FABRICATION OF HIGH ASPECT RATIO NANOSCALE SILICON STRUCTURES BY UTILIZING CARBON NANOTUBES AS REACTIVE ION ETCH MASKS

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Carbon nanotubes (CNT) exhibit a wide range of unique physical, electrical and chemical properties which make them a very interesting material choice in a wide range of applications. Multiwalled carbon nanotubes (MWCNT) are chemically inert [1][2] and physically robust, which in addition to their minute size make them useful as reactive ion etch masks.

We demonstrate that a 20 nm diameter MWCNT macromolecule can successfully be used as an etch mask in the selective reactive ion etch (RIE) of silicon to create high aspect ratio (5-15) silicon ridges with 100-300 nm tall vertical sidewalls, see Figure 1. The etch parameters are tuned to avoid damaging the nanotube while still being able to remove the unmasked silicon. The circular cross section of a CNT increases the risk of silicon removal underneath the nanotube (underetching) and the etch process was further optimized to prevent this. We present a road map as how this process can be adapted to any RIE system. Since MWCNT with diameters down to 10 nm can be manipulated with Atomic Force Microscopy or using microfabricated tools [3], the concept of using nanotube as etch masks opens the path to making 10 nm silicon structures.

We suggest the application of the created silicon ridges with intact CNT on them in the fabrication of nanofluidic channels. Channels with diameters less than 50 nm and with extreme smoothness are crucial for stretching and analysis of individual DNA molecules. Wider channels allow the DNA to curl up, and rough channels disturb the liquid flow and the passage of the biomolecules [4]. Smooth channels can be created by using CNT covered silicon ridges as nanoimprint lithography (NIL) stamps. We show further examples of CNT stamp pattern transfer to a PMMA thermoplast substrate [5], as illustrated in Figure 2, as well as molding with the PDMS elastomer. Finally, we suggest how the method can be adapted to parallel wafer scale production of CNT defined NIL stamps using catalytic chemical vapour deposition.

References:

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[2] Lee S B, Robinson L A W, Teo K B K, Chhowalla M, Amaratunga G A J, Milne W I, Hasko D G, Ahmed H 2003 *J. Nanosci. Nanotechnol* **3** 325-8
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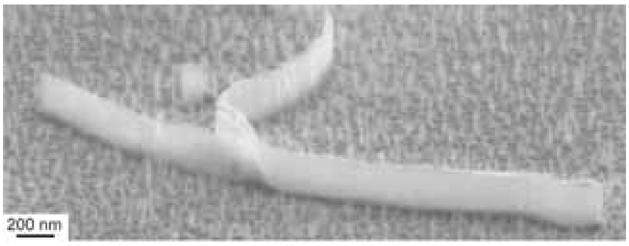
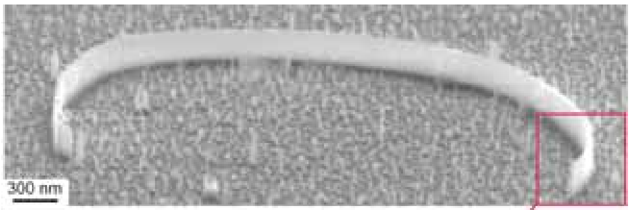
[4] Tegenfeldt J O, Prinz C, Cao H, Huang S R L, Austin R H, Chou S Y, Cox W E C, Sturm J C 2004 *Anal. Bioanal. Chem.* **378**, 1678-92
[5] Schmidt M S, Nielsen T, Madsen D N, Kristensen A, Bøggild P 2005 *Nanotechnology* **16** 750-3

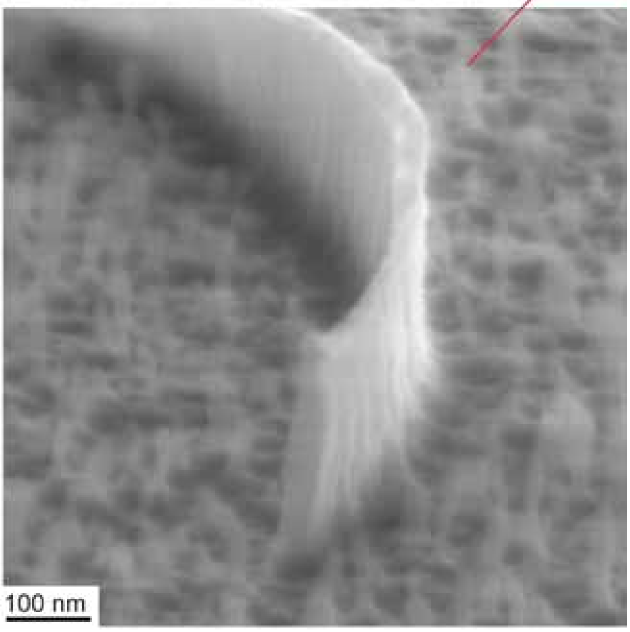
Figures:

1a)



1b)





1c)

Figure 1: (a) Complex structures can be formed by combining nanotubes with other nanotubes or microfabricated features. (b) A 5 µm long multiwalled carbon nanotube on top of a 260 nm tall silicon ridge. (c) The diameter of the nanotube is around 20 nm.

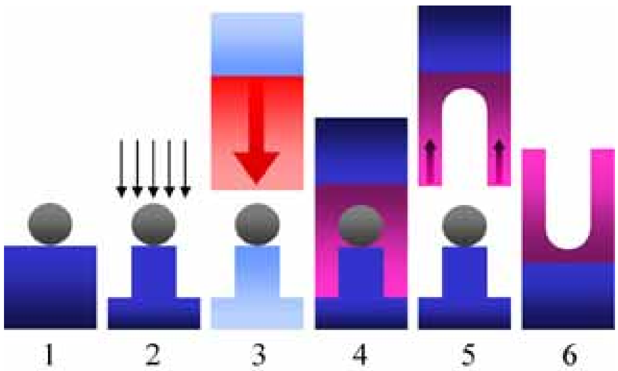


Figure 2: The principle of using CNTs to create stamps for nanoimprint lithography. (1) A nanotube is placed on a Si surface. (2) RIE process forming the NIL stamp. (3) Stamp and polymer are heated and pressed together. (4) The stamp and polymer are cooled. (5) Release of stamp from polymer. (6) The finished imprint in PMMA.