Single layer PDMS flexible parallel wall microvalvets†

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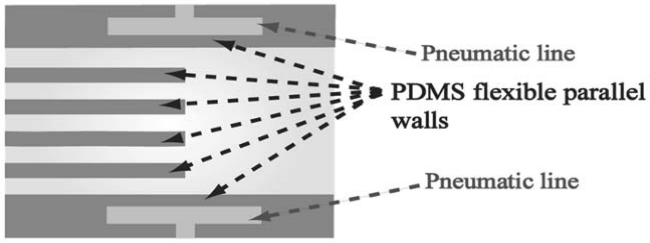
KEY WORDS: (Sampling), (Horizontal pneumatic valve), (PDMS), (Droplet)

1. Introduction

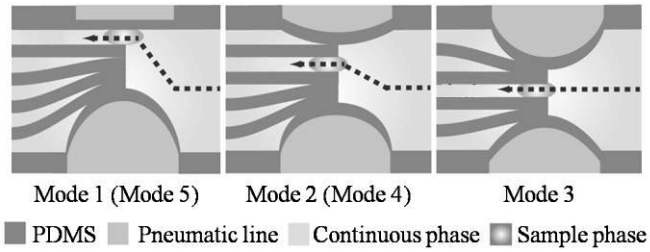
Micro/nano liter sampling technologies are in high demand for a wide range of applications in areas such as clinical diagnosis and biomedical/chemical researches. To control the sample flow in integrated micro fluidic systems, electrokinetic methods [1], hydrodynamics [2], and mechanical valves are used. Among them, pneumatic flexible valves of horizontal type and vertical type have been widely used because of their simple structure and good controllability [3, 4].However, issues are remain to be solved for the complicated stacking process of the vertical type and insufficient multiple control of the horizontal type. We propose a novel type of the multiple droplet sampling system realizing minimum numbers of active horizontal microvalves.

2. Principle

Figure 1 shows a working principle of single droplet sampling by horizontal valves and flexible parallel walls. PMDS walls on both sides of the micro channel are deformed by controlled air pressure. The deformation, especially, overshot deformation of valves makes a sequential deflection of the flexible walls inside the channel. Each fluidic channel is designed to have the same flow resistance initially. However, flow resistances of channels between parallel walls are changed by controlled deformation amounts from one side or both sides. As a result, it is possible to control the flow resistance of each channel and to sort only single droplets to a specific chamber (**Fig. 2**).



(a) Construction of multi mode sorting part



(b) Images of deformed walls by pneumatic pressure

Fig. 1 The concept of droplet sorting by pneumatic valves and moving flexible walls.

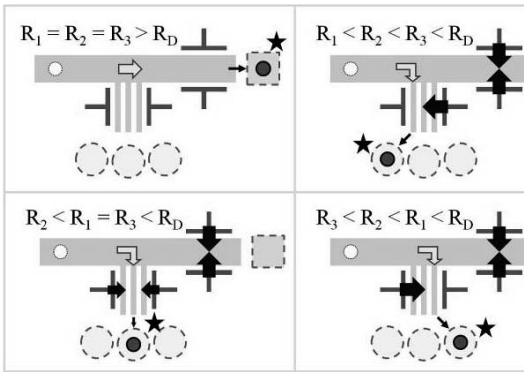


Fig. 2 The principle of multi modes droplet sampling.

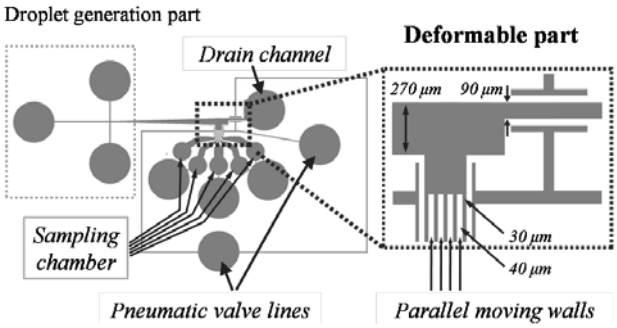


Fig. 3 Design of total system and detailed size of multi modes sorting part.

3. Design and Fabrication

The whole system consists of a droplet generation part, pneumatic valve lines, a deformable part, sampling chambers, and a drain channel. **Figure 3** shows the designed total system and detailed sizes of deformable parts. Width of fluidic channel is about 30 μm, thickness of the parallel walls is about 40 μm, and the height of all structures is about 200 μm. Positions of the moving walls and pneumatic valves were optimized by calculations to obtain maximum deflection of the parallel walls. Also, the drain channel width was designed as 90 μm to drain the

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main stream out of the device under initial condition. Designed structures were formed from PDMS using a SU-8 mold. It is bonded to the PDMS coated glass substrate after plasma pretreatment. The fabrication results by single step SU-8 patterning and PDMS replication are shown in **Fig. 4**. In order to realize flexible PDMS structures, resin and curing agent were mixed in a 15:1 ratio. For fluidic experiments, syringe (1750CX, HAMILTON) and syringe pump (KDS210, kdScientific) were used. The air pressure was controlled by pressure regulator (2657 pneumatic pressure standard, YOKOGAWA).

Also, a CCD camera (JK-TU53H, TOSHIBA) and a data processing computer were utilized for visualization and storage of the droplet sampling processes.

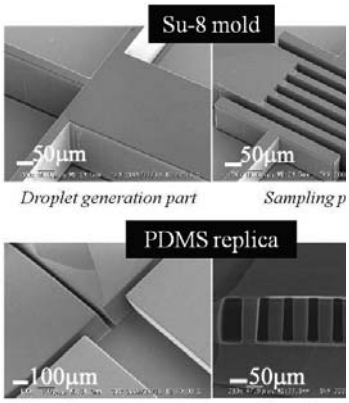

Fig. 4 Fabrication results of the sampling device.

4. Experimental Results and Discussion

In the droplet generation part, 40 μm diameter aqueous droplets were generated. As shown in **Fig. 5**, generated droplets initially flow into the drain channel, because the flow resistance of the drain channel was designed as three times higher than that of the parallel sampling channel (a). According to deformation by pneumatic pressure, the flow resistance of the drain channel increases and a target droplet flows into the sampling channel (b).Simultaneously, selection of sampling chamber is performed with the multiple channel selection principle described in Fig.2. As a result, the target droplet is delivered to one objective micro chamber (c). By pressure release, droplet sampling finished, and the main stream is restored to the drain channel (d). The other delivery behaviors under different pressure conditions are shown in **Fig. 6**. It is demonstrated that five different modes droplet are sorted by combination of applied pneumatic pressures from 0 kPa to 250 kPa. Furthermore, the pneumatic line for drain and sampling channel is connected to each other for simple control. As a result, the walls of the drain channel are deformed in proportion to the pressure at different sampling modes. The adequate combination of PDMS pneumatic deformations enables multi droplet sorting. The multi mode sorting and manually controlled single droplet sampling was performed within about 1 second. This device can be used effectively for sampling of biological cells and biomolecules. Slow switching speed compared to the electric methods and instability of droplet generation during sampling are the remaining issues. It is expected that integration of an automatic pressure control system will be a solution of these problems. Some specific structures which can realize independent control of droplet generation from sampling are considered.

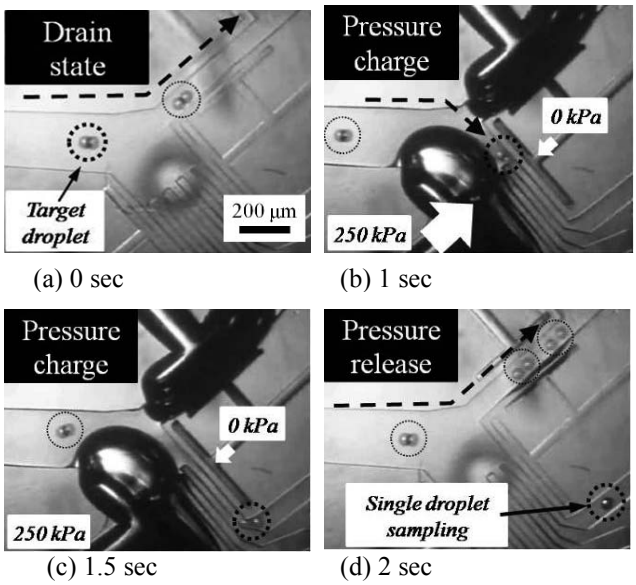

Fig. 5 Captured images of single droplet sampling with time sequence (Mode 1).

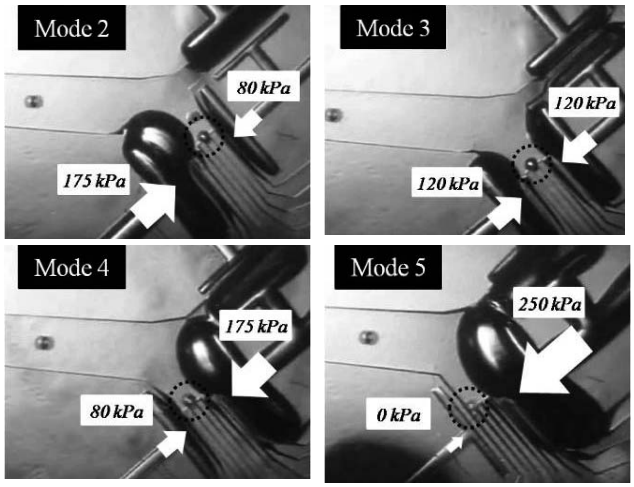

Fig. 6 Captured images of droplets placed at entrance to their objective chamber and pressure conditions.

5. Conclusions

Proposed multiple sampling was successfully demonstrated. The valves and flexible moving walls were operated precisely and one droplet sampling from continuous droplet phase flow was also realized. The total flow sampling system was fabricated by single step PDMS molding and bonding. We improve the structure of the total flow system to realize stable particles and bio molecules sampling.

References

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