A MICROFABRICATION-FREE PROCEDURE TO FABRICATE 3-DIMENSIONAL MICROFLUIDIC DEVICES USING HYDROGEL MOLDS

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ABSTRACT

We present an original microfabrication-free procedure to flexibly design and fabricate 3-dimensional microchannels in polydimethylsiloxane (PDMS) elastomer with a single-step process using hydrogel molds. In this process, arranged small wires of agarose-gel serve as a mold for a microchannel formed within a piece of PDMS. The advantages of the method are that 3-dimensional microchannels can be flexibly designed and fabricated by a simple procedure without using any specialized equipment or processes. This method would make microfluidic processes more accessible for laboratories of a variety of fields, and would also provide an attractive educational material for students.

KEYWORDS: Hydrogel, Agarosegel, Mold, Microfabrication-Free

INTRODUCTION

Microfabrication-free techniques or rapid-prototyping methods of microfluidic devices fabrication are now becoming an active area of research [1-3]. Especially, recent studies on “water molds” provided a novel concept on the microfabrication of PDMS-based devices; forming smooth, streamline-shaped structures with simple procedures [4-6]. However, the flexibility of fabrication has been rather restricted because of the fluidity of the molds.

THEORY

To form 3-dimensional microstructures, we utilized hydrogel mold as “shape-controlled” water. Wires of agarosegel are embedded in PDMS composite and serve as mold for microchannels due to the immiscibility of hydrogel and PDMS composite.

EXPERIMENTAL

The fabrication process is described in Figure 1. Briefly, small wires of agarose-gel (2% (w/v) Agarose L, Wako: diameter: > 250 μm, length: > 2 mm, supplemented with 16 % (v/v) glycerol in order to make its specific weight larger than uncured PDMS) were embedded in uncured PDMS (Silpot184, Dow Corning) and manually arranged in the pattern of desired microchannel design. After curing PDMS, gel wires were thermally melted and pneumatically washed out. In the successive process, arranged gel wires serve as a mold for a microchannel formed within a piece of PDMS.

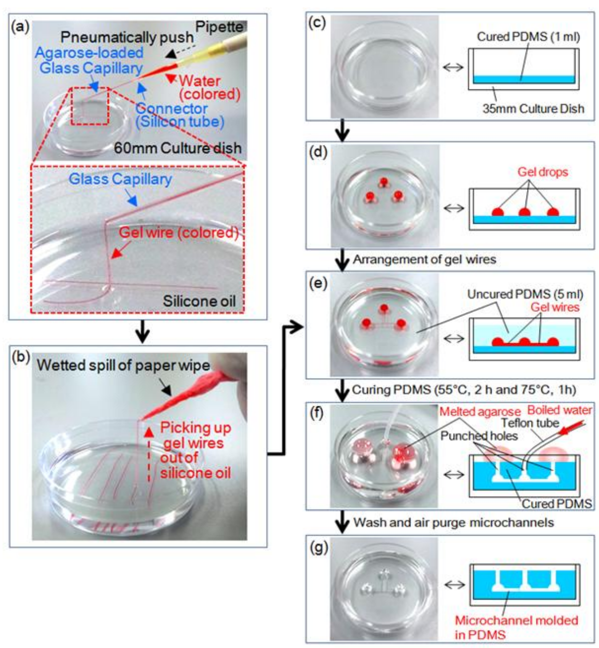

Figure 1. Fabrication process of a microchannel device “in dish” by using agarose-gel wires and PDMS. Gel wires were formed by casting them in glass capillaries, handled by simply touching their tips with a spill of wet paper wipe, embedded and arranged in uncured PDMS and serve as a disposable mold for a microchannel.

RESULTS AND DISCUSSION

The most important point of this process is that "junctions" of microchannels can be formed simply by grafting pieces of gel wires with each other without any adhesive agents or treatment (just bringing them in touch with each other) in uncured PDMS. This phenomenon effectively expands the freedom degree of designable microchannel topology. In this study, "T-junctions" or "cross-junctions" were adopted as the design of microchannels in order to simply perform the total process of "fabrication and application (droplet generation)" of a microfluidic device. Magnified views of a fabrication process of a T-shaped microchannel and its microscopic structures are shown in Figure 2. As shown in the micrographs, microchannels with circular cross-sections, smooth inner walls and junction structures were successfully fabricated by a single-step process.

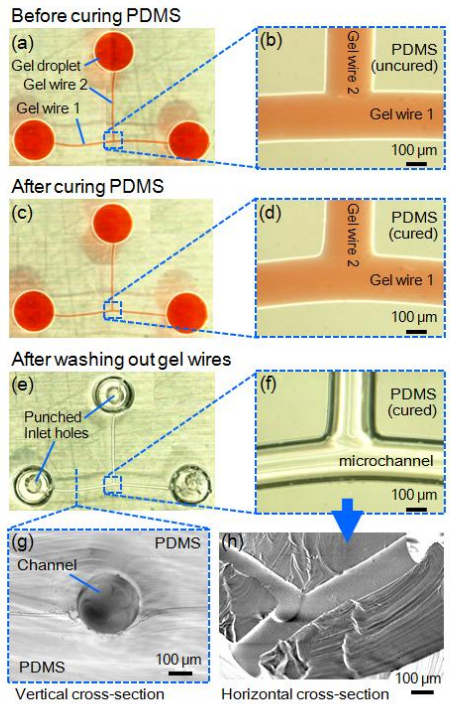

Figure 2. Magnified views of a fabrication process and structures of a microchannel. Note that two pieces of gel wires attached with each other in uncured PDMS (b), and smooth structures were formed in PDMS (g, h). These phenomena could be explained by immiscibility of water and PDMS and lager surface tension of water in comparison with PDMS.

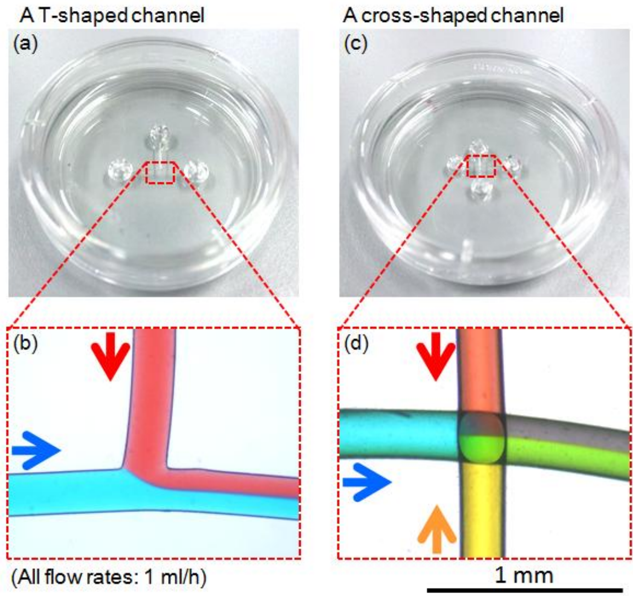

Figure 3. Laminar flows formed at a T-junction (a, b) and a cross-junction (c, d); each structures formed by simply bringing two pieces of gel wires in touch horizontally (T-junction) or vertically (cross-junction) in uncured PDMS and removing gel-wires after curing PDMS.

Flows in these microchannels were shown in Figure 3 and 4. Laminar flows were formed in the microchannels (all fluids were water colored with food dye, except the sideway flow in Figure 4). Among them, Figure 3 (d) shows an characteristic pattern of 3-dimensionally overlapping laminar flows formed at a cross-junction. Droplet generation at cross-junctions resulted in formation of two-colored microdroplets (Figure 4).

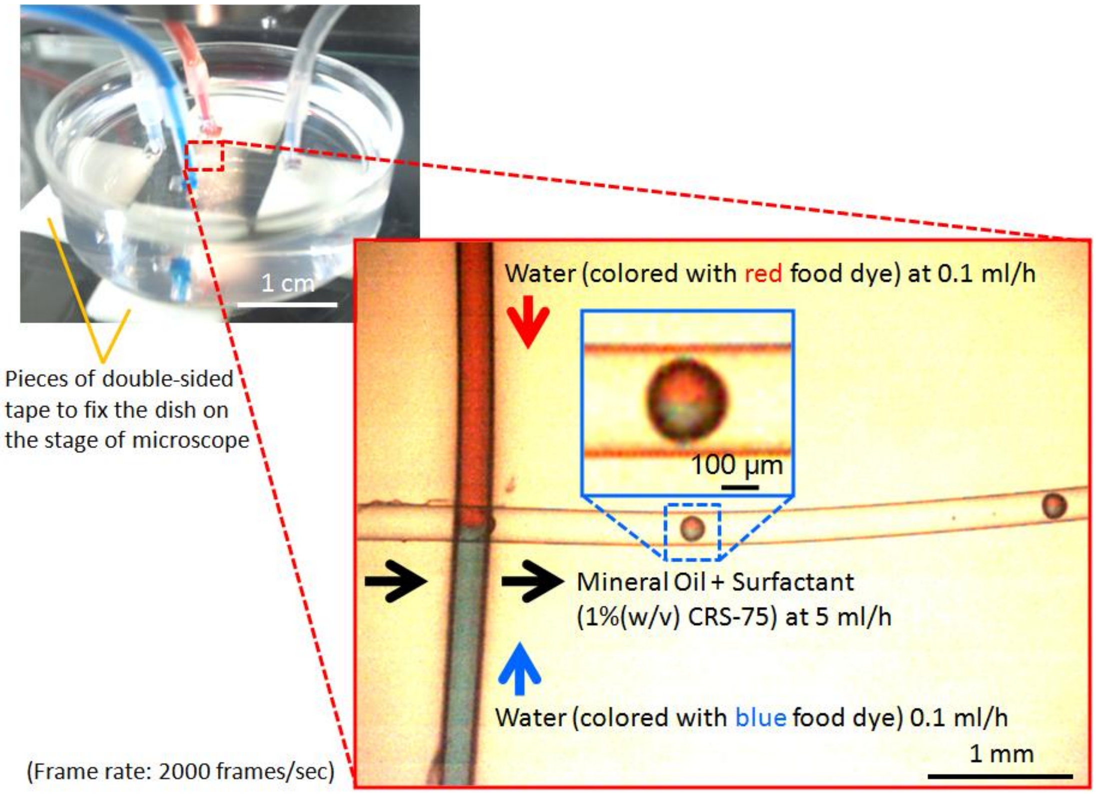

Figure 4. Two-colored droplet formation at a cross-junction.

CONCLUSION

The advantages of this method are that microchannels with 3-dimensional shapes and configurations (e.g. microchannels with circular cross sections or "interchange" of microchannels) can be flexibly designed and fabricated by a simple procedure without using any specialized equipment or processes. This method could be an accessible procedure for the application of microfluidic processes in laboratories of a variety of fields, such as fundamental biology, biomedical engineering, material sciences or mechanics, and would also provide an accessible educational tool for students.

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