

ELECTROKINETIC INDUCED MIXING IN MICRODEVICES

Danesh K. Tafti and Sundaram Narayan

Department of Mechanical Engineering
Virginia Tech
Blacksburg, VA 24061
dtafti@vt.edu
nasundar@vt.edu

Micro-total-analysis-systems have the potential for the integration of multiple functional units for the processing of chemical/biochemical samples. The processing might include sample injection, mixing with reagents, chemical reactions, pre-concentration, separation, and detection. By using micro-fabrication techniques developed in the electronics industry, these devices can be mass produced at low cost. Because of the small length scales of $O(10\text{-}100\text{ microns})$, and working volumes typically in the range of nano- to picoliters, the time response of these devices surpasses their macro-counterparts by orders of magnitude. In most applications, networks of microchannels are utilized for transporting buffers, analytes, and reagents through different functional units on the chip. Because of the extremely small velocities encountered in these devices ($< 1\text{ mm/s}$), and the small features, typical flow Reynolds number are less than one with mass diffusion coefficients for large macro-molecules are of $O(10^{-10}\text{ m}^2/\text{s})$. Hence rapid mixing of constituent species is a challenge.

A common form of motive force used in microdevices is the application of external electric fields. The externally applied electric field applies a force on free ions in the charged Debye layer very close to the surface (1-10 nanometers) and induces a flow velocity, which is proportional to the electroosmotic mobility and the electric field. In the study we investigate the use of time varying electric fields to generate mixing in microdevices. This work is motivated by the experiments of Oddy et al. [1], in which they showed experimentally that electrokinetic instabilities were found to develop under certain conditions in microchannels as well as in semi-enclosed microchambers. These instabilities were responsible for increasing the material contact surface and hence augmented the rate of mixing by an order of magnitude or more over pure diffusion.

The present computations study the mixing characteristics of electrokinetic instabilities induced in a microchamber. Through dimensional analysis and numerical experiments it is found that there is an optimal choice of non-dimensional frequency and driving potential which leads to the best mixing characteristics. This is given by the relationship $Re_{eof}/f^* < 5$ and the condition that $f^* = O(10)$. Here, Re_{eof} is a Reynolds number based on the electroosmotic velocity, and f^* is the non-dimensional frequency of the applied voltage. It is also shown that a modified chamber geometry with strategically placed microbaffles leads to mixing which is faster by a factor of two. The microbaffles introduce a rotational fluid cell in the chamber which continuously deforms and augments the material interface between constituent species. The characteristic time scale for mixing is reduced from $O(10^4\text{ sec.})$ by mass diffusion alone to $O(10\text{ sec.})$. Physical models, assumptions, numerical approximations will be highlighted along with parametric studies of different geometrical configurations and excitations.

References

[1] M.H. Oddy, J. G. Santiago, and J. C. Mikkelsen "Electrokinetic Instability Micromixing," *Anal. Chem.* v. 73, p. 5822-5832, 2001.