An Effective Design and Simulation for Microfluidic Passive Mixing with Geometric Variation

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Introduction
To accomplish a complete and rapid mixing of numerous sample in micro-scale devices is the main objective of microfluidic devices. Generally, in micro-scale devices, low Reynolds number is considered which reflects the viscous force also has a great influence. Thus, the flow would be laminar and diffusion plays a dominant role in microfluidic mixing instead of turbulence. In this study, we have designed a passive microfluidic mixer to mix the fluid without any external energy force. Here, we have observed, the mixing efficiency is improving with appropriate choice of geometric variation. In this paper, a passive microfluidic mixer with and without obstacles has been designed and simulated to improve the mixing efficiency of fluids.

Method
All the simulation work has been done by using Comsol Multiphysics software. We chose Laminar flow (spf) and Transferred diluted species (tds) for the simulation of microchannel fluid mixing by coupling of convective-diffusion and Navier-Stokes equation. Two fluid with different concentration 0 and 1 mol/m³ respectively. Ideally, we would achieve the complete mixing at the last reservoir with average concentration of both fluids i.e. 0.5 mol/m³.

Navier-Stokes Equations
\[ \rho \left( \frac{\partial \mathbf{u}}{\partial t} + \mathbf{u} \cdot \nabla \mathbf{u} \right) = -\nabla p + \nabla \cdot (\mu (\nabla \mathbf{u} + (\nabla \mathbf{u})^T)) - \frac{2}{3}\mu(\nabla \cdot \mathbf{u}) + \mathbf{F} \]
\[ \nabla \cdot \mathbf{u} = 0 \]

Convection and Diffusion
\[ \frac{\partial c}{\partial t} + (\mathbf{u} \cdot \nabla) c = D \nabla^2 c \]

Result and Discussion
As a result, we achieved the complete mixing at the third reservoir. The significant mixing has been performed with ±0.03 mol/m³ tolerances. The efficiency of mixing is 96% with the corresponding values of 0.47 and 0.53 mol/m³.

Conclusion
In this paper, we have compared the mixing efficiency of micro-channel with and without barrier. As a result, we have achieved the complete mixing in the third reservoir of device with barrier compared to without barrier. We can conclude that the geometry variation has great impact on the mixing efficiency of microfluidic devices. In addition, this model could be useful in the macromolecule dynamics, single molecule studies, protein folding/misfolding as well as in the field of μTAS and lab-on-a-chip devices.

References