Ferrofluid Mixing In Double-Layer Microfluidic Device With Microscale Magnet

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Abstract

Microfluidics-based mixing has been widely used in various areas such as chemical engineering, biomedical engineering and materials science. The micromixer can be strategies into two categories as passive and active method depending on the mixing principle. Magnetic mixing integrated into microfluidic system has been proved to be an efficient active method. Ferrofluid has been widely used as carrier medium in biological micromixer due to its advances of compatibility with bio-samples. Both permanent and electromagnet have been applied to actuate the mixing of ferrofluid, but the bulky size brings the problem that the precise manipulation is hard to be achieved.

In this work, a magnetic micromixer with embedded microscale magnet was developed and the simulation of mixing performance and working mechanism were done by COMSOL Multiphysics®. The the modelling work includes the Navier-Stokes equation, convective diffusion equation and magnetic fields generated by the micromagnet. The simulation of microscale mixing can be achieved by two steps. The magnetic field was calculated first and then coupled the mixing phenomenon processed by the Laminar Flow and Species Transport physics interfaces. Some variables such as total flow rate and magnetic field intensity were studied to characterize their effect on the mixing performance. The benchmark with four magnetic bars and total flow rate of 0.2 mL/h was developed and compared with experimental results indicating good agreement with each other. The conclusion of this work includes 1) the new design provides an efficient method for high-throughput ferrofluid mixing; 2) higher flow rate decreases the mixing performance due to the short resident time of magnetic force; 3) the increase of magnetic field intensity can accelerate the mixing performance of ferrofluid in microfluidic channel. This work enables the rapid magnetic mixing of ferrofluid on microscale and brings the its potential to be applied in biomedical applications.