DEVELOPMENT OF A NOVEL PNEUMATIC DISPENSER USING AN INTEGRATED BACKFLOW STOPPER

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ABSTRACT

This paper introduces a novel pneumatic dispenser with an integrated backflow stopper. The main difference and advantage of our dispenser compared with other conventional dispersers is the replacement of the flow restrictor by the integrated back flow stopper. According to our design, a fluid with a large particle can be dispensed without clogging which can be a problem in many dispensing systems containing a restrictor.

KEYWORDS: pneumatic, dispenser, restrictor, backflow stopper, particle

INTRODUCTION

Recently, many types of micro-dispensers have been developed to manage microdroplets including thermal-bubble, piezoelectric, thermal-buckling, acoustic wave and electrostatic [1-5]. Many of these dispensers contain a restrictor, which provides a function to prevent backflow and supports droplet dispensing during the droplet ejection. However, the restrictor can be an obstacle when the ejected fluid contains large sized particles since the dimension of the restrictor is the smallest in the dispensing system. In order to overcome the dimensional limitation of the restrictor function, we propose a novel pneumatic dispenser with a backflow stopper which provides the function of the restrictor while enabling the liquid ejection with the large sized particles.

CONCEPT

Fig. 1 shows the mechanism of our dispensing system. Initially, a flexible membrane is deflected by a negative pressure (Fig. 1a). When a positive pressure pushes the membrane onto the stopper (Fig. 1b), it closes the inlet. Then, further membrane deflection causes the droplet ejection (Fig. 1c). Since the bump structure (i.e., back flow stopper) provides the function of a restrictor in the conventional system, a fluid containing large particles can be used as long as the particle size is smaller than the outlet diameter of the disperser (i.e., ~50μm in our device).

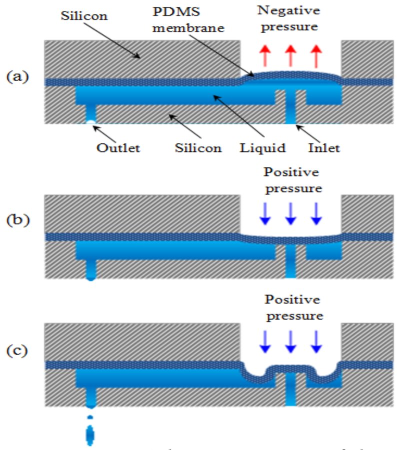

Figure 1. Schematic views of the dispensing and backflow stopping mechanism

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FABRICATION

Fig. 2 shows a detailed process to fabricate our dispenser. In order to construct the backflow stopper in the chamber, we use a unique two-step deep reactive ion etching (DRIE) which provides a step pattern as shown in Fig. 2-a4. Also, the outlet and inlet through holes are patterned by DRIE using a thick photoresist layer as an etch-mask. SEM images of fabricated device are shown in Fig. 3 which shows well aligned inlet/outlet holes as well as the bump structure. A layer of Polydimethylsiloxane (PDMS) membrane is formed using a spin-coating method on a separately-prepared SiO_2 deposited silicon substrate. After the PDMS layer is bonded on the patterned silicon substrate (Fig. 2-c1), a pneumatic actuation site is patterned by DRIE (Fig. 2-c2). The SiO_2 layer between the PDMS and the silicon substrate works as an etch barrier to protect the PDMS at the end of DRIE. Finally, the exposed SiO_2 layer at the pneumatic actuation site is removed using buffered-oxide-etchant (BOE) then PDMS membrane released (Fig. 2-c4).

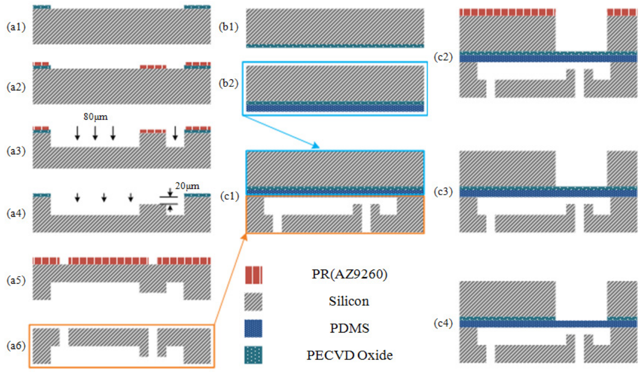

Figure 2. Process flow of the dispenser
(a1)~(a6): the stopper, inlet, and outlet fabrication
(b1), (b2): PDMS membrane fabrication
(c1)~(c4): dispenser assembly

EXPERIMENT & RESULT

Fig. 4 shows our experiment setup for dispensing test. Two mechanical regulators and a solenoid valve are used to control the time and pressure for the pneumatic actuation of the membrane. Since the ejected droplet is small and fast, we put the outlet area of the dispenser into silicone oil, which can capture the droplet, to visualize the ejected droplet. By doing this, we can calculate the droplet volume as well as

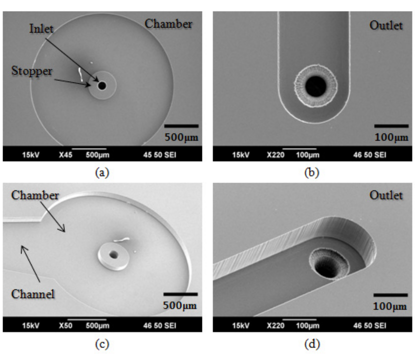

Figure 3. SEM images of the fabricated device

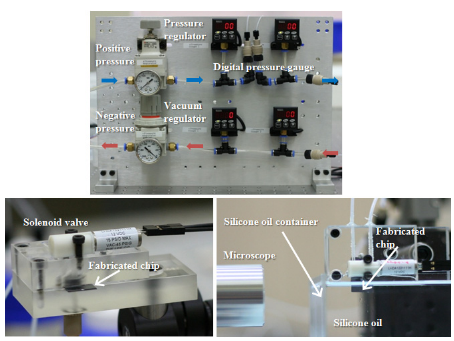

Figure 4. Experiment setup for dispensing test

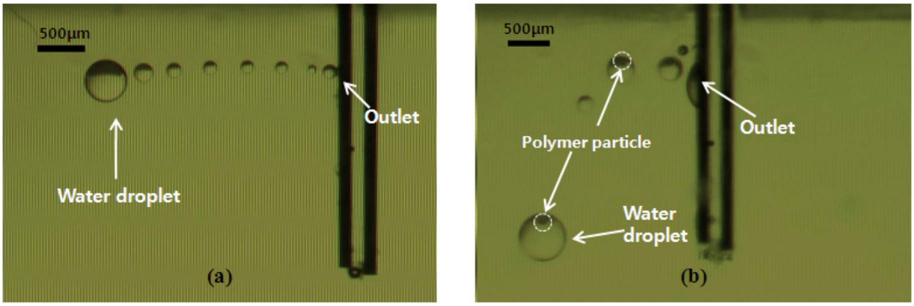

Figure 5. Droplet ejection in silicone oil (P=~100kPa)
(a) without particles and (b) with particles

observe the particles inside the droplet. According to our current disperser design, an ejected volume of ~90nℓ (including the satellite droplets), with applied pressure of 100kPa, can be obtained (Fig.5a). In addition, we also get the droplet ejection with particles (i.e., polymer particle of 30μm in diameter) as shown in Fig. 5b.

CONCLUSIONS

Using our novel pneumatic dispenser with the integrated backflow stopper, successful demonstrations of dispensing liquid droplets with and without the particles are performed. In addition, depending on the design parameters (e.g., outlet diameter, chamber size, etc.) and driving mechanisms (e.g., applied pressure, time duration, etc.) various droplet volumes can be dispensed to satisfy specific requirements in micro-dispensing systems.

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