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Magnetofluidics for Mass Transfer and Mixing Enhancement in a Micro Scale Device

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Abstract : Over the past few years, microfluidic devices have generated significant attention from industry and academia due to advantages such as small sample volume, low cost and high efficiency. Microfluidic devices have applications in chemical, biological and industry analysis and can facilitate assay of bio-materials and chemical reactions, separation, and sensing. Micromixers are one of the important microfluidic concepts. Micromixers can work as stand-alone devices or be integrated in a more complex microfluidic system such as a lab on a chip (LOC). Micromixers are categorized as passive and active types. Passive micromixers rely only on the arrangement of the phases to be mixed and contain no moving parts and require no energy. Active micromixers require external fields such as pressure, temperature, electric and acoustic fields. Rapid and efficient mixing is important for many applications such as biological, chemical and biochemical analysis. Achieving fast and homogenous mixing of multiple samples in the microfluidic devices has been studied and discussed in the literature recently. Improvement in mixing rely on effective mass transport in microscale, but are currently limited to molecular diffusion due to the predominant laminar flow in this size scale. Using magnetic field to elevate mass transport is an effective solution for mixing enhancement in microfluidics. The use of a non-uniform magnetic field to improve mass transfer performance in a microfluidic device is demonstrated in this work. The phenomenon of mixing ferrofluid and DI-water streams has been reported before, but mass transfer enhancement for other non-magnetic species through magnetic field have not been studied and evaluated extensively. In the present work, permanent magnets were used in a simple microfluidic device to create a non-uniform magnetic field. Two streams are introduced into the microchannel: one contains fluorescent dye mixed with diluted ferrofluid to induce enhanced mass transport of the dye, and the other one is a non-magnetic DI-water stream. Mass transport enhancement of fluorescent dye is evaluated using fluorescent measurement techniques. The concentration field is measured for different flow rates. Due to effect of magnetic field, a body force is exerted on the paramagnetic stream and expands the ferrofluid stream into non-magnetic DI-water flow. The experimental results demonstrate that without a magnetic field, both magnetic nanoparticles of the ferrofluid and the fluorescent dye solely rely on molecular diffusion to spread. The non-uniform magnetic field, created by the permanent magnets around the microchannel, and diluted ferrofluid can improve mass transport of non-magnetic solutes in a microfluidic device. The susceptibility mismatch between the fluids results in a magnetoconvective secondary flow towards the magnets and subsequently the mass transport of the non-magnetic fluorescent dye. A significant enhancement in mass transport of the fluorescent dye was observed. The platform presented here could be used as a microfluidics-based micromixer for chemical and biological applications.

Keywords : ferrofluid, mass transfer, micromixer, microfluidics, magnetic
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