Three-Dimensional Microstructures in Silicon via the Combination of Light-Ion Beam Writing and Electrochemical Etching

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Many state-of-the-art technologies, such as micro-/ nano-electromechanical systems, optoelectronics and photonics, require the fabrication of precise, very small, three-dimensional structures in semiconductor materials, typically silicon. A major limitation of conventional lithography and silicon etching technologies is that multiple processing steps are required to fabricate free-standing multilevel structures.[1] However, it is known that the mechanism by which a silicon wafer can be electrochemically etched in solutions of hydrofluoric acid depends, in part, on its conductivity.[2,3] This has enabled the development of an alternative mask-less patterning process that combines proton irradiation with electrochemical etching.[4] A high-energy beam of light-ions (e.g. protons or helium ions), focused to a small spot by a nuclear microprobe, selectively damages the semiconductor lattice in the irradiated regions. A higher beam dose at any region produces a higher damage concentration, so by pausing the focused beam for times at different locations, any pattern of localized damage in the semiconductor can be built up. This damage acts as an electrical barrier during subsequent electrochemical etching, so the un-irradiated regions are preferentially removed, leaving a copy of the patterned microstructure. Furthermore the ability to control the depth of damage/implantation introduces the possibility of producing three-dimensional structures. Examples of microstructures produced to date include: high aspect ratio needles with tips that have a radius of curvature of about 15nm (Figure 1); tilted columns (Figure 2); and free standing bridges (Figure 3). This paper will discuss both the mechanism by which the irradiation influences the electrochemical etching and potential applications of the technique.

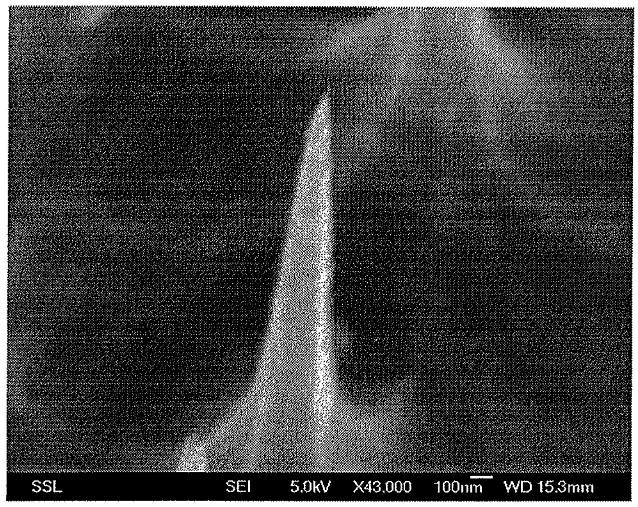

Fig 1: High aspect silicon needle; radius of curvature of tips about 15nm.

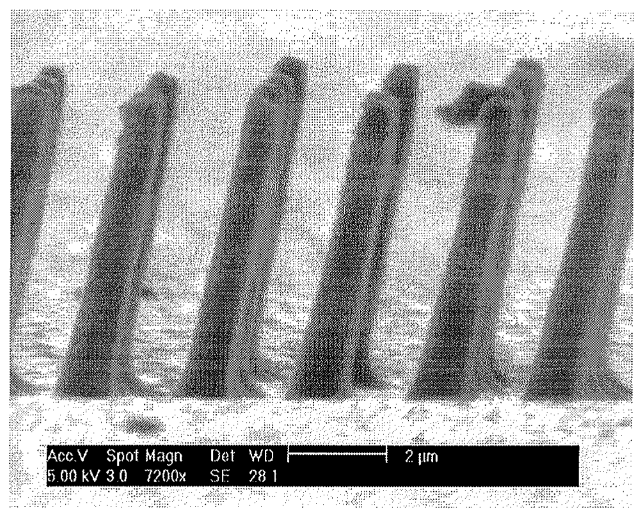

Fig.2: Tilted columns

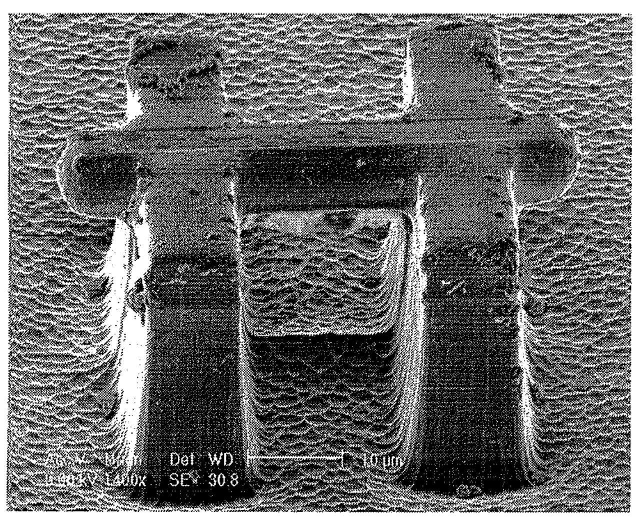

Fig. 3: Free standing bridge etched from silicon wafer.

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