

Advanced Microfluidic Mixing Device for the Study of Macromolecule Dynamics

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Introduction

Micromixing is a crucial process within microfluidic systems such as micro total analysis systems. We have demonstrated a microfluidic mixer device to characterized and study the macromolecule dynamics such as kinetics of protein folding, DNA/RNA sequencing, single molecule study and detection etc. Geometric variation such as length, height, geometric shape and number of channel helps to enhance the mixing efficiency without applying any external force or energy. Low Reynolds number is considered to control the viscous force, thus the flow would be laminar. The Comsol Multiphysics platform has been used to study the simulation.

Method

In particular we use Laminar flow (spf) and Transported diluted species (tds) for the simulation of microchannel fluid mixing by coupling of convective-diffusion and Navier-Stokes equation. We chose two fluid with different concentration of 0 and 1 mol/m³ respectively. Ideally the last reservoir will give the average concentration of both fluids i.e. 0.5 mol/m³.

Navier-Stokes Equations

$$\rho \left(\frac{\partial u}{\partial t} + u \cdot \nabla u \right) = -\nabla p + \nabla \cdot (\mu(\nabla u + (\nabla u)^T)) - \frac{2}{3}\mu(\nabla \cdot u)\mathbf{I} + \mathbf{F}$$

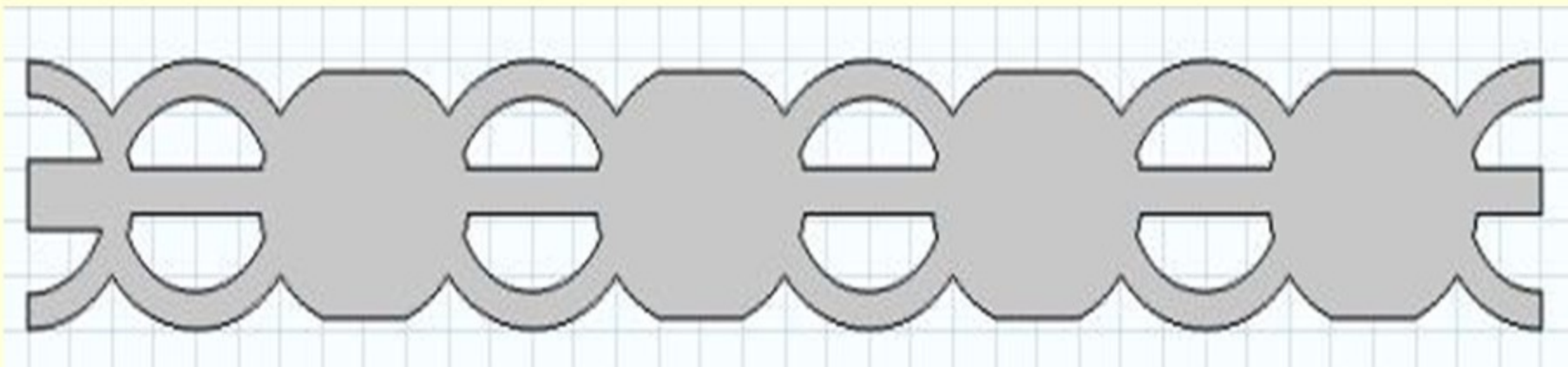
$$\nabla \cdot \mathbf{U} = 0$$

Convection and Diffusion

$$\mathbf{N}_i = -D_i \nabla c_i + c_i \mathbf{u}$$

$$\frac{\partial c_i}{\partial t} + \nabla \cdot \mathbf{N}_i = R_i$$

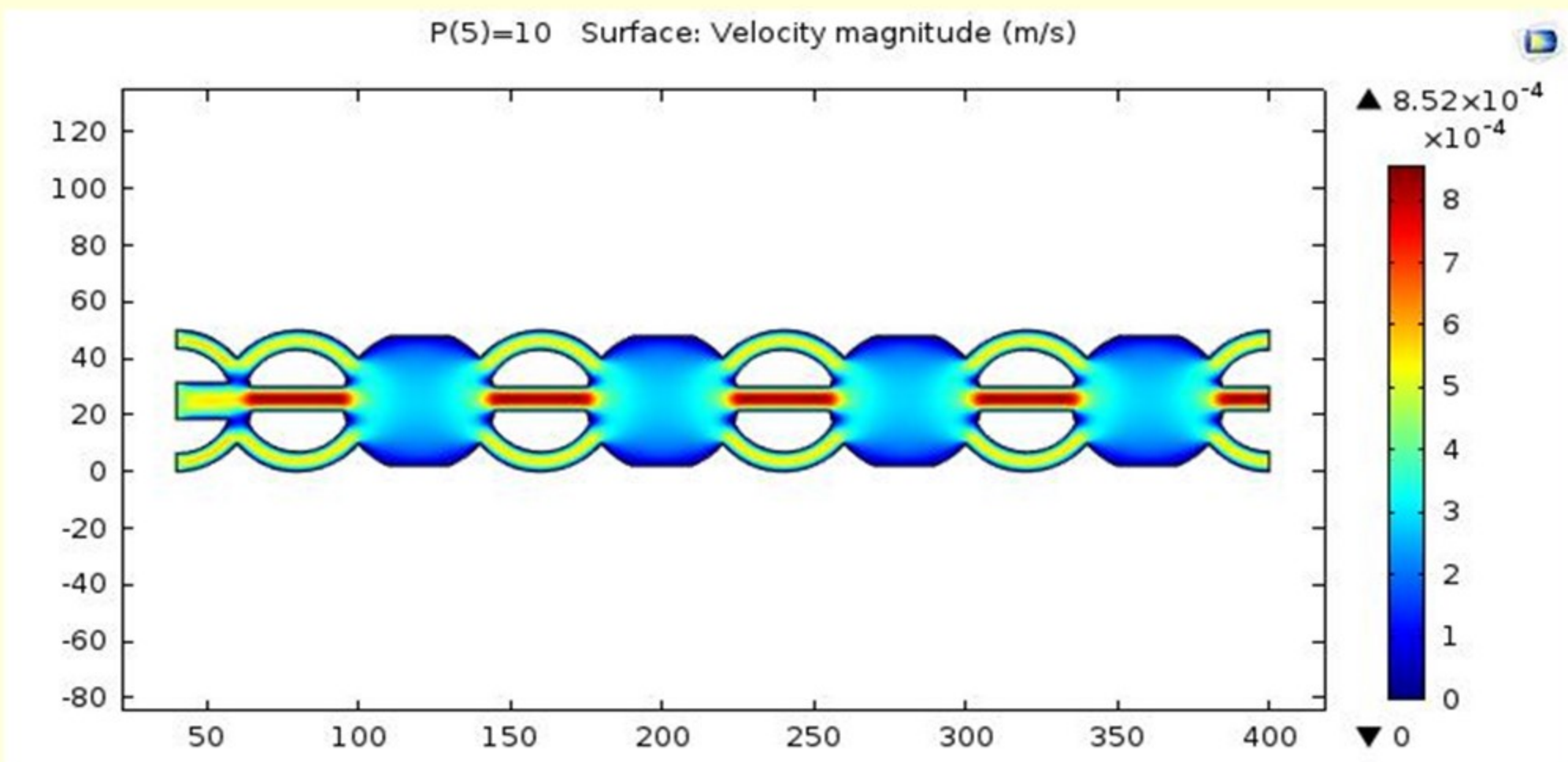
Geometry



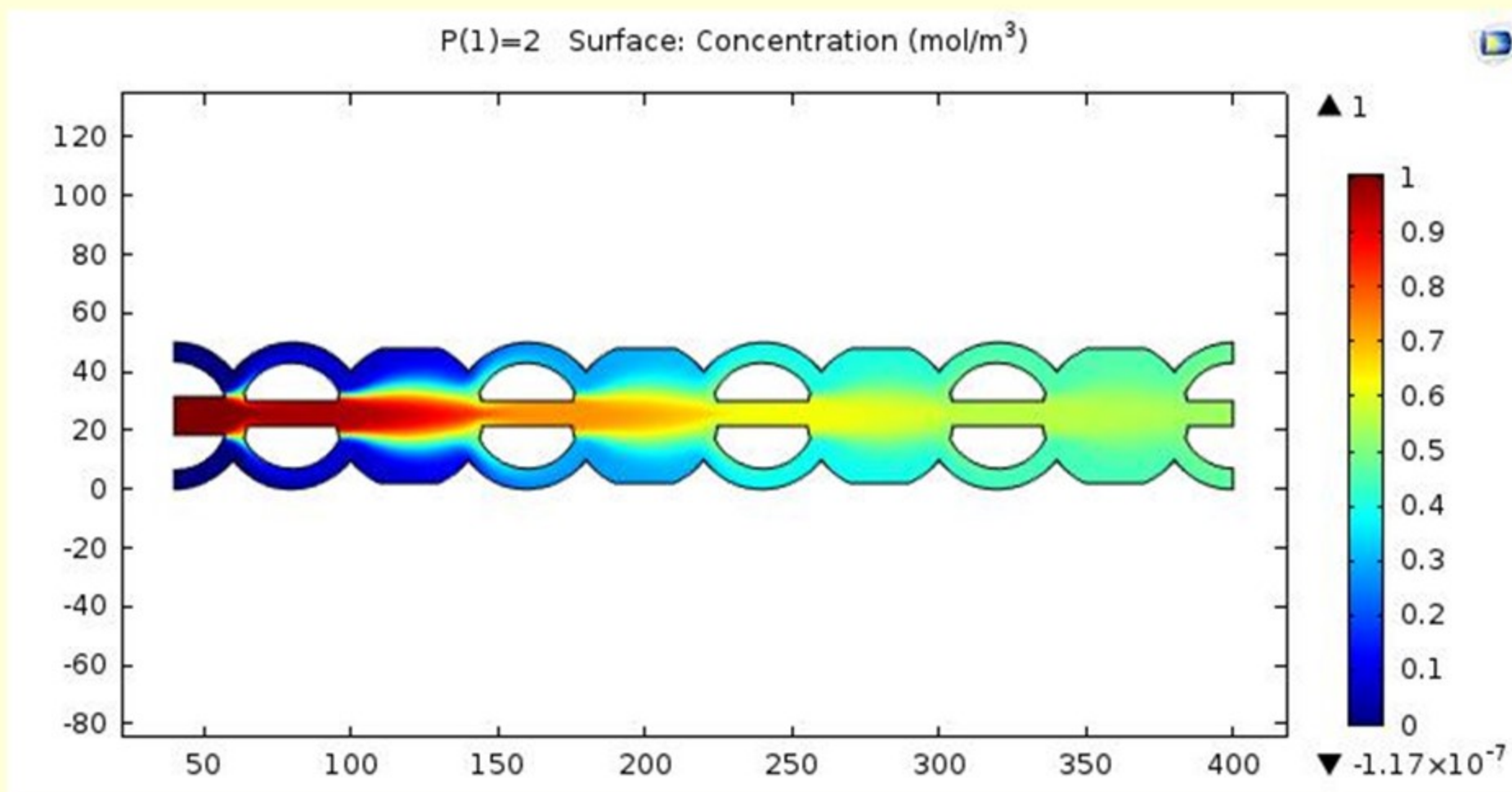
Result and Discussion

As a result we achieved the complete mixing at the end 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.

Velocity



Concentration



Conclusion

As we achieved the complete mixing in microchannel. Using the information gathered from the above simulation, by integrating the concept of microfluidic mixer with magnetic beads, make feasible to study the next-generation sequencing applications like genomic DNA sequencing of microbial species from single cell and protein RNA interaction.

References

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