A HIGHLY EFFICIENT 3D MICROMIXER FABRICATED BY STANDARD SOFT-LITHOGRAPHY EQUIPMENT

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ABSTRACT

This paper reports a stereolithography-like 3D fabrication method based on soft-lithography techniques. It only requires standard equipment for photolithography, but it makes true 3D structures fabrication possible. We developed a rotating partition by this method in a microfluidic channel, which cannot be achieved by conventional soft-lithography, and demonstrated a prototyping three-dimensional flow mixer.

KEYWORDS

3D fabrication, microfouidics, micromixer.

INTRODUCTION

3D microfabrication techniques are one of the most important things for furthering the progress of microfluidics research. Although a lot of reports for microfluidics have been published so far, most of them use research with two dimensional or sub-3D structured microfluidic devices due to limitations of a conventional photolithography and an injection molding. True 3D structures can be fabricated using laminated object manufacturing such as micrstereolithography and multilayer devices. [1] Micerostereolithography can achieve complex 3D structures, but it needs a special instrument. These techniques also limit throughput of large-area lithography due to using a scan method. As for multilayer devices, we have to use a messy process to bond layers chemically.

To overcome these problems, we suggest laminated object manufacturing based on a soft-lithography with a UV-curable polymer for high throughput fabrication. It does not need without a special instrument and troublesome chemical bonding.

EXPERIMENT

Figure 1 shows a schematic diagram of a fabrication method based microfluidic device fabrication. A UV-curable polymer (NOA 81) was used as a material to fabricate microfluidic device. [2] In this fabrication method, devices were fabricated using a combination of UV-exposure and casting technique against a Polydimethylsiloxane (PDMS) mold. A standard soft-lithography was used to fabricate SU-8 based masters on silion substrate to produce PDMS mold. Subsequently the PDMS replicas were used as molds for making NOA 81 sheets to retain a sticky thin layer since the NOA curing is inhibited by oxygen. NOA 81 was poured into interspaces between PDMS molds, and it was cured by UV irradiation. Then all NOA 81 layers were laminated and bonded by UV irradiation in a regular order with help from sticky thin layers after the NOA 81 replicas were peeled off from PDMS molds.

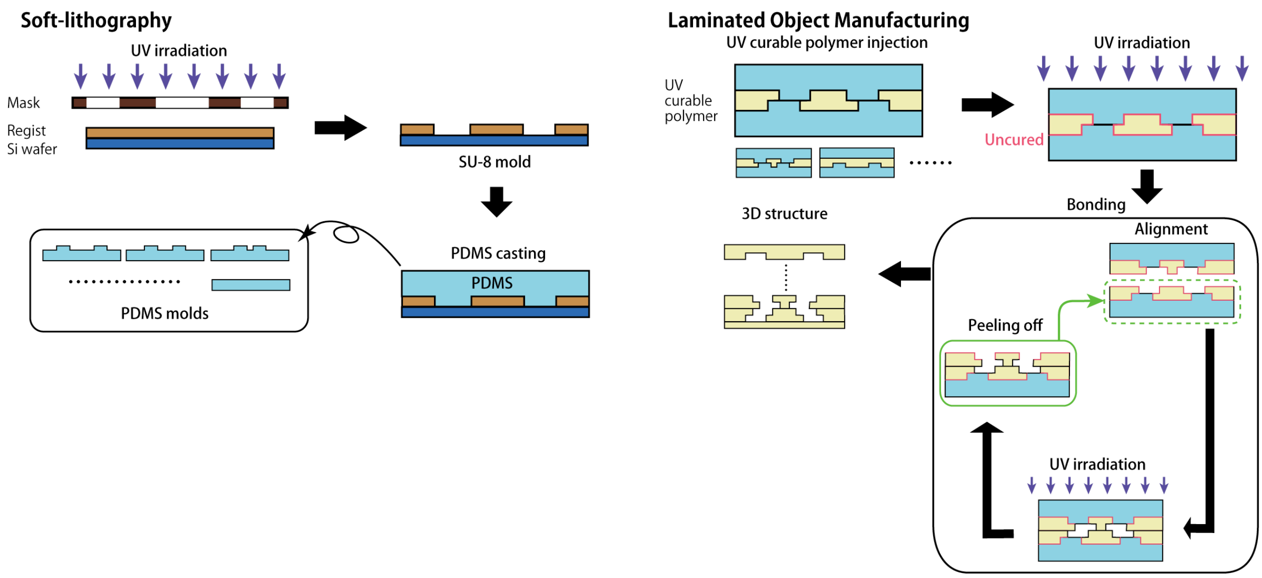

Figure 1. A schematic diagram of UV-curable polymer based miscrofluidic device fabrication

To visualize 3D structures, it was observed from vertical cross-section with confocal microscope after injecting fluorescein into the channel.

RESULTS AND DISCUSSION

We fabricated a rotating pertition embedded in a microfluidic channel. The microfluidic channel was Y-junction and the structure was shaped that a horizontal separator rotated 180º round on center of an axel. One cycle of the structure was 2 mm in length and 5 cycles were in a channel. Figure 2 was cross sectional images taken with a confocal microscope at 0, 200, 600, 1000, 1400 and 1800 µm in a flow direction. We also achieved to fabricate a microfluidic channel with two rotating partitions. The horizontal separators that cannot be fabricated by a conventional soft-lithography were achieved by the fabrication method with UV-curable polymer.

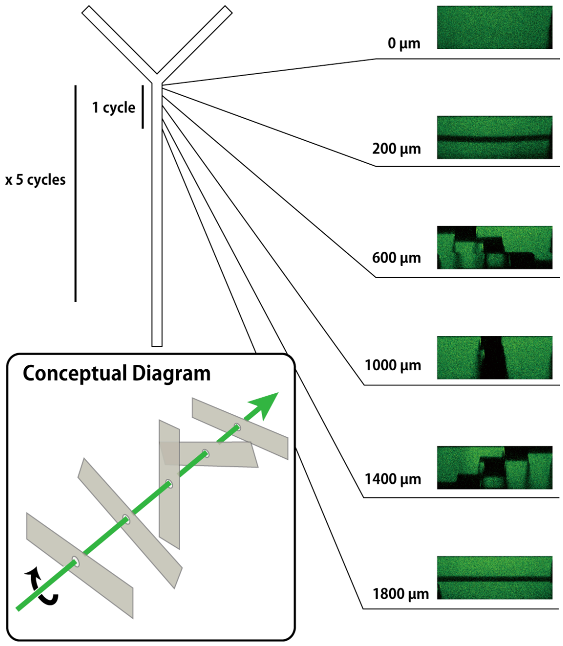

Figure 2. A structure of a mixer with a rotating partition.

Fluorescent reagent was introduced into the channel from right side of the Y-junction, and water was introduced into from another side to observe flow in the channel. Two kinds of liquids were rotated with a change in cross section structure and they were mixed roughly after 5 cycles. We confirmed that 3D fabrication was achieved by our method and the structure worked as a mixer. Although mixing efficiency was worse than the simulation prediction, flow dynamics coincided with the simulation results. We consider that bubbles and low alignment accuracy caused a decrease in mixing efficiency. (Figure 3)

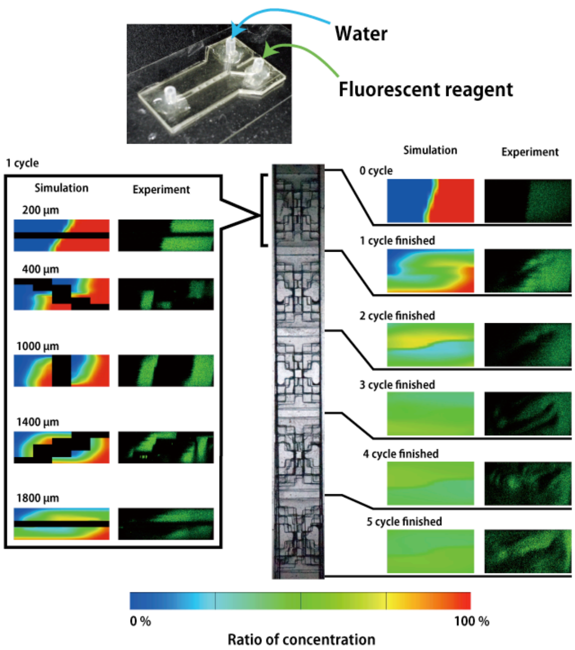

Figure 3. Fluorescent confocal micrographs of vertical cross-sections of the channel and simulation prediction while mixing. Mixing dynamics was almost coincided with simulation prediction.

The rotating partition has an application for the mixer to prevent sedimentation of particles in microfluidic channels. While there is almost no flow upward in a chaotic mixer [3], the rotating partition has upward flow in the channel. It will work like a concrete mixer and lift particles to a channel ceiling. (Figure 4)

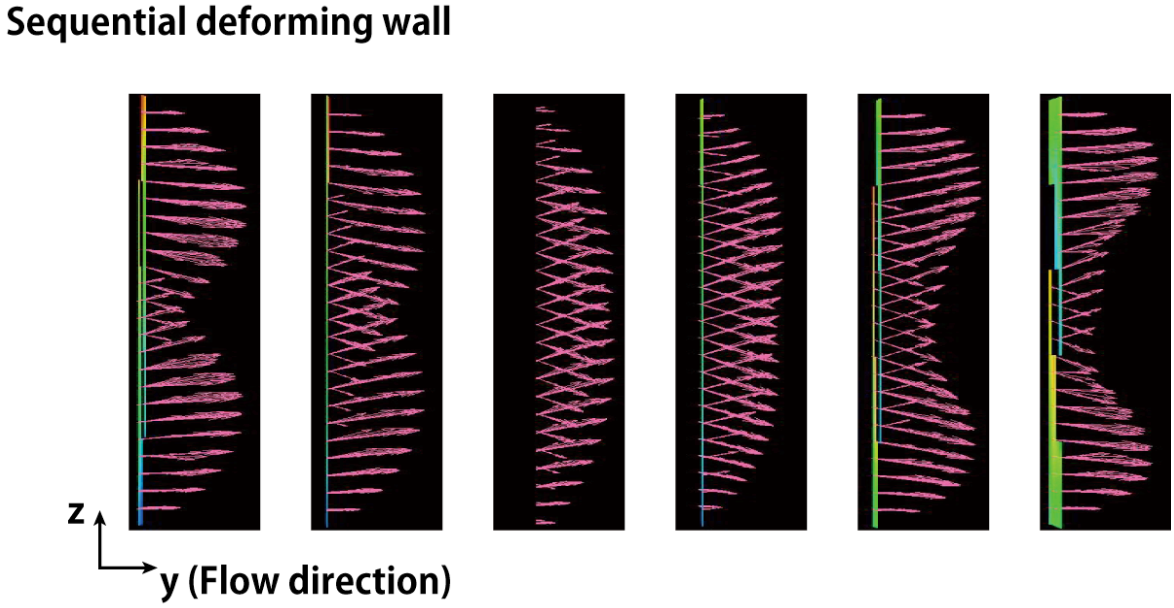

Figure 4. Flow direction allows on y-z plane in microluidic channels with a deforming wall mixer

CONCLUSIONS

We reported here the 3D microfabrication method without any special instruments, which has the possibility of high volume production in principle. We also demonstrated the production of the rotating partition fabricated with the standard soft-lithography equipment. This fabrication method makes it possible to design various microfluidic devices with 3D structures and control flow three dimensionally.

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REFERENCES

[1] K. Ikuta, K. Hirowatari, "Real three dimensional micro fabrication using stereo lithography and metal molding," *Proc. of International Workshop on Micro Electromechanical Systems (MEMS'93),* pp. 42-47 (1993)
[2] D. Bartolo, G. Degré, P. Nghe, V. Studer, "Microfluidic stickers," *Lab Chip*, **8**, pp. 274-279 (2008)
[3] A. D. Strook, S. K. W. Dertinger, A. Ajdari, I. Mezic, H. A. Stone, G. M. Whitesides, "Chaotic mixer for microchannels," *Science* **295**, pp. 647-651 (2002)

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