HIGH-EFFECIENCY BLOOD CELL SEPARATION USING STANDING SURFACE ACOUSTIC WAVES

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ABSTRACT

Here, we demonstrate a label-free particles/cells separation technique using interdigital transducers. The separation device is an integrated microfluidic chip and utilizes the contrast in the acoustic properties of a continuous liquid phase and the objects contained therein, so it can separate particles and cells based on the differences of many properties such as volume, compressibility, and density. Our non-invasive acoustophoresis based separation method shows extremely high separation efficiency and has potential significance in biomedical and diagnostic applications.

KEYWORDS

Particle separation, cell separation, surface acoustic waves, microfluidics, lab on a chip.

INTRODUCTION

To date, many methods capable of particle and cell separation in microfluidic systems, such as centrifugal methods [1], magnetic force [2], hydrodynamic force, dielectrophoretic (DEP) [3], and bulk acoustic waves (BAW) [4] have been developed. These methods have pioneered many new avenues to on-chip cell separation; however, they also suffer from drawbacks such as limited control, low cell viability and proliferation and/or requirements on bulky equipments. DEP and BAW based separation methods suffer from specific requirements on the conductivity and density of medium. Here we introduce a microfluidic separation device using tilted standing surface acoustic waves (SAWs). Our approach can separate particles/cells using tilted standing SAW without labeling or medium modification. Previously we demonstrated continuous polystyrene beads separation through standing surface acoustic wave (SSAW)-induced acoustophoresis in a microfluidic channel [5]. However, the separation efficiency in our previous study [5] is only 85%, and has not shown any cells study. Built upon our previous work, here we demonstrated an improved cells separation technique that achieves a high separation efficiency of 95% or higher.

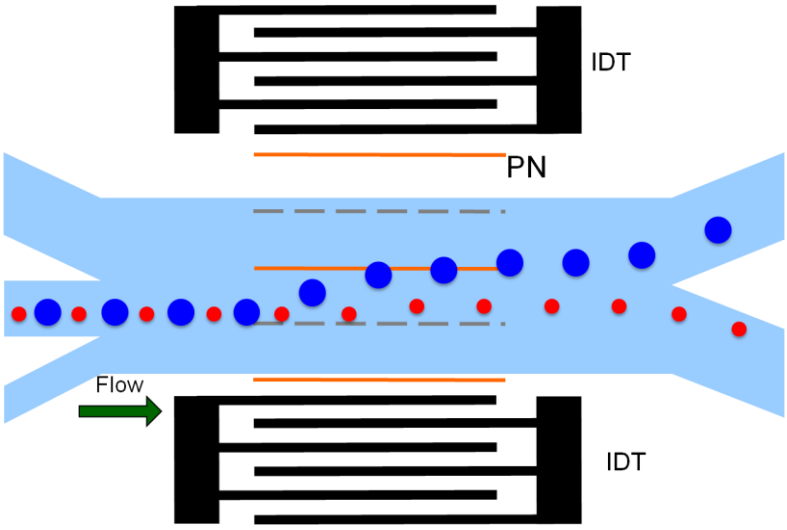

Figure 1: Schematic and working mechanism of the SAW-based cell separation device

EXPERIMENT

The SAW-based cell separation device (Fig. 1) consists of a polydimethylsiloxane (PDMS) channel and a piezoelectric substrate with a pair of interdigital transducers (IDTs). The channel locates in between the two IDTs in the 1-dimensional (1D) standing wave field. Applying AC signals to the IDTs generated two series of identical-frequency surface acoustic waves (SAWs) which propagated

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in opposite directions toward the channel. The constructive interference of these two SAWs resulted in a standing SAW in the area where the microchannel was bonded. Such standing SAW field consists of a series of pressure nodes parallel to each other, called 1D pressure nodes. Fig. 2 is an optical image of the cell separation device. When the particles enter the standing SAW field, they will be pushed to the parallel 1D pressure nodes. Simultaneously, the hydrodynamic force will push the particles along the flow direction. Since the acoustic force is proportional to the particle size, they will be pushed towards the sidewall across the channel with different velocity. Particles with different size will travel along different distance. Larger particle will travel farther, as shown in figure 1. By optimizing the amplitude of SAW and the flow rate, we can ensure that the acoustic force is large enough to push large particles out of the small particles flow stream in the standing SAW region.

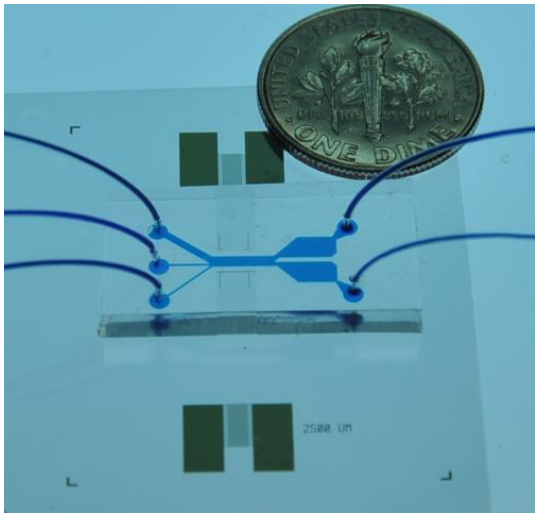

Figure 2: An optical image of the SAW-based cell separation device.

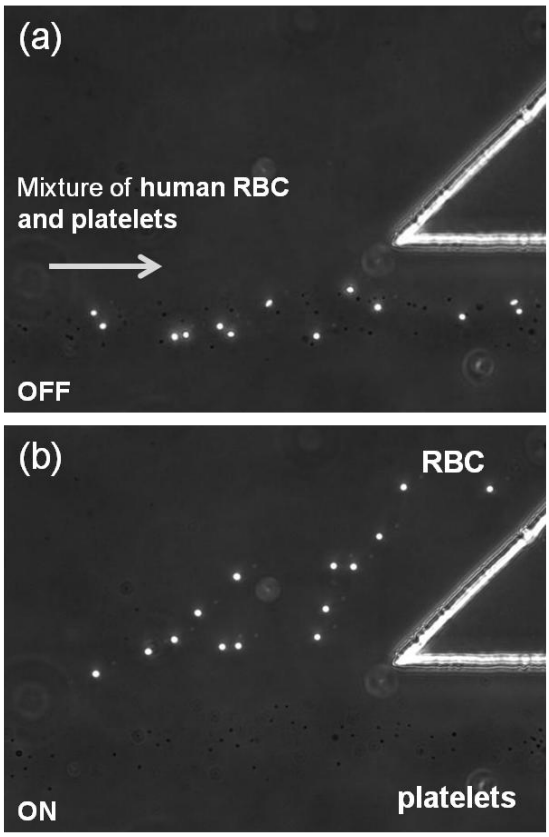

Figure 3: The sepaeration of human red blood cell (RBC) and platelet. When the power is off (a) human BRC and platelet are mixed, when power is on (b), BRC and platelet are separated and go to different outlet channel.

Figure 3 shows the separation process of human red blood cell (RBC) and platelet under phase contrast microscope. The bright large cells are human red blood cells, and the black small cells are platelets. When the standing SAW field is off, both small and big particles are mixed and follow the flow to lower outlet channel (Fig. 3 a). When the standing SAW field is on, big particles are extracted from the main stream and move to upper channel (Fig. 3b), while the small particles remain in the original flow and go to lower outlet channel. The separation efficiency is defined by the ratio of cells collected in the outlet to the cells in the inlet. Our preliminary experiments demonstrate a separation efficiency of ~95% for red blood cells and a separation efficiency of ~100% for small platelets. The separation efficiency is plotted in figure 4. The data was collected through cell counting based on the recorded video.

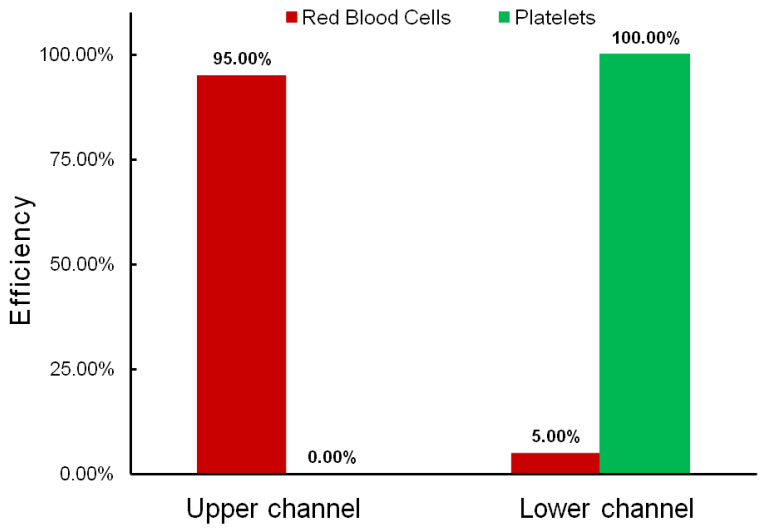

Figure 4: Separation efficiency of cells in each outlet channel based on preliminary results.

Our SAW-based particle separation method features high separation efficiency, low power consumption, easy fabrication and handling, low cost, versatility, and rapid response time. It is able to separate particles based on the differences of many properties such as volume, compressibility, and density. These characteristics, including the label-free feature, make our method promising in many biomedical, chemical, and diagnostic applications.

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