Fabrication of Complex Three-Dimensional Multilevel Silicon Micro- and Nano-Structures using High Energy Ion Irradiation

S. Azimi[a,b], Z. Y. Dang[a], M. B. H. Breese[a,b].

[a] *Centre for Ion Beam Applications (CIBA), Department of Physics, National University of Singapore*
Singapore 117542

[b] *Singapore Synchrotron Light Source (SSLS), National University of Singapore, 5 Research Link*
Singapore 117603

slssa@nus.edu.sg

We have developed a new process to fabricate arbitrary-shaped, multilevel, three-dimensional free-standing micro- and nano-structures on bulk silicon using focused high energy proton beam irradiation, followed by electrochemical anodization.[1] We make use of the fact that high-energy protons create significantly more localized defects at their end–of-range than close to the surface. By controlling the fluence of an irradiated area, the resistivity can be controlled and increased locally for selective porous silicon formation during subsequent electrochemical anodization. During the electrochemical process, the flow of electrical holes from the back surface bends around the high defect regions to the front surface. As a result PSi forms around these regions, leaving the core region intact.This has enabled us to produce complex free-standing microstructures such as arrays or long wires, grids, wheels, vertically stacked wires and wires which can be controllably bent upwards and downwards in the vertical plane. The two most important factors which determine the wire cross-section dimensions and depth are the irradiation ion fluence and energy. We can controllably vary the width of wires from tens of nanometers to tens of microns by varying the fluence of high energy protons and the depth of wires from about 800 nm to 50 μm by varying the proton energy, Fig. 1 and Fig. 2. By using a combination of multiple energy proton irradiation, different ion penetration depths and hence multilevel free-standing three-dimensional silicon structures can be obtained, Fig. 3. This is the only technique capable of making such complex free-standing structures on bulk silicon after a single-step etching. We believe this process is an important development in fields such as silicon photonics and MEMS.

References:

[1] **S Azimi, M B H Breese, et al.** *J. Micromech. Microeng.* 22: 015015, 2012.

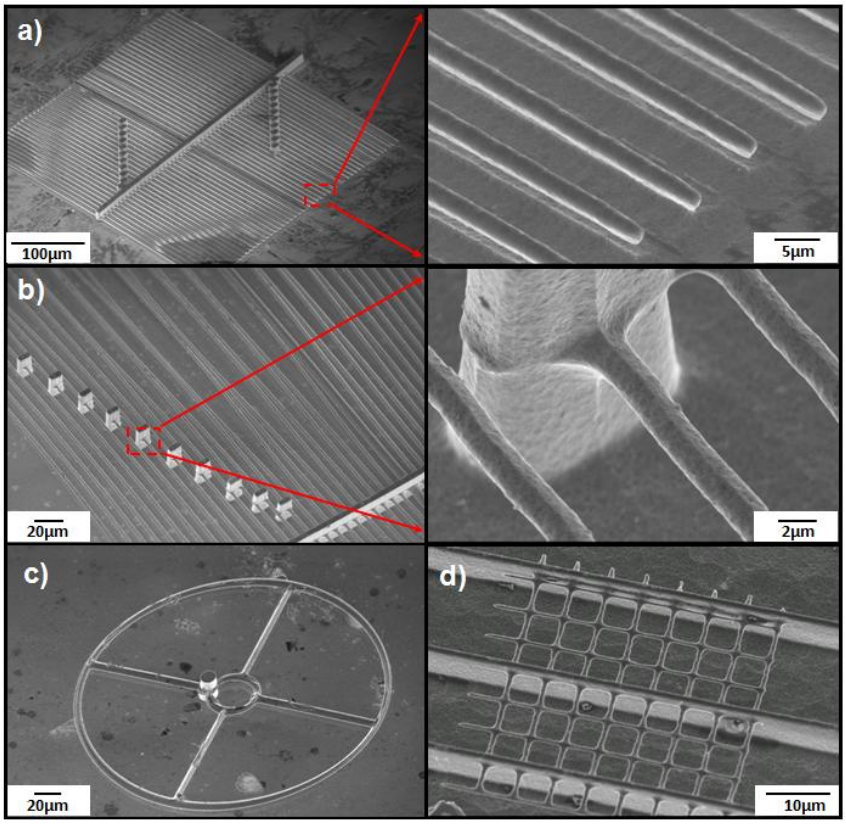

Figure 1. SEM images of 3D machined arrays of free standing cores forming various shapes, supported by heavily irradiated silicon walls.

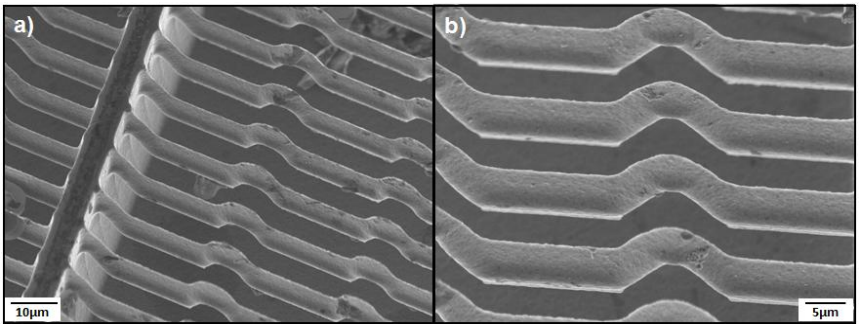

Figure 2. SEM images of micromachined curved 3D wires.

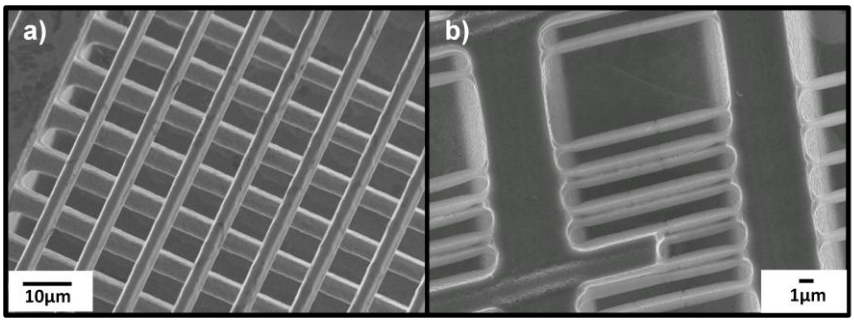

Figure 3. SEM images of two-level array of wires