High Aspect Ratio Silicon Nanowires and 3D Nanostructures via Selective Focused Ion Beam Implantation and Wet Etching: Fabrication and Characterization

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Silicon (Si) is a widely adopted material in electronics and semiconductor industry for micro/nanoscale devices due to its attractive optical, mechanical, and electrical properties along with low-cost. Conventional lithography techniques such as electron beam lithography (EBL) for Si machining consists of multiple steps, and require fabrication of masks for resist development and nanofabrication. The fabrication of 3D and complex features with lithographic methods becomes especially challenging due to the design intricacy, with limitations on feature size and aspect ratio. Alternatively, the use of a Focused Ion Beam (FIB), inducing localized Gallium (Ga) implantation and Si amorphization can be employed for nanostructure fabrication via improving the etch selectivity of ion beam processed Si [1], [2].

Here, we have used selective implantation of Si by Ga-FIB. The implanted regions act as masks for subsequent anisotropic wet etching by potassium hydroxide (KOH). The etch-stop mechanism of Ga implanted Si has been investigated, with threshold ion dose determined between implanted and non-implanted Si. We have used single crystalline (100), p-doped Si, and etching experiments were carried out with 1.5mol/L KOH solution. Given the high resolution of FIB, we have successfully fabricated nanowires with a high aspect ratio (≈625) and diameter as small as 40nm. The nanowires are suspended over two parallel Si walls created via high dose implantation and subsequent KOH wet etching. We have further demonstrated the application of the proposed approach for fabrication of various suspended and 3D nanostructures such as nanomesh, pyramids etc. including freestanding Si nanostructures on pyramid array. The developed approach for fabrication of various suspended and 3D structures exhibit process capability and will be useful for fabrication of Si micro/nano-mechanical resonators, sensors and semiconductor devices. The fabricated nanowires will be demonstrated through high-resolution SEM/AFM imaging and geometric evolution of nanowires' cross-section with ion-beam parameters will be discussed.

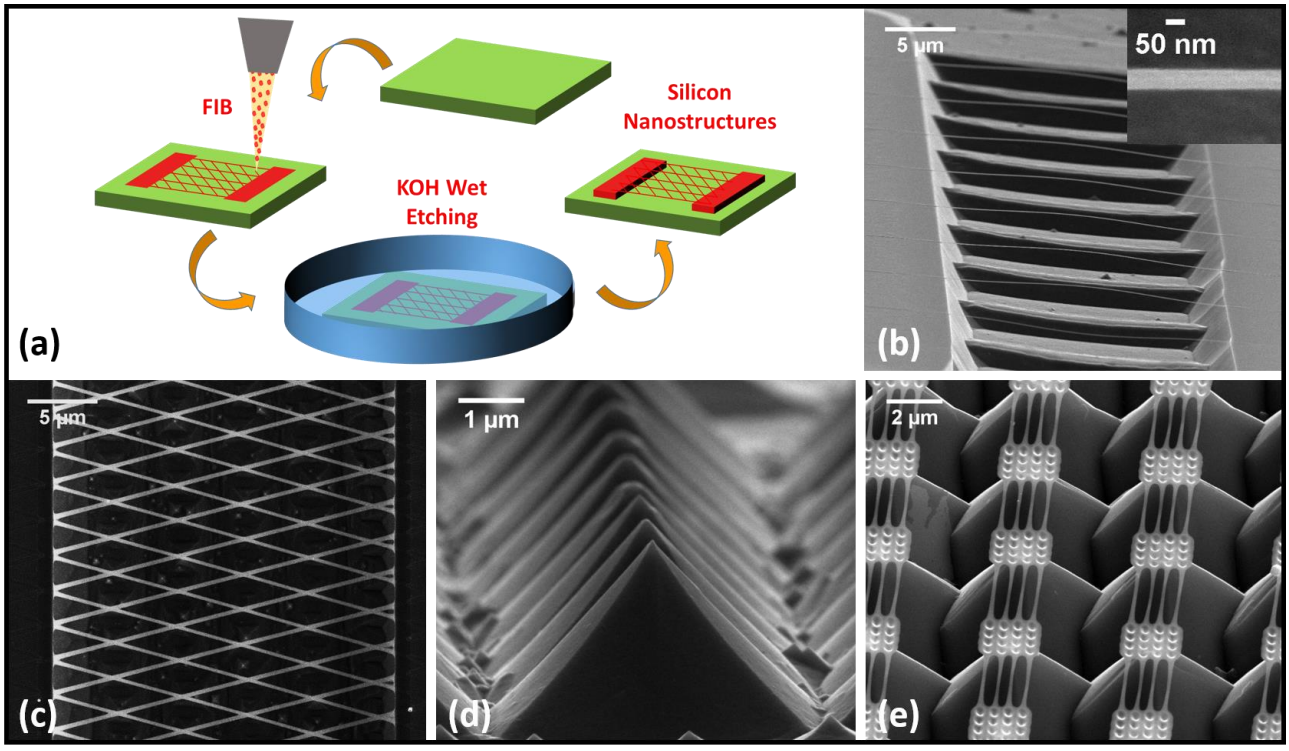

Figure: (a) Implantation in Si through a focused ion beam (FIB) of Gallium and masks writing with a nanometer resolution. Subsequent anisotropic wet etching in KOH solution and fabrication of Si nanostructures via selective removal of un-implanted region. SEM image of fabricated nanostructures: (b) High aspect ratio (≈625) suspended Si nanowires with length ≈25μm and diameter ≈40nm, with inset showing high resolution SEM image, (c) Suspended Si nanomesh, (d) Submicron 3D pyramid array, (e) suspended 3D Si nanostructures over pyramid array.

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