APPLICATION NOTE

In Situ SEM Characterization of the Fracture Strength of a Single-Crystal Silicon Nanowire Resonator

The high resonant frequencies and quality factors of nanowire resonators make these NEMS (nano-electromechanical systems) of high interest for many applications as resonators and switches. For these applications, both the pull-in and resonator properties are important, and thus it is often necessary to evaluate the strength of clamping when a bending force is applied [1]. However, when the nanowire being tested is only a hundred nanometers wide and a few micrometers in length, it is difficult to apply a displacement with the required positioning and motion resolutions.

In this experiment, under SEM, a miBot nanomanipulator with a 500 nm tungsten probe is used to displace single-crystal silicon nanowires (SiNW) 194 nm in diameter and 50 µm in length [Figure 1] at the middle of the wires, while the ends are clamped. The SiNWs are slowly displaced [Figure 2] until fracture occurs either at the clamping points or elsewhere in the wires to determine the clamping or fracture strengths, respectively. This is acquired by observing the displacements just before failure in SEM then using this data with a large-scale displacement model in COMSOL to determine the fracture strengths.

The nanometer positioning resolution of the miBot nanomanipulator and its high mechanical stability made these tests possible by being able to displace the SiNW until fracture with vibration free motion. Furthermore, the mobility of the miBot over four degrees of freedom allowed the nanomanipulator to quickly be moved into the appropriate position for applying the force normal to the nanowire under the SEM.

[1] Evren F Arkan, Davide Sacchetto, Izzet Yildiz, Yusuf Leblebici and B Erdem Alaca, Monolithic Integration of Si Nanowires with Metallic Electrodes: NEMS Resonator and Switch Applications. December 2011, J. Micromech. Microeng. 21 125018 doi:10.1088/0960-1317/21/12/125018

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Imina Technologies products in use:
- miBot™ BT-11 micromanipulator
- miBase BS-42 stage
- syDrive SD-10 piezoelectric controller
- Vacuum kit for SEM FEI XL-30

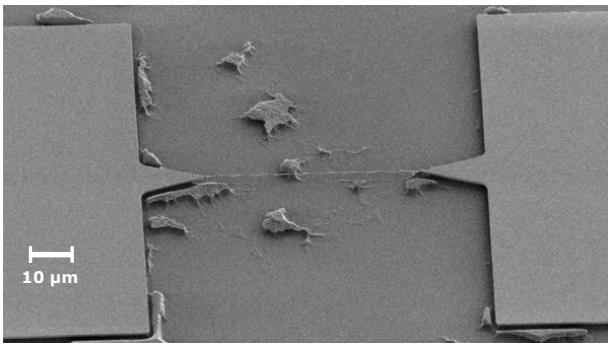

Figure 1. Single-crystal silicon nanowire fabricated from etching a silicon on insulator (SOI) wafer.

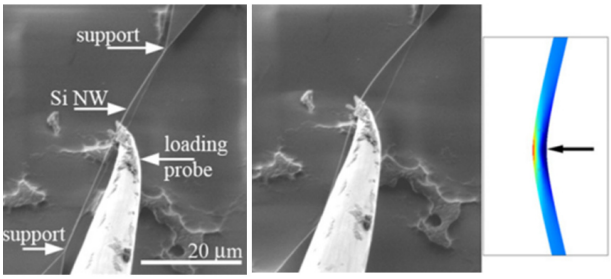

Figure 2. Loading of the silicon nanowire with the miBot nanomanipulator probe (left); displacement just before fracture (middle); and COMSOL model showing calculated stresses at the loading point. (Source: [1])

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