INERTIAL MICROFLUIDICS WITHIN NON-RECTANGULAR CROSS-SECTION MICROCHANNELS AND CONTROL OF ACCESSIBLE FOCUSING POSITION

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ABSTRACT

Inertial focusing and ordering in non-rectangular microfluidic channels are studied. Triangular channels have 3 focusing positions and half-circular channels have 2 focusing positions. A microchannel with varying cross-sectional shape (rectangular, 54.7° triangular, half-circular) is fabricated to control accessible focusing positions and provides particle focusing in single focusing position with ratio >99%. These results show that channel cross-sectional shape can be new control parameter for inertial microfluidic systems.

KEYWORDS: Inertial focusing, Micro-particle manipulation, Flow cytometry, Non-rectangular microchannel.

INTRODUCTION

Inertial microfluidic systems provide methods for passive, high-throughput particle manipulation for various applications [1-3]. Current understanding of inertial microfluidics are mainly based on inertial effects in circular capillary tubes and microchannels with rectangular cross-section (Figure 1). With a slight symmetry breaking, rectangular channels show clear difference in focusing positions. Near the long side wall of rectangular channels, the blunted region of the velocity profile leads to a dominant wall effect lift, hence, particles migrate toward the centerline in the long channel dimension [4]. We investigated inertial focusing and ordering behavior in non-rectangular cross-section channels. More specifically, half circular channels and triangular (54.7 and 45 degrees equilateral triangles) channel are used to better understand mechanism of inertial focusing.

Figure 1: Inertial focusing in capillary tubes, square and rectangular channel. Particles in capillary tubes are focused along the channel perimeter and there are 4 or 2 focusing positions in square and rectangular channel.

Owing to high-throughput and passive nature, flow cytometry has been considered as one of the promising application areas of inertial focusing. Chung et al. [5] showed that inertial focusing to a single equilibrium position is possible by inducing secondary flow. The limitations of this technique are rather long channel length (6 cm) and the fact that the relative strength of secondary flow to inertial lift force is dependent on Reynolds number.

Different focusing positions in non-rectangular cross-section channels can be used to control accessible focusing positions, which can be applied for single-stream particle focusing. We fabricate the channel with varying cross-sections aiming for focusing particles in two focusing positions in rectangular channel then reducing the number of accessible focusing positions (Figure 2b).
EXPERIMENTAL

The half-circular channel mold was fabricated by reflow process of positive photoresist and the triangular channel molds are fabricated by Si anisotropic wet etching. Figure 2a shows the microscope images of the PDMS channel cross-sections. For the single-stream focusing device, we connected a rectangular channel and the non-rectangular channels (triangular channel and half-circular channel) to control the accessible equilibrium positions (Figure 2b).

![Figure 2: (a) Channel cross-sections of the non-rectangular channels. (b) Microfluidic channel with varying cross-sectional shapes. The bottom focusing position in the half-circular channel become inaccessible.](image)

RESULTS AND DISCUSSION

A half-circular channel has 2 focusing positions and triangular channels have 3 focusing positions as shown in Figure 3. Similar to rectangular cross-section channels [4], focusing positions appear near the middle of channel side walls for the 54.7° triangular channel while top two focusing positions are closer to the corner in the 45° triangular channel. Particles also display regular inter-particle spacing.

![Figure 3: (a) High speed microscopy images of particle focusing and ordering (Top view & Side view). (b) Velocity profile overlapped with measured equilibrium position from statics of high speed microscopy images (N>3000, R_p=3.4) and confocal microscopy images of fluorescent particle streaks in the cross-section of channels](image)

In the single-stream focusing device, particles are first focused at two equilibrium positions in the rectangular cross-section (R_p=3.4). As the particles move to the triangular channel in the down-stream, they migrate to the top two equilibrium positions (blue circles in Figure 2b). At the end of the triangular
channel, 99.15% ± 0.22% of particles are found at the top focusing position as shown in Figure 4a. The particles at the top focusing position in the triangular channel then migrate to the top focusing position of the half-circular channel. The ratio of particles found at the top focusing position was 99.23% ± 0.12% (Figure 4b). This ratio does not change noticeably with varying $R_p$ (1.7~3.4).

Figure 4: Population of particles focusing at side position of triangular channel and top position of semi-circular channel ($N=1000, R_p=3.4$ in rectangular channel)

CONCLUSION

We investigated focusing positions in non-rectangular channels and used the channel with varying cross-section to focus the particles in a single stream. These results demonstrate new methods to manipulate particles using inertial microfluidic systems.

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REFERENCES


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