Integrated Microfluidic and Optical Sorting System

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Introduced in 1969, optical force method utilizes a focused electromagnetic beam to exert forces on microparticles, allowing them to be easily manipulated. This non-invasive and sterile method requires no other mechanical support, making it an ideal choice for handling sensitive samples in many biophysics applications. Furthermore, since the strength of the force varies with particle's properties such as flow speed, size, and refractive index, this method proves itself extremely useful in sorting microparticles. With the above technique, we constructed a microfluidic device for sorting yeast cells according to their intrinsic properties. The system comprises a network of crossed, coupled channels cast in poly(dimethylsiloxane) (PDMS) and an infrared laser beam emerging from the objective lens in an optical microscope. When suspended yeast cells matching specific criteria approach the junction from the lower channel, they are pushed to the upper channel by the optical force due to the laser beam. We also formulated the optimal parameters, namely flow rate and size, in order to maximize sorting efficiency, which could be used as a reference for further industrial development.

Introduction

•Optical force involves using a ***focused electromagnetic beam*** to exert forces on microparticles.

•It is ideal as it is non-invasive, sterile and requires no other mechanical support.

•Compared to other procedures, optical force has many advantages.

•Motivation: Separation of cancer cells in blood sample

Objective

•Use optical force to separate yeast cells

•Capture videos of the separation of yeast cells

•Determine the optimal parameters for maximum separation efficiency

Experimental Procedures

Three main steps: fabrication of PDMS chip, introduction of microparticles into PDMS, data analysis

•1. Fabrication of PDMS chip

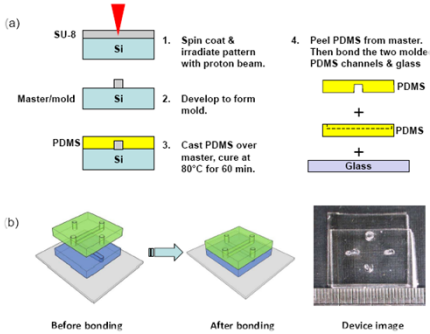


Fig. 1: Process of making the chips

•2. Introduction of microparticles into PDMS chip

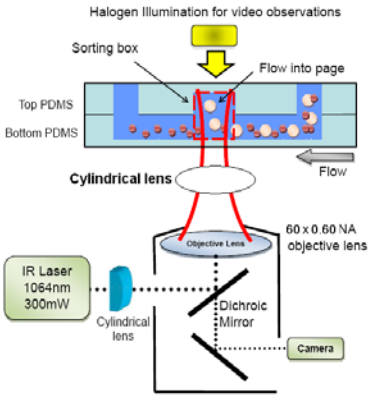


Fig. 2: Schematic of optical sorting microfluidic system with focused laser applied at the junction of the two overlapping channels

•***Gradient force*** slows down the cells while ***Scattering Force*** pushes them up.

•With a low numerical aperture objective lens, the scattering force outdoes gradient force, deflecting the cells up

•***Scattering force*** increases as the ***size, refractive index*** of the cells and ***intensity of the laser beam*** increase.

Results and Analysis

By analyzing more than 1500 seconds of videos (about 38000 frames***).***

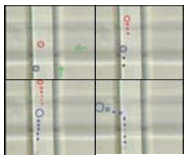
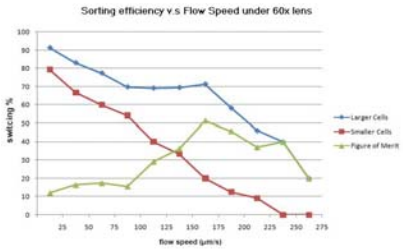


Fig.3*: Trajectories of sorted and unsorted cells produced by the device.*

1. Effect of flow speed on sorting efficiency.



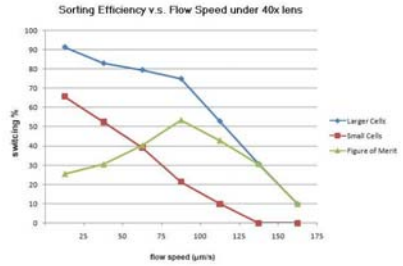


Fig 4: Graph of sorting efficiency (%) versus flow speed(um/s)

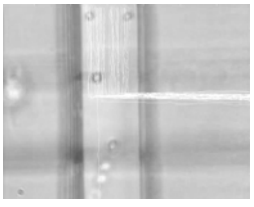
•Switching percentage gradually decreases for both big and small cells.

•However, it drops faster for small cells as the scattering force on them is smaller

•This difference in switching percentage is the sorting efficiency (FOM)

•FOM peaks at 175-200 μm/s for 60X lens and 75-100 μm/s for 40 X

•At very high speeds, essentially no cells are switched



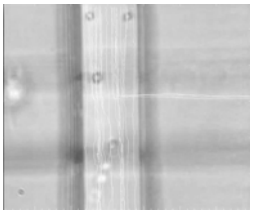


Fig. 5*:*

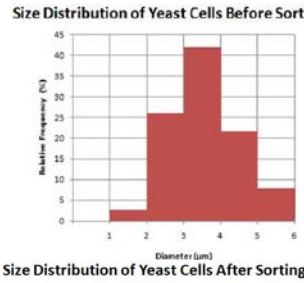
(a) Trajectory of big cells (diameter > 3 μm)

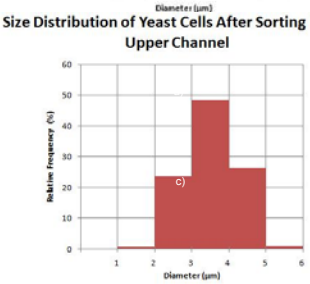
(a) Trajectory of small cells (diameter < 3 μm)

•Essentially all big cells are switched to the upper channel

•Nearly all small cells continue straight ahead in the lower channel

2. Effect of cellular size on sorting efficiency.





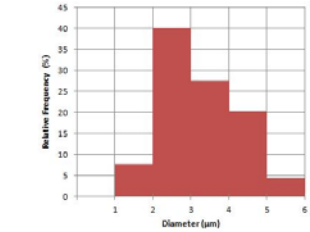


Fig 6: *Histograms of yeast cell size distribution*

•Before sorting, distribution peaks at 3-4 micron

•In the upper channel, distribution peaks at 4-5 micron

•In the lower channel, distribution peaks at 2-3 micron

Conclusion:

•The relationship between flow speed and sorting efficiency has been determined, allowing for more efficient separation with future potential.

•As seen from the graphs and microscope images, the maximum sorting efficiency is achieved at 175 μm/s to 200 μm/s for 60x lens and 75 to 100 μm/s for 40x lens.

•The plated inverse structure seems to show optical properties of the metal used at on a nano-scale.

•The fabrication of spheres depend on the amount of energy each sphere has.

Future Extensions

•Using the technique to purify spherical impurities from rod-shaped ZnO nanowires.

•Sorting biological cells from 8-10μm.

•Multiplexing a high-powered laser beam to multiple sorting junctions, enabling parallel sorting with higher thoroughput.

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