Conducting FIB milled nanowires

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In this work a focused ion beam (FIB) is used to mill conductive silicon nanowires on prefabricated chips from a silicon-on-insulator wafer. The FIB equipment used is a FEI Quanta 3D dual beam microscope with a gallium liquid metal source. The device layer is 130 nm thick with a resistivity of 0.001 Ωcm. Nanowires with designed widths of 100 nm, 200 nm and 400 nm and length of 1000 nm, 2000 nm and 4000 nm respectively have been milled, see Figure 1. The wire width is generally 5-10 nm narrower than designed, as seen in Figure 2. This narrowing is expected to originate from the ion beam having a finite broadening. It is expected that a considerable part of the outer regions of the nanowires is damaged by the ion beam[1], giving the effective conductive nanowire smaller dimensions. These effects are investigated using high resolution TEM.

The electrical resistivity of the nanowires is measured using the integrated 4 point geometry, with constant current applied to the two outer connections, while measuring the voltage drop across the nanowire using the two inner connections on each side of the wire. The expected resistance of the nanowires is 770 Ω, but the measured resistance lies from around 11 kΩ to 17 kΩ. This indicates that the impact of the ion damage and implanted gallium ions is substantial. These damage effects are simulated using the tool SRIM[2] and involves estimates of the amorphous silicon layer thickness, and the range and impact of ions in the bulk nanowire.
The scope of the work is to mill out a variate of prototype electromechanical or electrical nanostructures such as nanogrippers and 4 point nanoprobes using prefabricated chips.

[1]Naoko I. Kato, *Journal of Electron Microscopy* **53(5)**: 451–458 (2004)

[2]Stopping and Range of Ions in Matter, James F. Ziegler, http://www.srim.org

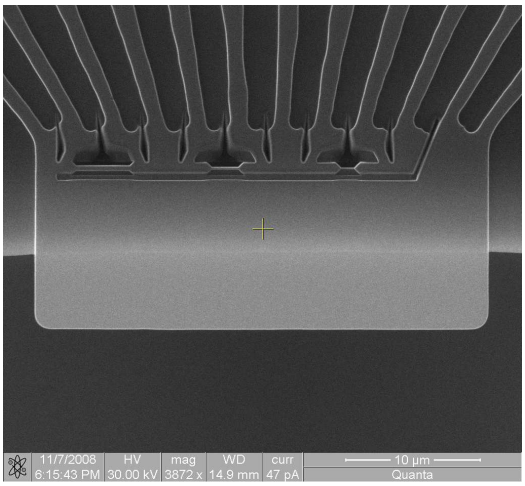

Figure 1: SEM image of the prefabricated SOI chip with FIB milled silicon nanowires. SOI thickness is 130 nm. The nanowires are from left to right designed to have widths of 400 nm, 200 nm and 100 nm, and lengths of 4000 nm, 2000 nm and 1000 nm respectively. The FIB has milled through the SOI layer reaching the silicon dioxide beneath. Future test will involve free hanging nanowires.

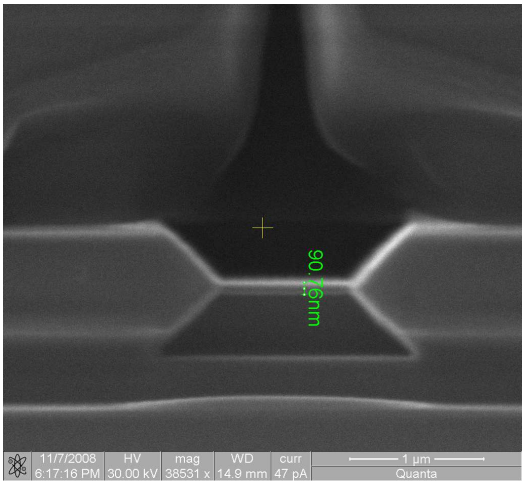

Figure 2: SEM image of the FIB milled 100 nm wide silicon nanowire. The thickness of the nanowire is seen to be smaller than designed. This is expected to originate from the beam having a finite broadening, which should be be considered in future designs.