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Efficiency test on the experimental design of micromachined blood separation system based on Zweifach-Fung effect

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Abstract

When aiming a complete microfluidic analysis system for human blood tests the blood plasma separation should be preferably also integrated in the device. The sensitivity of the analysis is significantly affected by the sample quality, so in this work the efficiency of the Zweifach-Fung effect based microfluidic separation systems was characterized. The microstructures were fabricated by simple replication in polydimethylsiloxane applying SU-8 photoresist master beside extensive variation of the geometric parameters.

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1. Introduction

Significant number of the clinical tests are aimed to quantitatively or qualitatively analyse the presence of proteins, ions, crystalloids or diluted gases in human blood. In this case, the presence of blood cells in the sample could be a serious drawback, so the first stage of the tests must be the separation of plasma or serum from the whole blood. [1]

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Utilizing the Zweifach-Fung effect, cell-free, pure plasma can be yielded. The effect was described by Zweifach and Fung [2, 3] who observed blood cells following the direction of the critical stream between capillaries of different diameter according to the Bernoulli and shear force effects arising on the surfaces of the cells as schematically shown in Fig. 1. Several applications of the effect have been presented in Lab-on-a-chip devices fabricated by micromachining technologies. [4]

2. Fabrication

To evaluate the efficiency of Zweifach-Fung plasma filtering method, different test structures were designed and realised by micromachining technology in polydimethylsiloxane (PDMS) using SU-8 photoresist master as replica for the formation as Fig. 2 presents.

Fig. 1. Schematic view of the blood separation test structure

Fig. 2. Test structures fabricated in PDMS representing the parameter field denoted in Table I.
The geometric parameters were varied to define the optimal microfluidic structure that can be integrated to a sample preparation system. Three different side channel widths, and angles and five different main channel lengths were tested, applying all possible parameter permutation as given in Table I.

Table I: parameters used to fabricate passive filters (Zweifach-Fung)

<table>
<thead>
<tr>
<th>Side channel widths</th>
<th>16 µm / 10 µm / 6 µm</th>
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<tr>
<td>Hydrodynamic resistance ratios (determined by the main outlet channel length)</td>
<td>1:2 / 1:4 / 1:6 / 1:8 / 1:10</td>
</tr>
<tr>
<td>Crossing angles</td>
<td>90° (a) / 60° (b) / 30° (c)</td>
</tr>
</tbody>
</table>

3. Results

The hydrodynamic resistance ratios as significant parameters were set by the length of the main transport channels. These parameters absolutely influence the flow rates in the main and side channels and therefore the pressure gradients and shear forces, too. The efficiency of several structures was investigated applying fungi dispersed in buffer solution (Fig. 3) modelling the human blood regarding particle sizes and hydrodynamic properties. The focusing effect was observed and characterized by the locality distribution of the particles in the lateral cross-section of channel (Fig. 4).

Fig 3. Particle transport in the microfluidic channels, representing the separation effect
Fig. 4. Probability of the cross-sectional locality of the particles inside the main fluidic channel.

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