A THREE-DIMENSIONAL MICROFLUIDIC NETWORK FOR CELLULAR PERFUSION

Yoonsu Choi, Richard Powers, Yong-Kyu Yoon, and Mark G. Allen
School of Electrical and Computer Engineering
Georgia Institute of Technology
791 Atlantic Dr. Atlanta, GA 30332-0250 gte810q@mail.gatech.edu

ABSTRACT
This paper presents a simplified fabrication technique for a multi-layer microfluidic dispensing system for culturing three-dimensional networks of cells utilizing the photosensitive epoxy SU-8. An unusual double exposure technique was utilized to fabricate the dispensing system. This double exposure technique allowed tower structures and an integral SU-8 substrate to be formed from the same epoxy deposition. Then, precisely controlled laser machining was used to make side holes on the hollow towers.

Keywords: Microfluidic system, SU-8, Inclined hollow tower, Excimer Laser

1. INTRODUCTION

Two-dimensional cell culturing has become routine for basic science studies ranging from toxicity to cell attachment and growth. However, it is critical to develop cellular systems for in vitro measurement that mimic the three-dimensional in vivo environment as closely as possible. This is necessary for enhanced cellular survival as well as functionality in networks more representative of tissue-engineered structures and systems[1][2]. Fine control of the cellular microenvironment by means of diffusive and convective fluidic processes enables the high-resolution spatial and temporal manipulation of critical cell functions. The photosensitive epoxy SU-8 is an attractive candidate for these microfluidic systems because of its mechanical stability, biocompatibility, and high aspect ratio fabrication potential. Fabrication is effectively simplified by an unusual double exposure technique with an inclined direction, allowing tower structures and an integral SU-8 substrate to be formed from the same epoxy deposition[3]. Then precisely controllable laser machining are used to make side holes on the hollow towers. Due to the inclination of the towers, a normal-incidence laser produces vertically-staggered holes along the sidewalls of the towers, achieving three-dimensional perfusion capability. Fig. 1 shows a perspective view of the inclined hollow tower array.

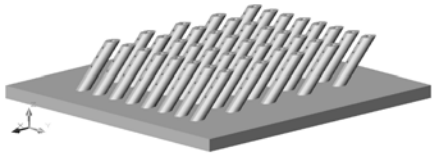

Fig. 1. Perspective view of the inclined structure

2. FABRICATION

The fabrication sequence is summarized in Fig. 2. A one-millimeter-thick layer of SU-8 was spun on a glass substrate. After soft baking, the sample was exposed at an incline to a large exposure dose to cross-link 700μm tall SU-8 hollow towers. Post-baking-induced shrinkage of the cross-linked SU8 hollow towers facilitated the visual alignment of the second mask to make an SU8 hollow tower substrate. Fig. 3 illustrates the difference between cross-linked and uncross-linked sections of the SU-8 surface aligned to the second mask patterns. With the second mask, which covered the center holes, the sample was exposed to a relatively low UV radiation dose in the same inclined direction to cross-link a 300μm thick SU-8 plateau (still embedded in the unexposed SU-8 film). Only a 300 μm depth of SU-8 was cross-linked due to the low exposure dose utilized. This mask also contained a checkerboard pattern to facilitate separation of individual arrays from each other as well as from the glass substrate. The sample was then developed, removing the un-crosslinked regions and resulting in individualized tower arrays on polymeric substrates, with fluidic communication between the backside of the substrate and each fluidic port. Finally, side holes were created by ablation with an excimer laser (193nm) utilizing a shadow mask aligned to the tower formations.

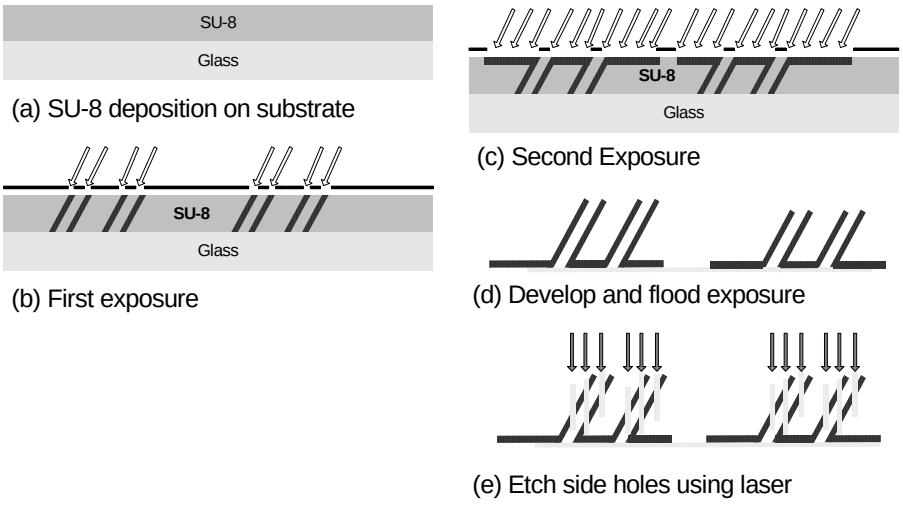

Fig. 2: Process Steps

3. RESULTS

Structures over 700 μm tall with three side holes have been fabricated with good repeatability. Arrays of 8x8 and 8x4 towers with tower diameters ranging from 150 μm to 300 μm, center-hole diameters ranging from 30 μm to 100 μm and laser hole diameters ranging 20 μm to 80 μm were fabricated using the technique outlined above. Fig.4 and Fig5. show the completed SU-8 towers before addition of the side holes. Fig. 6 shows the subsequent laser created side holes.

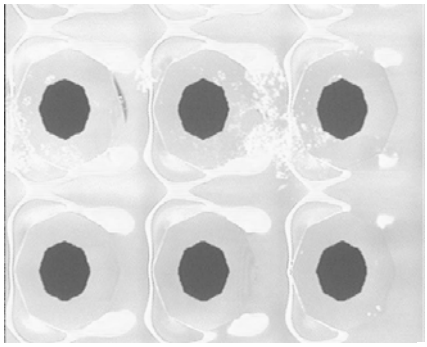

Fig. 3. Cross-linked SU-8 and mask patterns

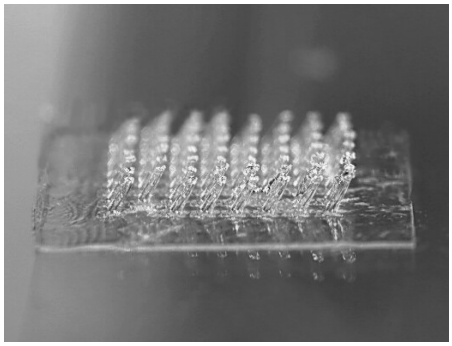

Fig. 4. Side view of the completed towers

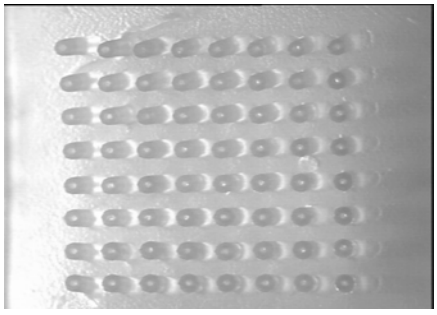

Fig. 5. Top view of the completed towers

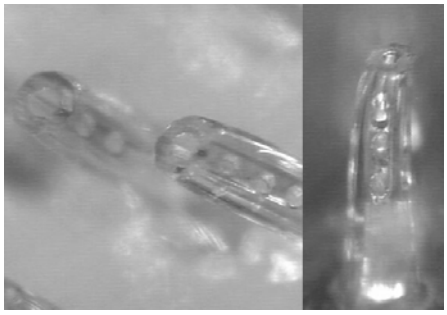

Fig. 6: Towers with laser created side holes

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