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Microfluidic particle sorting system for environmental pollution monitoring applications

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Abstract

Microfluidic system was designed and fabricated for particle separation and sorting by their hydrodynamic parameters such as cell size or density to be applied for sample preparation in optical scattering based pollution monitoring device. The hydrodynamic behaviour of the microfluidic structure was modelled and predicted by Finite Element Method (FEM) using COMSOL Multiphysics code to calculate the flow field and the geometry dependent particle trajectories. The microfluidic system was manufactured by soft lithography and tested by fluorescent microscopy applying two different labelled particles with 10 and 16 μm diameters. The results of the experimental analysis were in accordance with prior FEM estimations and showed successful size dependent sorting of particles.

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Keywords: microfluidics; Lab-On-a-Chip; cell sorting

1. Introduction

The rapid development of microscale diagnostic (Lab-on-a-Chip) devices has underlined the importance of microfluidics enabling fast and effective preparation and analysis of liquid samples. Although on microscale, classical sample preparation methods might become challenging, such as the effective mixing of fluids as well as the size-dependent separation of corpuscles and their sorting or filtering from the liquid samples. This leads to the development of novel microfluidic structures based on the physical laws of this size domain. [1] The aim of our

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work was to develop a passive microfluidic separation system applicable for pre-sorting pollutant particles (pollens, bacteria, grains) in environmental samples having different geometric or physical parameters. To achieve effective size dependent sorting of the particles dispersed in the liquid sample a combination of different inertial separation methods were applied, utilizing the pinched flow fractionation, the Dean and the lateral migration based separation subsequently [2].

2. Experimental

Computational fluid dynamics (CFD) simulations, trajectory modelling and its experimental validation were covered to characterize in details the performance of the combined inertial microfluidic separator systems. The different separation structures were characterized by numerical modelling to reveal and predict the effects of the shear, Dean-drag and viscous lift forces evolving in the low Reynolds regime. COMSOL Multiphysics code was applied to calculate laminar and stationary velocity field by solving the Navier-Stokes equation. This velocity field was used for the determination of individual particle trajectories influenced by the hydrodynamic forces. A number of spherical particles were initiated with random position at the inlet plane to determine their spatial distribution at the outlet.

The results were verified experimentally after fabricating the system (Fig. 1) in polydimethylsiloxane by rapid prototyping.

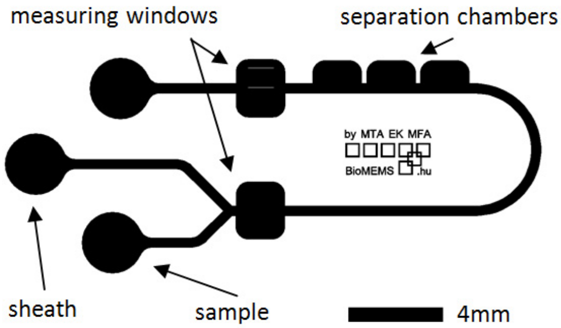

Figure 1. Schematic structure (mask layout) of the microfluidic system fabricated by soft lithography.

3. Results

The modeled particle trajectories were visualized (Fig. 2) and colored according to their size. The separation of black (10 µm particle diameter) and white (16 µm diameter) lines were visible and also demonstrated by their spatial distribution in Fig. 3.

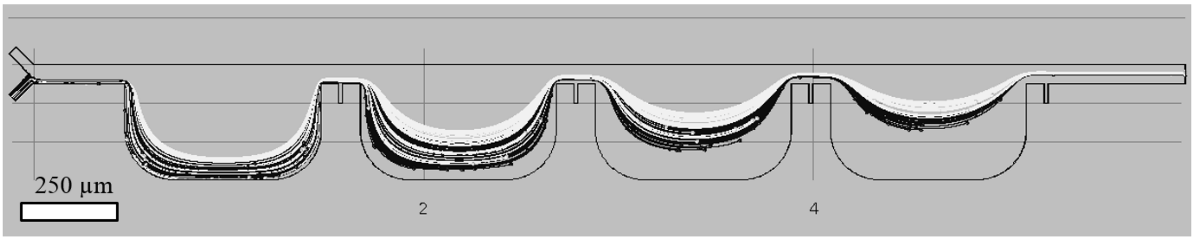

Figure 2. Modelled particle trajectories developing in the lateral migration based passive separation system (particle diameters: 16 µm – white lines and 10 µm – black lines)

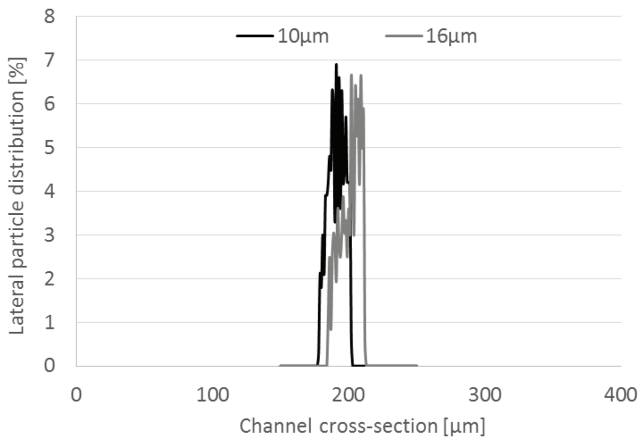

Figure 3. Modelled size dependent lateral distribution of the particles at the cross-section of the outlet of the lateral migration based microfluidic separation system.

The trajectories of fluorescently labelled particles (diameters: 10 µm - FITC and 16 µm - DAPI) were recorded experimentally also in the proposed and fabricated microfluidic system presented in Fig. 1. At the inlet particles were uniformly mixed (Fig. 4).

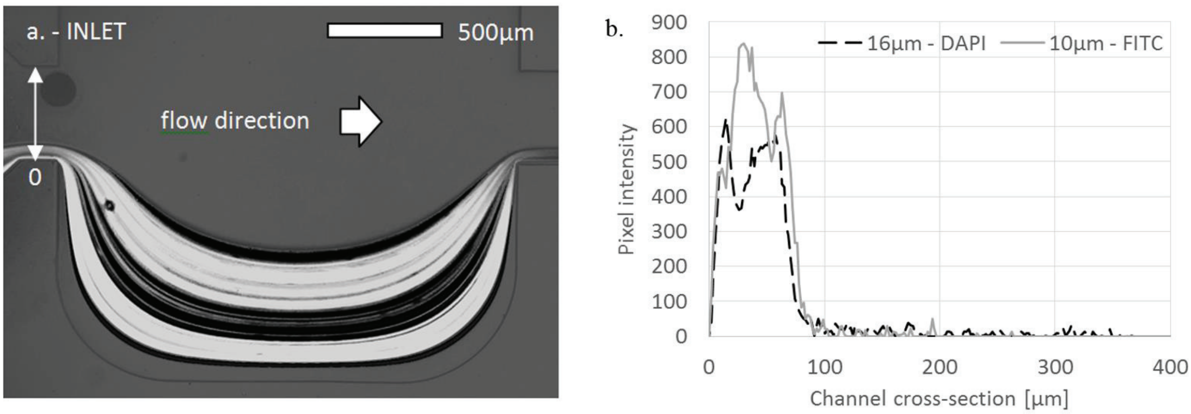

Figure 4. Recorded trajectories (a) and intensity analysis (b) of different fluorescent labelled beads at the inlet (diameters: 16µm – white lines – DAPI and 10µm – black lines – FITC). The two bead sizes are well mixed, their distributions overlap.

Particle trajectories recorded at the outlet shows clearly the separation of the two sizes (Fig. 5). Sorting performance of the microfluidic system was demonstrated by the spatial distributions of the particle populations (Fig. 4b – 5b).

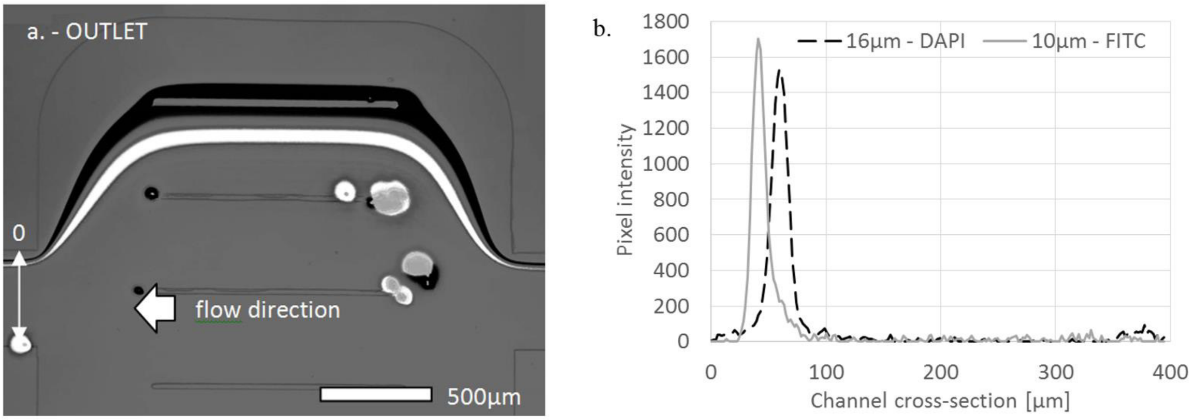

Figure 5. Recorded trajectories (a) and intensity analysis (b) of different fluorescent labelled beads at the outlet (diameters: 16 µm – white lines – DAPI and 10 µm – black lines – FITC). The two bead sizes hence their peak of distributions are separated.

4. Conclusions

Based on the simulation and measurement results, the main characteristics of the proposed substructures were described and their functional efficiencies were compared, and technical recommendations were also provided for further improvement of separation structures to be integrated into environmental monitoring device.

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The support of the National Research, Development and Innovation Office (NKFIH) EUREKA HU 13-1-2013-0016 grant, the KAP grants (KAP15-061, KAP16-71005, KAP15-166) and the grant KTIA-NAP 13-1-2013-0001 are greatly acknowledged.

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