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The Effect of the Using Hybrid Micro Mixers in Mixing Efficiency Enhancement

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Abstract

In this paper the effect of using Hybrid Micro Mixers in Mixing Efficiency of Mixer is evaluated via simulations and Three Mixers with different performance are simulated. Simulations show that with using Hybrid Micro Mixer, the performance is improved. Therefore, Hybrid Mixers have the advantages such as lower cost and simpler structure compared with Active Micro Mixers.

Key Words: Micro Mixer; Micro Fluid; PERFORMANCE; flows; Passive; Active.

1. Introduction

Microfluidic devices have had a considerable impact on the fields of biomedical diagnostics and drug development , and are extensively applied in the food and chemical industries [1]. For example, Micro laboratories for biochemical applications often require rapid mixing of different fluid streams. At the microscale, flow is usually highly ordered laminar flow, and the lack of turbulence makes diffusion the primary mechanism for mixing. While diffusional mixing of small molecules can occur in a matter of seconds over distances of tens of micrometers, mixing of larger molecules can require equilibration times from minutes to hours over comparable distances. Such delays are impractically long for many chemical analyses. However, the specific Reynolds number of liquid flows in such microchannels is very small. These problems have led to an intense search for more efficient mixers for microfluidic systems.

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Most microscale mixing devices are either passive mixers that use geometrical stirring, or active mixers that use moving parts or external forces, such as pressure or electric field. However, Passive mixers often require very long mixing channels because the different fluids often run in parallel. Another way of improving mixing efficiency is to use active mixers with moving parts that stir the fluids [2,3]. In comparison, active micromixer requires moving element either within the channels, a time-variant, or a pressure field. Although, active micromixer provides higher efficiency than a passive Micro Mixer but integration of moving elements increases the complexity of the system and also need complicated fabrication process [4]. In this paper, we propose a novel mixing method that is based on hybrid structure by using the capabilities of Active and Passive Mixers to improve its mixing efficiency and performance.

2. Theorical Analysis

The fluid stream in micro channel is laminar flow without turbulence which is expressed as Navier-Stokes equation for an incompressible flow as Equation (1) [5]. For predicting the flow characteristics, a dimensionless parameter called Reynolds number is defined. Reynolds number is the ratio of inertial forces to viscous forces as Equation (2). At the microscale, the Reynolds number is small in value and viscous effect is dominant and the mixing efficiency is derived from DM (Mixing Degree) equation for different mixers as Equation (3). where ρ is the density of fluid, u is the velocity, μ is the viscosity and p is the pressure, DH is the hydraulic diameter of channel and μ is the fluid viscosity, N is the number of the inputs, c_i is the concentration of the output and $\bar{c}$ is define for an ideal mixer. When the amount of the Mixing Degree is high , the mixing efficiency is optimum.

$$\rho\frac{\partial u}{\partial t} - \nabla\mu(\nabla u + (\nabla u)^T) + \rho u.\nabla u + \nabla p = 0 \qquad (1)$$

$$Re = \frac{\rho.u.DH}{\mu} \qquad (2)$$

$$\text{DM}= 1 - \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(\frac{Ci-\bar{C}}{\bar{C}}\right)^2} \qquad (3)$$

3. Simulation Method

In this work, COMSOL Multiphysics Software is used, which includes models of laminar flow, transport of diluted species for concentration profile of mixing, and particle tracking for fluid flow. Three different Micro Mixers, Active Mixer, Passive Mixer and Hybrid Mixer with the 2-dimensional structure model are being simulated. The value of fluid density, and viscosity are 1000 kg/m3 and 10-3 kg/(m.s). The fluid flows are laminar and there are no slips at the walls. there are two inlets and one outlet with fixed pressure equal to 0 Pa. The velocity profile is constant at the boundaries. The concentration profile and stream Line Velocity Field for three Mixers are shown in Figure 1. It is obvious, the Mixing efficiency is improved by making changes in Geometry. The Mixing profile for an improved shaped passive Mixer (No.2) is better than a Passive Mixer with a normal shape (No.1). Also, it is better than the Mixing Profile for an active Mixer without any changes in the shape of the channel (No.3). When an electric field is applied, it generates the flow in the direction of the electric flow. Therefore, we can increase the velocity u by increasing the potential V. The relation between the velocity u and the component of the electric field is shown as followed:

$$u = \frac{\varepsilon_w \zeta_o}{\eta} \nabla_T V \quad (4)$$

Whereas $\varepsilon_w = \varepsilon_0 \varepsilon_r$ denotes the electric field permittivity and ζ_o shows the potential at the wall of the channel [6]. The simulation results prove that the geometry is an important factor in Passive Mixers. Therefore, we proposed a Mixer with the advantages of both Active and Passive Mixers, the Hybrid Micro Mixer. Hybrid Mixer with improved-shaped channel, that compared with Passive Mixed, uses electrical Force as an external Force just at the beginning of the Process. The fluids enter a ring-shaped mixing chamber that has four micro-electrodes placed on the outer wall at angular positions of 45, 135, −45, and −135 degrees, respectively. Figure 2 shows, the Concentration profile of the Passive and Hybrid Mixers. It is shown that by using Hybrid Mixer, the Mixing efficiency is improved.

4. Conclusion

In this paper Three different Mixers are simulated. The results show that by using Hybrid Mixers, we can have the advantages of both Active and Passive Mixers. Hybrid Micro Mixers are more efficient that Passive Mixers with simpler structure than Active Mixers.

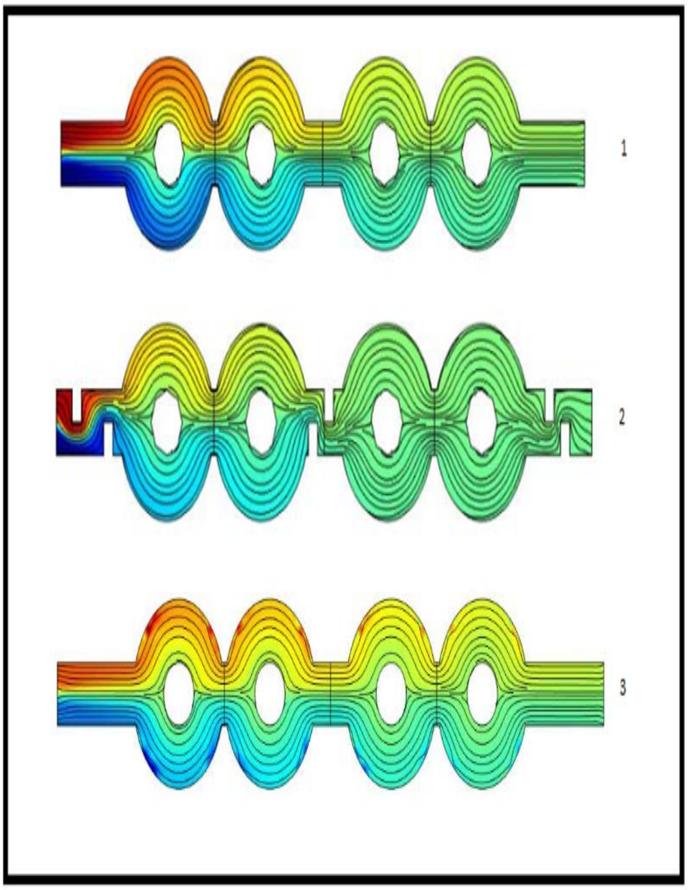

Figure 1: Concentration profile and stream line velocity field for three different Micro Mixers

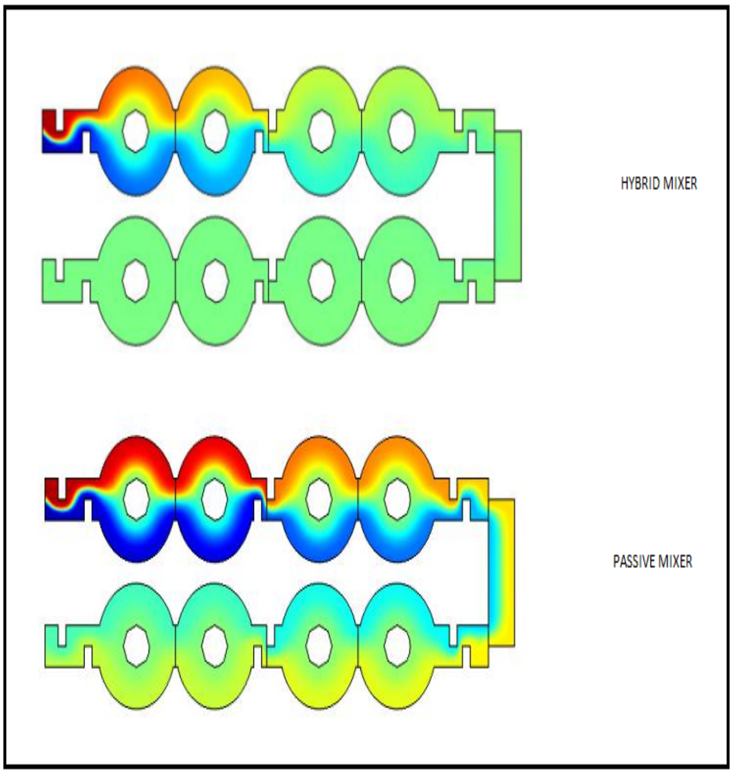

Figure 2: Concentration profile for Hybrid Mixer and Passive Mixer

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