Fabrication of SOI-Based Nanowires

CNF Project # I353-05
Principal Investigator: Mark Reed

Abstract:

The goal of this project is to realize Si nanowires from the active Si layer of silicon-on-insulator (SOI) wafers. The potential use of nanowires for chemical and biological sensing applications is a subject of intense recent interest and study. Nanowires synthesized by chemical vapor deposition and other methods have shown much promise as sensors but must be transplanted from their growth substrate onto planar wafers for device fabrication, which is an inherently random process (no alignment is possible). Nanowires fabricated from SOI have the advantage of being fabricated with traditional top-down processing techniques, thus alignment is straightforward. Furthermore, such devices have the added advantage that they can be fabricated into Hall bar structures to determine Hall mobility for the first time in a Si nanowire.

Summary:

A critical shortcoming of nanowire-based sensors is the bottom-up assembly required for device fabrication: the nanowires must be deposited on a planar substrate (typically a silicon wafer with a thin oxide that serves as the gate dielectric in a backgate geometry) because they are generally synthesized on a growth substrate incompatible with processing. Additionally, there is a great variation in the device characteristics of nanowires. In order for any statistically relevant study to be performed, a multitude of similar devices must be fabricated, thus a bottom-up approach is impractical.

Using the tools available at the Cornell NanoScale Facility (reactive ion etching, e-beam, oxidation furnaces), we have developed a fabrication process to produce silicon nanowires from an ultra-thin SOI wafer with traditional top-down lithography.

We have successfully realized Si nanowires with widths of ~ 50 nm—the height of the active layer is 80 nm—using chlorine reactive ion etching (RIE). Large (3 µm wide) control structures produced by a fluorine RIE process have been fabricated and their electrical characteristics have been measured. We are currently investigating the electrical characteristics of Hall bar nanowire samples and the use of these nanowires as chemical and biological sensors.

References:

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Figure 1: Device fabrication. A. Optical micrograph showing the die layout: four devices in the center fanning out to pads. The darker pads are contacts through the BOX to the handle Si; B. Optical image of a 3-µm-wide control structure defined by a fluorine reactive ion etch. The device is light on the dark BOX background; C. SEM of a control (3 µm) Hall-bar structure. The light lines within the leads are regions of degenerate doping; D. Optical micrograph of a thin ~ 50 nm nanowire. This structure is defined with e-beam lithography and realized with a chlorine reactive ion etch after the initial optical lithographic steps are complete. The original fluorine RIE etches the BOX whereas the chlorine RIE does not, thus the BOX is multi-colored.

Figure 2: Control structure transport properties. A. $I_{SD}$ vs. $V_{SD}$ with varying $V_{GD}$ plot for the device shown in Fig. 1B. The Si handle wafer serves as the backgate; B. Plot of $I_{SD}$ vs. $V_{GD}$ for $V_{SD} = -1V$. There is a clear hysteretic effect in the sweeps of this control structure.