Computational Simulation of Electrohydrodynamic Systems Pertaining to Micro and Nano scale Fluid Flow Phenomenon

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Introduction

In this analysis we investigate the modeling challenges of computationally calculating systems of fluid flow phenomenon governed by A/C Electroosmosis in the micro and nano scale regime. Modeling of 3D AC electro-osmotic pumps is relevant to the creation of portable or implantable lab-on-a-chip devices for mm/s tunable fluid flows attainable with battery scale voltages.[1] It presents a modeling challenge as there exist analytic solutions to only the simplest of electroosmotic systems.

The development of a working model of A/C Electroosmotic fluid flow took the following sequence. First a model accounting for the Electric Potential, and the flux of two oppositely charged ions in a one dimensional domain due to both diffusive and convective flux of a DC potential was solved and expressed in a nondimensionalized representation as can be seen in Figure 1. This analysis was then extended to a two dimensional domain that was driven by a A/C potential. Proper solution of this model required the adaptation of Comsol Knowledge Base: 952 regarding the handling of negative concentrations whereby an expression for the concentration of an ion is replaced by its logarithm and the equations are handled accordingly. Figure 2. shows the representation of the two dimensional AC problem in relation to the uses of COMSOL Multiphysics. Lastly this model was extended and the Navier-Stokes Application Mode was incorporated with the relevant force body expressions of the electric fields on the local net charge of the fluid. Solution of this model corresponds to the solution of A/C Electroosmotic flow phenomenon.

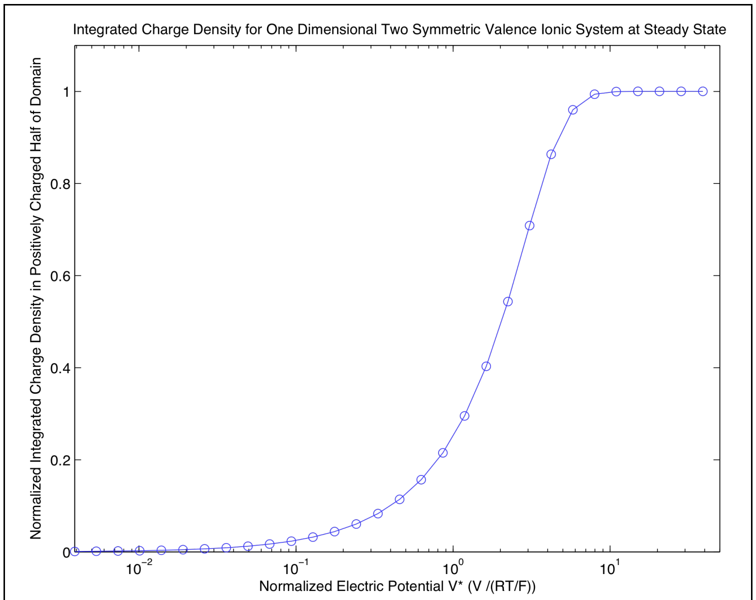

Figure 1. Integrated Charge Density normalized by the initial concentration of the positive ion and the length of the domain.

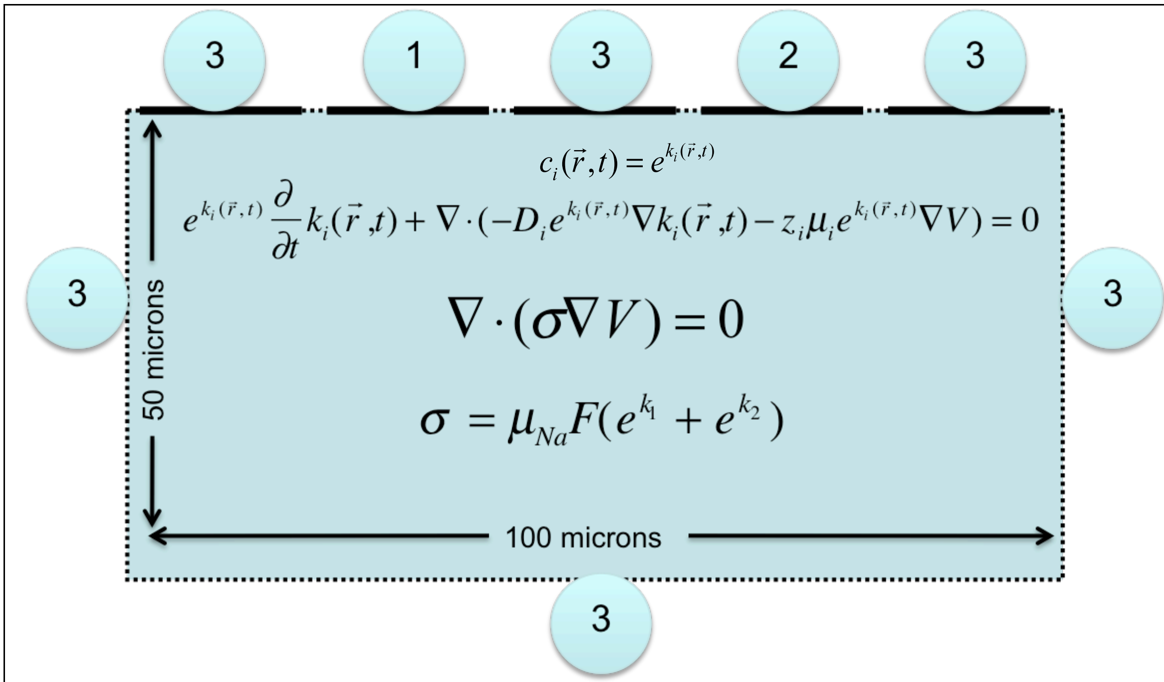

Figure 2. Diagram of model used for analysis of the logarithm model driven by A/C electric potentials.

Use of COMSOL Multiphysics

The system of Figure 2. was solved over a range of two orders of magnitude of the driving potential to find the resonance of the electrical system for ions with an electrophoretic mobility magnitude of that of sodium ions. Finding this resonance was accomplished by the execution of a script in Matlab. The values of the concentration of both ion species was made available to Matlab using the Postinterp() command. After which the time averaged integral of the error term squared between the least squares fit of the electric charge density at the driving harmonic and the numeric solution normalized by the number of degrees of freedom of the fit and the oscillation period was compared over the periods in which the model had been simulated, Figure 3. In such a way the harmonic resonance of the system can be expected at points in which there are local minimums in this graph.

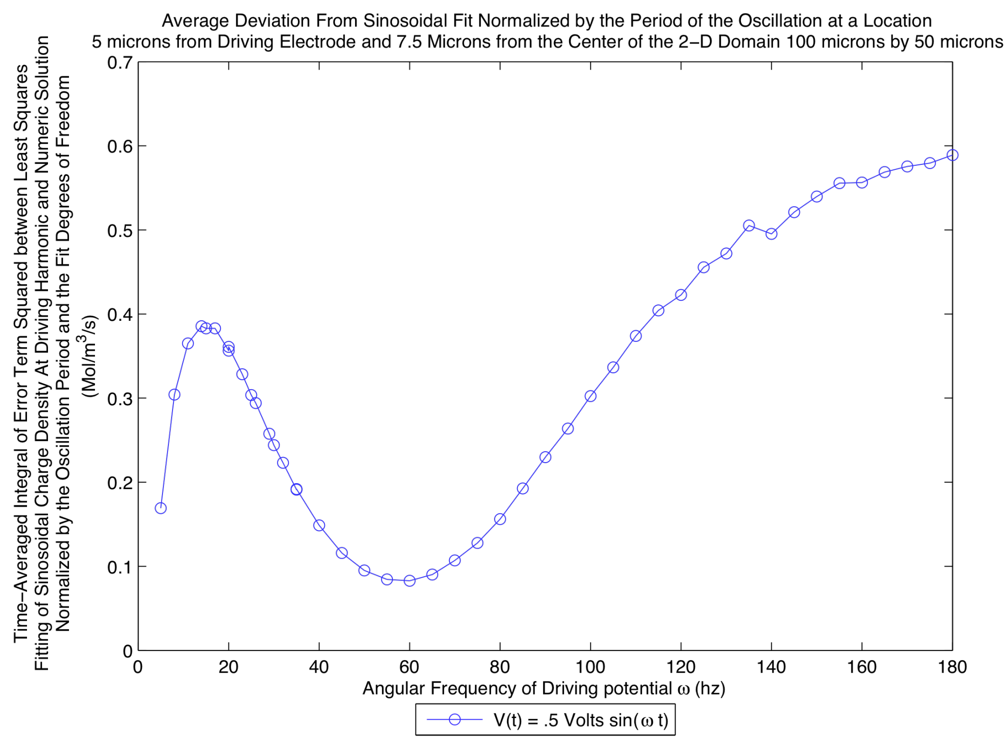

Figure 3. Plot of the average squared deviation per period 7.5 microns from the center of the domain

Expected Results

Once the harmonic response of the ion flux in response to the driving potential had been established, the Navier-Stokes Application Model was added to the model. The model was solved and the A/C Electroosmosis Fluid Flow was observed.

Please see the url http://www.youtube.com/watch?v=S7vmCKI9J9Q for the results of such a simulation

Reference

1. M. Z. Bazant and Y. Ben, *Theoretical prediction of fast 3D AC electro-osmotic pumps*, Lab on a Chip, 6, 1455-1461 (2006).