IN SITU FABRICATED MICROCHANNELS USING POROUS POLYMER AND XENON DIFLUORIDE ETCHANT

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Abstract

A novel microfluidic fabrication technique which allows in situ formed silicon microchannels and does not necessitate substrate bonding is presented. A gas-permeable polymer membrane acts as the top surface of the microchannel, allowing xenon difluoride (XeF_2) etchant to pass unobstructed to the silicon substrate. Exposed silicon areas on the wafer are then etched isotropically.

Keywords: Microchannels, Xenon Difluoride, Porous Polymer

1. Introduction

A microchannel is a fundamental component of most microfluidic systems, which is typically used for reactant delivery, biochemical reactions, particle separations as well as for heat exchanging. Application areas where microchannels have been used include miniaturized systems of electrophoresis, gas and liquid chromatography and chemical analysis systems [1]. Standard microchannel fabrication techniques are usually divided into two categories: 1) Discrete fabrication such as substrate bulk etching followed by various bonding techniques in silicon, glass and plastic, and 2) Integrated fabrication which involves using thin films to create structural layers of a microchannel; these techniques include substrate bulk etching with subsequent sealing by film deposition (such as LPCVD), as well as surface micromachined channels created by the removal of a sacrificial material.

A major limitation of most fabrication methods is the final sealing step, microchannels are usually open-roofed after being created. Substrate bonding usually requires surfaces to be relatively clean and flat in order to produce intimate contact between substrates. Other problems encountered are complication in packaging, process compatibility and fabrication techniques that can only provide a certain microchannel geometry, shape or arraying capability.

2. Fabrication

The fabrication process begins with a lithography step that defines the location where the microchannel will be created using XeF_2 (see Figure 1). Silicon dioxide is used as the masking material, defining the exposed silicon regions and protecting the areas that

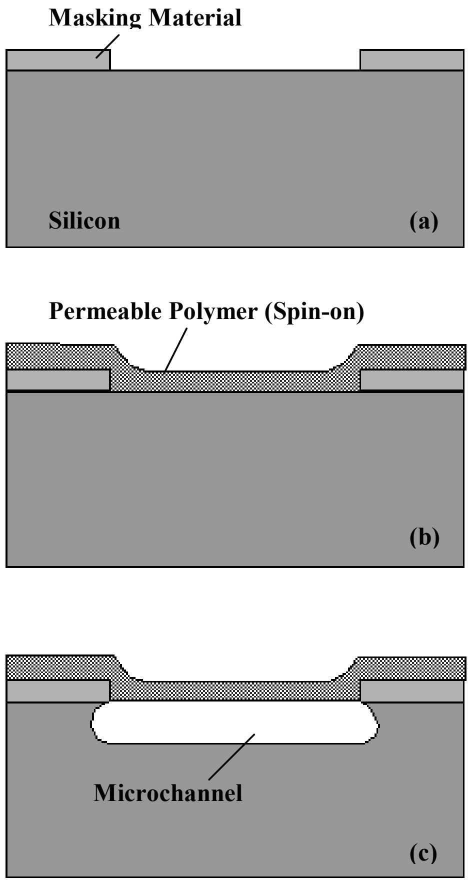


Figure 1. The fabrication process starts with (a) a patterned masking material, (b) deposition of a gas-permeable polymer over the substrate by spin-casting, (c) XeF_2 etch through the polymer to create microchannels.

will not be etched. Other masking materials, such as metal or photoresist, can be used instead of silicon dioxide. A gas-permeable polymer is then deposited over the entire substrate. This polymer can be deposited by various methods such as spin-casting, plasma-deposition or vapor-deposition. Spin-casting was used due to its simplicity, speed and cost. Finally, XeF_2, a small molecule that passes through the permeable polymer, is used to etch exposed silicon regions. Chemical species that are by-products of the XeF_2 and silicon reaction must be able to pass through the membrane as well. The major by-product during the etching process is silicon tetrafluoride.

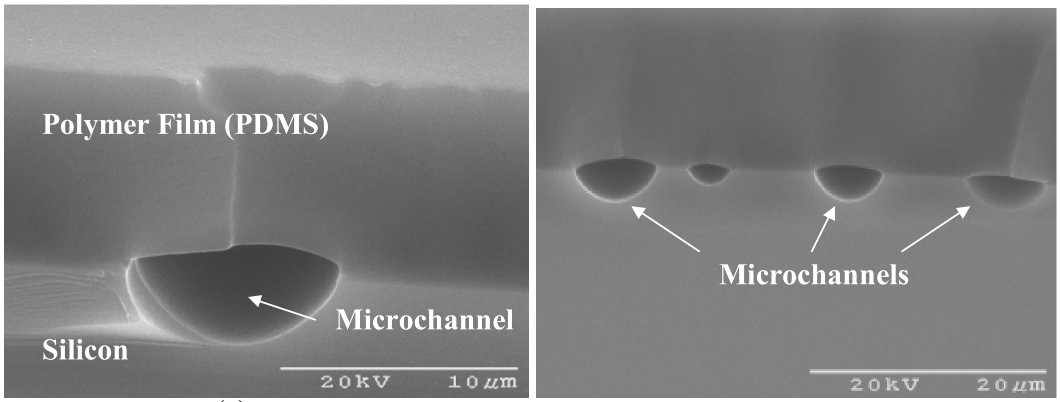
Xenon difluoride is a gas-phase, room-temperature, plasmaless, isoptropic silicon etchant that can be used for bulk or thin film etching [2]. Since XeF_2 does not require external energy or ion bombardment for silicon etching, it easily penetrates the polymer.

3. Experimental

Poly(dimethylsiloxane) (PDMS), a readily available polymer commonly used in microfluidic applications, was used during the experimentation process. Polysiloxanes have a much higher permeability to gases than most polymers, yet due to their hydrophobic nature, fluids are excluded. The PDMS prepolymer was spun at speeds up to 6000 RPM to create a 5-10 micron thick film. To create thinner films, the mixing of thinning agents can be used to lower the viscosity of the polymer. After curing the polymer film, the sample was then placed into a XeF_2 etching system where it was pulsed at 60 second intervals using 3 Torr of XeF_2 for a total of 30 minutes (see Figure 2).

4. Results and Discussion

At various locations across the sample, the PDMS demonstrated some neglible reaction to the XeF_2 etch. Since small concentrations of hydrofluoric acid are produced



(a) (b)

Figure 2. Micrographs showing: (a) cross-section of an 8 μm wide microchannel with a 10 μm PDMS film above, (b) cross-section with multiple microchannels.

in the etching chamber, due to the combination of fluorine radicals and moisture, this could explain the phenomena observed. Polymer permeability values for xenon difluoride are being researched to determine the optimal polymer. Polymers deposited on the silicon substrate must be sufficiently thin to allow easy transmembrane flux of reactants and products. This technology is particularly suited for developing separation membranes over microchannels. By depositing a liquid-permeable polymer over the substrate, it is possible to create suspended membranes that can be used for analyte concentration or isolation, such as with microdialysis applications.

5. Conclusion

A new microchannel fabrication technique is presented. The favorable integration of silicon's micromachining properties along with the flexibility of polymers, allows a monolithic microfluidic device.

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