Post Fabrication of Foundry-Fabricated CMOS Serpentine Nanowire Biosensor with Focused Ion Beam

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Si nanowire field-effect transistors (NW FETs) have demonstrated great potential as highly sensitive, label-free, portable biosensors for the detection of chemical and biological analytes. In this work, we report the implementation of SiNW biosensors using industrial standard CMOS processes by semiconductor foundries (SMIC). The use of standard CMOS process to make biosensors offers many advantages such as high chip quality, ultralow unit cost at mass-production, miniaturized system with integrated circuits. However, biosensors require the NW to be exposed to solution for device biasing and analyte capture, which is incompatible with the CMOS processes targeted for use under dry conditions, as the NWs are buried inside the chip. In this work, we developed a post fabrication process with focused ion beam (FIB) to expose the NW FET biosensors. This is also our first time to demonstrate a novel design of serpentine NWs defined in the polysilicon gate layer as the channel of junction-less FETs.

The chip was fabricated by SMIC using 180 nm Si technology node. First, a dummy pad and a NW sensor were etched by FIB to reveal the cross section of the biosensor chip and the NW, followed by SEM and EDAX to study the dimensions and material composition of the major layers, as shown in Figure 1. The 180 nm-wide serpentine NW was defined in the polysilicon gate layer, with all the layers above it blocked from dummy fill patterns. Accordingly there is only transparent oxide and nitride above the NW, which makes it visible under optical microscope, as shown in Figure 2a. This was utilized to find the relative positions between the NW and top dummy structures, in order to precisely locate the area to be etched, as marked by the lines in Figure 2b. This position accuracy is of vital importance since there are limited margins around the NW to the metal layers. Prior to etch, a Pt frame was selectively deposited to mark the region to be etched. Due to the non-selectivity of the Ga beam, the FIB etch was stopped at 8.1 μm (converted from 6.38 μm measured at 52°) with approximately 0.8 um oxide left above the NW to avoid over-etch, as shown in Figure 3a. After that, buffered oxide etchant with 7:1 volume ratio was used to selectively etch the residual oxide. The exposed Serpentine NW with on-chip dual silicide electrodes are shown in Figure 3b.

In the full paper, the serpentine NW junction-less FET will be characterized in solution, and the charge-sensing capability of the sensor will be demonstrated in pH sensing tests.

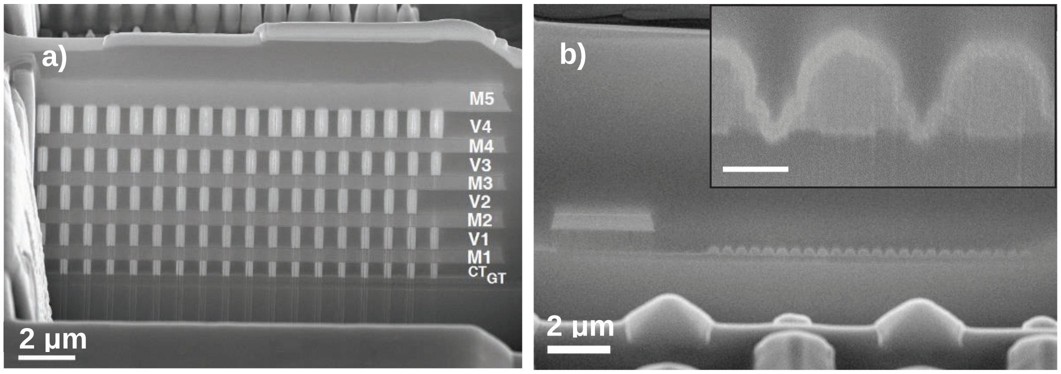

Figure 1: SEM micrographs to reveal the cross-section of the biosensor chip (a) and serpentine NW (b): (a) the major layers labeled include the polysilicon gate (GT), contact (CT), metal (M1 - M5, Al) and via (V1 - V4, W/Ti with oxide as filler) layers. There is also a top silicon nitride layer (not labeled). (b) the inset (200 nm scale bar) shows a close-up view of the NW. The chip was tilted at 60°.

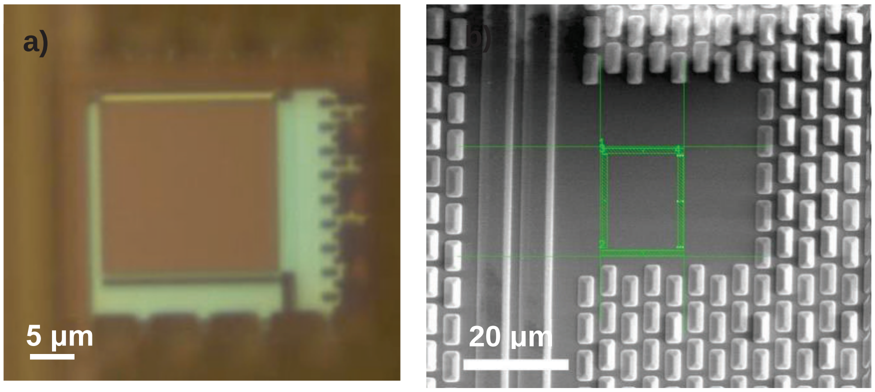

Figure 2: (a) The optical micrograph of the serpentine NW biosensor before post fabrication: All layers above GT were blocked from dummy fill patterns, so the NW is visible under optical microscope. *(b) SEM micrograph of the same sensor before FIB etch:* Pt was deposited in the shaded frame to mark the region to be etched.

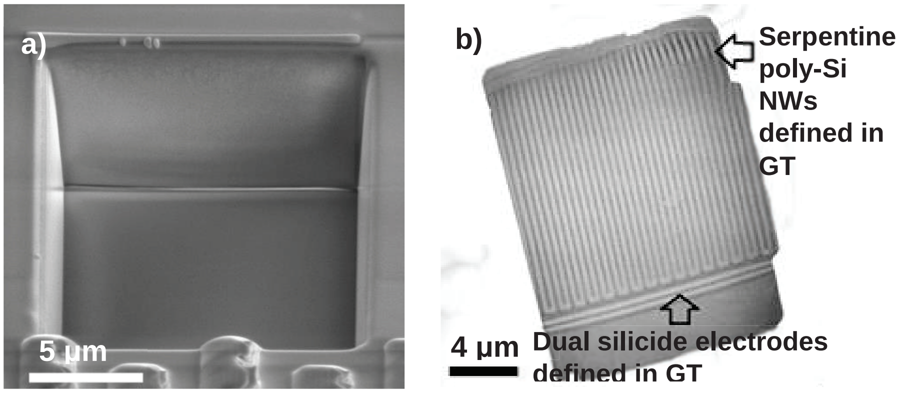

Figure 3: SEM micrograph to show the area after FIB etch (a) and after the following BOE etch (b): The chip was tilted at 52° in (a) and 15° in (b).