation process, microfabricated grippers based on electro-thermal actuation with integrated force-feedback were also demonstrated [2].

Electron beam deposition in an environmental SEM, with a mixture of water vapour and metalorganic molecules as the environmental gas, it was discovered that the deposited structures contain a core of solid polycrystalline gold (Fig. 2) [3]. Environmental electron beam deposition (EEBD) was developed as a method for soldering nanotubes in electrical circuits and constructing highly conductive three-dimensional nanostructures with solid gold cores [4-6]. The gold core was found to be highly conductive and capable of carrying high current densities.

Together the developed set of tools comprise a nanolaboratory for building and characterising nanoelectromechanical systems and other devices inside an electron microscope - which in many ways can accomplish the same tasks as an electronic workshop, but using components that are some 10000 times smaller [7].

Figures:



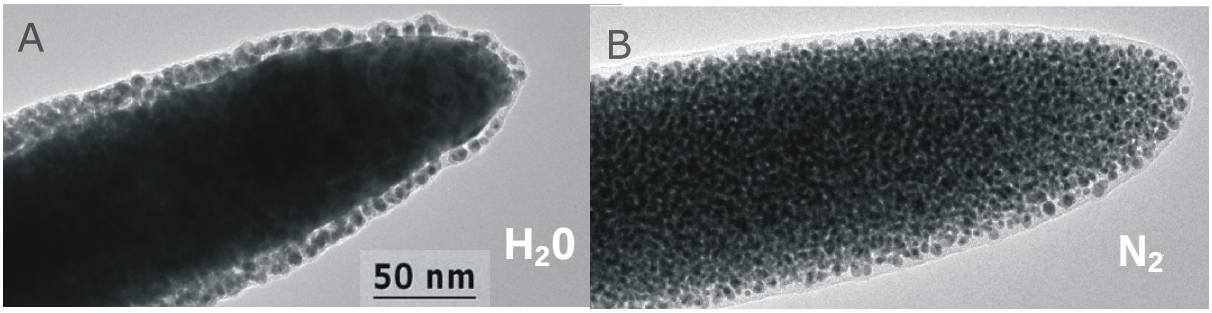


Figure 2: TEM images showing the effect of using either water vapour or nitrogen as the environmental gas during electron beam deposition of gold. A core of solid polycrystalline gold can be deposited when using water vapour.

References:

[1] **Molhave, K., *et al.*, Journal of Nanoscience and Nanotechnology, 4 (2004) 279-282.**

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[3] **Molhave, K., *et al.*, Nano Letters, 3 (2003) 1499-503.**

[4] **Molhave, K., *et al.*, Ultramicroscopy, 102 (2005) 215-219.**

[5] **Molhave, K., *et al.*, Nanotechnology, 15 (2004) 1047-1053.**

[6] **Madsen, D.N., *et al.*, Nano Letters, 3 (2003) 47-49.**

[7] **Mølhave, K., Ph.D. Thesis: *Tools for In-situ Manipulation and Characterization of Nanostructures*, Department of Micro and Nanotechnology. 2004, Technical University of Denmark.**