MONOLITHIC FABRICATION OF NOVEL MICROFLUIDIC COMPONENTS WITH FIXED ASPECT RATIO ROUND MICROFLUIDIC CHANNELS USING NOVEL RAPID MOLDING

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ABSTRACT

In this work, a new method of fabricating microfluidic channels with fixed aspect ratio is described and characterized. This provides a unique way to attain a desired channel depth by simply altering channel width. This approach offers the ability to fabricate an infinite range of channel depths simultaneously in a single lithographic step and fabrication of channel geometries previously unachievable.

KEYWORDS: Rapid prototyping of microchannel, Round microfluidic channel, Fixed Aspect Ratio

INTRODUCTION

There has been a large demand for the development of microchannels with multiple depths on a single substrate. The ability to produce molds with multiple channel depths has been demonstrated by repeated exposures of thick photopolymer films to increasing doses of collimated UV radiation [1]. Rounded channel fabrication has also been achieved by exposing SU-8 films to diffuse UV light [2]. Here we demonstrate a new method for fabricating rounded channels with macroscopic down to microscopic depths in a single exposure step to create fluidic devices in almost any polymer material. This rapid fabrication scheme enables complete device fabrication in around one day, with reduced labor and increased reliability over molds requiring thin-film resist and injection processing. The fabrication of conventional structures and devices and a novel 3D tapered channel has been achieved using the rapid prototype molding technique developed in this work.

FABRICATION

For the characterization of the channel fixed aspect ratio (width to length) relationship, channels with varying widths are defined by a transparency mask. Fabrication by this method (Figure 1) involves diffuse UV light masked exposure of thick film (1mm) stamp photopolymers (Nyloprint, BASF) using a transparency mask and subsequent development to produce a mold containing trenches (mold 1) (E.C. Shaw Company). Mold 1 is then used to produce a high-T_g thermopolymer mold by injection molding or hot embossing (mold 2). This high-T_g thermopolymer mold is finally used to produce rigid microfluidic devices in low-T_g polymer materials by hot embossing or injection molding, or flexible microfluidic devices by elastomer casting.

Twelfth International Conference on Miniaturized Systems for Chemistry and Life Sciences
October 12 - 16, 2008, San Diego, California, USA

978-0-9798064-1-4/µTAS2008/$20©2008CBMS

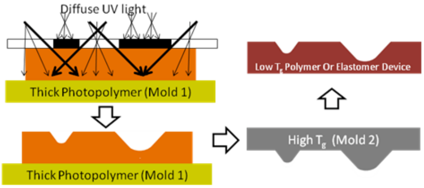

Figure 1. Scheme for rapidly prototyping fixed aspect ratio rounded chanels.

CHARACTERIZATION

Characterization of mold 1 by confocal microscopy demonstrates rounded channels (Figure 2(a)) and multiple channel depths fabricated in a single photolithography step and described by a linear relationship (Figure 2(b)). As expected, the 3-Dimensional channel structure is transferred to the final embossed cyclic olefin copolymer (COC), as shown in Figure 2(c).

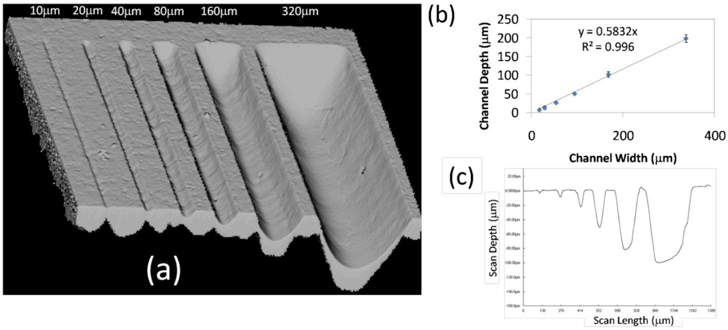

Figure 2. Mold Characterization: (a) Confocal microscopy image of mold 1 demonstrating multiple channels with depths that increase with channel width; b) Plot of channel depth versus width; and c) Profilometry scan of final embossed COC device.

Sealed microfluidic channels in rigid and flexibile polymers fabricated with this method (Figure 3(a), (b)), indicating its suitability for typical microTAS applications.

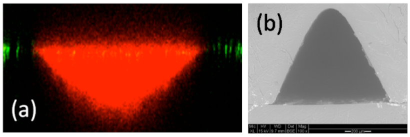

Figure 3. Sealed Channels: a) Cross-section of thermally bonded COC channel (280 µm width) with Nile Blue dye filling the channel (confocal microscopy); and b) ESEM image of plasma bonded polydimethylsiloxane (PDMS) channel (1 mm width).

RESULTS AND DISCUSSION

Microfluidic components requiring abrupt changes in channel dimensions can be easily fabricated by this monolithic scheme. For example, passive valves (Fig4A) and slurry micro-bead packing (Figure 4(b),(c)).

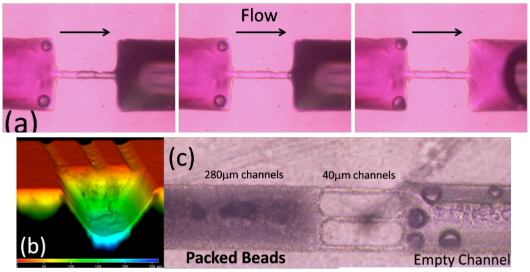

Figure 4. Fabrcated microfluidic components: (a) Passive valve; (b) 3D reconstruction of bead packing channel; and(c) Sealed channels with 10 µm beads limited by 40 µm wide channels causing bead packing.

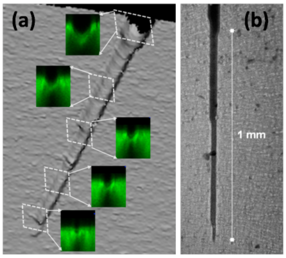

Figure 5. 3D Tapered Channel: (a) 3D reconstruction of tapered channel with insets showing increasing cross-sectional area as the channel widens; (b) Top view of tapered channel.

Finally, a microfluidic channel with true 3D tapered shape is demonstrated for the first time where cross sections of the tapered channel show the change in cross sectional area as the channel moves from its widest point to its narrowest point (Figure 5).

CONCLUSIONS

These results demonstrate for the first time monolithic fabrication of rounded microfluidic channels with constant aspect ratio profiles. Furthermore, 3-dimensional variation of the channels can be easily achieved using just 2-dimensional variation of the channel width on the same substrate in a very rapid single lithographic step. Finally, this fabrication scheme can be applied to devices in thermopolymers by hot embossing and injection molding as well as elastomer curing methods.

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