A. Abstract

We have designed a novel pumpless acoustofluidic device for the concentration and separation of different particle sizes inside a single-layered straight polydimethylsiloxane (PDMS) microchannel. The proposed device comprises two parallel interdigitated transducers (IDTs) positioned underneath the PDMS microchannel. The IDTs produce high-frequency surface acoustic waves that generate permittively-interactive virtual acoustic radiation force fields that selectively trap and concentrate larger particles at different locations inside the microchannel and allow the smaller particles to pass through the acoustic filter. The performance of the acoustofluidic device was first characterized by injecting into the microchannel a uniform flow of suspended 1.2-µm-diameter particles with various initial concentrations (as low as 10 particles/µL/mL) using a syringe pump. The particles were trapped with ~100% efficiency by a single IDT actuated at 73 MHz. The acoustofluidic platform was utilized to demonstrate the pumpless separation of 1.2-µm, 4.8-µm, and 2.1-µm microspheres by trapping the 12.µm and 4.8-µm particles using IDTs actuated at, respectively, 75 MHz and 140 MHz. Most of the 2.1-µm particles flowed past the IDTs unaffected.

Pros:
- Device operation could be visualized without a microscope.
- The position of the aggregates could be shifted inside the channel by precisely controlling the input power.
- Each concentration colony of different particle sizes could be collected at the outlet for further analysis.
- Disposable PDMS microfluidic chip could be replaced with a new one and the IDTs could be reused.

B. Introduction: Literature review

Surface acoustic wave-based particle concentration and separation devices

1. Schematic diagram of the microchannel, along with an experimental image of the particles (0.9 µm green fluorescent) concentrated inside the microchannel due to the ARF (middle). Hemocytometer images of the inlet sample solution and the outlet collected sample illustrating the efficient concentration of microspheres inside the microchannel (left).

2. Characterization of the particle trapping concentration inside the microchannel

3. Concentration of particles by TSAR

C. Working mechanism

Surface acoustic wave interacting microchannel:

- A particle suspended in a fluid within a microfluidic channel experiences a direct acoustic radiation force (ARF), which draws particles to theRayleigh angle, thus producing two components of the ARF.

High-throughput particle separation device:

- Since the magnitude of the vertical component (Fz) of the ARF is more than twice the magnitude of the horizontal component (Fx), a high-throughput acoustofluidic device was presented that effectively utilized the major force component to separate hydrodynamically focused particles in the vertical plane.

D. Results: Characterization

1. A pumpless device for the concentration and separation of particles

(A) Power on: blue particles flowed through the microchannel unaffected, whereas the red and green particles were trapped. (B) Power on: after washing with ethanol, red and green particle bands were clearly observed. (C) Naked eye view of the concentrated different diameter particles inside the microchannel. (D) Hemocytometer images displaying the separated particle samples collected at the outlet of the microchannel.

1. Frequency = 73 MHz
   - Particle size = 9.4 µm
   - Sample concentration = 10 particles/µL/mL
   - Flow rate = 5 µL/hr

E. Results: Trapping & Separation

1. A novel acoustofluidic technique is presented for manipulating particles of different diameters inside a single-layered microchannel without the presence of any pump. Particles from an extremely low-concentration solution could be detected, trapped, and concentrated in an efficient manner inside the microchannel. This device feasibility is particularly useful for concentrating and isolating disease markers, such as cancer cells, bacteria, or viruses. The operational simplicity of the TSARs has rendered the TSARs as a virtual wall for the concentration of selective particles in the microchannel while allowing non-target particles to pass through it. The proposed method is non-contact, non-mixing, and label-free. These features are particularly significant for biotechnological and biomedical research. The present acoustofluidic chip does not require the induction of external pumping action to inject a sample solution into the microchannel. Moreover, the operation of this device (trapping, concentration, separation) can be visualized without a microscope. These device characteristics reduce the need for external equipment and could be useful for point-of-care testing applications.

F. Conclusions

H. Contact information

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