Convective Transport in Micro-Fuel Cells

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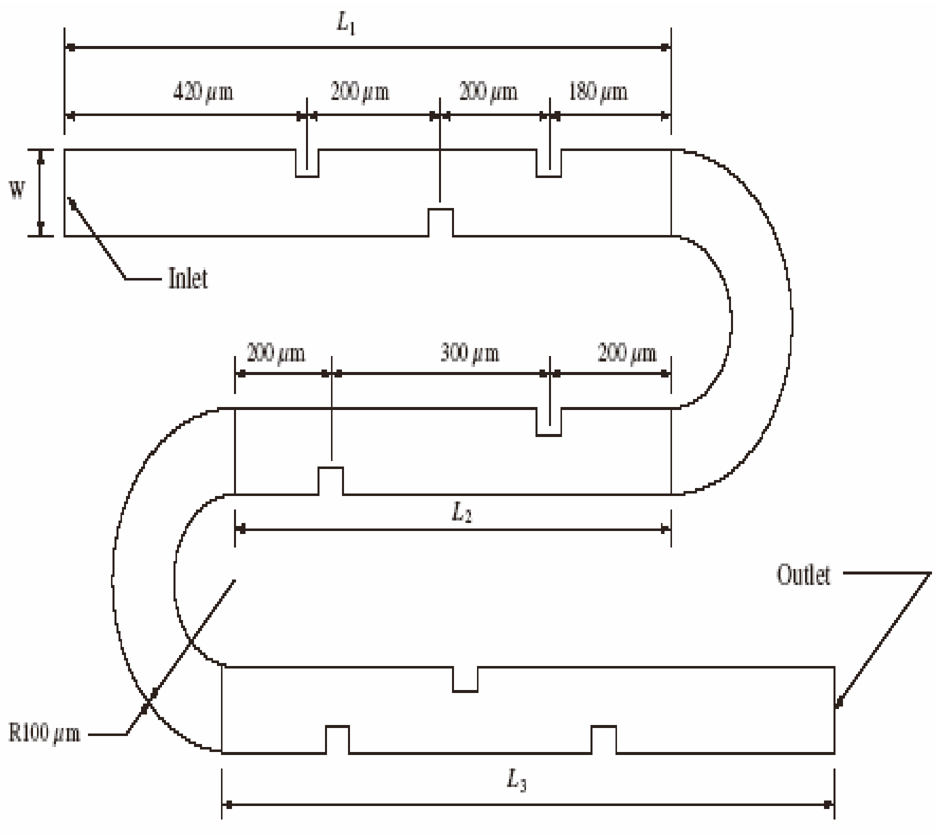
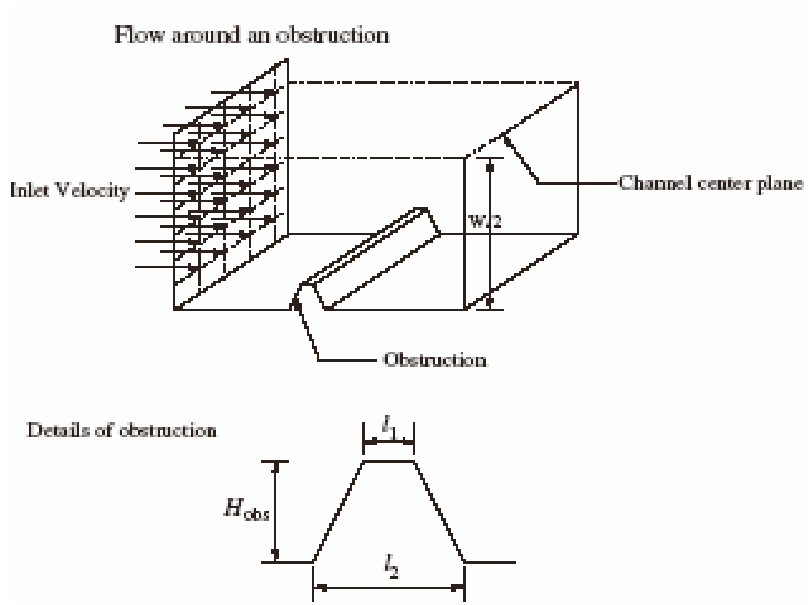
Bipolar Plates



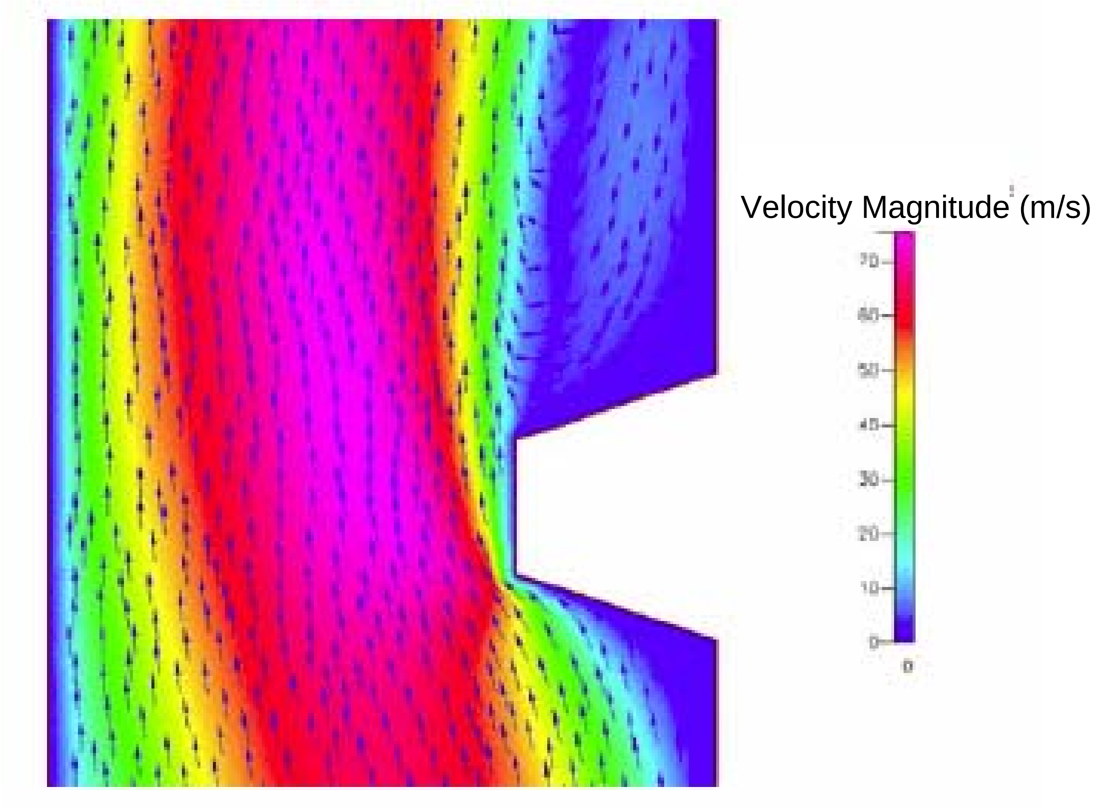


Governing Equations :

$$\nabla . V = 0,$$
$$\rho V(\nabla . V) = -\nabla P + \mu \nabla^2 V.$$

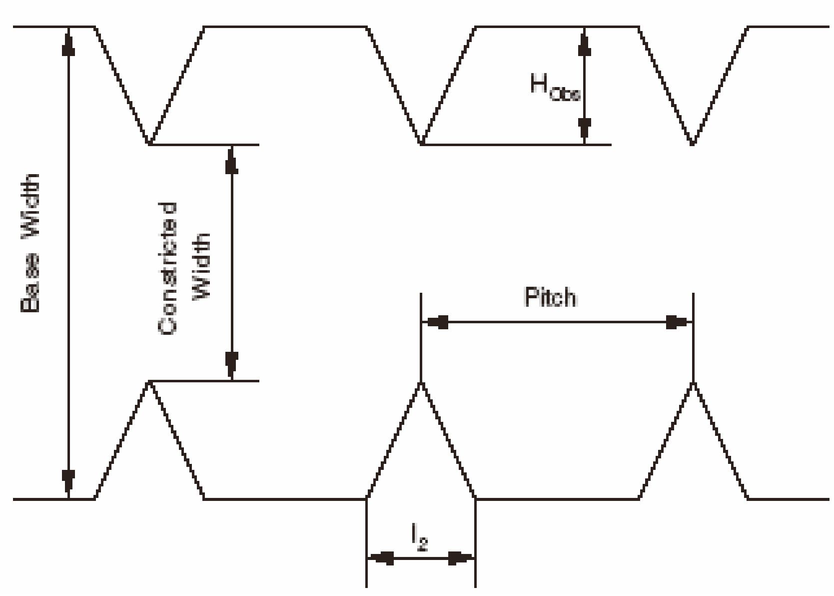
A. S. Rawool, S. K. Mitra, S. G. Kandlikar, ***Microfludics Nanofluidics***, Vol. 2, 215-221, 2006

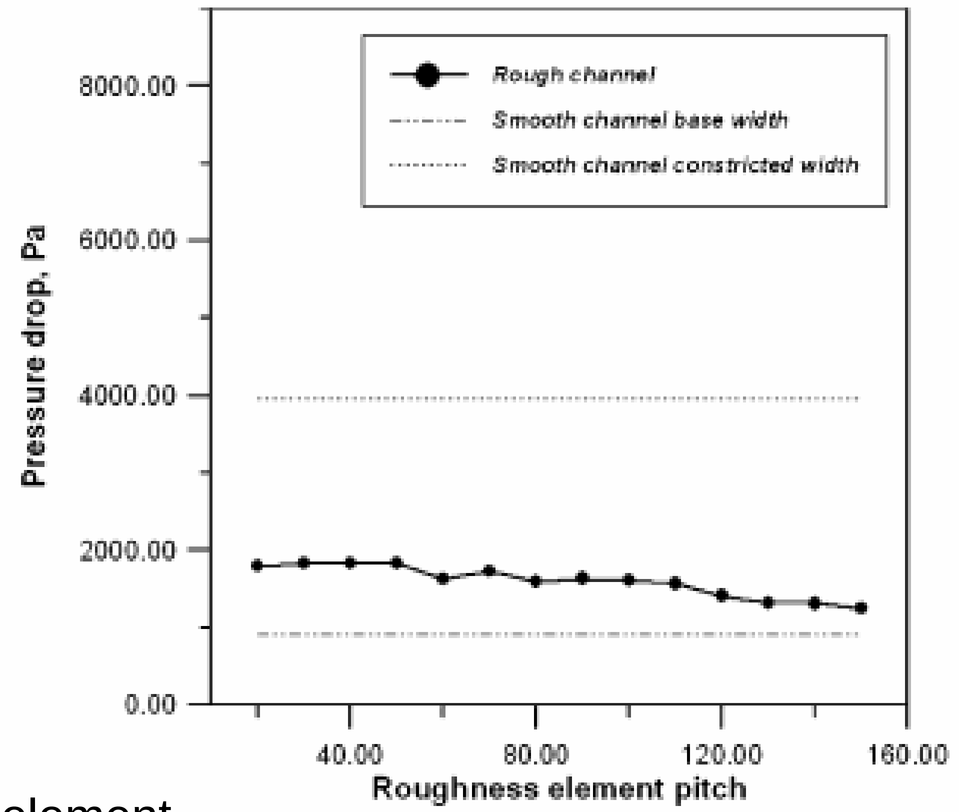
Velocity Profiles



Flow over trapezoidal roughness element

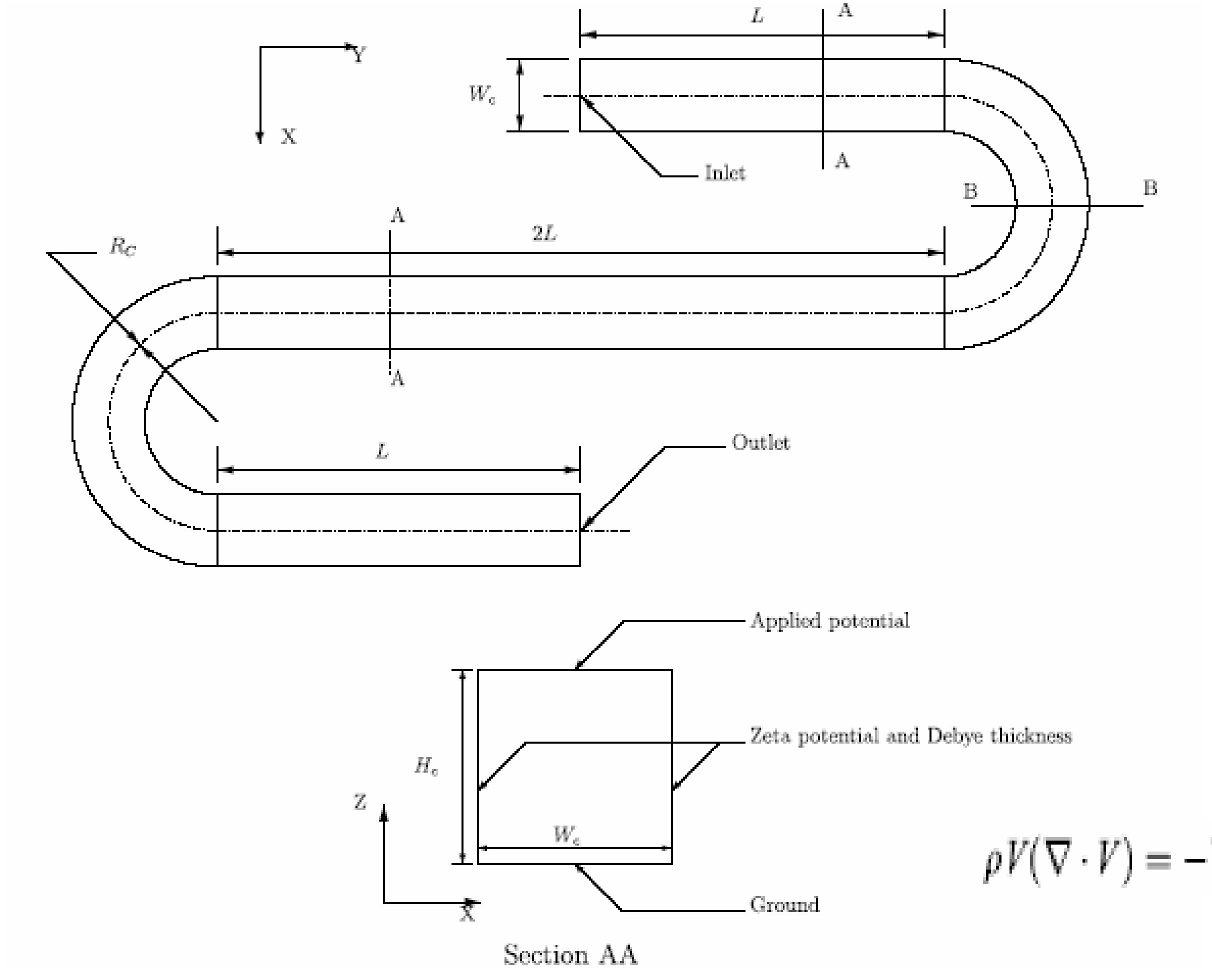
Pressure Drop





Microchannel with triangular roughness element

Electroosmotic Driven Flow



$$\rho V(\nabla \cdot V) = -\nabla P + \mu \nabla^2 V + \rho_E E,$$

A. S. Rawool, S. K. Mitra, ***Microfluidics Nanofluidics***, Vol. 2, 261-269, 2006

Concept of Electric Double Layer (EDL)

Poisson-Boltzmann Equation

$$\nabla^2 \psi = -\frac{4\pi \rho_q}{D}$$

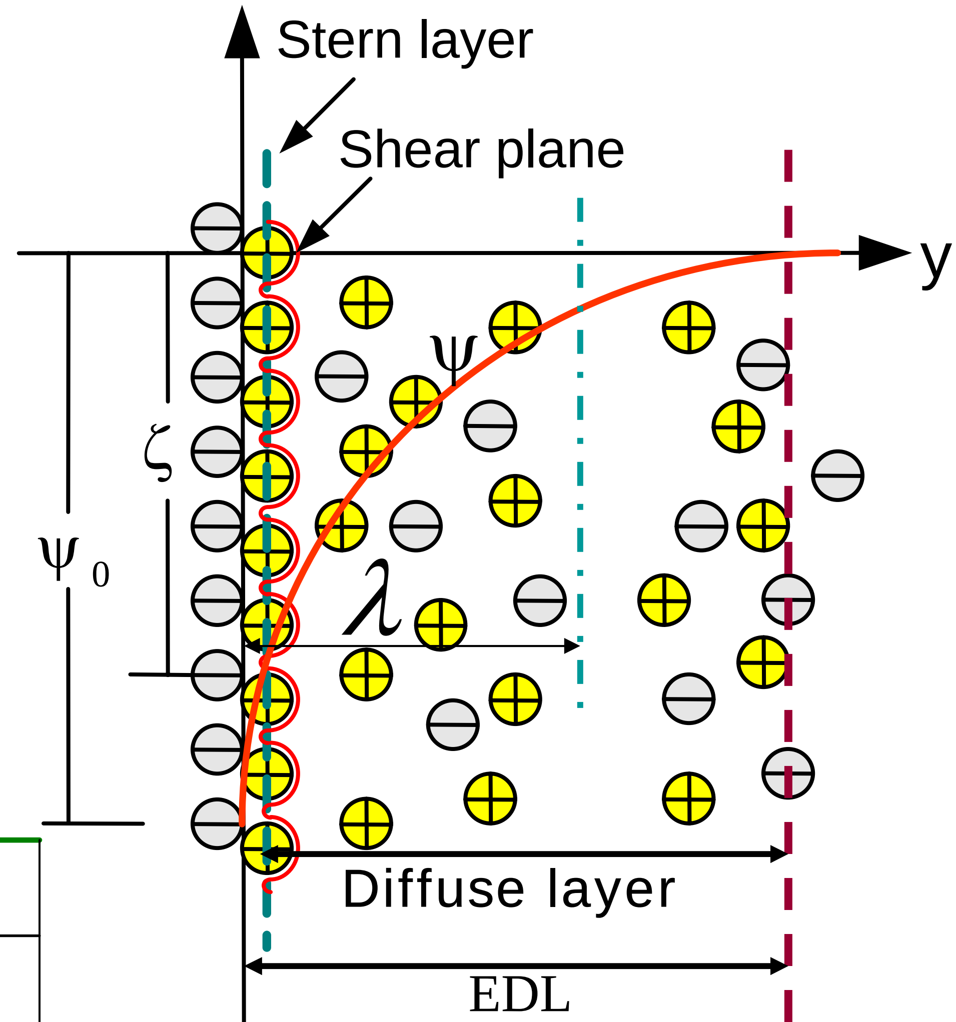
$$\rho_q = -2 n_o e z \underline{\sinh(e z \psi / k_b T)}$$

↑ Boltzmann Distribution

$$\alpha = e z \zeta / k_b T$$

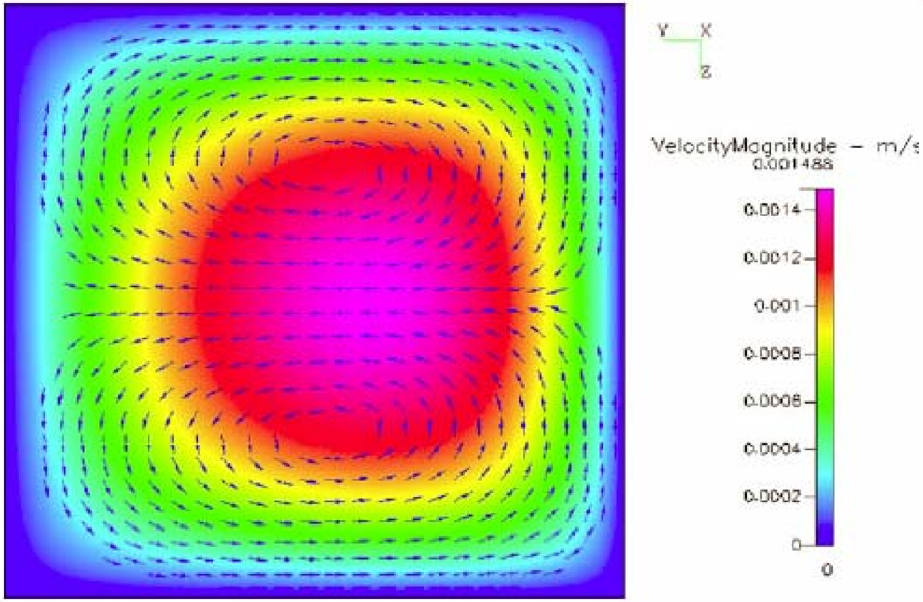
$$\omega = \frac{1}{\lambda} = \sqrt{\frac{8 \pi n_o e^2 z^2}{D k_b T}}$$

n_0 [M]	λ [nm]
1e−2	3
1e−5	100
1e−6	300

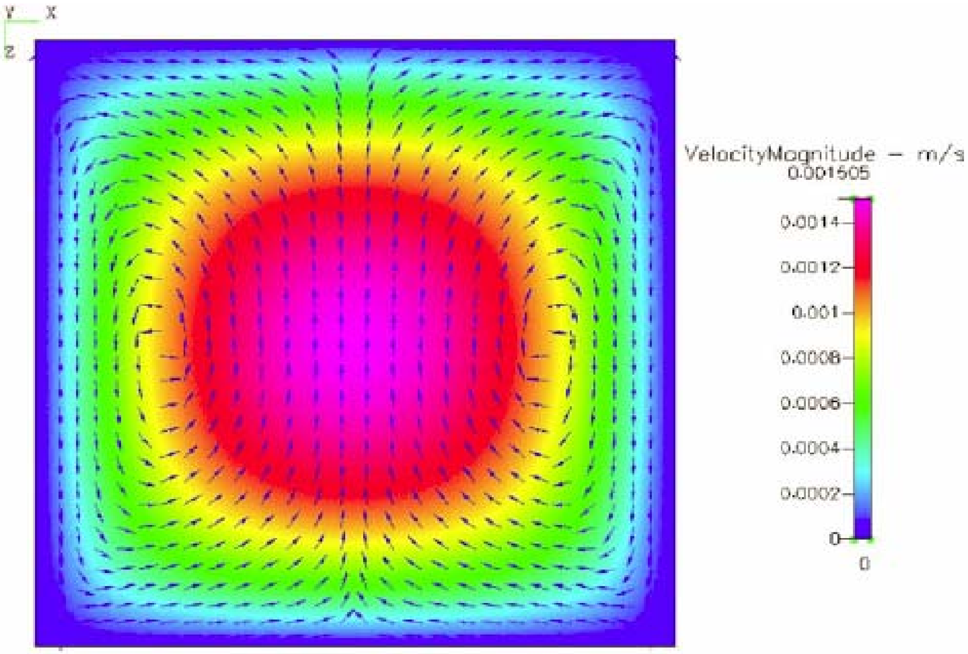


- ζ on the surface is negative
- ζ on the liquid side is positive

Velocity Profiles

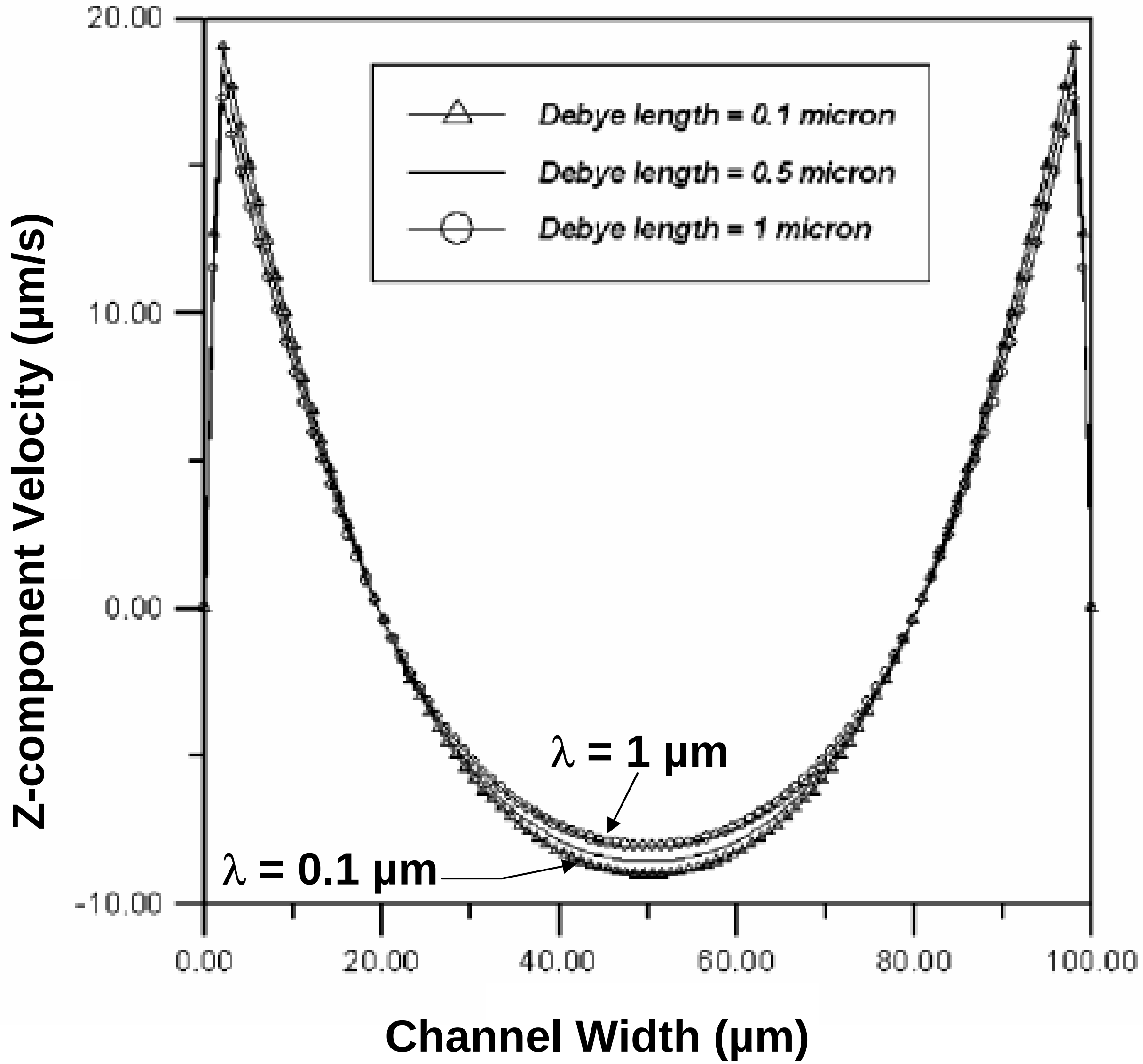


At bend (Section BB)



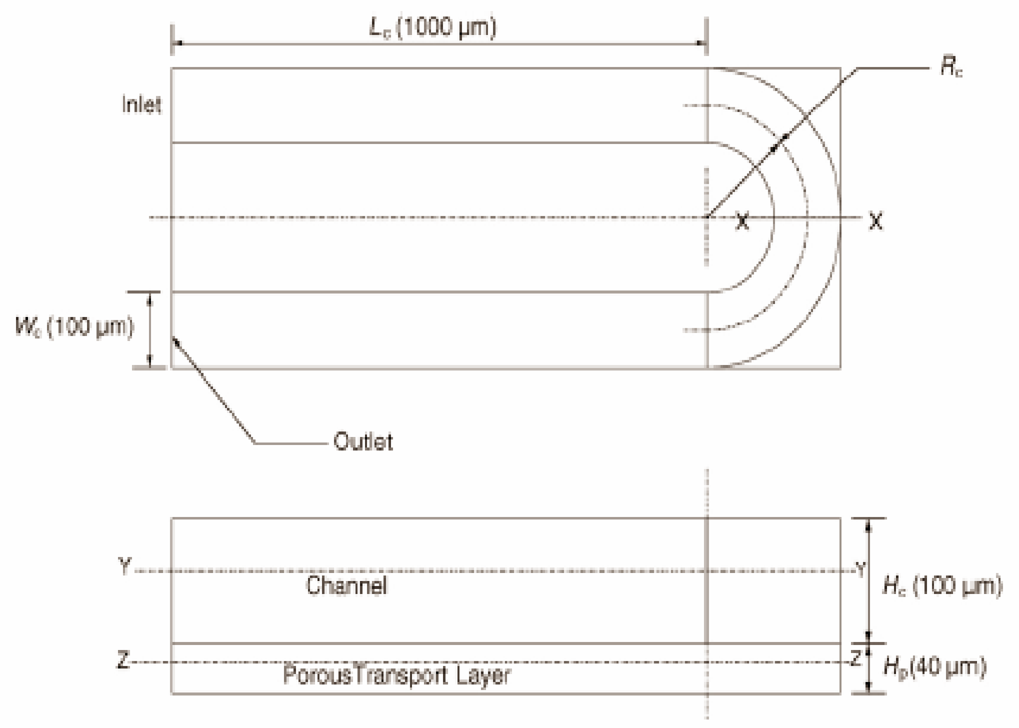
At straight portion (Section AA)

Flow profile for R_c=120 μm, Re=0.1, ζ_w=40 mV, and λ=0.1 μm



Variation of velocity component w along the channel width for R_c=120 μm, Re=0.01, and ζ_w=40 mV

Porous Transport Layer



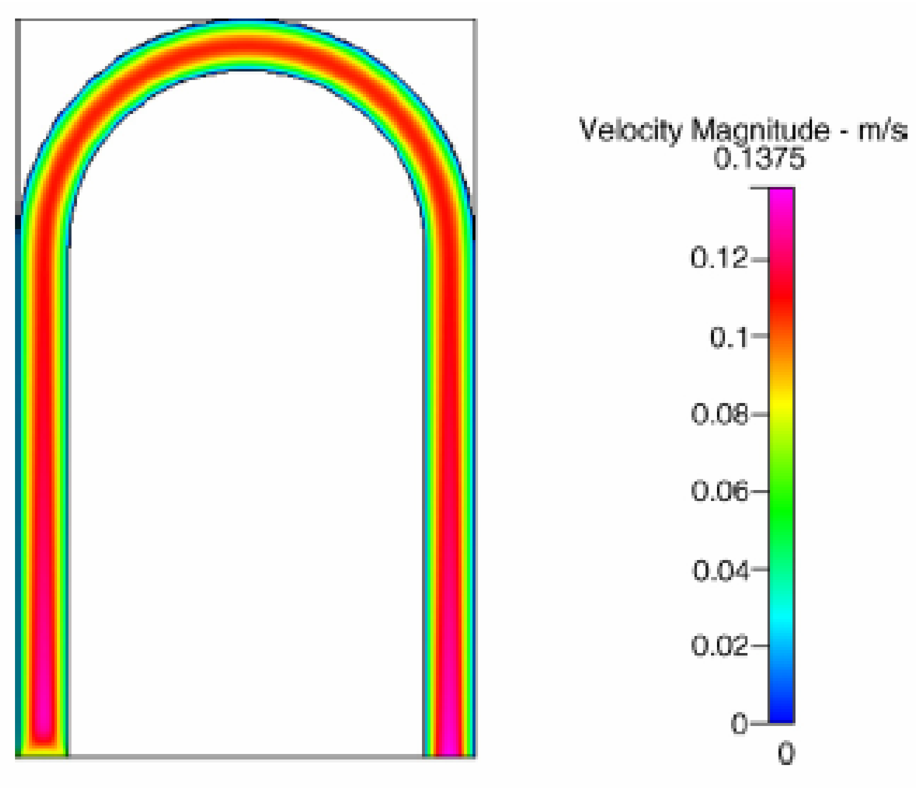
Upper Limit of Permeability :

$$K = \frac{H_P^2}{12} \Rightarrow K = 1.3 \times 10^{-10}\ m^2$$

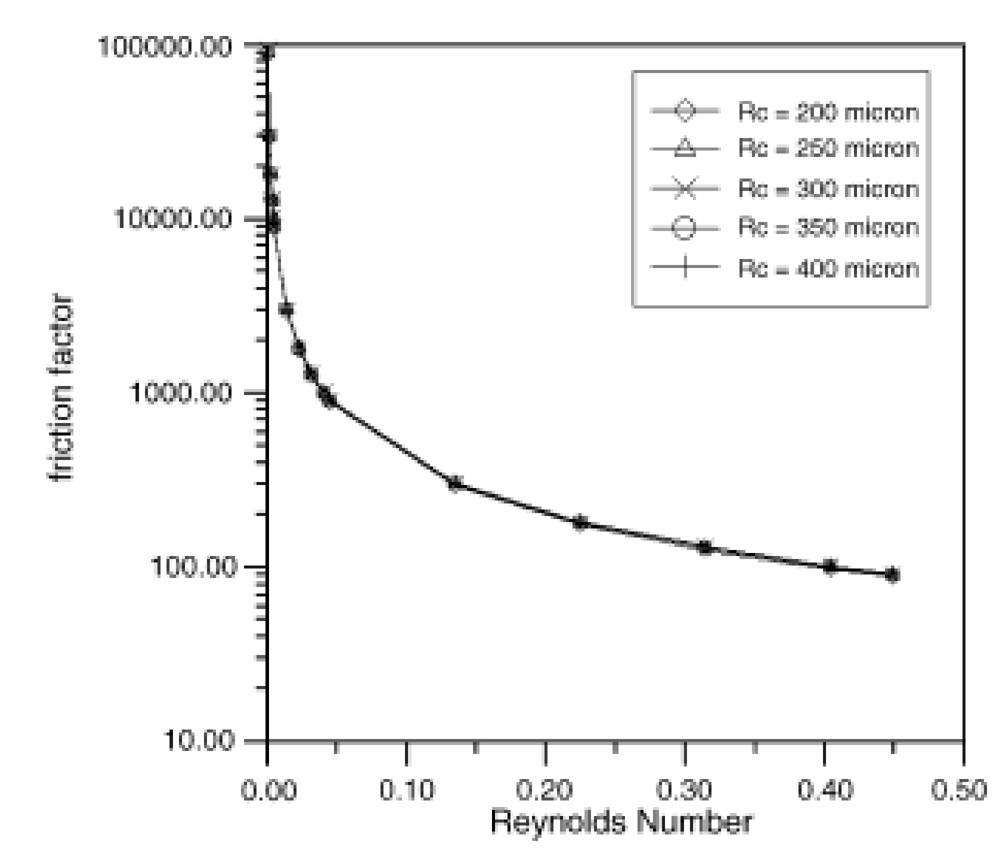
- Traditional fibrous PTL material is not suitable
- Cylindrical microwares connecting the flow field with the catalyst layer

$$\frac{K}{a^2} = \frac{1}{8\phi}\left(-\ln\phi - \frac{3}{2} + 2\phi\right)$$

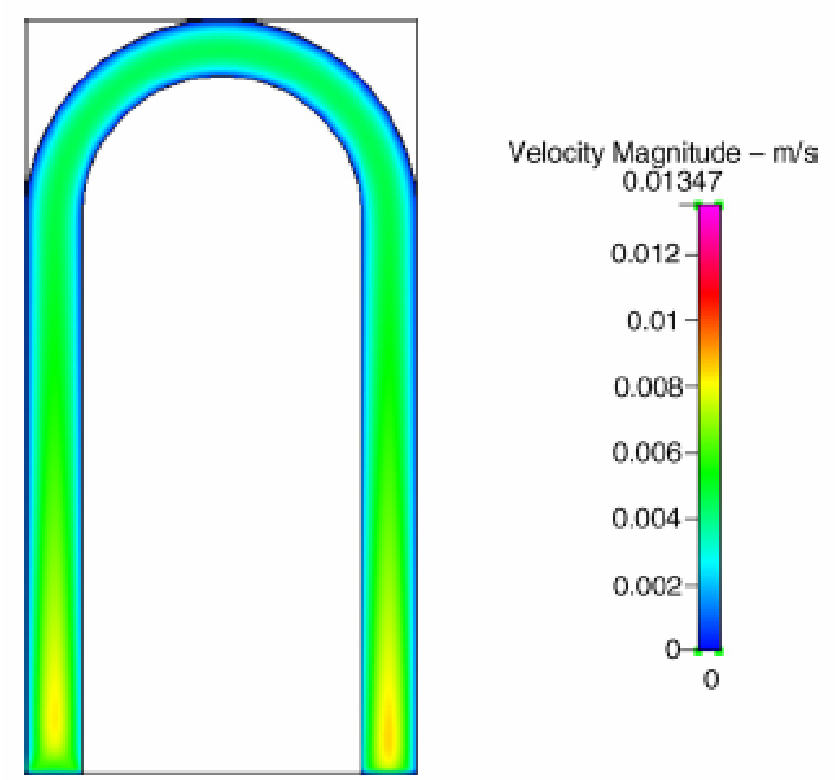
A. S. Rawool, S. K. Mitra, J. G. Pharoah, ***Journal Power Sources***, Vol. 162, 985-991, 2006



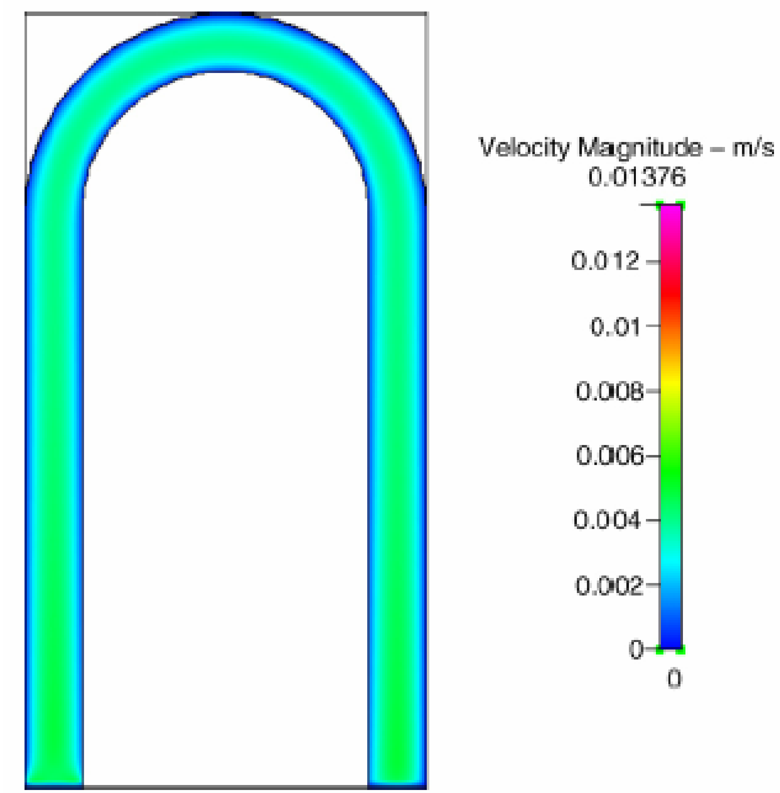
Velocity profile in section Y-Y for Re = 0.45, ε = 0.4, and K = 10^{-11} m^2



Variation of Friction factor with Re = 0.45 for $\varepsilon = 0.4$ and $K = 10^{-11}\ m^2$



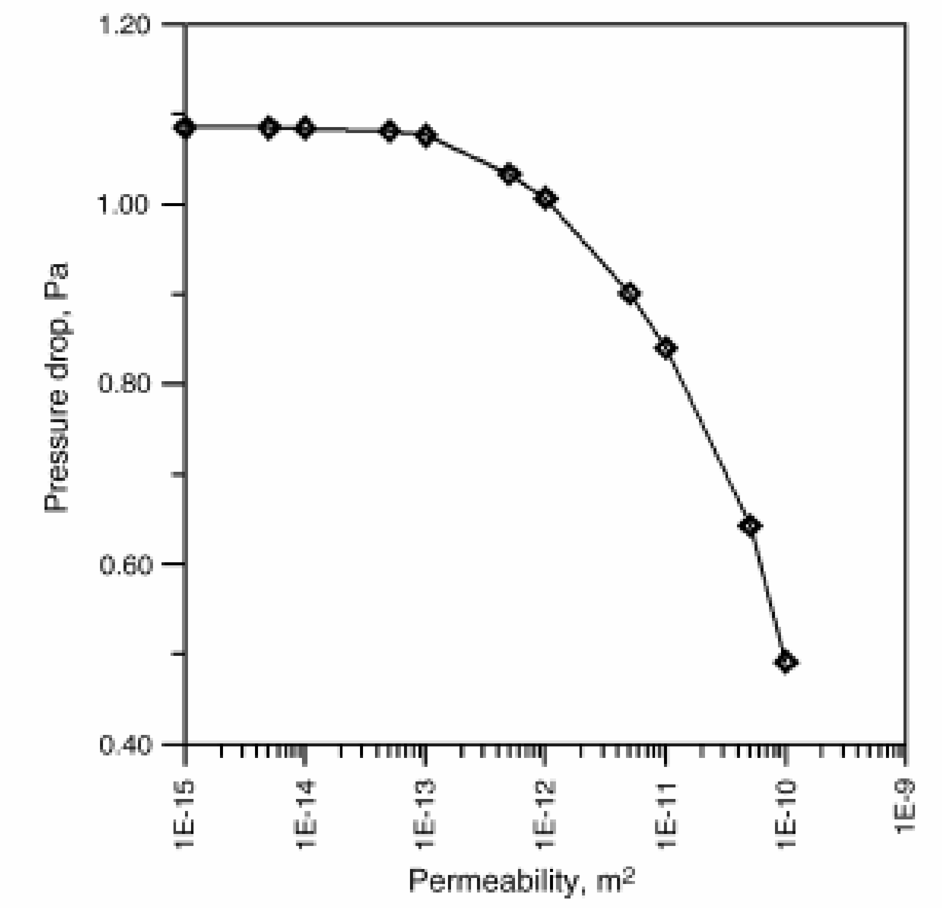
$K = 10^{-10}\ m^2$



$K = 10^{-11}\ m^2$

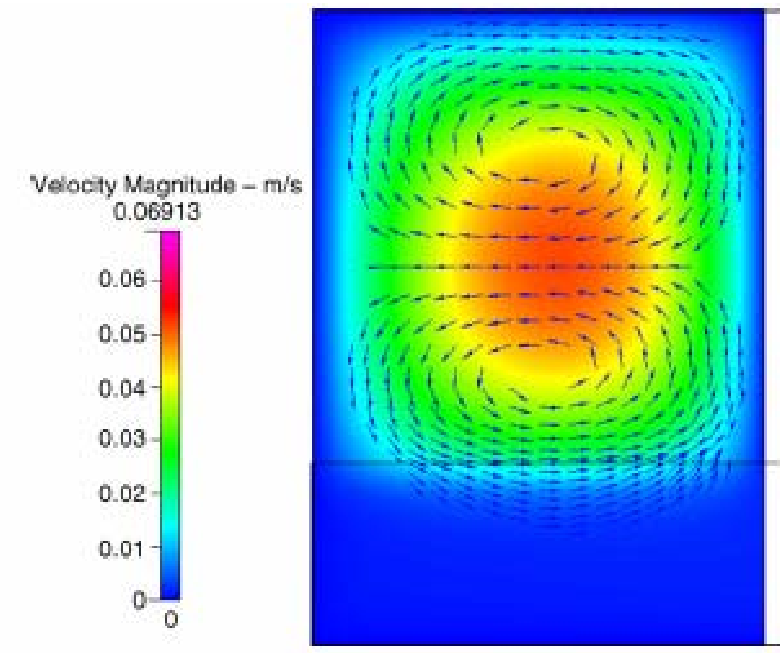
Velocity Profile at interface between channel and PTL for Re = 0.34 and $\varepsilon = 0.4$

Pressure Drop

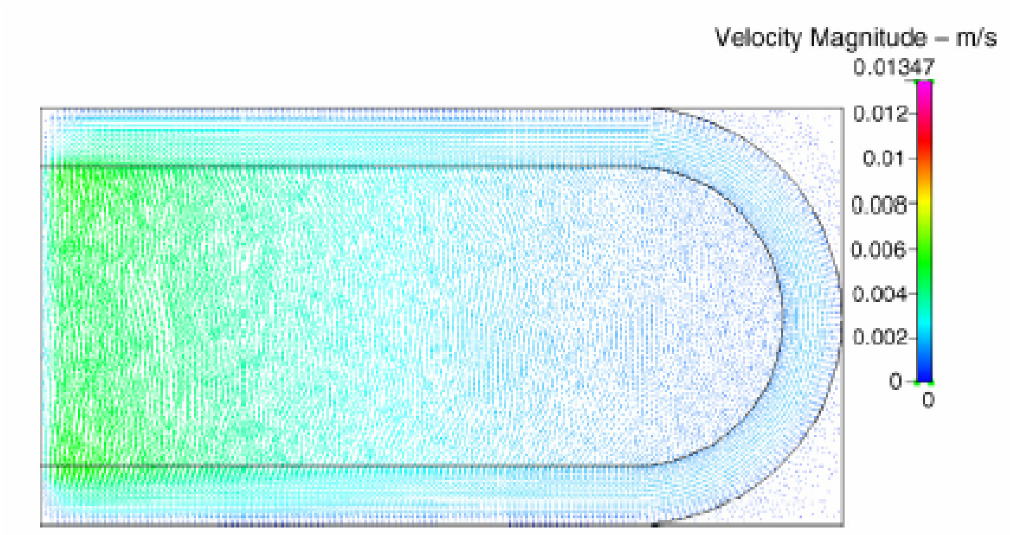


Variation of Pressure Drop with permeability for Re = 0.045, R_c=300 µm, and ε = 0.4

Velocity Profiles

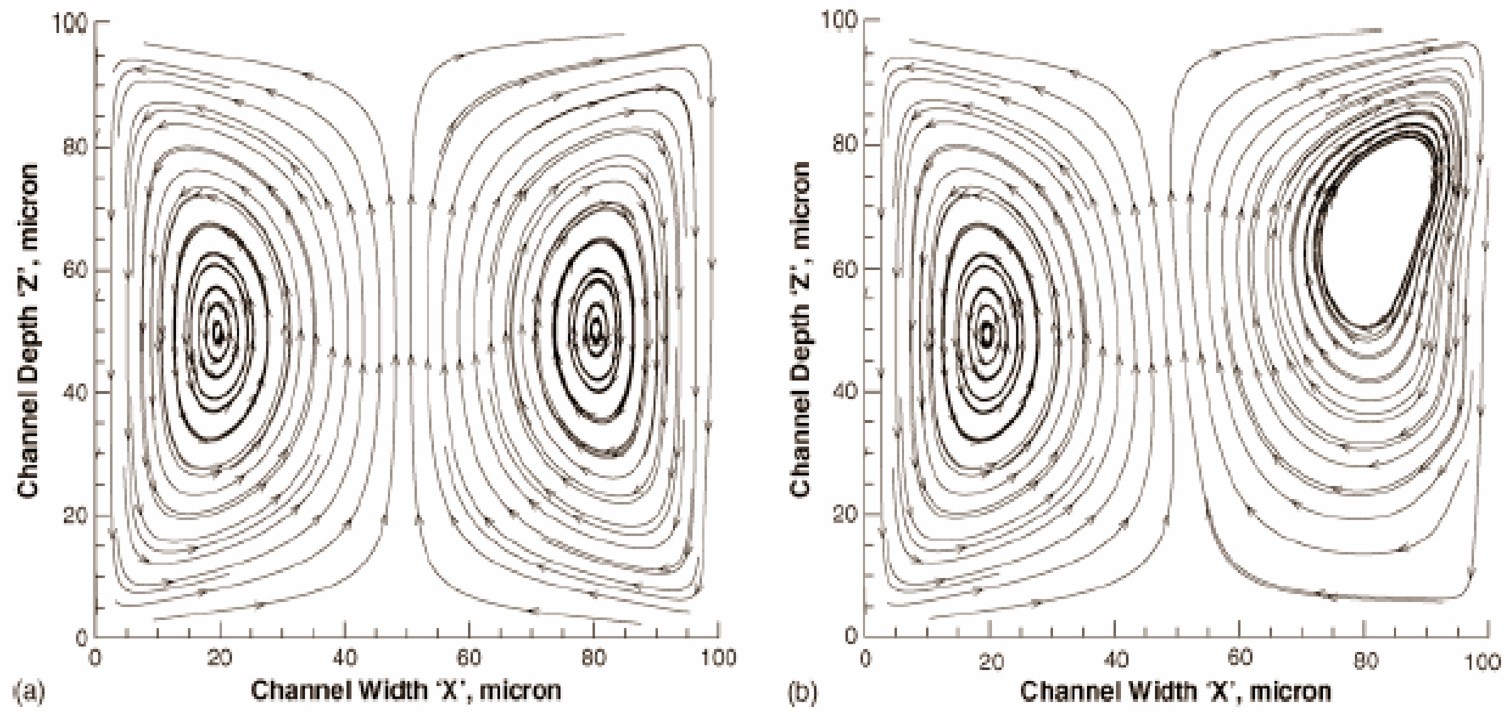


At bend (section X-X)



Within PTL (section Z-Z)

Variable Zeta Potential



ζ_w = -50 mV on both walls

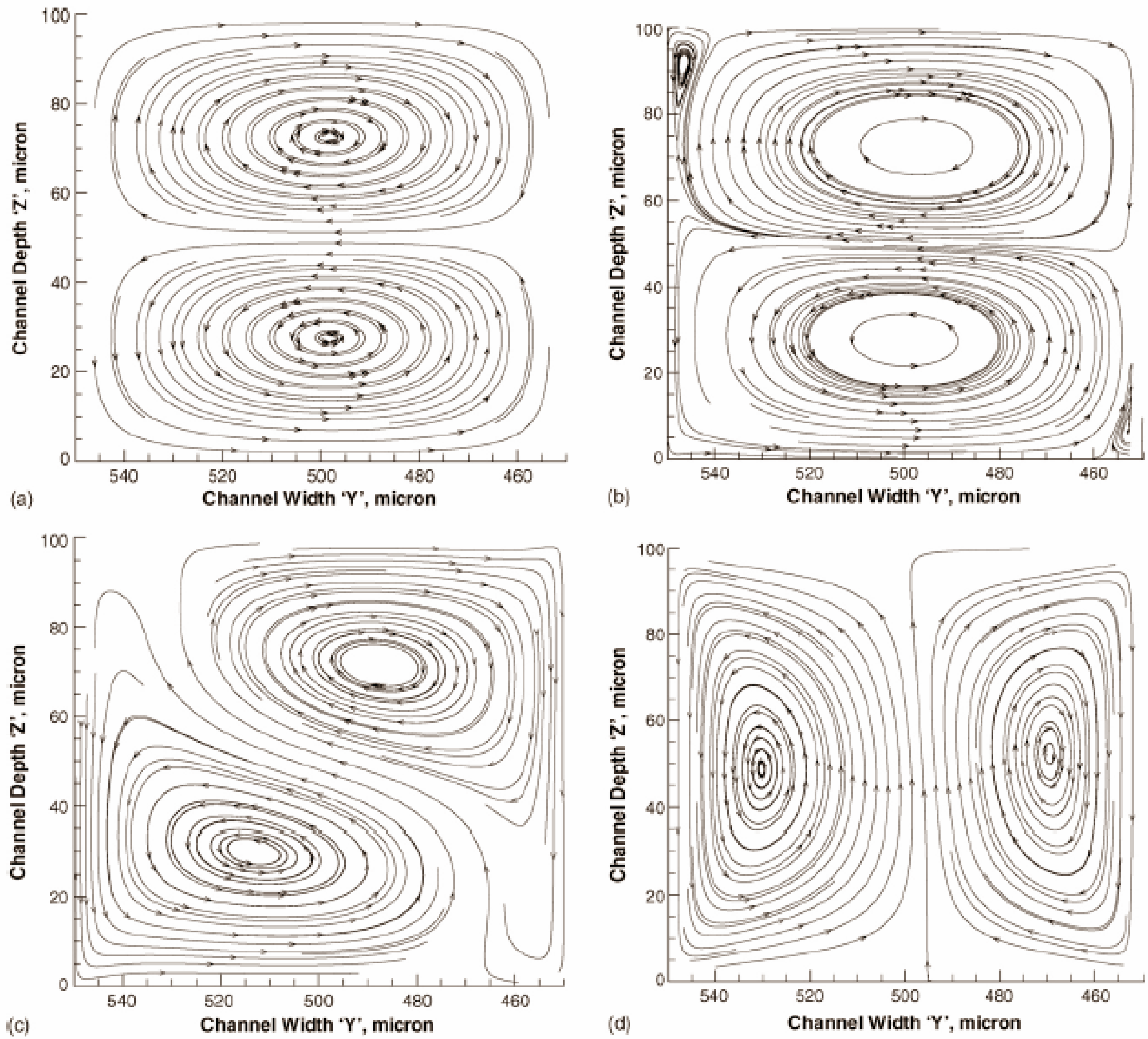
ζ_w = -50 mV on left wall

Stepwise ζ_w on right wall

A. Saha, S. K. Mitra, X. Li, ***Journal Power Sources***, DOI: 10.1016/j.jpowsour.2006.09.106, 2006

$\zeta_w = 0.0$ mv

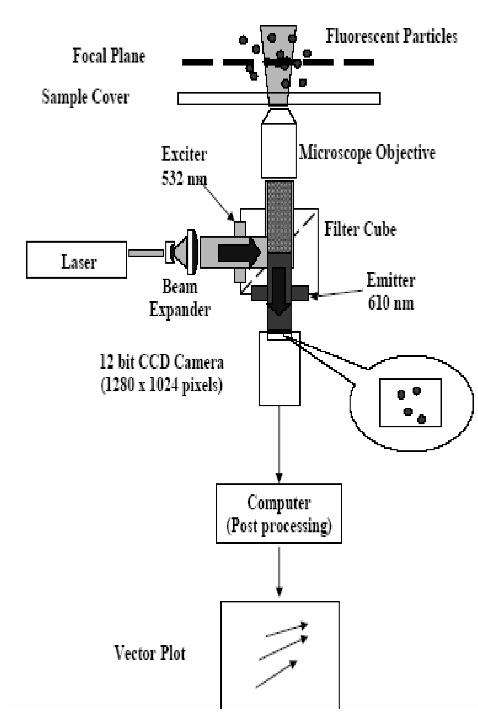
$\zeta_w = 0.1$ mv

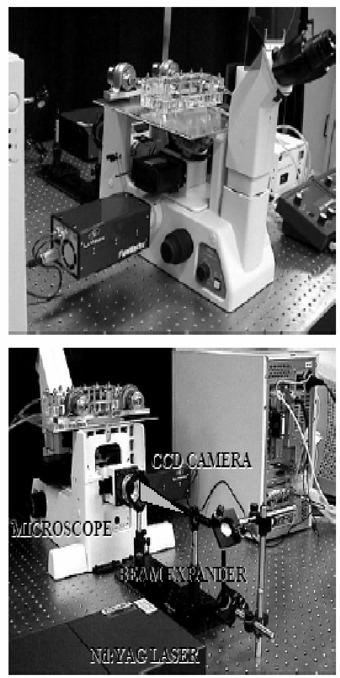


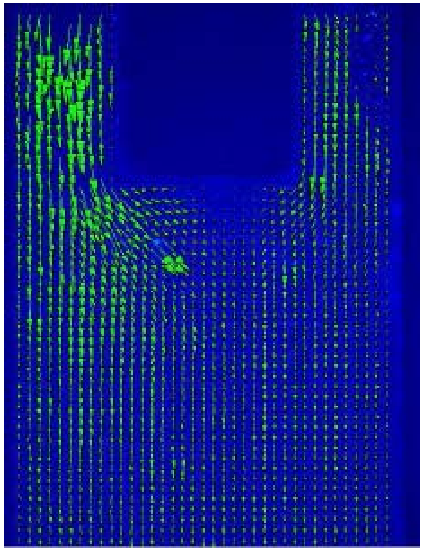
$\zeta_w = 1.0$ mv

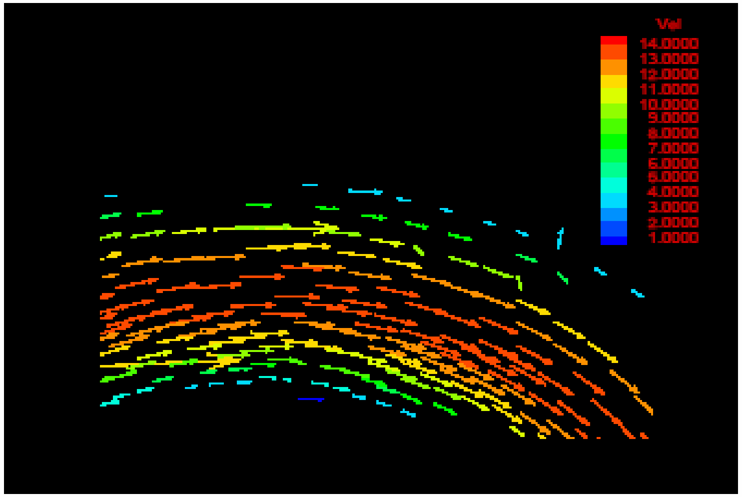
$\zeta_w = 50$ mv

µ-PIV – Flow Visualization



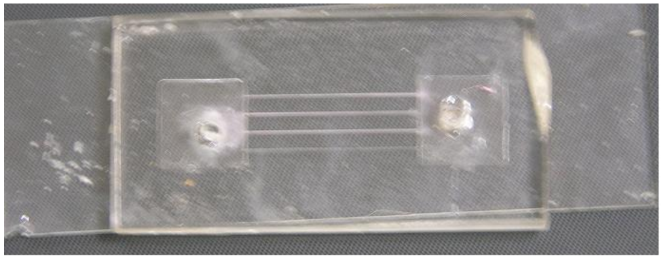




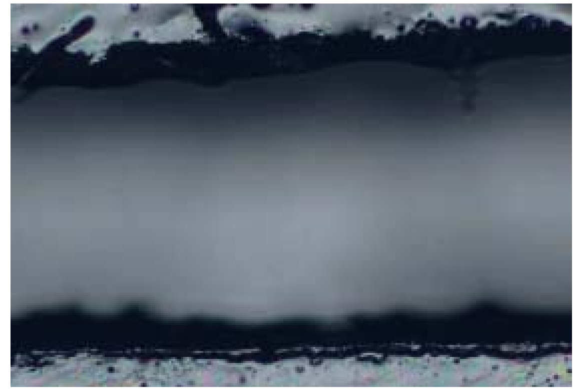


S. K. Mitra, ***Keynote Lecture***, ASME 4th International Conference on Nano, Micro and Mini Channels, Ireland, 2006

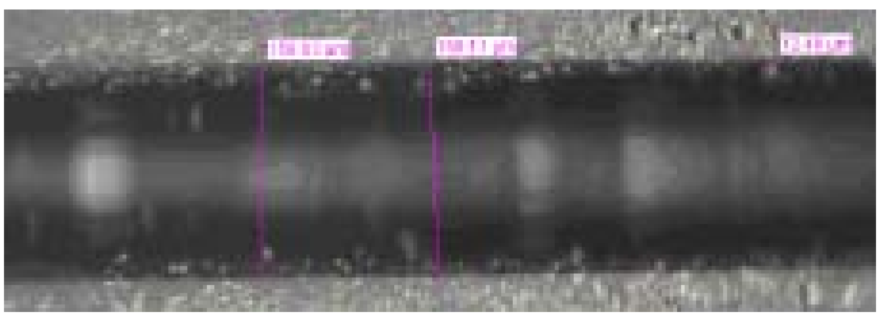
Micro-Fabrication



Etched Channel on Plexi-glass



Surface Roughness



Excimer Laser – PMMA channel with Styrene Mask

500 shots

5 Hz, 0.740 J/cm^2

Concluding Remarks

- Convective transport is critical for the design of micro-Fuel Cells
- Certain multi-physics need to be tackled which are characteristics of micro-Fuel Cells
- Surface roughness in the flow field is directly related to the pressure drop
- Electrokinetic effects are predominant
- Permeability of porous transport layer effects the flow distribution
- Flow control can be achieved using applied potentials
- Non-intrusive flow measurement is needed
- Micro-fabrication with newer materials is explored