Microscale buried patterns in silicon using MeV ions

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For more than two decades, high energy focused ion beam (HEFIB) systems, primarily high energy proton microprobes, have been used for various microanalysis techniques of different materials, but more recently, these systems have been used for microscale modification of materials. However, although it is difficult to focus high energy (MeV) ion beams due to the relatively large mass, these ion beams tend to travel with negligible scattering through tens of microns into a substrate. This very useful physical characteristic allows these focused ion beams to be used for maskless patterning and fabrication of high aspect ratio microstructures in various resist and semiconductor materials such as Poly(methyl)methacrylate (PMMA), glycidyl-ether-bisphenol-A novolac (SU-8), and silicon.

It is well known that as high energy ions travel through a material they produce damage along the path which results in resistance to chemical wet etching. Therefore, a series of preliminary experiments have been performed at the Louisiana Accelerator Center (LAC) to examine the feasibility of implanting high energy (keV-MeV) ions such as protons, gold, and xenon through microscale masked structures on a Si substrate followed by KOH etch for attaining deep micromachining in Si. Some of the microscale structures were patterned by P-beam writing in resist coatings on the Si substrate at LAC, the patterns developed and the Si substrate subsequently implanted through the masks with 1.5 MeV Au^{+3} ions, while other test structures were produced using commercially available scanning electron microscope grids as masks. The effectiveness of KOH etching on the implanted structures via these two types of masks was recently reported in more detail, but two of the results are particularly relevant. Chemically cleaned and baked single crystal Si(100) (n-type) samples were spin coated with 40 μm thick SU-8 negative resist, and micropatterns were exposed using 3 MeV proton beams focused to dimensions less than 1 μm x 1 μm by the LAC HEFIB system. The P-beam patterned structures were developed and some of the developed samples on Si(100) were then implanted with 1.5 MeV Au^{+3} ions, using the etched microscale patterns in the SU-8 resist layers as masks.

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