A NOVEL COAXIAL SHEATH FLOW DEVICE FOR SAMPLE FOCUSING

G. Hairer, G.S. Pärr, P. Svasek, A. Jachimowicz, and M.J. Vellekoop

Vienna University of Technology, AUSTRIA

ABSTRACT

In this paper we present a novel coaxial sheath flow device where the sheath flow surrounds the sample flow at all sides. This micro fabricated device consists of a simple design and the dimensions of the channel have been chosen such that sample flow diameters of a few microns are feasible in a relatively large channel of $25 \times 40 \ \mu\text{m}^2$. This focusing technique prevents channel clogging and undesired sample adsorption on the channel walls. In this contribution we studied the sample flow profile using laser scanning confocal measurement method. The achieved sample flow dimensions of $1.5 \times 12 \ \mu\text{m}^2$ of the focusing section are verified with 3D simulations.

Keywords: microfluidics, hydrodynamic focusing, coaxial sheath flow

1. INTRODUCTION

The measurement of particles in solution (e.g. beads, cells or molecules) in a MEMS device for analytical purposes makes it necessary to deal with detailed aspects in microfluidics. Especially when it comes to single particle detection or manipulation it is inevitable to use focusing techniques. In literature hydrodynamic focusing techniques with coaxial sheath flow are illustrated in [1], [2], [3], and [4]. These devices are either complex to fabricate or do not have the flexibility in sample adaption inside the channel. Additionally all devices have channel sizes in the range of several hundred micrometers. The use of sheath flow allows focusing a sample flow with high accuracy, which was shown in non coaxial sheath flows [5]. In this contribution we investigate the creation of a very small diameter sample flow in a coaxial sheath flow setup. The dimensions of the channels and fluid inlets have been chosen such that sample flow diameters of a few microns are feasible in a relatively large channel of 25 x 40 μ m². This focusing technique prevents channel clogging and undesired sample adsorption on the channel walls. This fabricated coaxial sheath flow device allows single particle detection or manipulation in the range of a few micrometers.

2. DEVICE DESCRIPTION

In Figure 1 a photograph of the fabricated chip is depicted. The chip consists of a silicon-glass sandwich with SU-8 in between. The access holes through silicon (360 μ m thick) are anisotropically etched with a KOH water solution. The dimensions of the access holes at the channel side are 330 x 330 μ m² (sheath inlet, side ports and outlet), 25 x 25 μ m² (sample inlet), and 25 x 50 μ m² (lifting inlet). The channel widths at the channel crossing area are 25 μ m. The 40 μ m thick SU-8 resist define the channel geometry and the channel height. Finally, a 200 μ m thick glass cover slide is bonded irreversibly via SU-8 to the silicon. The chip fabrication is carried out with wafers of 100 mm in diameter.

In Figure 2 the principle of the coaxial sheath flow device is shown. The sample liquid is vertically injected into the channel, where a sheath liquid is flowing. After a first focusing

section the sample liquid is lifted up by adding sheath liquid through the lifting inlet and a coaxial flow is formed. The side ports additionally focus the sample liquid. The influence on the shape, size and position of the sample flow can be controlled by the relative flow rates of the sheath inlets to the sample inlet.



Figure 1. Photograph of the fabricated coaxial sheath flow device (chip dimensions $4 \times 7 \text{ mm}^2$).



Figure 2. Schematic of the coaxial sheath flow cell.

3. EXPERIMENTAL

For experiments the coaxial sheath flow device is fixed on a custom made holder where silicone tubes are integrated for fluidic connections to syringes. A custom molded silicone gasket is put between the holder and the fluidic chip to achieve a tight connection. The syringe pumps (kdScientific model 200 series) define the flow rates at the different inlets. A diluted fluorescent dye (acridine orange) is used for the sample flow and the sheath flow consists of deionized water. To get information on the real sample flow profile and size we constituted measurements with a confocal laser scanning microscope (Confocal C1 TE300, Nikon).

4. RESULTS AND DISCUSSION

Figure 3 shows the sample flow at the region where the sample flow is lifted up and afterwards gets horizontally focused (top and side view). The images present the emitted green color of the fluorescent dye. The flow rates at the inlet ports are held at 15 μ l/min (sheath inlet), 0.5 μ l/min (sample inlet), 12.5 μ l/min (lifting inlet), and 40 μ l/min (side ports). The sample flow is lifted up to the middle of the channel and afterwards gets focused by the side ports. At the focusing region dynamic effects appear to the sample flow and before squeezing the sample flow broadens up. Figure 4 depicts the real sample flow profile at the region A, B, and C (see Figure 3). After lifting the sample flow its profile gets a bit broader and lower. After the side port focusing the height of the profile stays the same. The sample flow dimensions seen in picture C are 1.5 μ m horizontally and 12 μ m vertically. There is still potential to reduce the vertical dimension by reducing the sample flow height or fabricating the channel height with the same channel width. To verify the results of the measured sample profiles a 3D simulation with Comsol Multiphysics is carried out. The simulation results at the region A, B, and C of Figure 3 are shown in Figure 5. These results are in good agreement with the measured ones in Figure 4.



Figure 3. Measurement results with the confocal microscope. Top: Plan view of the section with lifting inlet and side ports. (The edges of the channels are outlined with a dashed line and the lifting inlet in silicon is outlined with a dotted line. The arrows indicate the flow direction). Bottom: Side view of the channel. The flow rates at the inlet ports are held at 15 μ l/min (sheath inlet), 0.5 μ l/min (sample inlet), 12.5 μ l/min (lifting inlet), and 40 μ l/min (side ports).



Figure 4. Confocal measurements inside the channel; the pictures reveal the sample flow profiles at the positions A, B, and C (Figure 3).



Figure 5. Simulation results of the coaxial sheath flow device; the pictures reveal the sample flow profiles at the positions A, B, and C (Figure 3).

5. CONCLUSIONS

In this contribution we demonstrate a novel coaxial sheath flow device for sample focusing. The sample flow is characterized using confocal measurements and a 3D simulation. The shown sample flow dimensions after the side ports belong to 1.5 μ m x 12 μ m, where the vertical dimension of the sample flow profile can be still reduced. The simulation results are in good agreement with the measured ones. This coaxial sheath flow device is suitable for focusing and alignment of asymmetric cells to carry out single cell detection.

REFERENCES

- N. Sundararajan, M.S. Pio, L.P. Lee, and A.A. Berlin, *Three-Dimensional Hydrodynamic Focusing in Polydimethylsiloxane (PDMS) Microchannels*, J. of Microelectromechanical Systems, Vol. 13, pp. 559-567, (2004).
- [2] R. Yang, D.L. Feeback, and W. Wang, *Microfabrication and test of a threedimensional polymer hydro-focusing unit for flow cytometry applications*, Sensors and Actuators A, Vol. 118, pp. 259-267, (2005).
- [3] A. Wolff, I.R. Perch-Nielsen, U.D. Larsen, P. Friis, G. Goranovic, C.R. Poulsen, J.P. Kutter, and P. Telleman, *Integrating advanced functionality in a microfabricated high-throughput fluorescent-activated cell sorter*, Lab Chip, Vol. 3, pp. 22-27, (2003).
- [4] C. Simonnet, and A. Groisman, *Two-dimensional hydrodynamic focusing in a simple microfluidic device*, Applied Physics Letters, Vol. 87, 114104, (2005).
- [5] G. Hairer, and M.J. Vellekoop, *Experiments on hydrodynamic focusing of non coaxial sheath flows*, IEEE Sensors 2006, Daego, p. 431, (2006).