PINCHED FLOW FRACTIONATION DEVICE FOR SIZE- AND DENSITY-DEPENDENT SEPARATION OF PARTICLES UTILIZING CENTRIFUGAL PUMPING

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ABSTRACT

We present herein a microfluidic device for the separation of particles according to size and density, utilizing the centrifugal force combined with the separation scheme called "pinched flow fractionation (PFF)". PFF devices have been previously developed for the size-dependent separation of particles, either by pressure-driven [1,2] or centrifugal [3] pumping. In the present study, we employed centrifugal force as the means both for the fluid transportation and particle migration perpendicularly to the flow direction, which enable particle separation based on size and density. In the experiment, microparticles with different densities were successfully separated by employing the centrifugal pumping. The presented microfluidic system is useful and versatile due to its accuracy and simplicity in operation.

KEYWORDS: Centrifugal Microdevice, Pinched Flow Fractionation, Separation, Density

INTRODUCTION

Among various techniques for particle separation, a scheme for density-dependent separation is useful for the selection of specific biological particles from a complex mixture. For example, separation of lymphocytes/granulocytes is conducted utilizing the difference in densities.

Recent studied have showed that microfluidic devices are highly useful for the separation of microscale particles. We have previously developed 'pinched flow fractionation (PFF)' scheme [1,2] for the continuous and size-dependent separation of particles/cells (Fig. 1(a)). We have also proposed PFF microdevices driven by centrifugal pumping, in which complicated pumping devices are not required [3]. In this study, we employ the centrifugal force both for pumping the fluid and exerting the centrifugal force to particles (Fig. 1(b)). The centrifugal force, exerted to particles perpendicularly to the flow direction, separates particles with different densities. Also, by precisely designing the microchannel structure, and properly adjusting the hydrodynamic resistances of channel segments, we can rigidly control the input/output flow rates, which is desirable for effective particle manipulation.

EXPERIMENTAL

PDMS microdevices were fabricated using usual replica molding techniques. The microdevice has four channel structures, and each structure has two inlets and

978-0-9798064-1-4/μTAS2008/$20©2008CBMS

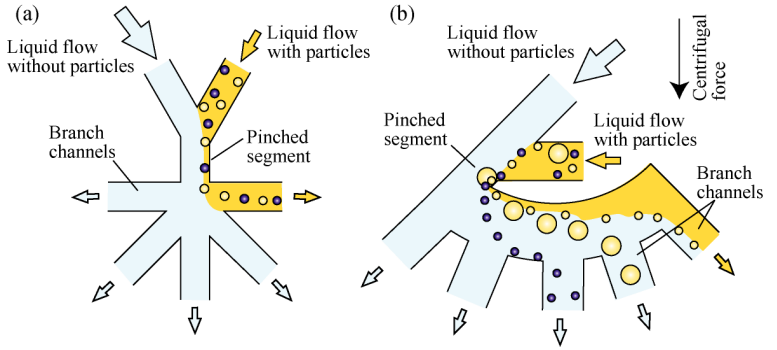

Figure 1. Principle of 'pinched flow fractionation (PFF)'; (a) conventional PFF performed by pressure pumping, and (b) PFF scheme for density-dependent separation, employing centrifugal pumping. In the pinched segment, particles are focused onto one sidewall, and then separated through the branch channels. In (b), particles with different densities are separated by exerting the centrifugal force to particles (white particles: low density; black particles: high density).

twelve outlets (Fig. 2). The pinched-segment width is 15 μm, and the channel depth is ~11 μm. The difference in the widths of the inlet channels arises the difference of the inlet flow rates; we expected that the ratio of flow rates from Inlets 1 and 2 is 1:15. An aqueous suspension containing 3.0 and 5.0 μm fluorescent polystyrene particles (1.05 g cm^{-3}) and 5.0 μm silica particles (2.0 g cm^{-3}) was dropped into Inlet 1, while distilled water was dropped into Inlet 2. Then the microdevice was rotated at 1500 rpm for 30 sec on a spin rotator, and after separation, particles in each outlet reservoir were observed.

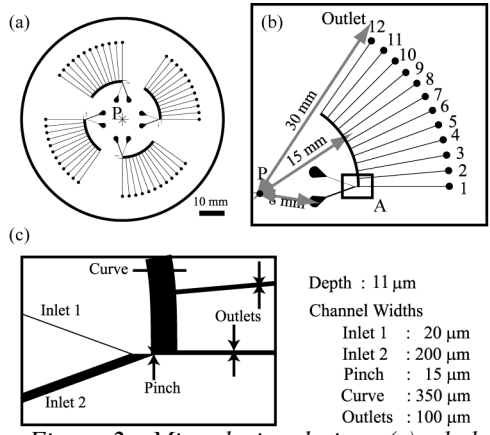

Figure 2. Microdevice design; (a) whole microdevice, (b) one of the microchannel structure, and (c) the enlarged diagram of area A in (b). The point P is the center of rotation.

RESULTS AND DISCUSSION

Fig. 3 shows the microscopic images of the separated particles in Outlets 4 and 8. As a result, 5.0-μm silica and polystyrene particles were respectively recovered from these outlets. This result demonstrates the ability of the presented system for rapidly separating particles of different densities. To compare the separation efficiencies between the centrifugal and pressure-driven schemes, we performed the particle separation via pressure-driven pumping, by using the same microdevice and syringe pumps. Fig. 4 shows the histograms of particles, separated either by pressure-driven (Fig. 4 (a)) or centrifugal (Fig. 4 (b)) pumping scheme. The contribu-

tion of the centrifugal force to the density-dependent separation of particles was therefore confirmed.

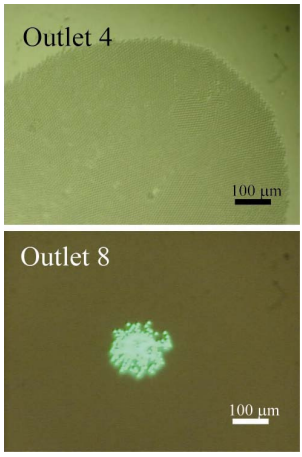

Figure 3. Photographs of the microparticles separated into the outlet reservoirs, by employing the centrifugal pumping; Outlet 4: 5.0 μm silica beads (non-fluorescent), and Outlet 8: 5.0 μm polystyrene beads (fluorescent).

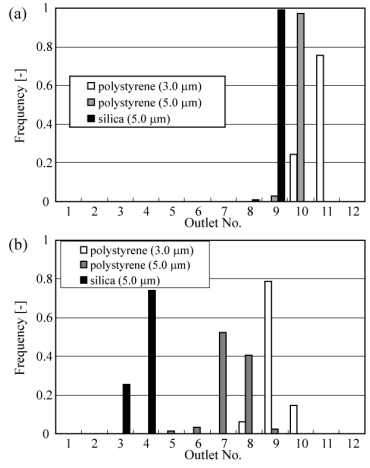

Figure 4. Histograms showing the ratio of particles recovered from each outlet, by employing (a) pressure-driven pumping or (b) centrifugal pumping scheme.

CONCLUSIONS

We demonstrated that the combination of PFF technique and the perpendicularly-exerted centrifugal force achieves the particle separation based on both size and density. The presented scheme will be useful for biological applications, including the selection of specific cells from a small amount of mixture.

ACKNOWLEDGEMENTS

This research was supported in part by Grants-in-aid for Scientific Research (A) (No. 20241031) from the Ministry of Education, Culture, Sports, Science and Technology, Japan, and JSPS fellows from Japan Society for Promotion of Science.

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