Chaotic mixing inside a droplet advecting in a serpentine microgeometry is universal or not?

Yogesh M. Harshe, Michael van Eijk, Chris Kleijn, Michiel Kreutzer, Pouyan E. Boukany

Droplet-based microfluidic systems have been used for various applications in chemical and biological community including fast kinetic measurements, synthesis of nanoparticles, protein crystallization, single cell level gene expression, DNA amplification and others [1-3]. Achieving fast mixing is a crucial step for all of these microfluidic applications. It has been reported in the literature that introducing chaotic advection through a serpentine geometry enhances the mixing otherwise controlled by inherent molecular diffusion [4,5]. However, qualitative and quantitative description of this mixing inside micro-droplets is still debatable. This leads to two key questions: Specifically, if this mixing can be seen as baker's transformation and if there exists a universal scaling of the mixing time.

In this work, we have carried out systematic experiments to address above questions. We have studied the mixing of a dye inside a droplet flowing through a serpentine microgeometry (Figure 1). The time required to achieve complete mixing is determined by processing images (Figure 2) captured using a high-speed camera. The mixing time is related to the geometry, flow rates of two phases, and a scaling is proposed. Moreover, qualitative analysis is performed to understand the mixing process. The obtained results will be useful for designing and choosing appropriate operational conditions in lab-on-a-chip systems.

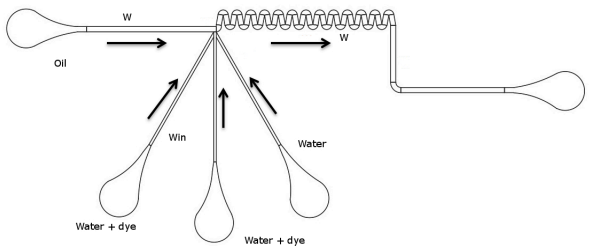


Figure 1: Schematic of microfluidic device

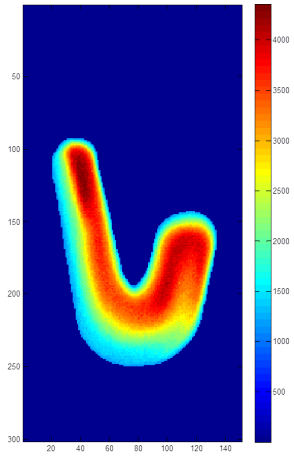


Figure 2: Concentration distribution of dye inside a micro-droplet at a bend in a serpentine microchannel

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