Narrowing Microfluid Width In Microchannel Using Air Boundaries

Sang Uk Son and Seung S. Lee
Pohang University of Science and Technology
Dep. of Mech. Eng., San 31 Hyoja-Dong Nam-Gu, Pohang 790-784, Kyungbuk, Korea
chairson@postech.ac.kr

Abstract

A novel method for narrowing microfluid width in microchannel is presented by utilizing of air boundaries of which inflation direction is perpendicular to microfluid flow. The air boundaries are generated by heating water with microheater. The microfluid width of 300 μm can be focused and maintained as up to 22 μm which is near cell size without affecting cell or microchannel structure. The narrowed width is regulated by pressure in the air boundaries and flow velocity of microfluid. The method can enhance sensitivity in flow cytometry by placing the air boundaries near sensing area and guiding cells.

Keywords: Microfluid width narrowing, microchannel, air boundary, sorting

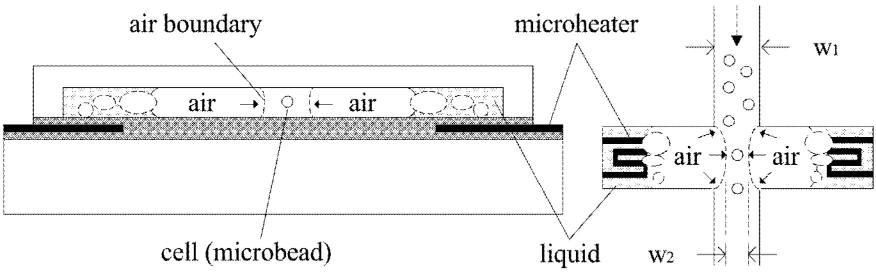
1. Introduction

Narrowing microfluid width in a microchannel is essential in flow cytometry to guide the cells to sensing area and enhance the sensitivity [1,2]. Sheathing by hydrodynamic force is conventional at the expense of external hydrodynamic system [3]. As alternatives various methods using ultrasound [4], v-grooved section [5], dielectrophoresis [6], and antibody magnetic particle [7] have been researched. In this paper, we present a novel method based on inflation of air boundaries in microchannel. It can control the width close to cell size flexibly maintaining the cells and microchannel intact during operation.

2. Principle and design

The air boundaries on microfluid become walls which can move back and forth perpendicularly to flow direction as shown in Fig. 1. The cells in microchannel detour along the surface of the boundaries therefore narrowing of microfluid width is realized by inflating the boundaries. Hydrogen dioxide (H_2O_2) or water (H_2O) in branch is heated and oxygen (O_2) or gaseous H_2O is generated, which forms the boundaries and reduces the width from w_1 to w_2. The change of width is dependent on the pressure inside the boundaries and the flow velocity. The device is simple consisting of microheater and microchannel. The width ratio of microchannel to branch is designed as 1 for the stable shpae of the boundaries and the minimum width.

0-9743611-0-0/μTAS2003/$15.00©2003TRF

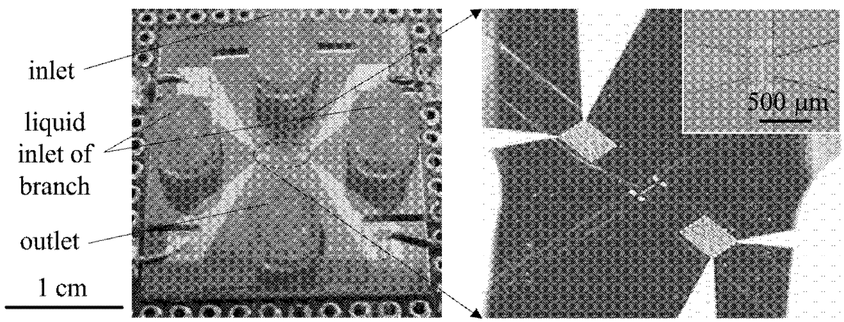


(a) cross section (b) top view

Fig. 1 Schematic view of narrowing microfluid width.

3. Fabrication

The fabrication consists of the microheater and the microchannel process. Firstly, it starts with a 2.5 × 2.5 cm^2 (100) n-type silicon wafer having a 0.7-μm-thick thermal silicon dioxide layer. A 0.2-μm-thick aluminum layer deposited by thermal evaporation is patterned for the microheater (60 Ω). A 0.8-μm-thick spin-on-glass layer is spin-coated on the microheater for electric insulation and patterned. Secondly, a SU-8 mold for the microchannel and the branches is made with height of 50 μm. A polydimethyl-siloxane (PDMS) layer is poured on the mold for replica of the microchannel and cured for 5 hours at 65 °C in a convection oven. Silicon tubes for inlet and outlet are attached on the PDMS layer and also cured. The peeled off PDMS microchannel is punched and oxidized with O_2 plasma cleaner (PDC-32G, Harrick USA) for 1 min and aligned with the silicon wafer using methanol as lubricant. The assembled device is cured for 1 day at 80 °C in a convection oven to enhance adhesion. Fig. 2 shows the fabricated device.



(a) overal view (b) microchannel and microheater

Fig. 2 Fabricated device.

4. Experiments and results

Fig. 3 shows gas (O_2 , H_2O) generation and inflation of its boundaries with microheater. The O_2 bubbles (Fig. 3a), by heating H_2O_2 (wt. 30 %) filled in the branches with power of 600 mW, form the boundaries. H_2O_2 shows instability of continuous O_2 generation after cutting off heating because it decomposes in the presence of dust particles or light which is inevitable practically [8]. In case of H_2O, it changes from liquid to gaseous state when heated and condenses on the contrary when cooled, therefore it is useful for back and forth motion of the boundaries. Polystyrene beads of 10 μm passing in the microchannel are invisible due to fast movement therefore dye is injected in the stream to illustrate the reduced width. The bottom becomes clean as the width reduces, which notes that the air contacts bottom and ceiling of the microchannel.

Fig. 4 shows the narrowed width of 140 μm and 22 μm where the microchannel width is 300 μm. The width is inversely proportional to the pressure inside the boundaries and the flow velocity. The width of 22 μm is maintained for several minutes and close to double of regular cell size, which notes that the method is useful to focus cells in flow cytometry. The arc shape of the boundaries begins unstable as the flow velocity increases or the inflation continues, and breaks at flow velocity of 17.8 mm/s.

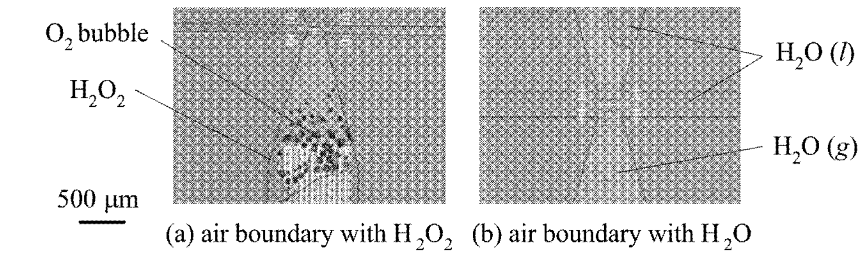


Fig. 3 Formation of air boundaries with microheater.

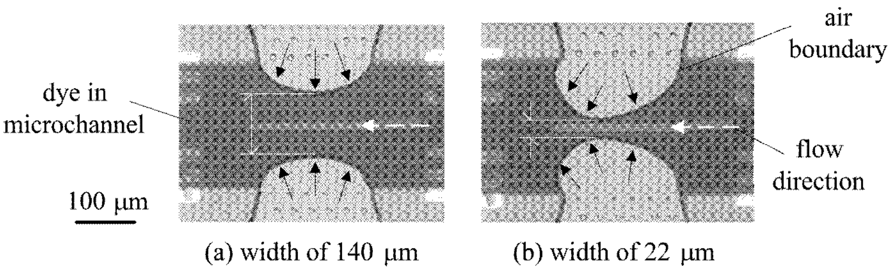


Fig. 4 Narrowing of microfluid width by inflating air boundaries.

4. Conclusions

A novel control method for changeable microfluid width is realized by utilizing the air boundaries. A device with microheater and microchannel is fabricated and experiments with dye shows the narrowed width of up to 22 μm, which is maintained for several minutes. The width shows inverse proportion to the pressure in the air boundaries and the flow velocity. The arc shape of the boundaries is stable on condition that the width ratio of microchannel to branch is less than 1. It becomes unstable when flow velocity exceeds 17.8 mm/s, which means that the minimum width can be determined by the flow velocity and the dimensions of microchannel and branches. The presented method can be used as a sorting means by guiding the narrowed flow at desired outlet, which can be carried out when the boundaries are inflated differently or the branch is placed on one side of the microchannel.

Acknowledgements

This research was supported by a grant (02-K14-01-005-1-2) from Center for Nanoscale Mechatronics & Manufacturing, one of 21st Century Frontier Research Programs, Ministry of Science and Technology, KOREA.

References

1. P. K. Horan and Leon L. Wheeless. Jr., "Quantitative single cell analysis and sorting", Science, Vol. 198, pp. 149-157, 1977.
2. W. M. Grogan and J. M. Collins, Guide to flow cytometry methods, Marcel Dekker, New York, 1990, pp. 1-21.
3. James B. Knight, Ashvin Vishiwanath, James P. Brody, and Robert H. Austin, "Hydrohynamic focusing on a silicon chip: mixing nanoliters in microseconds", Physical Review Letters, Vol. 80, No. 17, pp. 3863-3866, 1998.
4. K. Yasuda, S.-I. Umemura, and K. Takeda, "Concentration and fractionation of small particles in liquid by ultrasound", J. Appl. Phys., Vol. 34, pp. 2715-2720, 1995.
5. E. Altendorf, D. Zebert, M. Holl, and P. Yager, "Differential blood cell counts obtained using a microchannel based flow cytometer", Transducer'97, pp. 531-543, 1997.
6. T. Muller, G. Gradl, S. Howitz, S. Shirley, Th. Schnelle, and G. Fuhr, "A 3-D microelectrode system for handling and caging single cells and particles", Biosensors & Bioelectronics, Vol. 14, pp. 247-256, 1999.
7. J.-W. Choi, Kwang W. Oh, Jennifer H. Thomas, William R. heineman, H. Brian Halsall, Joseph H. Nevin, Arthur J. Helmicki, H. Thrurman Henderson and Chong H. Ahn, "An integrated microfludic biochemical detection system for protein analysis with magnetic bead-based sampling capabilities", Lab on a chip, Vol. 2, pp. 27-30, 2002.
8. R. Chang, "Chemistry", 2nd edition, Random House, p 591, 1981.