DESIGN OF A RADIAL MICROFLUIDIC FILTER FOR CONTINUOUS HIGH-THROUGHPUT CLOG-FREE OPERATION

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ABSTRACT

Pillar-based microfluidic filters for size-based particle separation are limited by clogging. In dead-end filters, micropillars are arranged perpendicular to the flow to facilitate capture of rare cells. But these filters get clogged fast (~ minutes). Cross-flow filters avoid clogging by arranging the pillars parallel to the main flow and use side flows to sort smaller particles. We report a novel microfluidic filter that combines the respective advantages of dead-end and cross-flow designs. We have separated 1µm polystyrene beads from 7µm beads with 99% purity. The device could operate for ~ 8 hours without clogging or needing any reverse flow.

KEYWORDS: Microfluidic Sorting, Radial Pillar Filter, Clogging-Free, High Throughput

INTRODUCTION

Dead-end pillar-based microparticle separation devices have an inherent clogging problem. One of the simplest ways to avoid clogging is to use cross-flows [1], leading to a larger device footprint. We report a small-footprint RAdial PIllar Device (RAPID), which combines the clogging-free operation of cross-flow devices with the ability of the dead-end pillar geometry to capture rare cells. The device (fig. 1A) has a central sample inlet and several concentric rows of pillars arranged in three zones. There are two final outlets at the device periphery and an intermediate outlet (in Zone B) perpendicular to the final outlets. Aggregates and large debris are filtered in Zone A. Zone B has an angular displacement in successive rows of pillars, which leads to strong tangential cross flows towards the intermediate outlet. The cross flow carries with itself most of the large beads.

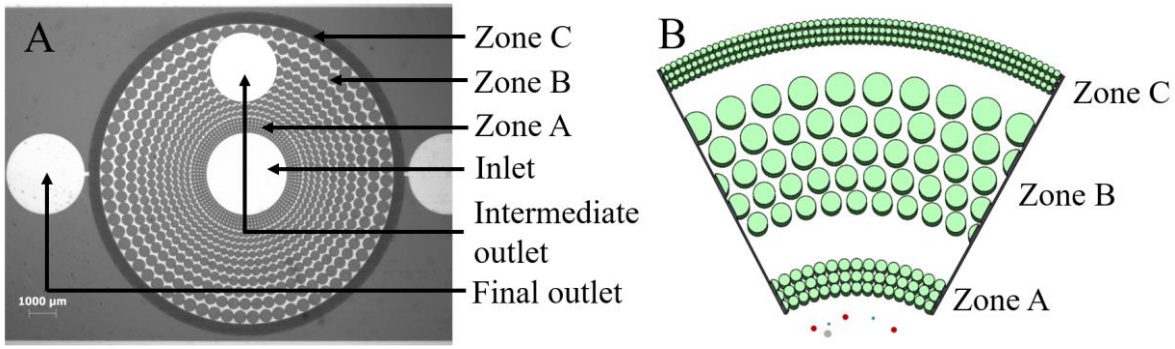

Figure 1: Radial Pillar Device (A) A photo of the device shows the concentric arrangement of pillars in different zones. The sample is loaded through the central inlet. Smaller particles move radially through the device and are collected from the final outlets, while larger particles move tangentially along the cross flows set up in zone B and reach the intermediate outlet. (B) A schematic diagram shows the arrangement of pillars in RAPID. Zone A has appropriate pillar gaps to filter out bead aggregates. Zone B has an angular displacement between successive pillar rows to create tangential cross flows for carrying large particles to the intermediate outlet. Zone C stops large beads and allows the smaller beads to reach the final outlets.

EXPERIMENTAL

Devices were fabricated in polydimethylsiloxane (PDMS) using standard soft lithography. We mixed microparticles of two different sizes (1µm and 7µm) and separated them using RAPID. 7µm diameter polystyrene particles (Sigma 78462) were diluted with DI water in the ratio 1:250 (v/v). Next, 1µm diameter fluorescent polystyrene particles (Sigma L1030) were added to the 7 µm particle solution in 1:1000 (v/v) ratio. To avoid microparticle aggregation, 1% Tween 20 was added to the sample and sonicated for 5 minutes. Finally, the bead sample was loaded into a 1ml syringe and mounted on a syringe pump. Sorting was performed using different flow rates from 100 µl/min to 3ml/min. Sorted samples were collected from the intermediate and the final outlets simultaneously until 100 µl sample was collected from each. The collected sample was sonicated for 5 minutes,

followed by 5 minutes of vortexing. The number of beads in the inlet and the outlets were collected using a hemocytometer.

RESULTS AND DISCUSSION

RAPID is extremely efficient in separating small (1µm) particles, with a sample recovery of 90%, separation purity of 99% and continuous clog-free operation. Fig. 2 (A-D) shows the path of an air bubble (red arrow) along the cross flow in zone B. Fig.2 (E) shows the tangential path taken by a 7µm bead (green) in zone B and the radial path taken by a 1µm bead (yellow) through zone C. Fig.2 (F-H) compares the filtration performance of the device with a dead-end filter design (with the same number of pillars in the first row). The dead-end device gets blocked within ~ 3 minutes due to stacking of large beads, while the throughput of RAPID remains at ~90%. We can achieve a throughput of ~3 ml/min, which is much higher compared to the size-selective filters reported in the literature. Compared to the dead-end design, our radial design achieves up to 4-fold increase in separation purity and sample recovery for larger (7µm) beads.

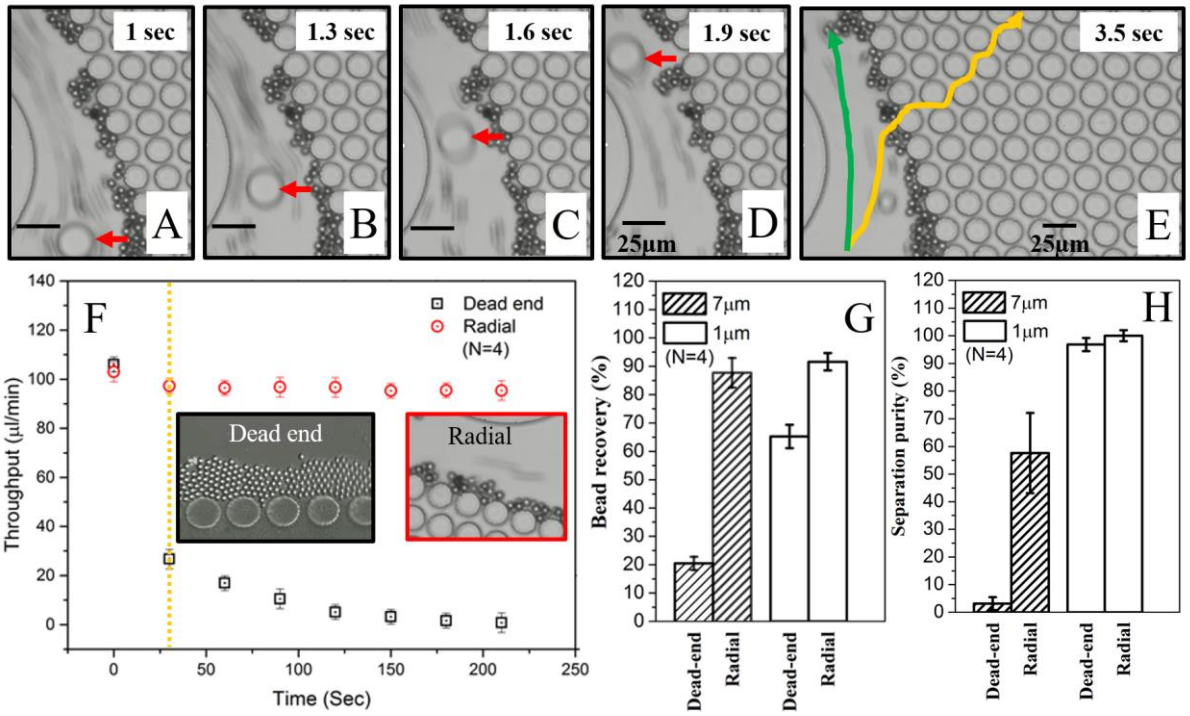

Figure 2: (A-D): Time-lapse images show the tangential path taken by a bubble (successive positions shown by the red arrow). (E): Tracks of a 1µm bead (yellow, along radial flow) and a 7µm bead (green, along tangential cross flow). For similar operating conditions, throughput (F), purity (G) and recovery (H) of larger beads in RAPID is much higher compared to dead-end pillars.

CONCLUSION

RAPID combines the advantages of dead-end pillar and cross flow devices for long time clogging-free operation, while maintaining high throughput, purity and recovery.

ACKNOWLEDGEMENTS

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REFERENCES

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