FIB-assisted bending of patterned grown silicon nanowires

Kimin Jun[a,b], Jaebum Joo[a,c] and Joseph M. Jacobson[a]
[a]*The Center for Bits and Atoms, MIT Media Laboratory,*
[b]*Department of Mechanical Engineering,*
[c]*Department of Materials Science and Engineering*
Massachusetts Institute of Technology, Cambridge, MA 02139

Nanowires attract a great attention for the applications as electronic, structural and molecular building block. Therefore, it is important to manipulate nanowires into desired alignment or shape for further device fabrication. With the help of crystal substrate, various semiconductor nanowires can be grown epitaxially mostly through vapor-liquid-solid process. However, this growth gives only one directional alignment, toward energetically preferred crystal direction. Although some conditions results in planar nanowires array[1], individual control of the single nanowire has not been demonstrated.

Previously, Focused Ion Beam (FIB) process was suggested to modify nanostructure like nitride membrane[2] and carbon nanotubes[3]. Our research applies this FIB technique to regular silicon nanowires array to investigate the potential of arbitrary complex structure fabrication.

The schematic of the process is shown in Fig. 1. Vertically aligned silicon nanowires with 10 um length were grown on Si (111) substrate from gold pattern prepared by electron beam lithography (Fig. 2a). Gallium FIB (Strata DB235, FEI) was scanned at the side of nanowires to fold the nanowires. Required dose for the specific angle was characterized with nanowire thickness and bending length. To find optimal condition, low dose line patterning was repeated until desired bending angle was achieved. When the nanowires were thin (d ~ 150 nm), relatively small dose (60pC/um) was required to fully bend vertical nanowires to planar array at the near bottom, as shown in Fig. 2b. The thicker nanowires (d ~ 250 nm) needed higher dose (100pC/um) to generate the same angle even at the shorter length (Fig. 2c). However, this low sensitivity allowed more precise bending control. By adjusting irradiation dose, gradual bending was readily obtained, showing intermediate angled structure like Fig. 2d.

As demonstrated from the result, this technique could provide interface between simple 3-D nanowires array and complex structure or even 2-D planar array. This result could be applied to nanowire based device fabrication with precise position and shape control.

---

[1] S. A. Fortuna, J. Wen, I. S. Chun and X. Li, Nano Lett. **8**, 4421(2008)
[2] W. J. Arora, S. Sijbrandij, L. Stern, J. Notte, H. I. Smith and G. Barbastathis, J. Vac. Sci. Technol. B **25**, 2184(2007)
[3] B. C. Park, K. Y. Jung, W. Y. Song, B-. O and S. J. Ahn, Adv. Mater. **18**, 95(2006)

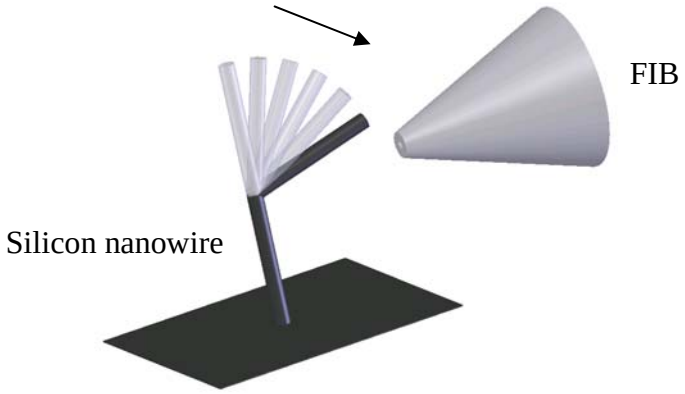

Fig 1 : Schematic bending process : FIB irradiated nanowire is bent. Arbitrary angle of bending is achieved by controlling beam dose.

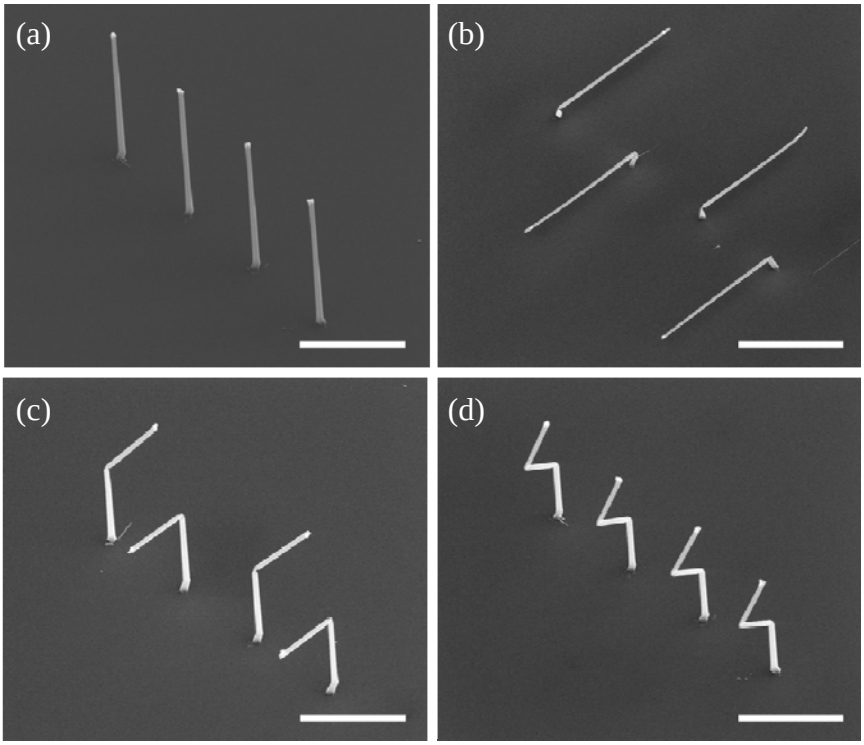

Fig 2 : SEM micrographs : (a) Vertically grown silicon nanowires array (b) Planar nanowires array by bending at the bottom (c) Right angled bending at the middle point (d) 'hook' shape array by multiple bending. All pictures viewed from 45 degree rotation and 45 degree tilting. Scale bar = 5 um.