COMSOL Simulation of Bio-MEMS Rotating Microfluidic Mixer

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Abstract

Microfluidic flows in MEMS devices are generally laminar flows, hence the mixing is difficult. To improve the mixing of microfluidic flows, a passive or active micromixer device is needed. In this poster, the design and simulation of a Bio-MEMS rotating microfluidic mixer is proposed. The micromixer takes three input flows and generates one output flow. A rotating blade is used to stir the microfluid inside the mixer to introduce extra turbulence, hence resulting in better mixing outcome. Compared to passive micromixer, the proposed active rotating micromixer leads to better mixing efficiency. The microfluidic mixer is designed and simulated in COMSOL. COMSOL simulation reveals the mixing mechanism of the microfluid flows. Based on the analysis, a set of optimized design parameters of the micromixer is achieved. The proposed micromixer can be used for micro drug delivery system, lab-on-a-chip and other biomedical applications.

Introduction

Micromixer is a device used to mix different fluidics, which is an essential process in microfluidic systems such as micro total analysis systems (µTAS). Micromixers are generally implemented onto Lab-on-a-Chip devices in a microscale to provide an intimate contact between the reagent molecules for interactions/chemical reactions. They can be either passive or active. Compared to passive micromixers, active micromixers needs external energy, but generally result in better mixing efficiency. Various active micromixers based on electrical, magnetic, electrokinetic, thermal, hydrodynamic or other actuation techniques have been reported. In this poster, a bioMEMS (bio-Microelectromechanical Systems) micromixer utilizing rotating blade to enhance the mixing efficiency is proposed. COMSOL microfluidic simulation is used to verify the effectiveness of the micromixer. The pressure and velocity plots of the microfluid inside the mixer is achieved. Simulation results show that by introducing a rotating blade, more turbulence is achieved and it results in significant improvement on the mixing efficiency.

Micromixer Design

In this poster, we designed the micromixer using COMSOL in order to simulate the performance. It consists of three channels as inlet and one as outlet, and four rotating blades, as shown in Figure 1. The blades can rotate either clockwise or counter-clockwise. COMSOL 2D model is developed to simulate the microfluid behavior of the mixer. The design parameters of the micromixer are listed in Table 1. Three inlets are fed with microfluid flows with different concentrations (0, 1mol/m^3 and mol/m^3) to verify the mixing effectiveness of the micromixer.

Table 1. Micromixer Design Parameters

Micro Mixer Design Parameters	
Chamber width/height	6mm/6mm
Inlets width/height	0.5mm/1mm
Outlet width/height	1mm/1mm
Blades width/height	0.2mm/5.25mm
Inlet#1 concentration	0 mol/m^3 (pure water)
Inlet#2 concentration	1 mol/m^3
Inlet#3 concentration	2 mol/m^3
Inlet velocity	0.02 m/s
Inlet pressure	6 Pa
Blades rotating speed	1 revolution/sec

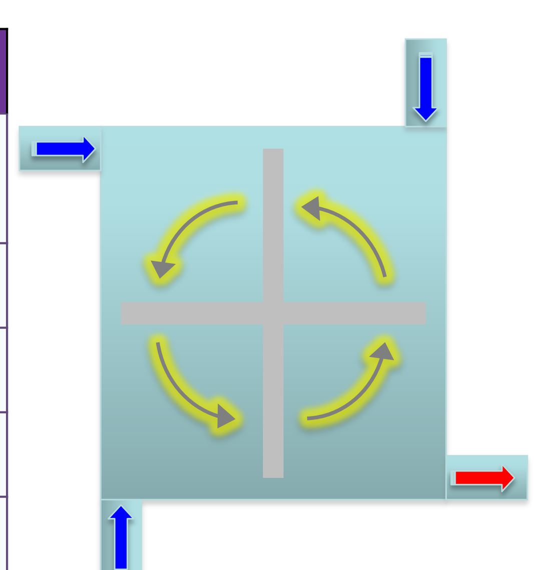
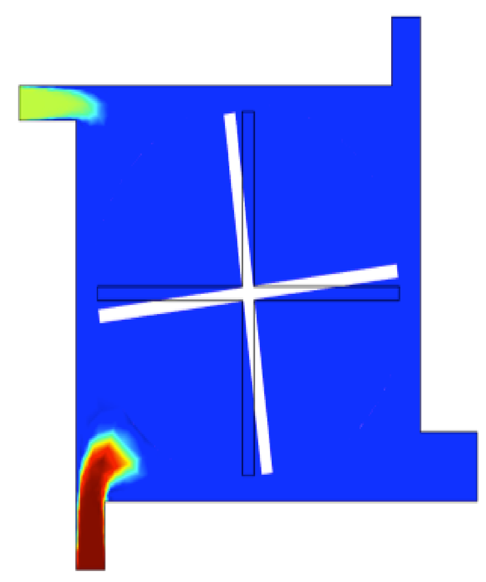


Figure 1: 2D view of MEMS Micromixer design.

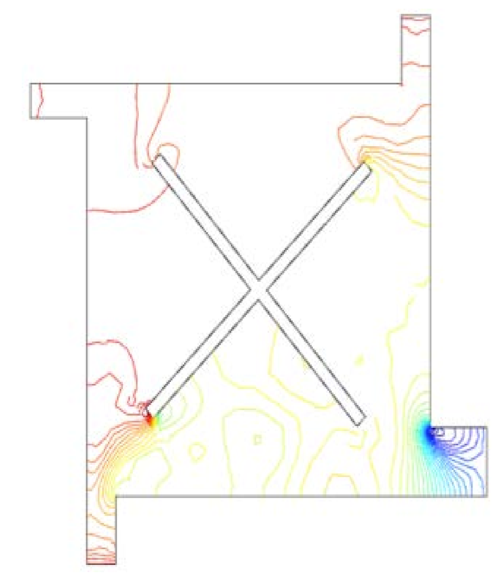
Working Principle

The proposed BioMEMS rotatory micromixer has three inlets and one outlets. Passive microvalves are pre-fabricated at the inlets and outlet to ensure that the microfluid can flow only along one direction, but not the opposite direction. The microblades can be activated to rotate either clockwise or counterclockwise. By introducing rotating blades, it induces more turbulence, hence leads to significantly improved mixing efficiency.

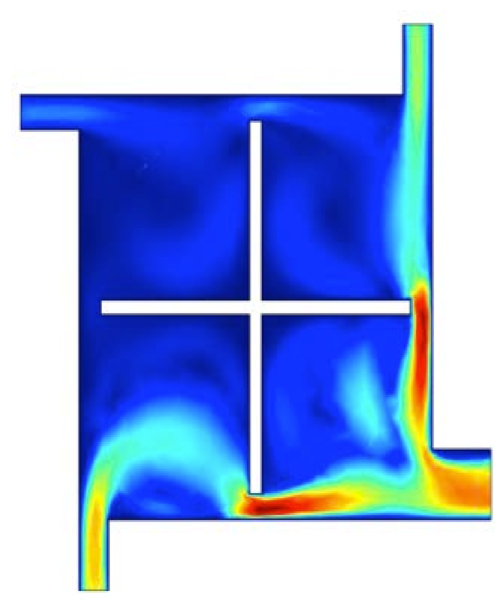
COMSOL Simulation



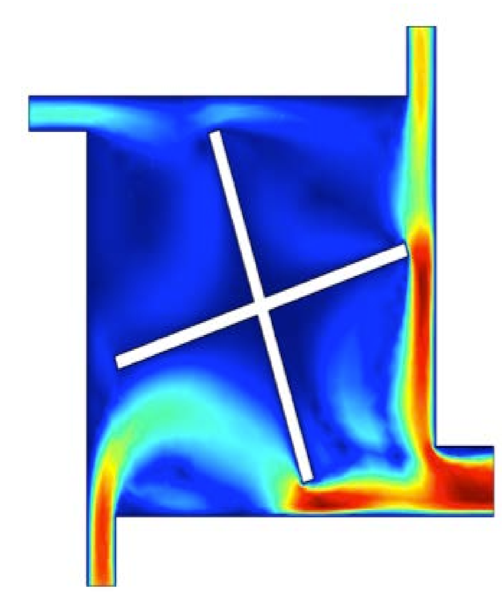
Concentration(mol/m^3) at t=0.2s
c1=0, c2=1mol/m^3, c3=2mol/m^3



Pressure= 6Pa at t=0.6s



Velocity (m/s) plot at t=1.0s



Velocity(m/s) plot at t=1.5s

Mixing Efficiency

In order to explain the microfluidic behavior inside the mixer, we need to find the optimal flow operation conditions by:

$$\mathcal{E}_{\text{mixing}} = 1-\frac{1}{w}\int_0^w \left|\frac{X_{\text{Ax,outlet}}-0.5}{X_{\text{Amax}}-0.5}\right| dx \quad (1)$$

Where X_{Amax} is the maximum mole fraction of fluid A, X_{AX},outlet is the mole fraction of fluid A at the outlet, W=1mm denotes the outlet width. Reynolds number is calculated by:

$$\text{Re} = \frac{\rho V_0 W}{\mu} \quad (2)$$

where ρ is the density of fluid; V_0 is the average velocity of the inlet channel; W=0.5mm is the width of inlet channels or W=1 mm is the width of the outlet channel; μ is the dynamic viscosity of the working fluid. So, governing equations during the mixing process can be obtained by solving the continuity, momentum and diffusion equations, to come up with:

$$\frac{\partial V}{\partial t} + V * \nabla V = -\nabla p + \frac{1}{Re}\nabla^2 V \quad (3)$$

Conclusion and Future Work

In this poster, COMSOL simulation of an active microfluids mixer with rotating blade is proposed. The working principle of the micromixer is analyzed in details. The rotating blade significantly improve the mixing efficiency by introducing extra turbulence. In the future, we will see how multiple blades rotating at differential scheme would help the mixing efficiency.

References

Wang, C.-T., Hu, Y.-C., & Hu, T.-Y., "Biophysical Micromixer", *Sensors*, Volume *9, Issue* 7, pp. 5379–5389, 2009.