Methods For Rapid Prototyping Of Nanomechanical (NEMS) Devices

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Two methods to fabricate artificial nanoscale mechanical devices are presented. One is based on the combination of local Ga+ doping of silicon by a focused ion beam and KOH etching. The second is based on the use of nanostencil as miniature shadow mask to define metal nanowires that are subsequently underetched. Both method allow for rapid prototyping of novel NEMS elements having resonance frequencies up to several 100s MHz, and have distinct characteristics in terms of material properties.

Method 1: Selective Ga + ion implantation by focused ion beam exposure and subsequent wet chemical etching is used to fabricate micro/nanomechanical elements in Si. Freestanding elements with a ~ 30 nm membrane thickness are made by controlled selective underetching between unexposed and exposed areas. Ultrahigh-frequency cantilever beams have been made with resonances in the tens of MHz range. Using a U-shaped beam cross section, mechanical stiffness could be increased 100-fold, which in turn increased the beam resonance frequency to several hundreds of MHz. The direct-write patterning/milling technique was used to fabricate various arbitrary shapes with vertical sidewalls such as submicrometer-sized containers, cups, and other nanomechanical devices [1].

Method 2: We report an all-dry, two-step, surface nanoengineering method to fabricate nanomechanical elements without photolithography. It is based on the local deposition through a nanostencil of a well-defined aluminum pattern onto a silicon/silicon-nitride substrate, followed by plasma etching to release the structures. The suspended 100-nm-wide, 2-um-long, and 300-nm-thick nanolevers and nanobridges have natural resonance frequencies of 50 and 91 MHz, respectively. The fabrication method is scalable to a full wafer and allows for a variety of materials to be structured on arbitrary surfaces, thus opening new types of nanoscale mechanical systems.

[1] Silicon Micro/Nanomechanical Device Fabrication Based on Focused Ion Beam Surface Modification and KOH Etching J. Brugger, G. Beljakovic, M. Despont, N. F. de Rooij and P. Vettiger Microelectronic Engineering, 35, pp.401-404 (1997)

[2] Nanomechanical structures with 91 MHz resonance frequency fabricated by local deposition and dry etching G.M. Kim, S. Kawai, M. Nagashio, H. Kawakatsu, J. Brugger Journal of Vacuum Science and Technology B, 22(4), pp.1658-1661 (2004)