Optimization of the Herringbone Type Micromixer Using Numerical Modelling and Validation By Measurements

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Abstract

Biomedical sciences facilitated fast detection methods for many diseases recently. The development of this field has led to the dynamic development of Lab-On-a-Chip devices which are portable, require small sample size and have low cost. Fluid manipulation in such bioanalytical systems is a key issue. One of the key features of these devices is the sample preparation which includes the dilution and complete mixing of the analyte with reagents of adequate buffer solution. The mixing possibilities are limited on microscale, since turbulent flow cannot occur due to the dominant viscosity. Chaotic advection can be considered as an ideal mixing method in microfluidic channels as the flows are laminar. The herring-bone like ridges on the channel of the herring-bone type micromixers (Figure 1) act as anisotropic fluid resistance generating secondary transversal flow.

The Laminar Flow interface of COMSOL Multiphysics® software was used to solve the velocity field of the micromixer to characterize fluid flow properties. For modelling the mixing phenomena two approaches were used. Mixing by diffusion along the channel was modeled with Transport of Diluted Species interface. To avoid numerical diffusion and high computational cost we used the Particle Tracing module to observe mixing at the level of particles. To optimize the mixing efficiency we conducted a parametric sweep on the thickness of the ridges.

Secondary flow and the rotation caused by the herring-bone structure were well observable in the velocity field (Figure 2). The concentration distribution calculated by COMSOL Multiphysics® showed that a high concentration fluid layer was rotated into a low concentration region resulting more surface area for mixing by diffusion. Poincaré map of particle trajectories (Figure 3) showed the layered structure of particle distribution which was similar to the baker's transformation.

Modeled herring-bone structures were fabricated in polydimethylsiloxane (PDMS) using multilayer technology. The SU-8 epoxy-based photoresist was applied as molding replica. An improved 3D multilayer formation from SU-8 was developed so that microfluidic systems with high aspect ratio sidewalls and advanced functional parts could be fabricated well. Dye was

used for the measurement of mixing by diffusion and yeast cells were used for the particle approach. Pictures were recorded in inverted microscope with bright field imaging. The scattered light from the yeast cells provided good signal (Figure 4). The measurements confirmed the rotation caused by the ridges and also the layered flow characteristics.

COMSOL Multiphysics® was used in this study to simulate mixing by diffusion and by secondary flow. Particle tracing model was applied to simulate the mixing of cells in the microchannel. Results agreed well with the measurement, an optimal herring-bone structure was proposed for integration into a bioanalytical system.

Reference

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3. Aránzazu del Campo and Christian Greiner, SU-8: a photoresist for high-aspect-ratio and 3D submicron lithography – Topical Review, J. Micromech. Microeng., 17, R81–R95 (2007)

Figures used in the abstract

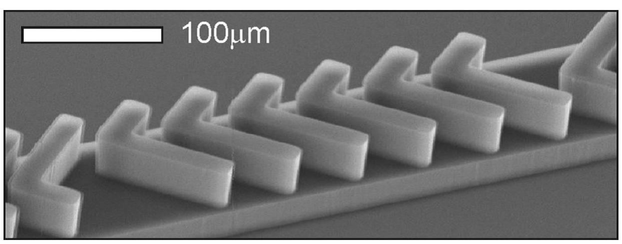

Figure 1: SU-8 moulding replica for the Herring-Bone type mixer structure fabricated by SU-8 3D multilayer technology.

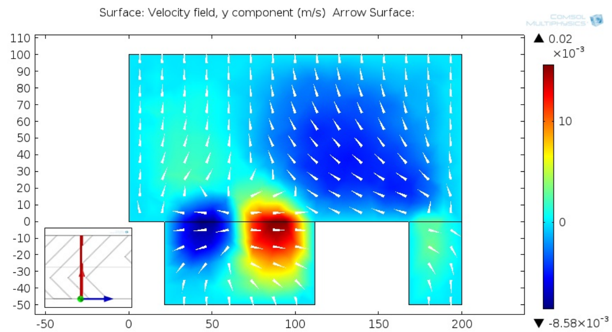

Figure 2: Rotation caused by the ridges in the velocity field plane. . Red and blue areas show the different flow directions in the same cut plane.

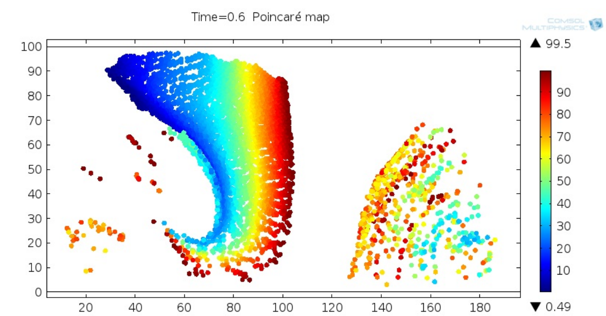

Figure 3: Poincaré map of particle trajectories at the outlet. Color of particles denotes their initial y coordinates. Layered distribution is well observable.

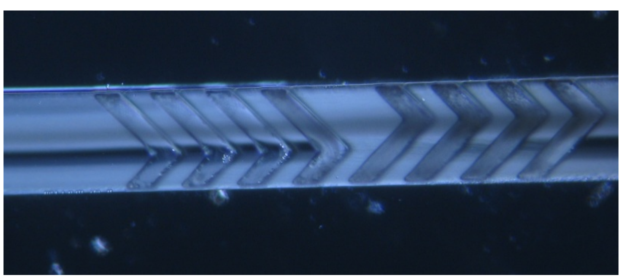

Figure 4: Measurement of the mixing using bright field microscopy and yeast. Bright areas have high yeast cell concentration. Layered structure of the fluid flow is visible.