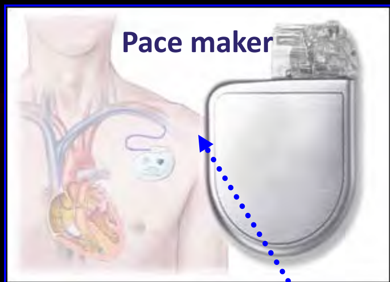
Finite Element Analysis of an Enzymatic Biofuel Cell:

The Orientation of the chip inside a blood Artery

Yamini S. Parikh, Yin song, Varun Penmatsa, Chunlei Wang

Mechanical and Materials Science and Engineering,
Florida International University
COMSOL Conference 2009

Need for biofuel cell

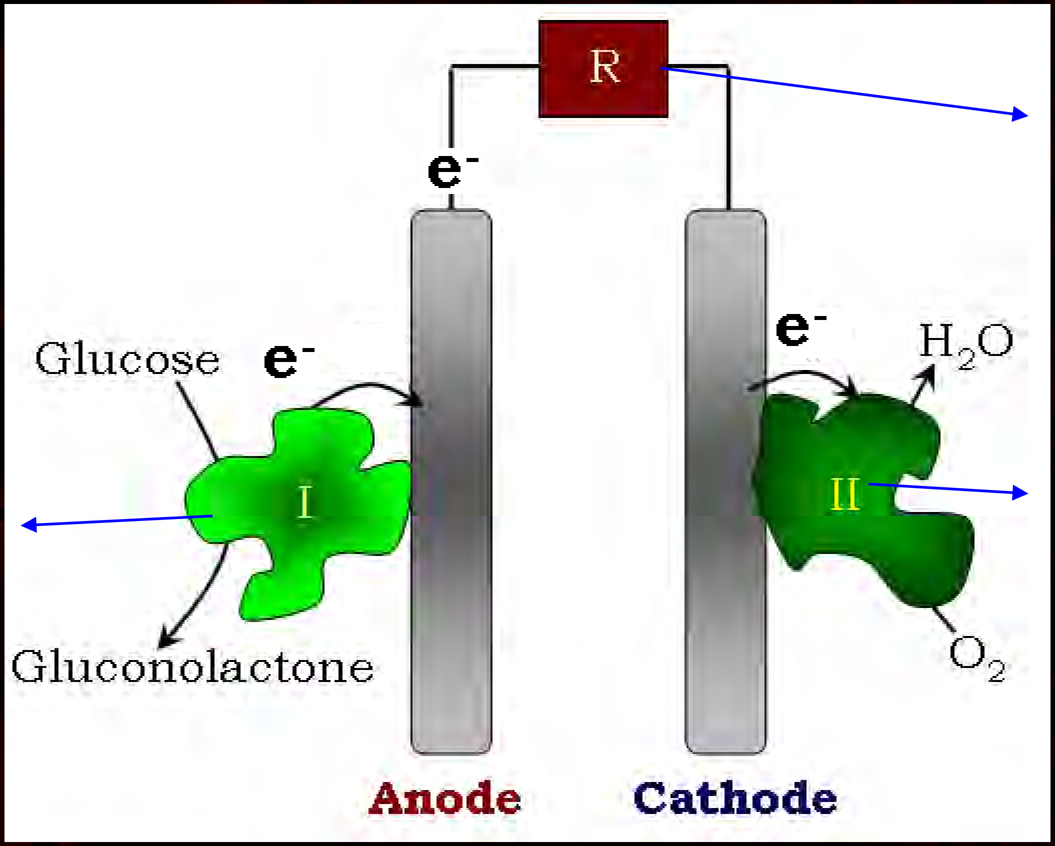


Enzymatic biofuel cell

- Enzymatic Biofuel Cells (EBFCs) are electrochemical power sources which utilize enzymes to biocatalyze the fuel and thus supply electricity
- Biofuel cells can be a safe solution
- Biofuel cells have a very promising theoretical efficiency of 90%
- Currently biofuel cells have the disadvantage of big size, low practical efficiency and longevity of enzyme

Mechanism of a Biofuel cell

Glucose in blood : 4mM-6mM



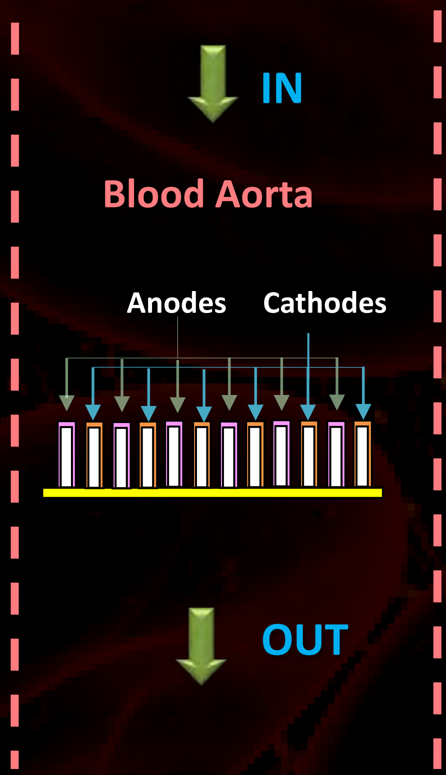
Load (implantable device)

Glucose oxidase

laccase

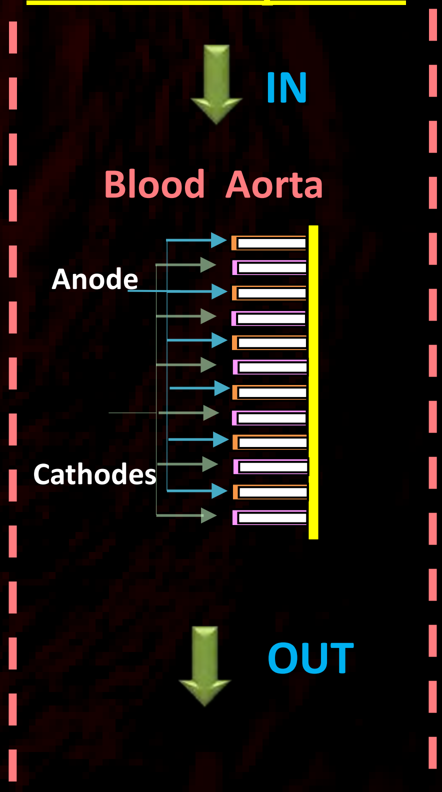
Computational Modeling – Orientation of the chip

HP-Horizontal position



Parts	Size
Artery diameter	1.5 cm
Electrode height	300 µm
Electrode diameter	30 µm
Electrode distance	40 µm
Enzyme thickness	10 µm
Foot print area	2 mm^2

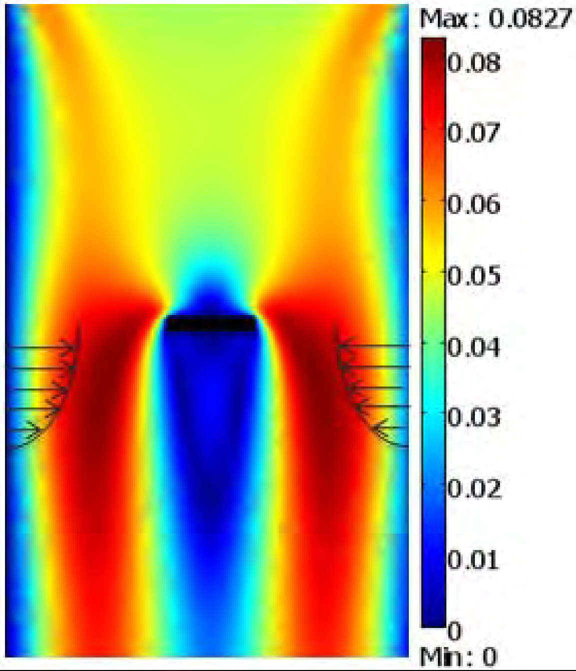
VP-Vertical position

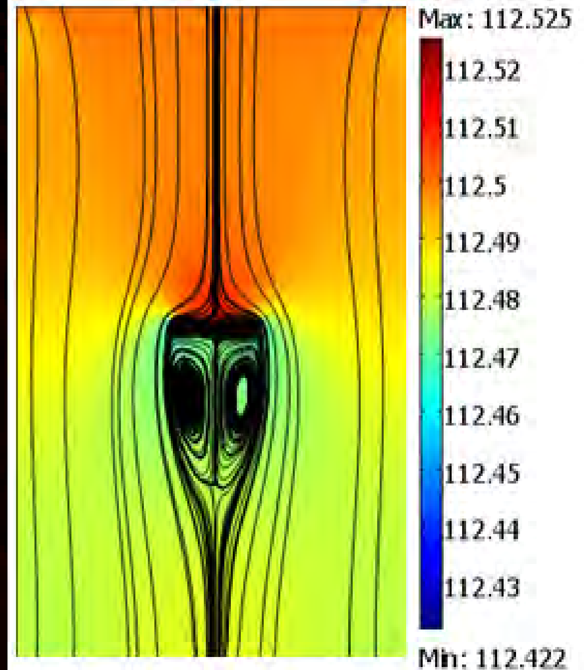


Boundary	Condition
1) Diffusion and Convection application module	
Anode – enzyme layer interface & Cathode – enzyme layer interface	Zero inward flux
Enzyme layers – bulk interface	Continuity
Inlet of an artery	Inward flux= 5 mM
Outlet of an artery	Convective flux
SiO_2 layer boundaries	Insulation
2) Navier – Stokes application module	
Anode – enzyme layer interface & Cathode – enzyme layer interface	Wall – no slip
Enzyme layers – bulk interface	Continuity
Inlet of an artery	Inlet pressure
Outlet of an artery	Outlet – No viscous stress
SiO_2 layer	Insulation

Results:

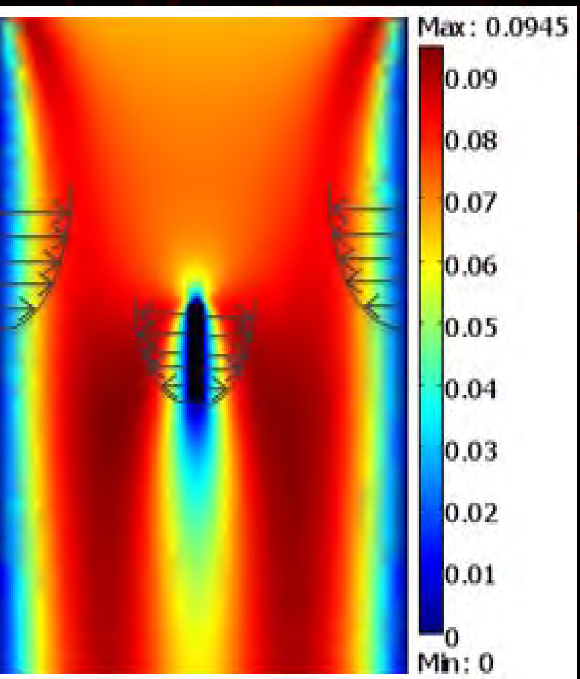
Pressure and Velocity distribution

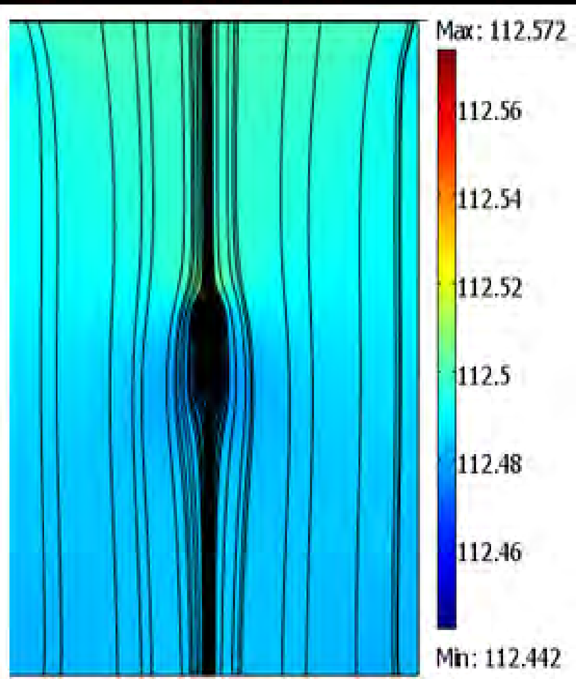


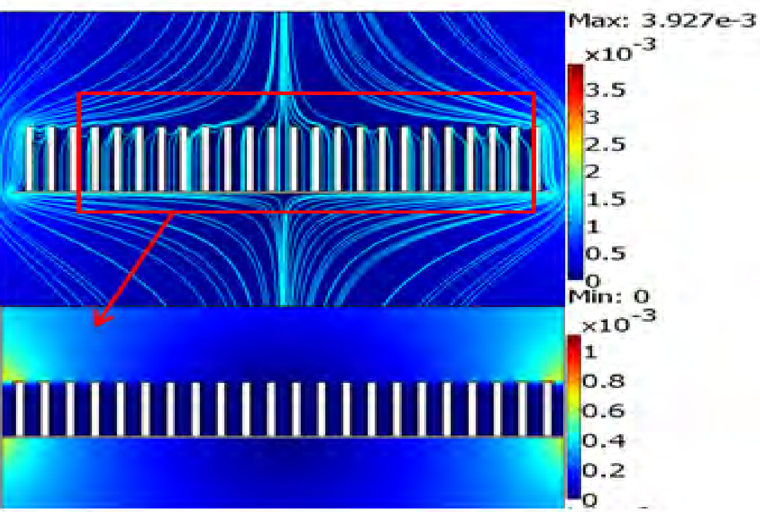


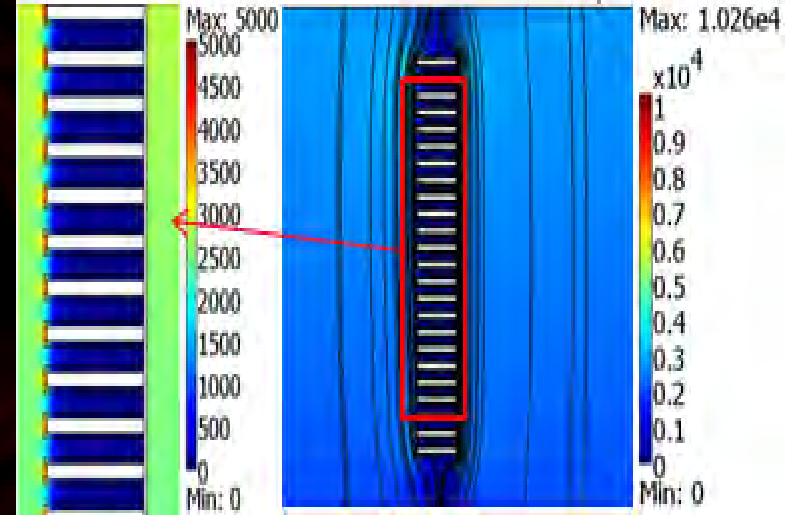
Velocity Profile

Pressure with velocity streamlines



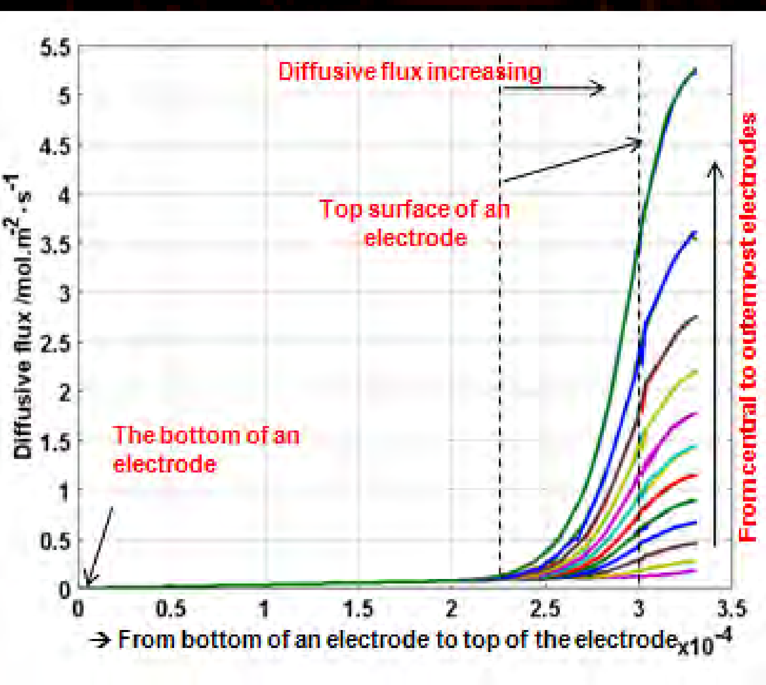




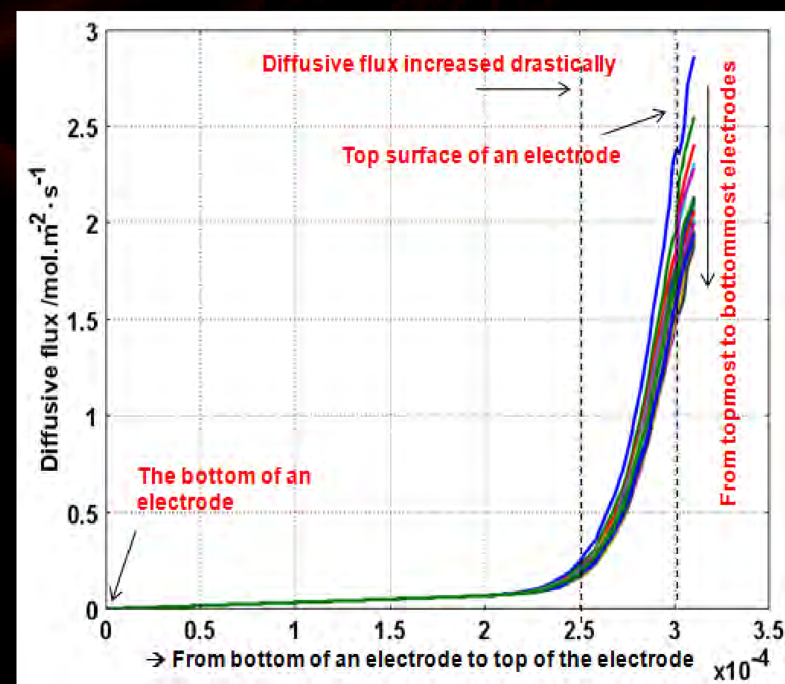


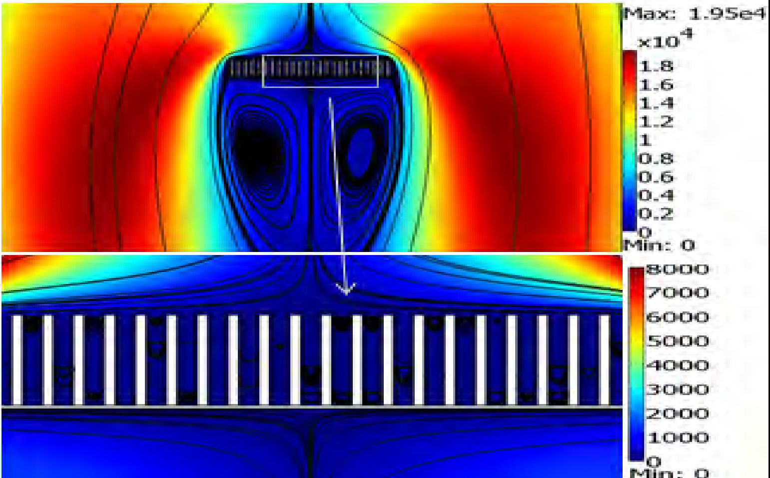
Diffusive Flux distribution in between micro-electrodes

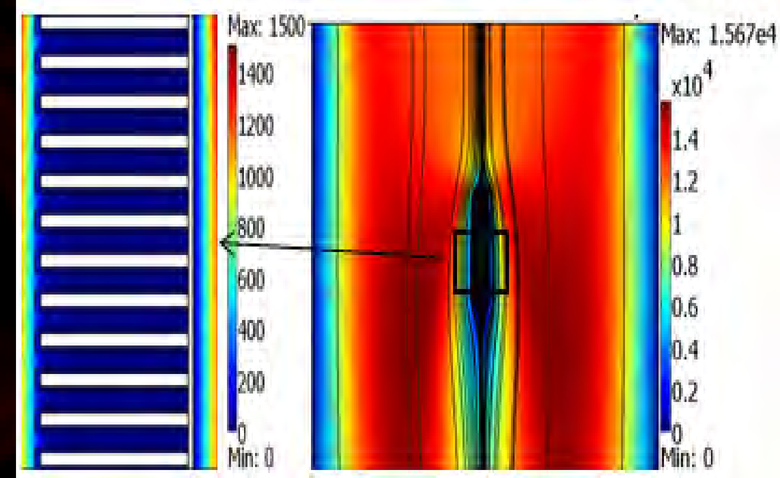
HP



VP

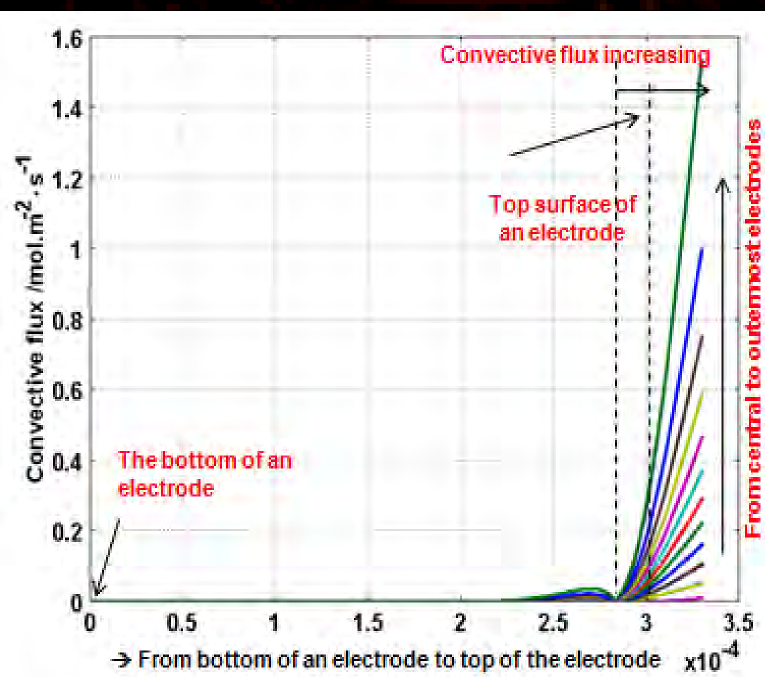




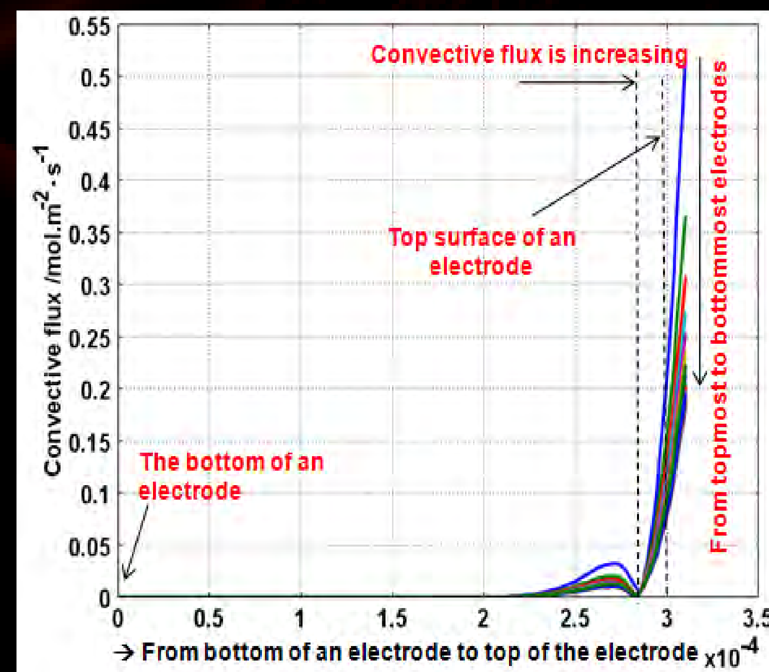


Convective Flux distribution in between micro-electrodes

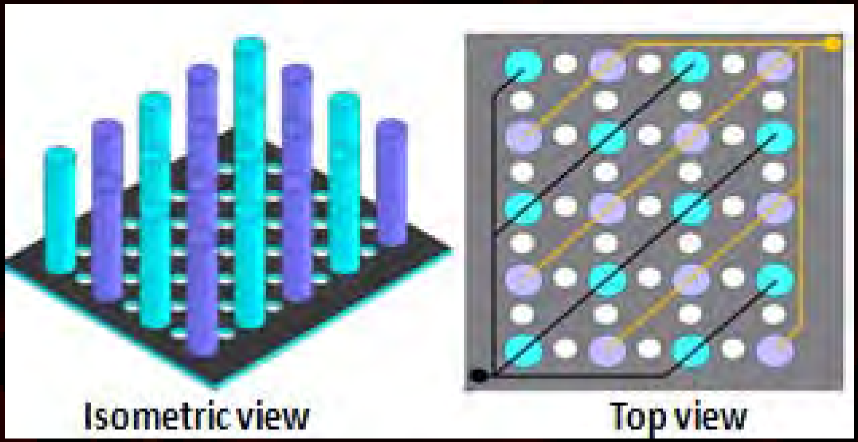
HP



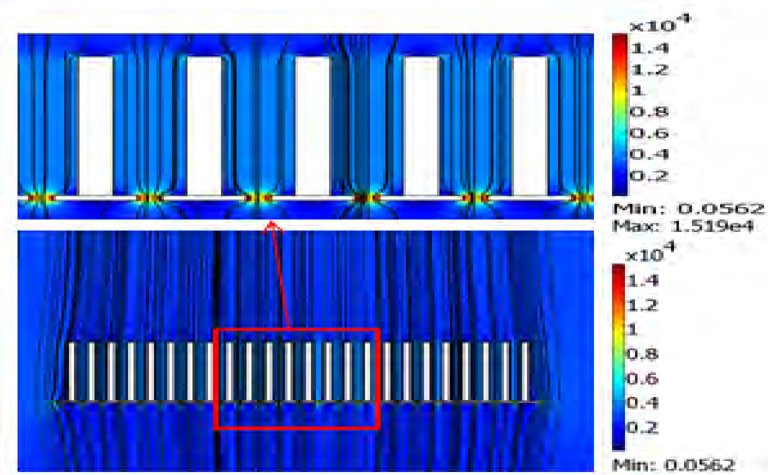
VP

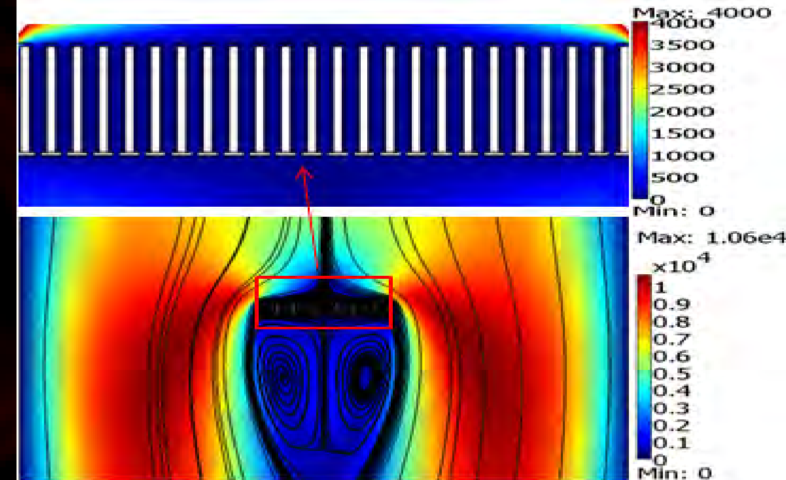


Proposed Design



Holes in the substrate between any two electrodes – 20 µm

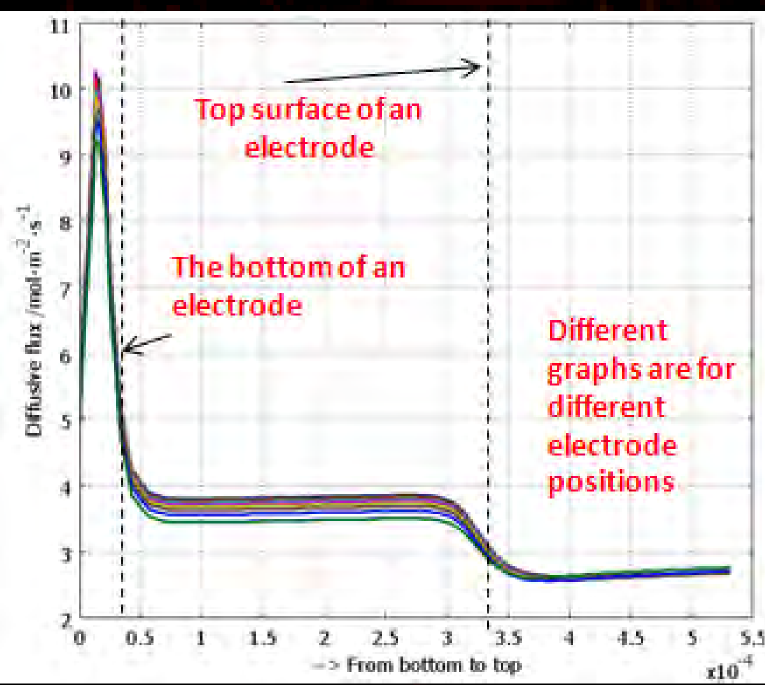


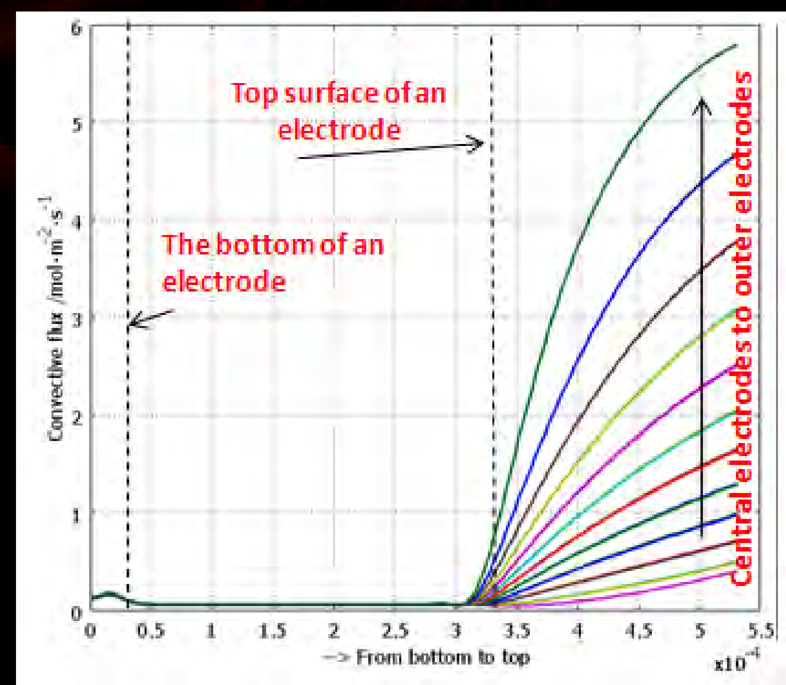


Diffusive Flux in between micro-electrodes

New Proposed Design with holes

Convective Flux in between micro-electrodes





Conclusions:

- Chip is more stable in VP, as there is no random turbulence formed under a chip in this position. In HP, due to high pressure region on the chip and small vortices formed below the chip causes chip to be unstable.
- Diffusion and convection is less in between electrodes in both the case of HP and VP.
- Our new proposed design significantly improves the diffusion in between electrodes.
- There is an improvement in convection in between micro-electrodes also.

Acknowledgement

National Science Foundation – NIRT#0709085

Collaborators

- Prof. Marc Madou @ UCI
- Prof. Sylvia Daunert @ UK
- Prof. Leonidas Bachas @UK

Thank you!

Yamini S. Parikh : ypari002@fiu.edu
Chunlei Wang: wangc@fiu.edu