Characterization of Helium-Ion Machined Fluidic Structures

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In previous work[1], we have demonstrated the ability to machine long, hollow cavities in a direct-write process using the focused helium ion beam. The non-negligible mass of the helium ion beam makes substrate nanomilling reliable in thin films;[2,3,4] however, varying results have been observed in bulk substrates where the irradiated region often distorts or swells rather than milling.[5] In the case of silicon, the sputter (removal) of atoms is surpassed by helium accumulation rates, thereby inducing dramatic swelling of the substrate surface at high doses ($\geq 10^{18}$ ions/cm^2).[6] When energetic helium ions irradiate silicon substrates at this high dose, small bubbles of helium coalesce to form large cavities, delaminating the surface layer.[7] Several researchers have noted helium implantation and bubble formation in various substrates, however, to our knowledge none have *utilized* the bubble coalescence and swelling phenomenon. With controlled dose patterning, we have produced larger and longer cavities directly forming pipe-like structures under the silicon surface. These pipe-like cavities have been sectioned via Ga^+ focused ion beam and imaged with SEM to characterize their fluidic capacity and function. Furthermore, the continuity of these cavities can be verified by pressure driven flow of fluorescent dye or via ionic current flow. In order to test the conductivity of the fluidic cavities a sealed fluidic device was fabricated. This process proved to be non-trivial since the surface of the chip had to be cleaned and activated in order to establish a stable bond between the silicon chip and a poly-dimethyl siloxane lid. This work may lead to the acceleration of lab-on-a-chip diagnostics, new application discovery, and rapid-prototyping design of fluidic devices to transport nanoliter volumes of fluids.

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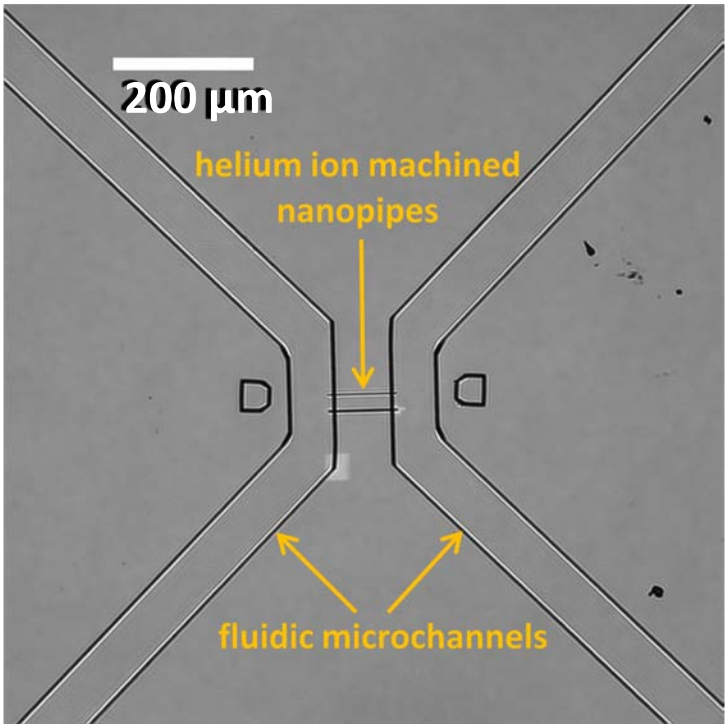

Optical image of a silicon chip showing the lithographically fabricated microchannels and connecting helium ion machined nanopipe for fluidic testing.