FABRICATION OF PDMS MEMBRANES WITH AQUEOUS MOLDS FOR MICROFLUIDIC SYSTEMS

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ABSTRACT

We report a fast method to fabricate freely suspended polydimethylsiloxane (PDMS) membranes in situ; the technique is based on the amphiphilic properties of PDMS precursors which spreads on the water/air and water/SU-8 interfaces to form membranes surrounding an aqueous drop. Membranes are manufactured simultaneously with channels patterned on SU8 mold with use of aqueous casts (drops of water or glycerol solution). To test applicability of the method for powerless pumping through microfluidic circuits, we fabricated 200 uL micropipette and droplets generation chip.

KEYWORDS: Polydimethylsiloxane Membrane, Water Molding, Pumping, Microfluidics, Fabrication, Surface Active

INTRODUCTION

We report a fast method to fabricate freely suspended PDMS membranes in situ. Our method is based on the amphiphilic properties of PDMS precursors which spreads on the water/air and water/SU-8 interfaces to form membranes surrounding an aqueous drop.

Previously PDMS membrane fabrication was reported by spin coating, a "Bond-Detach Lithography technique" and application of anti-adhesive layers in order to peel off PDMS membranes from a mold [1]. Unlike previously reported techniques [2,3], our method of manufacturing membranes and pumps incorporated into microfluidic circuits is fast and does not require any special equipment. It can be used for fast membrane fabrication for biological assays (cells aeration, toxicology, sensors) and for local PDMS thickness reduction to improve pneumatic and screwed valves. Spherical voids working as micropipettes could be used for manual pumping on-field in microfluidics.

EXPERIMENTAL

To form membranes and spherical voids with PDMS, samples of water or 5% water glycerol solution (100, 200, 300, and 400 uL) were loaded into uncured polydimethylsiloxane (PDMS, Sylgard 184, Dow Corning; mixing ratio 1:10) poured on patterned silicone wafers or clean polystyrene surfaces (Petri plates). PDMS loads with water were left in an 80 °C oven for 2-48 h after which PDMS slabs were peeled from patterned and plain surfaces according to standard procedures. If needed, excess water was removed with pipette (for this one of two membranes was punctured) and left in 80 °C oven to dry out for about 20 min.

Applicability of voids as micropumps for powerless liquid transportation in microfluidic circuits was tested with hybrid chip, fabricated on the chip master simultaneously with micropump casting (200 uL of water was loaded on the spot designated for outlet).

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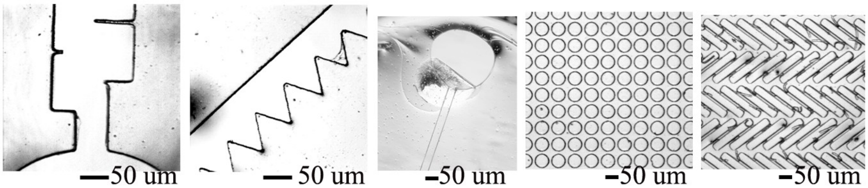
RESULTS AND DISCUSSION

PDMS cured with embedded water drop (or drop of 5% glycerol solution) resulted in complete or partly (in case of glycerol solution) liquid evaporation and formation of two PDMS membranes on the top and bottom of PDMS slabs. In case PDMS was cured on the patterned surface, fabricated membranes were also patterned. When PDMS was allowed to cure for prolonged time (24 h and more), membranes while peeled could lose patterned regions and in this way became perforated (Fig. 1. a, b). More often this phenomenon could be observed in the middle of the membrane. This fact can be explained by the fact that thickness of



(a) *(b)* *(c)* *(d)* *(e)*

Figure 1. Images of Membranes

fabricated membranes is not equal along their diameters, since liquid drop does not stick to the mold, but only touches it at the bottom, in particular in the middle of membrane. Moreover, on raised patterns PDMS membrane is thinner than on the regions close to plain mold surfaces. Hence, PDMS film is easily broken on those raised edges and then continues detaching on further edges as well (Fig. 1.c.). However, this problem may be overcome if PDMS is allowed to cure for short time in the oven or about 2 h at room temperature before aqueous cast is loaded. After precuring, PDMS becomes more viscous and water casts (having close density to liquid PDMS) consequently can not sink as deep as at the beginning of PDMS curing. For example, in our work we noticed thicker PDMS films fabricated with precured PDMS than with fresh mixed PDMS.

The reverse phenomenon takes place on the top membrane. In particular, membranes are easily formed with fresh PDMS mixtures, but can have holes if formed with precured PDMS. We can explain this by mobility of PDMS chains in recently mixed PDMS. After partial curing, fewer PDMS chains are available to form layers on the water/air interface.

We discovered that to use voids fabricated in PDMS as powerless pumps for microfluidics, membranes have to be enforced with additional slabs of PDMS (or other elastic materials) so one can safely press on them. Additionally, if all inlets are sealed (e.g., with tape), and voids covered with PDMS slabs are isolated with uncured PDMS; air in the chip placed in the oven expands while liquid PDMS cures. As a result, a dome-like layer will form on the slab. This last layer of PDMS adds resilience to the pump.

Testing of micropumps with water confirmed that generated flows are not consistent, but could be stabilized (and operation time increased) with higher channel resistance or application of viscous liquids. For example, experiments with hybrid chip (droplet generation and embedded pump, Fig. 2. a.) confirmed our previous observations. Specifically, loaded with oleic acid and 1.5% alginate solution, the chip operated for over an hour (Fig. 2.b.); operating time with water was less than one minute. Even though droplets generation efficiency decreased along with falling flow rate; droplets generation could be sustained during all operation time.

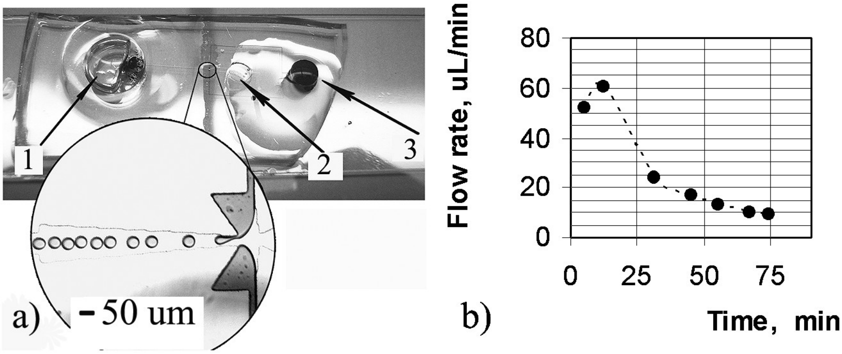


Figure 2. a) Hybrid chip. 1 – pump; 2 – oleic acid; 3- alginate solution. Insert showing a frame from droplet generation video. b) – Flow rate over time.

CONCLUSIONS

We proposed a method of manufacturing membranes and powerless pumps for microfluidic circuits with aqueous casts, which does not require any special equipment. Membranes fabricated with our method can be used for biological assays and local PDMS thickness reduction. Spherical voids working as micropipettes could be used for manual pumping on-field in microfluidics.

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