SELECTIVE DROPLET SAMPLING FLOW SYSTEM USING MINIMUM NUMBER OF HORIZONTAL PNEUMATIC VALVES FORMED BY SINGLE STEP PDMS MOLDING

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ABSTRACT
Selective droplet sampling system which can deliver target droplets to five different chambers is realized by pneumatically controlled horizontal PDMS microvalves. One inlet and five outlets sorting are performed by only two pneumatic valves using the high aspect ratio flexible parallel PDMS wall structures. Selective droplets sampling is obtained with outlet flow resistance control by deformable horizontal microvalves and walls. The proposed simple flow control structure enables total flow system with simple fabrication by a single PDMS molding. The sampling was performed within 1 second under pneumatic pressure from 0 kPa to 250 kPa.

KEYWORDS: Sampling, Horizontal pneumatic valve, PDMS, Droplet

INTRODUCTION
Micro/nano liter sampling technologies are in high demand for wide range of applications in area 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 remained to be solved that a 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.

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

![Figure 1: The concept of droplet sorting by pneumatic valves and moving flexible walls](image)

![Figure 2: The principle of multi modes droplet sampling](image)
DESIGN AND FABRICATION

Whole system consists of a droplet generation part, pneumatic valve lines, a deformable part, sampling chambers, and a drain channel. Fig. 3 shows the designed total system and detailed sizes of deformable part. Width of fluidic channel is about 30 \( \mu m \), thickness of the parallel walls is about 40 \( \mu m \), and the height of all structures is about 200 \( \mu m \). 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 \( \mu m \) to drain 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 (Fig. 4, (a)). The fabrication results by single step SU-8 patterning and PDMS replication are shown in Fig. 4 (b). In order to realize flexible PDMS structure, resin and curing agent were mixed in 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.

EXPERIMENTAL RESULTS AND DISCUSSION

In the droplet generation part, about 40 \( \mu m \) 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 extremely and a target droplet flows into sampling channel (b). Simultaneously, selection of sampling chamber is performed with the multiple channel selection principle described in Fig.2. As the results, the target droplet is delivered to one objective micro chamber (c). By pressure release, droplet sampling finished, and the main stream is restored to drain channel (d).
The other delivery behaviors under different pressure conditions are shown in Fig. 6. It is successfully demonstrated that different five modes droplet sorting by combination of applied pneumatic pressures from 0 kPa to 250 kPa. Furthermore, pneumatic line for drain and sampling channel is connected each other for simple control. As a result, the walls of 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 modes 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 issue. 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.

CONCLUSION

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.

ACKNOWLEDGEMENTS

This research was supported by Waseda University Global COE Program “International Research and Education Center for Ambient SoC” and Scientific Basic Research (A) No. 19206046 sponsored by MEXT, Japan.

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