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Effects of liquid viscosity, surface wettability and channel geometry on capillary flow in SU8 based microfluidic devices

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ABSTRACT

The capillary flow in SU8 based microfluidic devices fabricated in SF-100 by lithographic technique has been recorded and analysed in this report. Leakage free microfluidic flow is achieved by indirect bonding between polymethyl methacrylate (PMMA) coated glass lid surface and SU8 channel substrate during hard baking. The working liquids are dyed ethylene glycol, dyed ethanol, dyed isopropyl alcohol (IPA) and dyed liquid mixture (water and IPA). The capillary flow of dyed ethylene glycol is found to be slower in each device due to higher viscosity and lower surface wettability as compared to other working liquids. Square SU8 micropillar arrays (80 μm and 120 μm of side lengths) are fabricated on the glass bottom wall surface of SU8 based microchannel. The capillary flow of any particular working liquid is observed to be faster through the square micropillars of smaller side length due to their lower surface area to volume ratio in the device. Also, the capillary flow of polar liquids is found to be faster on the microchannel surface of higher polar component of surface free energy. The above results are highly significant to control the speed of capillary flow in lab-on-a-chip systems.

1. Introduction

Microstructures are useful in lab-on-a-chip systems for different microfluidic applications [1–4]. Microfluidics plays a major role in lab-on-a-chip systems [5]. Polymers are very suitable material for the fabrication of microfluidic lab-on-a-chip systems [6,7]. SU8 is a useful epoxy-based negative photoresist for the fabrication of microstructures. Maskless lithography is a useful technique to fabricate SU8 based microfluidic devices [8]. Also, proper sealing between the microchannel substrate and lid is a primary requirement for leakage free microfluidic flow [9].

Passive capillary flow has many advantages in microfluidic devices over active flow considering the factors of fabrication, cost and control [10]. There is a continuous demand to identify major factors which can control the speed of microfluidic flow in lab-on-a-chip systems [5]. Viscosity of working liquid has significant effect on the speed of microfluidic flow [11]. Surface wettability is also very important to control the capillary flow [12]. On the other hand, the fabrication of micropillars in microfluidic devices is found to be very successful for various applications [11]. In general, the microfluidic flow depends on the pillar side length, pillar height and pitch [13]. Specifically, micropillars can be applied for microparticles filtration in lab-on-a-chip systems [10]. Many authors reported several methods to fabricate micropillars arrays of different shapes and aspect ratios [1,2].

The authors in this paper report the fabrication of leakage free SU8 based microfluidic devices and observe the capillary flow of four working liquids through microchannels. Finally, the effects of polar component and dispersive component of solid surface free energy on the capillary flow phenomena are investigated.

2. Experiment

The schematic diagram of the microfluidic channel is shown in Fig. 1 [8]. The dimensions of different parts of the channel are also indicated in Fig. 1. Microfluidic devices of the following categories are fabricated: (i) device with flat inner walls (Fig. 2), and (ii) with square micropillars on the bottom wall of the devices (Fig. 3). In the devices of category (ii), the micropillars are fabricated on the bottom wall throughout the region 3 (neck), region 4 (chamber) and region 5 (neck). The effect of square micropillars on capillary flow has been studied in the devices of category (ii). A particular microfluidic device of category (ii) contained square micropillars of any particular side length. Square micropillars of either 80 μm or 120 μm side length have been used on the bottom wall of

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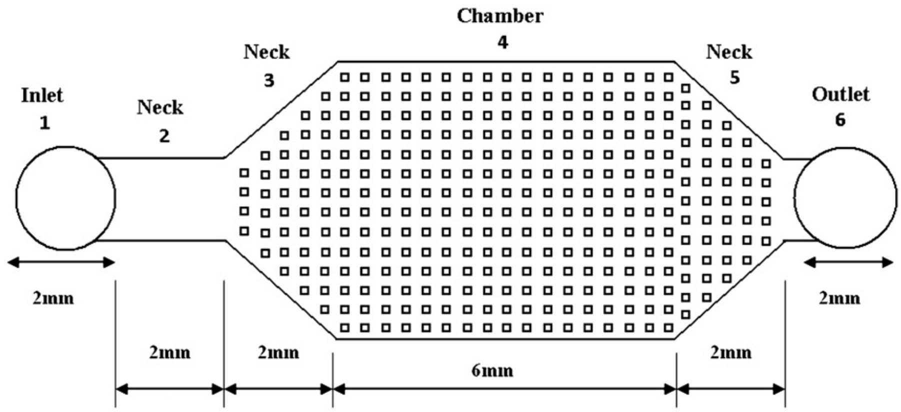

Fig. 1. Schematic diagram (top view) of the microchannel with proper dimensions.

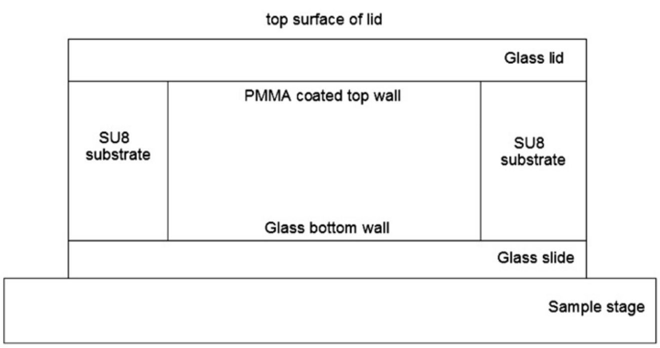

Fig. 2. Schematic diagram (cross-sectional view) of SU8 based microfluidic device of flat inner walls.

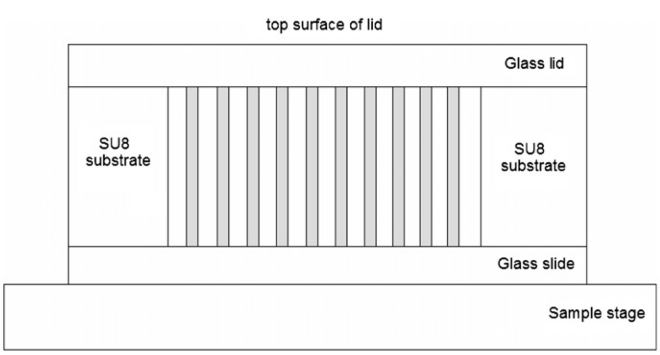

Fig. 3. Schematic diagram (cross-sectional view) of SU8 based microfluidic device with square SU8 micropillars (grey coloured in the diagram) on the glass bottom wall. The pillar height is equal to channel height.

different devices. So, the channel geometry is different in the device integrated with pillars and that without pillars.

2.1. Fabrication technique of SU8 micropillars and SU8 based microchannel

The SU8 based microchannel is fabricated on a glass slide. A glass slide is first cleaned by acetone and then dried by flow of N_2. The slide is dehydrated by keeping it on a hot plate at a temperature of 115 °C for 2 min. SU8 50 is then coated on the glass slide by means of a spin coater at 1000 RPM followed by soft baking at 65 °C during 10 min. Then, the temperature was ramped up from 65 °C to 95 °C. The sample is kept on the hot plate at a temperature of 95 °C for 30 min. Ultra-violet (UV) exposure for 35 s is used at UV intensity of 276 $\mu W/cm^2$ by maskless lithography

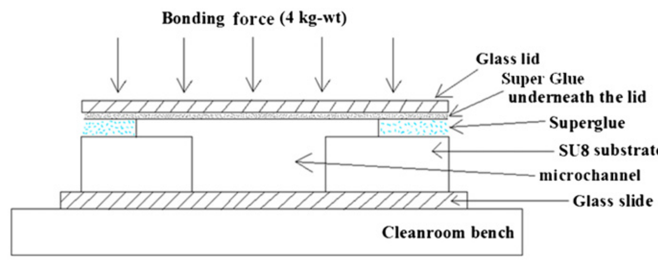

Fig. 4. Schematic diagram (cross-sectional view) of indirect bonding by one Super Glue layer on the channel substrate and another layer underneath the glass lid.

using SF-100 instrument [8]. Post exposure bake is started at 65 °C for 1 min. Then, the sample is ramped up again from 65 °C to 95 °C and kept at 95 °C during 10 min. The sample is developed during a period of 6 min in EC solvent and then hard baked on the hot plate by increasing the temperature to 195 °C. Similar procedure is adopted to fabricate the microchannels of both categories (with or without micropillars on the glass bottom wall). The channel height is measured to be 60 μm by surface stylus profilometer. The pillar height is measured to be equal to channel height. In this study, the inter-pillar distance is defined as the distance between two subsequent micropillars measured with reference to the pillar bottom. The inter-pillar distance is found to be around 200 μm (measured by surface stylus profilometer).

2.2. Indirect bonding between the lid and the microchannel substrate

The glass lid on SU8 microchannel substrate is sealed by indirect bonding technique. Glass is optically transparent. This is helpful to record the meniscus movement. So, glass is selected as the lid material. Two different liquid adhesives are used for indirect bonding: (i) Super Glue and (ii) polymethyl methacrylate (PMMA) solution (PMMA dissolved in EC solvent). Super Glue is a high performance adhesive with good strength, quality and durability. Super Glue forms strong bond between plastic materials. The chemical compound of Super Glue is Cyanoacrylate. The group of Cyanoacrylate includes methyl 2-cyanoacrylate, ethyl-2-cyanoacrylate and n-butyl cyanoacrylate. The leakage free bonding is achieved by following three subsequent steps. In the first step, the Super Glue layer is formed both on the SU8 substrate (outside region of the microchannel) and underneath surface of the glass lid. Then the lid is pressed on the channel substrate for proper bonding (Fig. 4). The bonding is tested by dyed water flow through the device. The liquid did not flow through the device. This may be due to the flow of Super Glue inside the channel for