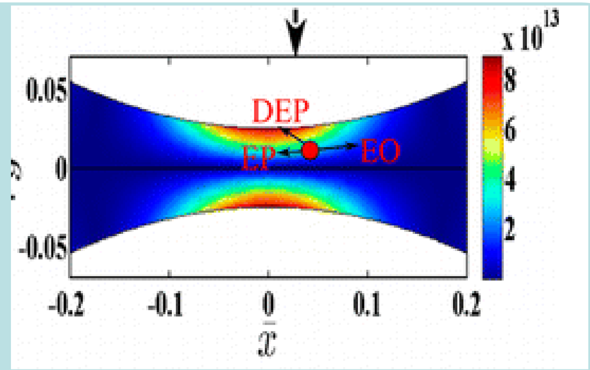
Mathematical Modeling of Electroosmotic Flow in Diverging- Converging Micro-channels in Tissue Engineering

Subhabrata Das , Grant Goldenberg, Ponisseril Somasundaran

Langmuir Center of Colloids and Interfaces, Columbia University, New York, NY 10017

The main objective of our project is to model fluid flow and transport of macromolecules through micro-channels in soft tissues as function of particle size, zeta-potential, constriction size of channels

Current artificial tissues have difficulty mimicking vascular pathways found in natural tissues. The trapping of charged micro-particles under confinement in a converging–diverging microchannel, under a symmetric AC field of tunable frequency has been well studied.



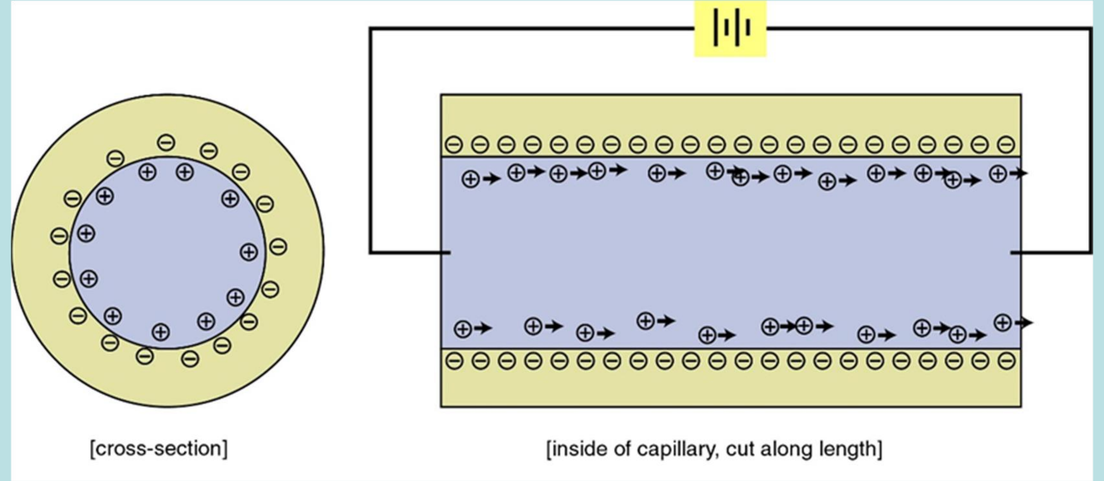
Chakraborty et al, 2015

The phenomenon of EOF has been studied for large scale industrial purposes but has been examined far less for the purpose of small-scale projects such as lab on a chip environments or tissue engineering. EOF can be applied to micro-scale conduits and as a result may show promise in the field of tissue engineering as an artificial transport system.

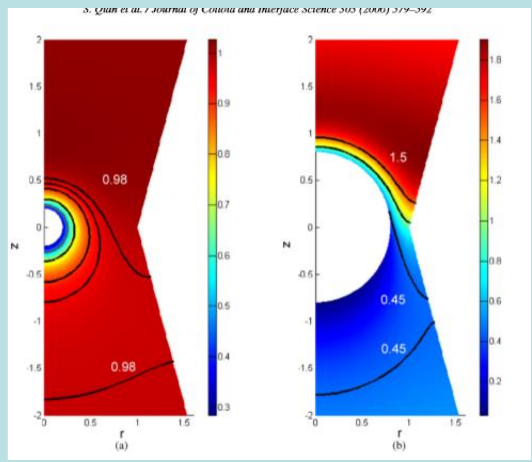
Method: We plan to model micro-channels in the Multiphysics software COMSOL to study protein or fluid transport in artificial tissues Engineering, cell entrapment

Problem Formulation

Electroosmotic flow (EOF) is the motion of a liquid brought about by an applied potential across a fluid conduit or passageway.



Bazant et al, 2013



Distribution of concentration species (a) 1 nm (b) 4 nm (Qian et al, JCIS , 2006)

Transport of Dilute species

$$\nabla \cdot (-D_i \nabla c_i) + \mathbf{u} \cdot \nabla c_i = R_i$$
$$\mathbf{N}_i = -D_i \nabla c_i + \mathbf{u} c_i$$

Creeping flow

$$0 = \nabla \cdot \left[-p\mathbf{I} + \mu\left(\nabla \mathbf{u} + (\nabla \mathbf{u})^T\right)\right] + \mathbf{F}$$
$$\rho \nabla \cdot (\mathbf{u}) = 0$$

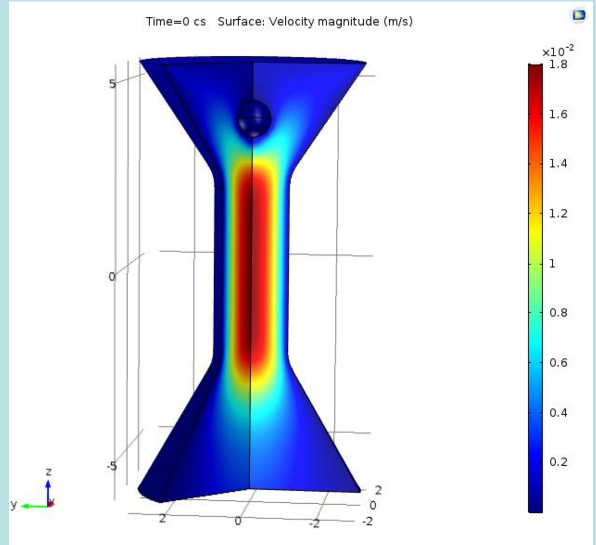
Electric current

$$\nabla \cdot \mathbf{J} = Q_j$$
$$\mathbf{J} = \sigma \mathbf{E} + \mathbf{J}_e$$
$$\mathbf{E} = -\nabla V$$

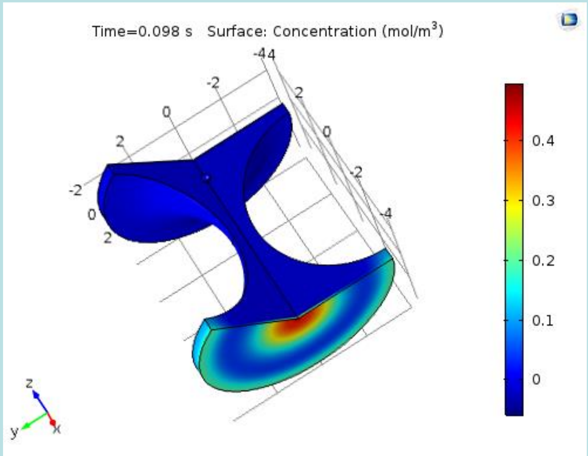
We solve for concentration (Ci) , velocity (v) and Electric field (E) in a time dependent system. Ni represents the concentration flux and Je represents the Electric flux

Results

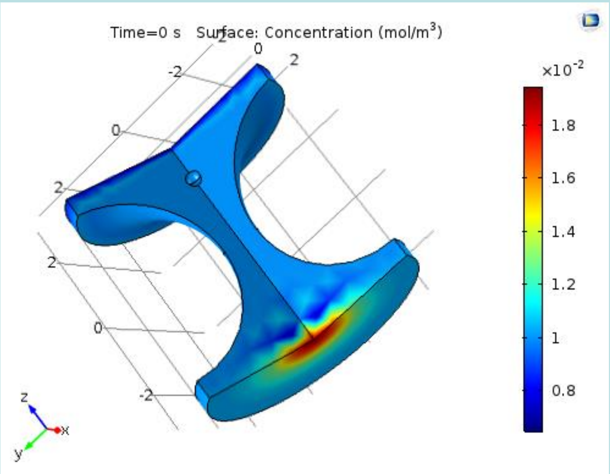
The microchannel was modeled in COMSOL and different geometries were tested. To reduce pressure build up around edges a curved channel was chosen.



Velocity profile around charged particle in a converging-diverging channel



Pressure Model



EOF Model

Opposite zeta-potential(+-0.1 V) present on particle surface(Small sphere)and channel walls, potential difference of 10 mV across the channel

Conclusions

After completing a time-dependent study for the transport of diluted species, the model featuring EOF showed much more rapid movement of the diluted species through the channel than did the model utilizing flow produced from a common pressure gradient.

Acknowledgement: This material is based upon work supported by the National Science Foundation under Grant No. 0749481/1362060 and by CPaSS industry members.

UF UNIVERSITY of FLORIDA
The Foundation for The Gator Nation

CPaSS

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

Fall 2016 IAB Meeting –Aug 10-11, 2016