Single Crystal Silicon Nanowires used as Cantilever for Femtonewton Detection

M. Hofer and Ivo W. Rangelow
Department of Microelectronic and Nanoelectronic Systems, TU Ilmenau, Germany, Gustav-Kirchhoffstr. 7, 98693
manuel.hofer@tu-ilmenau.de

B. Sanii and P. D. Ashby
Molecular Foundry, LBNL, Berkeley, California 94618, USA

A critical limitation of nanoelectromechanical systems (NEMS) is the lack of a high-sensitivity position detection mechanism. We introduce a noninterferometric optical approach to determine the position of nanowires with high sensitivity and bandwidth. Its physical origins and limitations are determined by Mie scattering analysis. This enables a dramatic miniaturization of detectable cantilevers, with attendant reductions to the fundamental minimum force noise in highly damping environments. Measurements in water with force sensitivity of 6±3fN/√Hz have been successfully demonstrated[1].

The simple operation scheme discerns the position of the nanowire at far-field working distances. The nanowire is placed near the focus of a laser beam polarized parallel to the length of the wire. The forward light pattern is incident on a split photodiode and its difference signal is used to measure the position of the nanowire with respect to the laser focus. Mie scattering analysis has been adapted to estimate the difference signal of a split photodiode[1].

To achieve higher force sensitivity we shrunk the physical dimensions of silicon nanowire below 50 nm in lateral width and 30 nm in thickness[2]. Due to the high stiffness of the silicon we are able to fabricate nanowires with total length in the range of 2- up to 100 µm free standing in air. The nanowires are based on silicon on insulator (SOI) technology and were defined with e-beam lithography by using hydrogen silsesquioxane (HSQ) - a negative e-beam resist which is acting as perfect etching mask stable to fluorine based plasma environments. A back side etch of the bulk silicon allows achievement of free standing nanowires. A final gently isotropic hydrofluoric acid vapour (HFV) etch technology was performed to etch the nanowires free (in air).

---

[1] B. Sanii, P.D. Ashby, Phys. Rev. Lett. 104, 147203 (2010)

[2] M. Hofer, Th. Stauden, I.W. Rangelow and J. Pezoldt: Mater Sci. Forum Vols. 645-648 (2010), 841

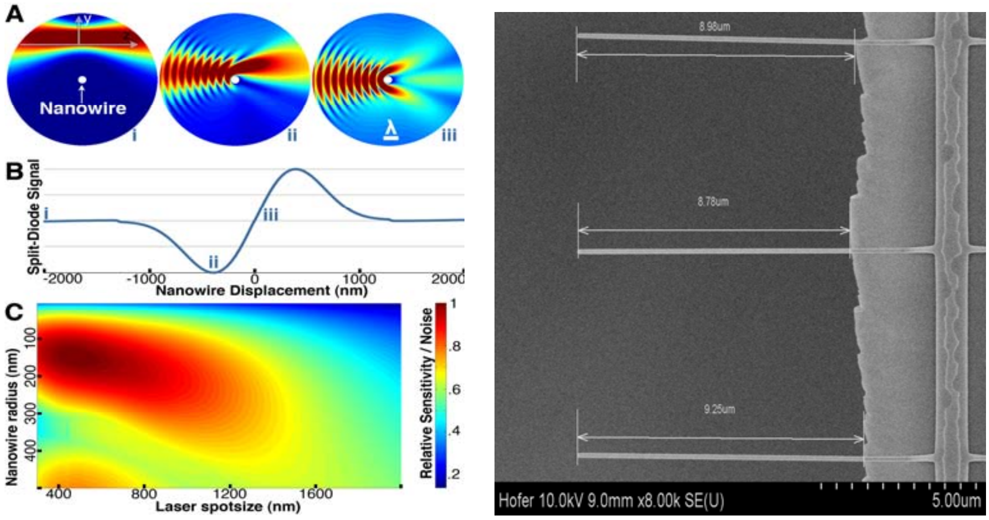

Figure 1: Operation principle for control the position of the nanowire at far-field working distances (left); Free standing single crystal silicon nanowires: Total length of 9 µm, width of 50 nm and thickness of 27 nm (right).

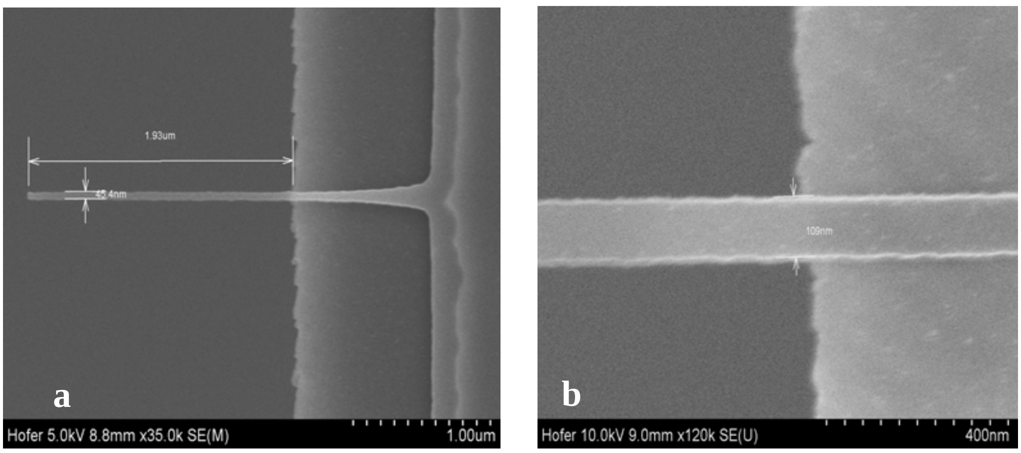

Figure 2: (a) 1.9 µm long and 45 nm width Single Crystal Silicon nanowire fabricated from SOI wafer; (b) SEM picture shows the line edge roughness of the nanowire.