Geometry Controlled Periodic Si Nanopillar Arrays by Dry Oxidation and Wet Etching

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Nanostructures such as nanorods, nanowires, nanotubes, and nanoparticles have potential applications in nanoelectronics, nanophotonics and nanobiotechnology. Templated silicon nanostructures can be useful as the basis for nano-imprint lithography, large scale fabrication of MEMS and NEMS component features, microfluidic chips, photonic crystal circuits, multi-probe scanning probe microscopy), Silicon nanopillar patterns are usually made by DUV, e-beam or nanoimprint lithography. However, these processes are often slow or expensive in fabricating different Si nanotemplates.

In this study, patterned circular holes on Si with ~100 nm to 1 µm diameters and spacings have been made for an area of 0.6 cm x 0.6 cm via deep UV lithography. These samples were oxidized at 1000^{o}C for various durations, and then subjected to controlled chemical wet-etching for removal of silicon oxide layer to create protruding nanofeatures. More than 100 million, nearly identical, high-aspect-ratio Si pillar array having the same height and geometry were obtained. The SEM micrograph, Fig. 1(a), represents an array of extremely sharp nano-needles, with the nano-tip diameter of ~10 nm and 500 nm height. These nano needles can be useful for multi-tip field emitter structures and nano-imprinting deformation. The image in Fig. 1(b), a flat-top Si pillar array shows ~80 nm square apex region and 900 nm height. The flat-top pillars can be useful as a nano-imprint mould or as an arrayed nano pedestal for sharp AFM or STM probes (e.g., with vertically grown carbon nanotube tips) for metrology, for nano field emission for electron source, or for massively parallel e-beam lithography for nanomanufacturing of semocinductor or photonic devices. The size of the flat-top region or the tip-end sharpness can be controlled by the oxidation temperature/time, wet-etch process and the geometry of the starting Si holes patterns. In this paper, the materials/process parameters for obtaining the intended final nanopillar geometry, the mechanism and kinetics of nano-pillar formation, and their potential applications will be discussed.

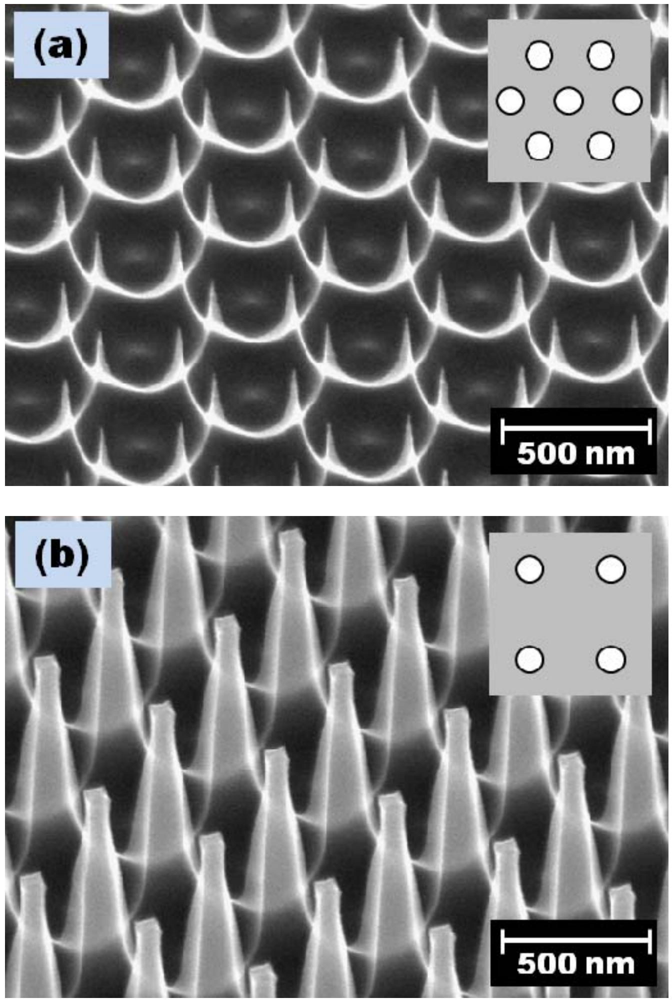

Figure 1. SEM images of Si nano pillar arrays formed by oxidization and wet-etching of DUV Si nanotemplates. (a) Hexagonal array of extremely sharp-tip nano needles. (b) Square array pillars with a flat-top configuration. These were fabricated by enlargement of circular pores (330 nm diameter starting hole array) in Si by oxidation and chemical etching. The inset illustrates the arrangement of Si holes patterns in the starting DUV pattern prior to oxidation and etching.