CONTINUOUS MICROFLUIDIC CELL/PARTICLE SEPARATION VIA COMBINATION OF ELECTROOSMOTIC AND HYDRODYNAMIC SPREADING

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Hydrodynamic spreading separation is an important technique for cells or particles sorting. In this paper, an electroosmotic flow (EOF) and a hydrodynamic flow are combined to control the spreading behavior for continuous cells or particles separation. The hydrodynamic spreading of fluids can be adjusted arbitrary with a tunable applied voltage. This spreading behavior is investigated through numerical simulation and experiment study. Based on the experimental results, particles of two different sizes, 10 and 2 μm, are separated. The experimental results are compared with the numerical results. The suggested technique provides a simple, flexible and versatile way for microfluidic cell sorting.

Keywords: Separation, electro-osmotic flow, hydrodynamic spreading, cell sorting

1. Introduction

Research on microfluidic devices for cell or particle separation has attracted strong interest from both of academia and industry. Various separation techniques including fluorescent-activated cell sorting, dielectrophoresis-activated cell sorting, magnetic-activated cell sorting and flow fraction cell sorting have been investigated. Thus far, the flow fraction or hydrodynamic spreading is one of the simplest techniques with high throughput. Cells or particles are sorted based on their respective sizes using a simple geometry design [1-2], where the spreading behavior of the flow for cells or particles separation can be affected by flow rate and viscosity ratio of the co-axis fluids among a pressure driven flow system [3]. In this paper, the spreading behavior for continuous cells or particles separation using a hydrodynamic flow system combined with an electroosmotic flow system is investigated. The hydrodynamic spreading behavior is studied through numerical simulation that is compared with experiment results. The two different sizes of particles are separated based on the hydrodynamic spreading behavior of fluids, which is controlled and adjusted arbitrary by the electroosmotic flow through a tunable applied voltage.
2. Principle of separation

Electroosmosis refers to the fluid flow that occurs when there is an electric double layer at a solid-liquid interface that arises from an electrostatic attraction between a charged surface and ions. When an external electric field is applied, the mobile positive ions in a diffuse layer move towards the cathode, resulting in a bulk fluid movement by dragging along the essentially electrically neutral bulk fluid that is far away from the microchannel wall. In general, the driven force of the electroosmotic flow is weaker than the pressure flow. However, when the pressure amplitude of the two flows is closely equal, the effect of the electroosmotic flow becomes very significant influence for the pressure driven flow. The hydrodynamic spreading of fluids is adjusted arbitrary by the electroosmotic flow control through the tunable applied voltage.

Figure 1 shows the principle of particle separation via hydrodynamic flow for cell or particle separation controlled by EOF. One fluid stream with different particles (sample flow) is converged to another fluid stream without particles (carrier flow) through a small channel. When the voltage is applied to the carrier fluid, the hydrodynamic behavior of the fluids changes according to the driven voltage of EOF. Since the fluid stream without particles occupies a broader channel width, when the amplitude of the applied voltage is proper, the larger particles are aligned against the channel wall and immersed in the carrier fluid, but the smaller particles remain changed in the original sample fluid. Through an abrupt channel amplified mechanism, the larger particles are forced into the carrier flow and the small particles are kept in the sample flow. The particles are then separated and can be collected into the different outlets.

The hydrodynamic spreading behavior controlled by electroosmotic flow is simulated using CFD-ACE+, the numerical simulation results of the fluid spreading behavior along the channels are shown in Fig. 2. The top branch occupies broader width than the bottom one when the voltage is applied.

Fig. 1 Schematics of particle separation using hydrodynamic spreading behavior through EOF control.

Fig. 2 Numerical simulation result of hydrodynamic spreading behaviors.
3. Experimental results and discussions

The biochip was fabricated using standard soft-lithography with polydimethylsiloxane (PDMS). Fig. 3 (a) shows the pure hydrodynamic spreading using fluorescent dye. Fig. 3 (b) shows that the hydrodynamic spreading behavior is controlled by the electroosmotic flow. The two experiment results show that the spreading behavior changes significantly with and without electroosmotic flow control. The mixed particles with different diameters of 2 μm and 10 μm are put in one inlet. Deionized water is used as the carrier flow that is put in the other inlet and kept at a height which is the same with the one in the mixed particles. When the applied voltage on the carrier flow is raised, the carrier flow occupies the broader channel width and the sample flow occupies the narrower channel width. The larger particles are aligned against the channel wall and forced into the carrier flow, the small size particles remain at the bottom as shown in Fig. 4. As a result, the particles with different sizes are separated. Higher voltage is applied to enhance the separation effect.

Conclusions
A technique of continuous particles separation using hydrodynamic fluid spreading through electroosmotic control is investigated. The hydrodynamic spreading behavior is studied through numerical simulation and verified by experimental results. The separation of particles with two different diameters is demonstrated. This technique provides a simple, flexible and versatile way for cell sorting using biochip.

References