Numerical modeling of microfluidic systems and microscale phenomena

Description:

The integration of multiple unit operations into a microfluidic system requires a thorough conception prior to manufacturing and testing. Too many iterations of this process are costly both with respect to time and money consumption and should be reduced to a minimum. Since critical parameters of fluid behaviour, mixing rates and pressure drop cannot be determined analytically for complex, arbitrary geometries, numerical simulations are required to aid a rational design process. We are using finite-element based methods to: (1) characterize system layouts with respect to fluid dynamics and mixing of fluid streams, (2) predict undesired cell damage during sample processing, (3) evaluate mechanical cell disruption in microstructures as part of sample preparation for metabolic analysis and (4) characterize other microphenomena, e.g. particle deflection by magnetic or mechanical forces, species release from disrupted cells etc. Our goal is the implementation of computationally efficient models, which have been verified experimentally in our lab and which can be generally applied during the microfluidic systems design process.

Fig. 1. Comparison of a numerical simulation (top) with experimental results (bottom) for the flow of six different fluid sheaths in a microfluidic system.

Fig. 2. Characterization of a serial split-and-recombine micromixer. Numerical simulation (top) and experimental observations (bottom) are in good agreement.

Fig. 3. Micromechanical cell disruption is a reagentless and therefore promising method for the quick release of intracellular metabolites and organelles during sample preparation. Numerical simulations (top) predict the rate of disruption, which has been shown using micronozzles manufactured and tested in our lab.

References (selected)


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