INTEGRATING NANOTUBES INTO MICROSYSTEMS WITH ELECTRON BEAM LITHOGRAPHY AND IN SITU CATALYTICALLY ACTIVATED GROWTH

Kjetil Gjerde, Jakob Kjelstrup-Hansen, Tommy Schurmann, Marc F. Mora, Lauge Gammelgaard, Masami Aono, Ken B.K. Teo*, William I. Milne*, Peter Bøggild*
MIC-Department of Micro and Nanotechnology, Bldg. 345 East, Technical University of Denmark, DK-2800 Kongens Lyngby, Denmark
**Univ. of Cambridge, Dept. of Engineering, Trumpington Street, Cambridge CB2 1PZ, UK*

kg@mic.dtu.dk

Integration of freestanding wire-like structures such as carbon nanotubes (CNT) and epitaxial grown GaAs NWs into microsystems have many potential applications. Devices such as AFM tips [1] or improved electrodes for electrical conductivity measurements [2] are obvious candidates. Previously such devices have been produced through manually mounting the NW on microfabricated probes [1,2]. Catalytically activated growth opens up the possibility of waferscale fabrication of such devices, drastically improving the throughput.

We combine conventional microfabrication techniques with state of the art electron beam lithography (EBL) to precisely position catalyst nanoparticles with sub-100 nm diameter into the microsystems. Although EBL is a serial lithography process, the small area of the catalyst dots allow a large number of these to be exposed in relatively short time. For CNT growth Ni is used, while Au is suitable for a range of nanowires including GaAs NW. Subsequent waferscale growth of NW can be achieved by plasma enhanced chemical vapour deposition (PECVD) or metal organic vapour phase epitaxy (MOVPE). Recent work [3] has previously shown this method capable of integrating CNTs on AFM probes, by depositing a protective nitride layer directly on top of an EBL defined Ni pattern. The introduction of metallic particles in many cleanroom processes is problematic; Ni may for instance lead to unwanted doping.

We have explored three different routes towards integrating nanosized catalyst particles in microsystems that are compatible with all cleanroom processes, as the only metal used is Al. First we demonstrate that highly regular sub-100 nm Ni dots can be formed on top of a surface that has already been microstructured. Using 100 keV acceleration voltage, large fluctuations in resist thickness can be tolerated, leading to high-quality results after Ni lift-off (fig. 1). The second approach involves the use of an in-situ polycrystalline silicon mask. Here we employ a sacrificial layer early on in the microfabrication process, with EBL defined holes for later catalyst deposition. After the processing of the devices is finished we deposit the catalyst material and conduct lift-off (Fig. 2). Our third approach makes use of an encapsulating layer of Al. Also here the EBL step is at the beginning of the fabrication. We have used these methods to produce microcantilever four-point probes with free-standing carbon nanotubes extending from each individual cantilever.

With a successful patterning of catalyst particles in the microsystem, subsequent NW growth may be accomplished. We have grown CNTs from EBL defined patterns inside microchannels several microns deep as can be seen in Fig. 3.

References:

[1] H. J. Dai, J. H. Hafner, A. G. Rinzler, D. T. Colbert and R. E. Smalley, Nature**,** **384**, (1996),147-150.
[2] R. Lin, P. Bøggild, and O. Hansen, J. Appl. Phys., **96**, (2004), 2895-2900.
[3] Q. Ye, A. M. Cassel, H. Liu, K.-J. Chao, J. Han, and M. Meyyappan, Nanoletters, **4**, (2004), 1301-1308.

Figures

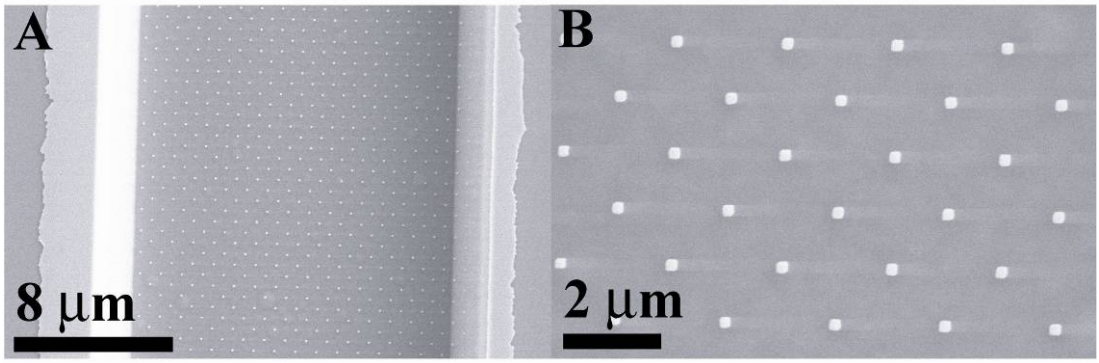

Figure 1 A) EBL defined catalyst particles inside a microchannel. The patterning was accomplished through employing EBL after the processing of the microchannels. B) A close up of the catalyst dots.

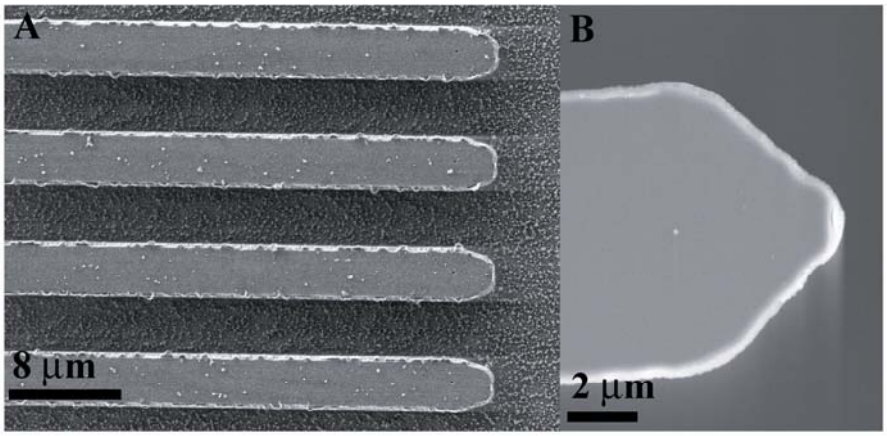

Figure 2 A) EBL defined holes in an in situ mask made of P-Si on a 4 point probe. B) After metal deposition and lift off the catalyst dots are left on the device.

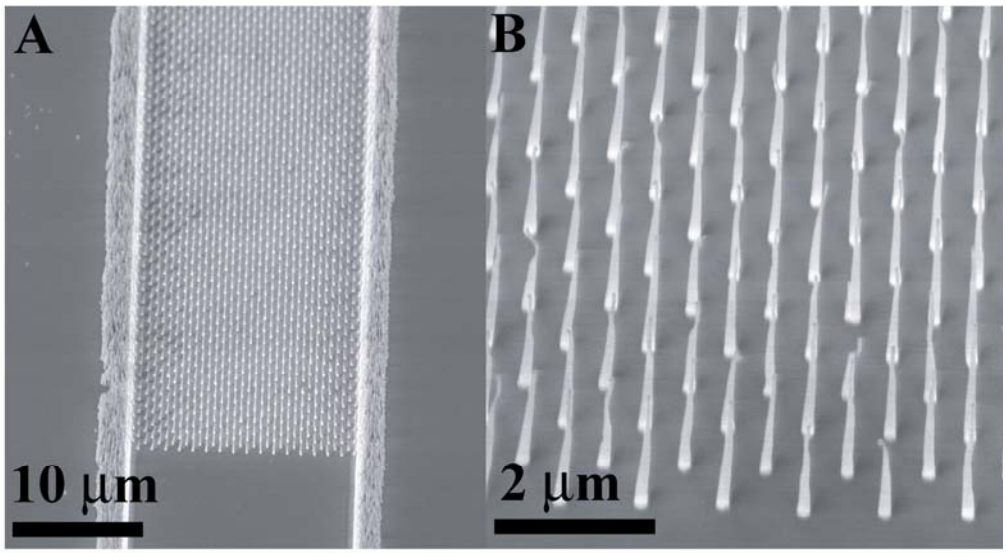

Figure 3 A) CNTs grown by PECVD on a sample similar to the one shown in Fig. 1. B) A close up of the CNTs.