Comsol Multiphysics 在微奈米電動力學於生醫之應用

- Speaker : **Jeng-Shian Chang**

- Date : **2010/11/26**

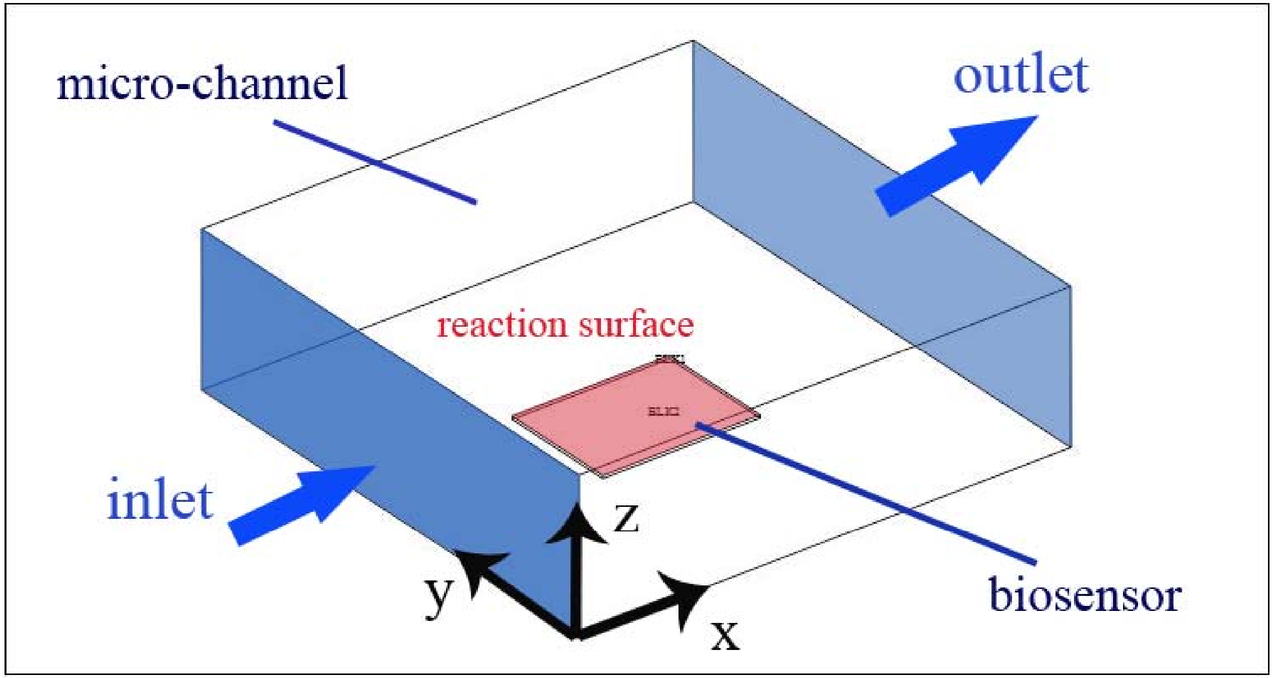
應用力學研究所 Institute of Applied Mechanics
National Taiwan University

Outline

I. Biosensor (Microcantilever)
II. Micromixer
III. Biosensor (Quartz Crystal Microbalance)
IV. Microseperator
V. AC electroosmosis

Ⅰ. Biosensor (MCB)

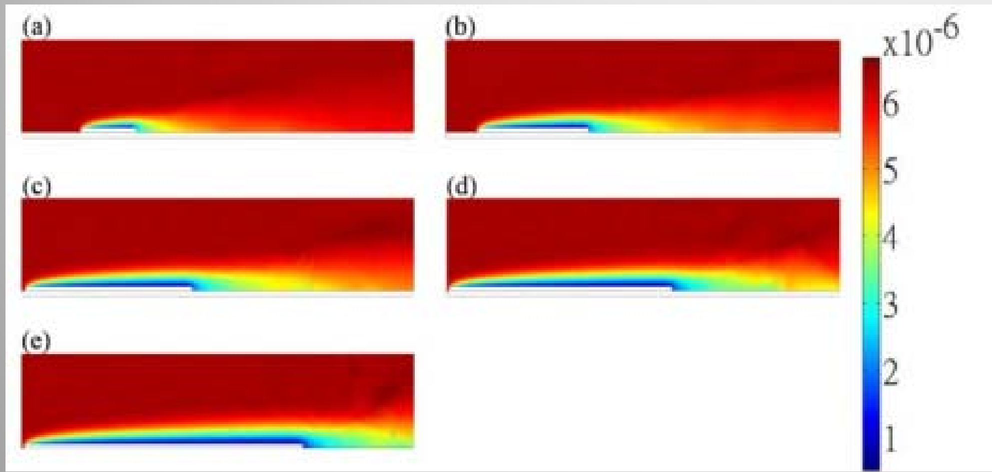
Three dimensional Simulation for Microcantilever-Based Biosensor



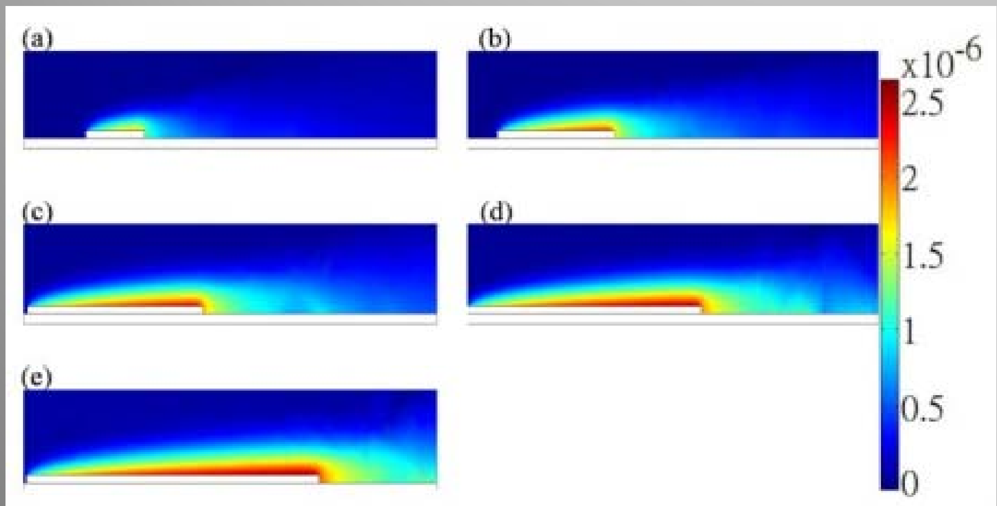
I. Biosensor (MCB)

Three dimensional Simulation for Microcantilever-Based Biosensor

Diffusion boundary layer (Association Phase)



Diffusion boundary layer (Dissociation Phase)



The flow field

In this work it is assumed that the fluid is incompressible

$$\nabla \cdot \vec{V} = 0$$

$$\rho\left(\frac{\partial \vec{V}}{\partial t} + \vec{V} \cdot \nabla \vec{V}\right) - \eta \nabla^2 \vec{V} + \nabla p = 0$$

$\vec{V}$: the velocity field

η : the dynamic viscosity

p : pressure

The concentration field

Transport of analytes to and from the surface is assumed to be described by the Fick's second law :

$$\frac{\partial [A]}{\partial t} + \vec{V} \cdot \nabla [A] = D \nabla^2 [A]$$

[A] : the bulk concentration of analyte,

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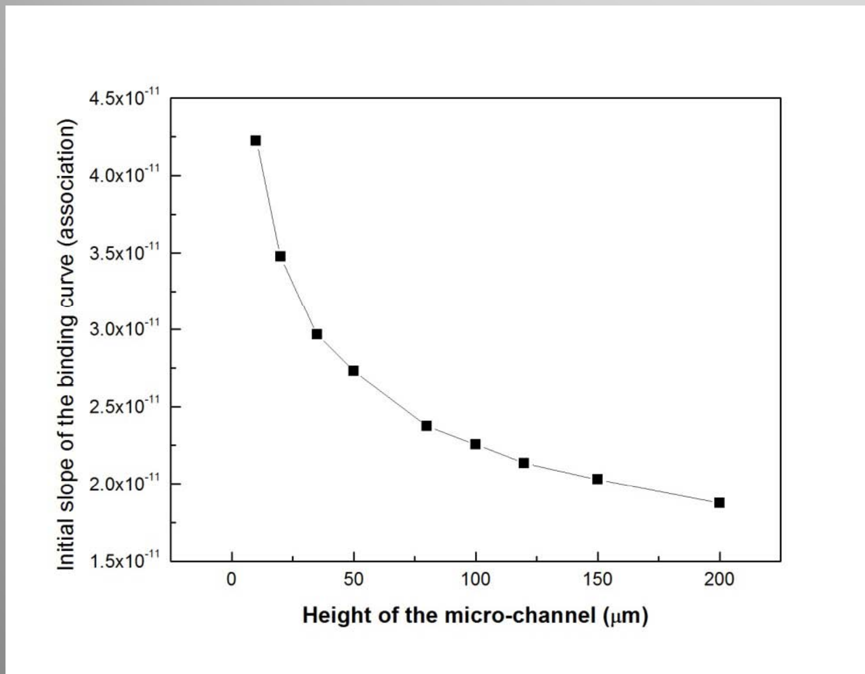
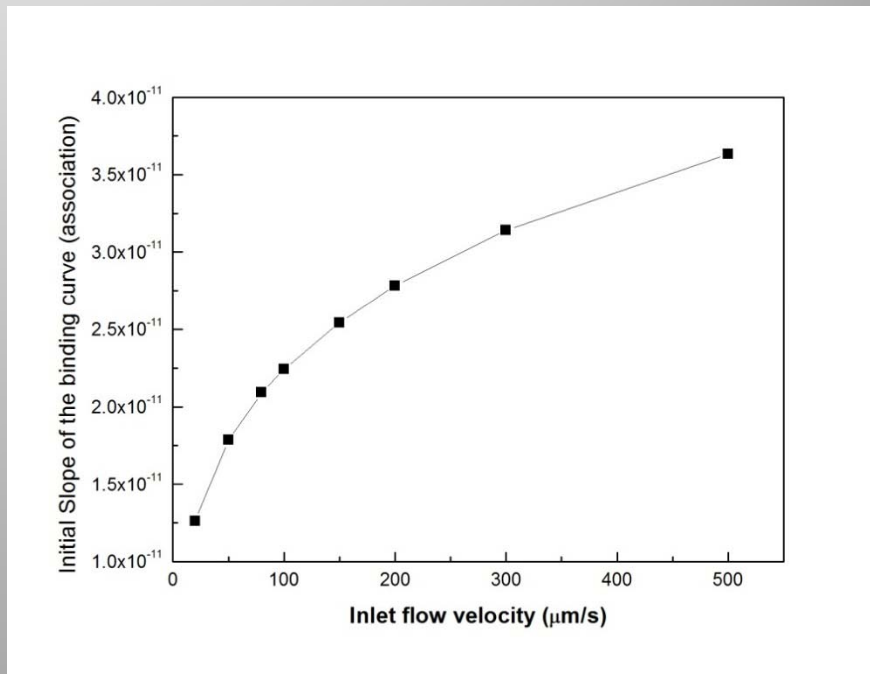
Channel height & Inlet flow velocity

Low channel heights and fast inlet flow velocities yields fast responses of the association and dissociation phases, because the velocity of the convective transport of the analytes to the reaction surface is accelerated with increase in the inlet flow velocity, and the time required for the diffusion of the analytes into reaction surface reduces with the height of the channel.



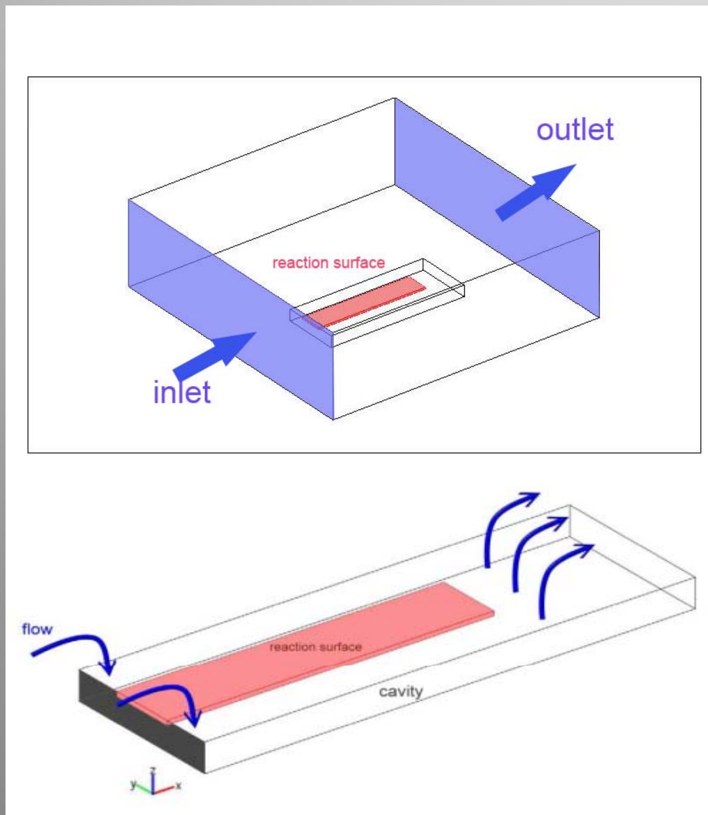
Slope of the binding curve as a function of the height of the micro-channel

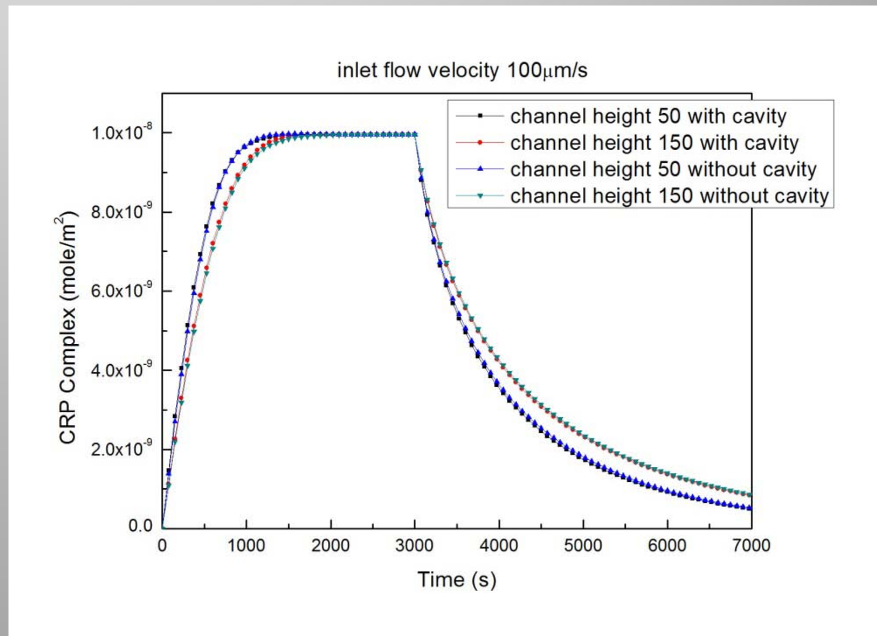


Slope of the binding curve as a function of the inlet flow velocity

Micro-channel with or without cavity

In the micro-cantilever based biosensor, the zone of the reaction surface is fabricated by etching. The mechanism involves the translation of bio-molecular recognition and its subsequent protein complex conformational change into bio-induced nano-mechanics of surface stresses.

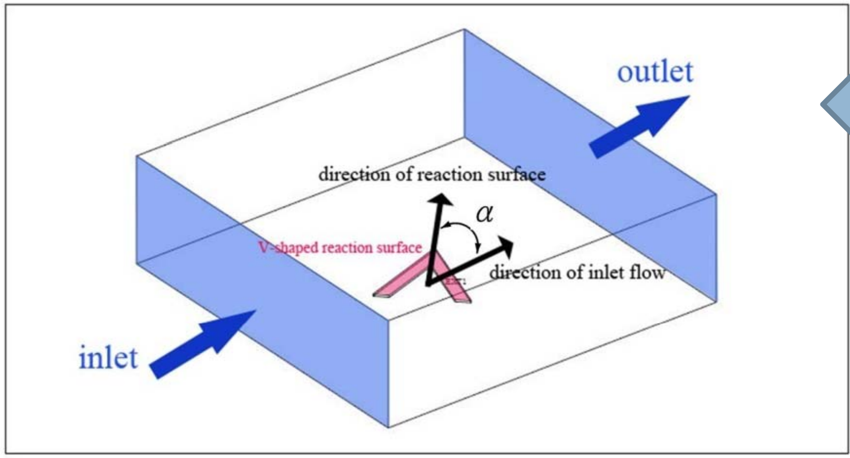




$300\mu m \times 100\mu m \times 20\mu m$ cavity

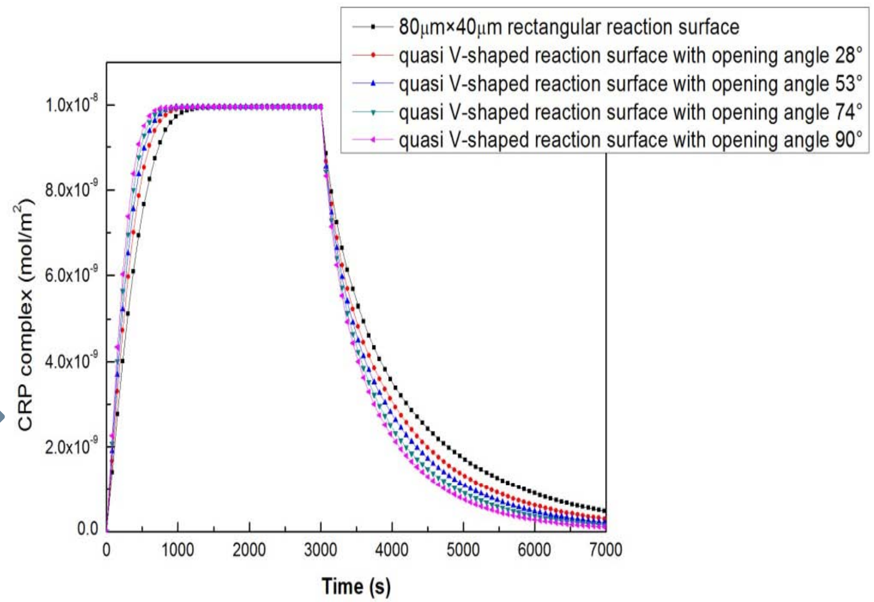
I． Biosensor (MCB)

The shape of the reaction surface



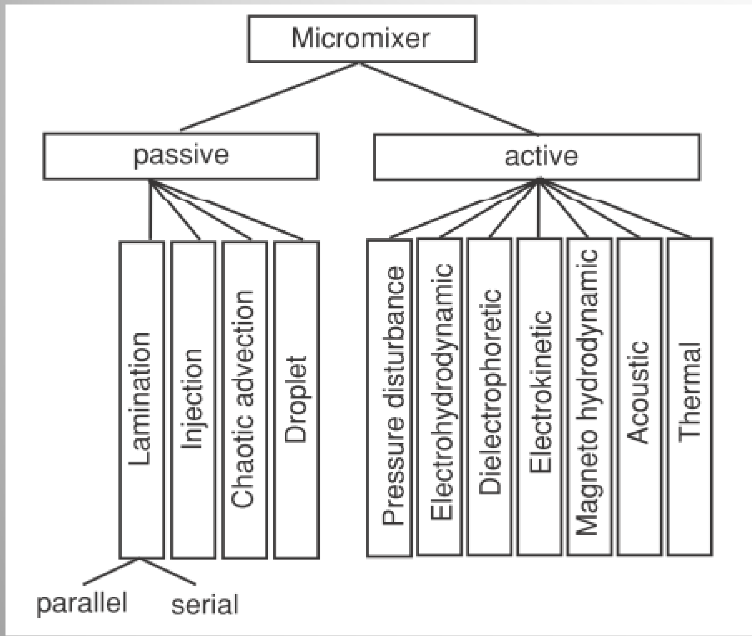
Sketch of the arrangement of the V-shaped reaction surface

The binding reaction curves for a rectangular reaction surface in comparison with V-shaped reaction surface



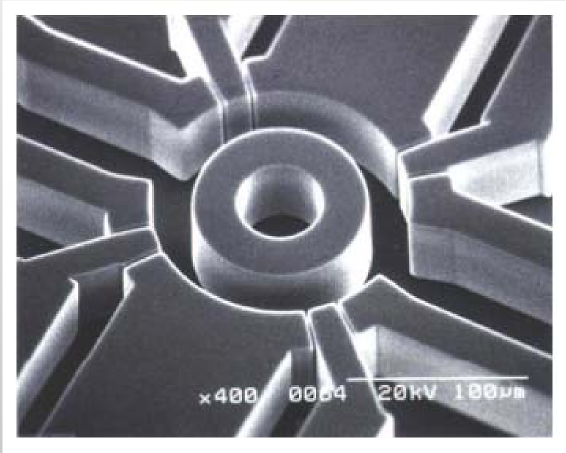
Nam-Trung Nguyen, Zhigang Wu, "TOPICAL REVIEW, Micromixers- a review"

II . Micromixer



Active micromixer :

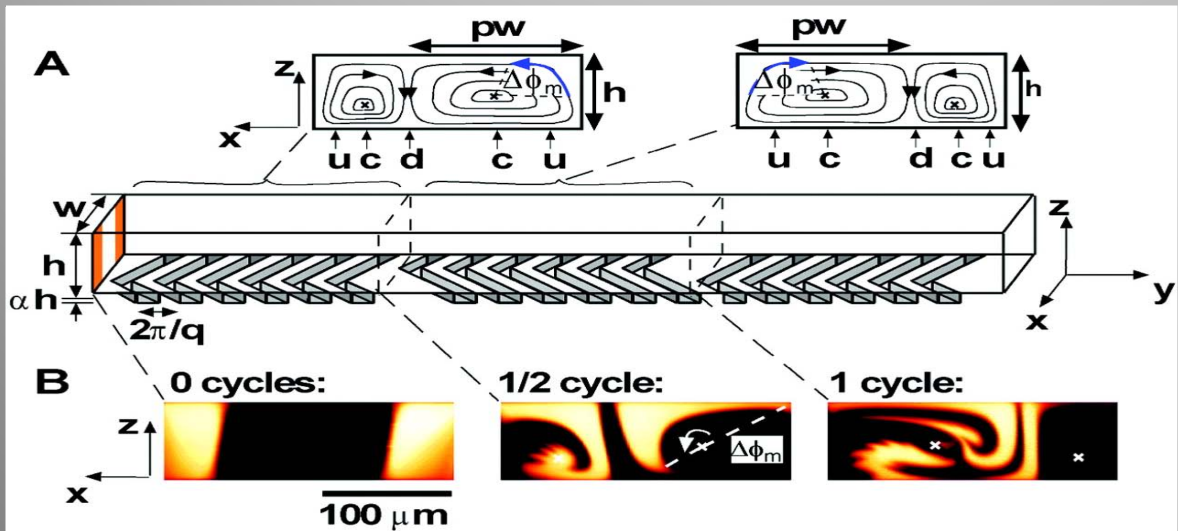
混合時間短、混合距離短、需外能



Electroosmosis micro-mixer

Han Chen, Yanting Zhang, Igor Mezic, Carl Meinhart, Linda Petzold, "NUMERICAL SIMULATION OF AN ELECTROOSMOTIC MICROMIXER"

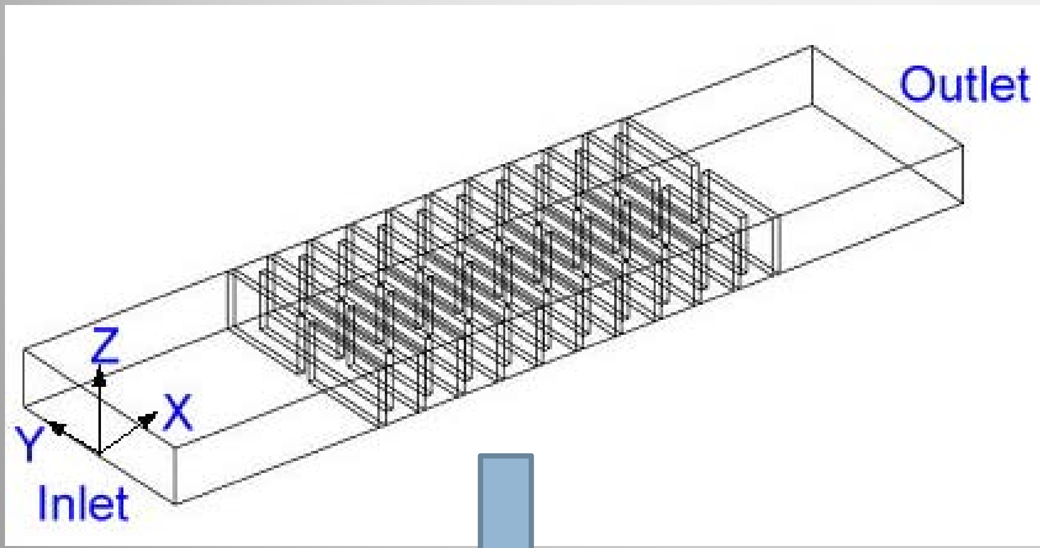
Passive Micromixer : 混合時間較長、混合距離長、不需外能

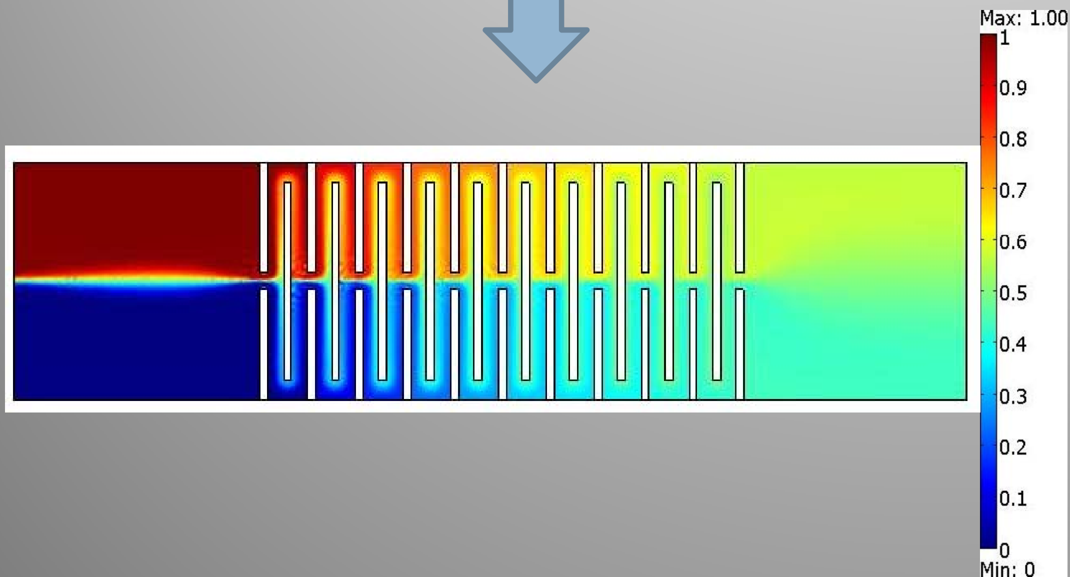


A.D. Stroock,* S. K. W. Dertinger, A. Ajdari, I. Mezic, H.A. Stone, and G. M. Whitesides,"Chaotic Mixer for Microchannels"

Three dimensional Simulation for The Passive Micromixer

II . Micromixer





<u>The flow field</u>

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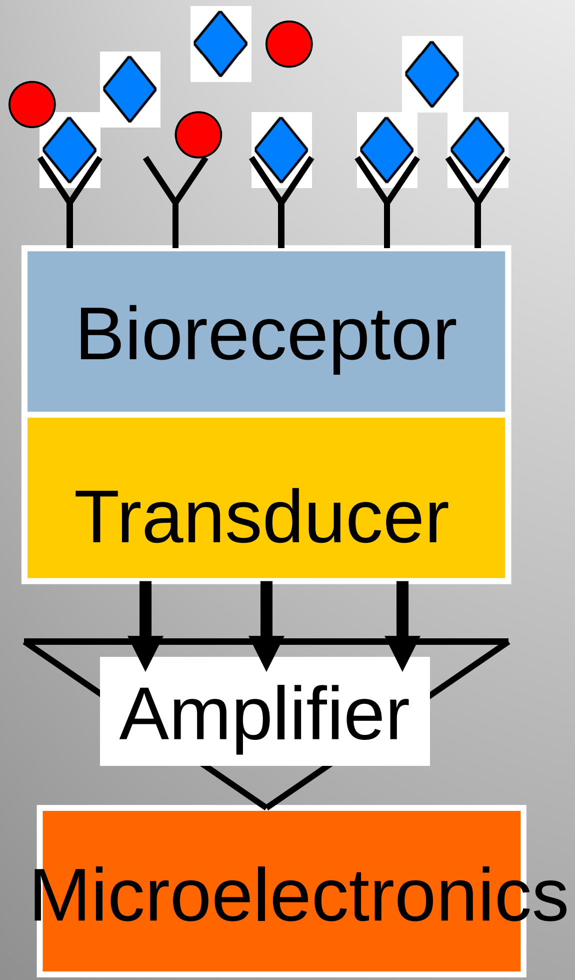
Introduction



1. Biomolecule
2. Immobilization

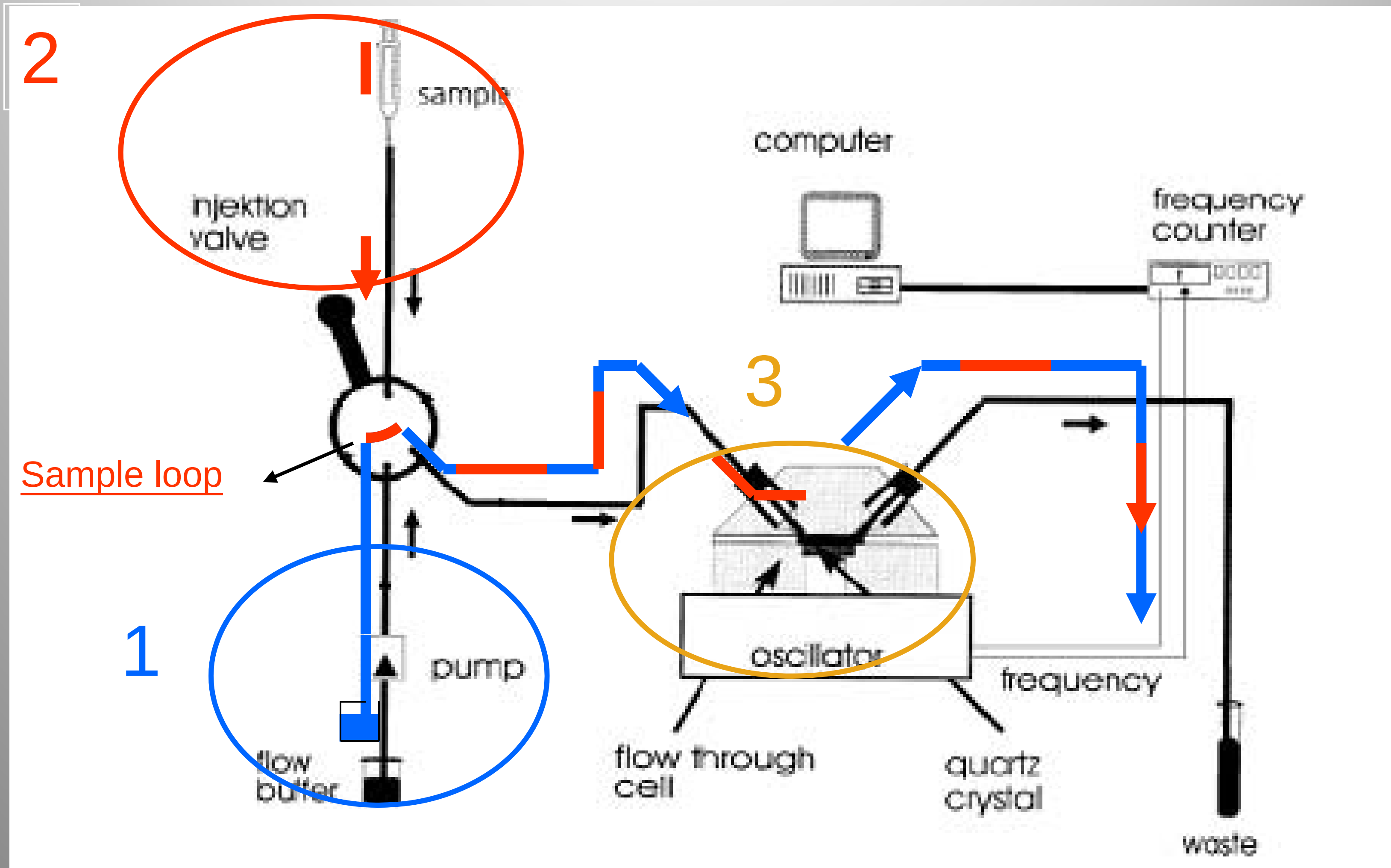
1. Microcantilever beam
2. Quartz crystal microbalance (QCM)
3. Surface Plasmon Resonance (SPR)

Signal

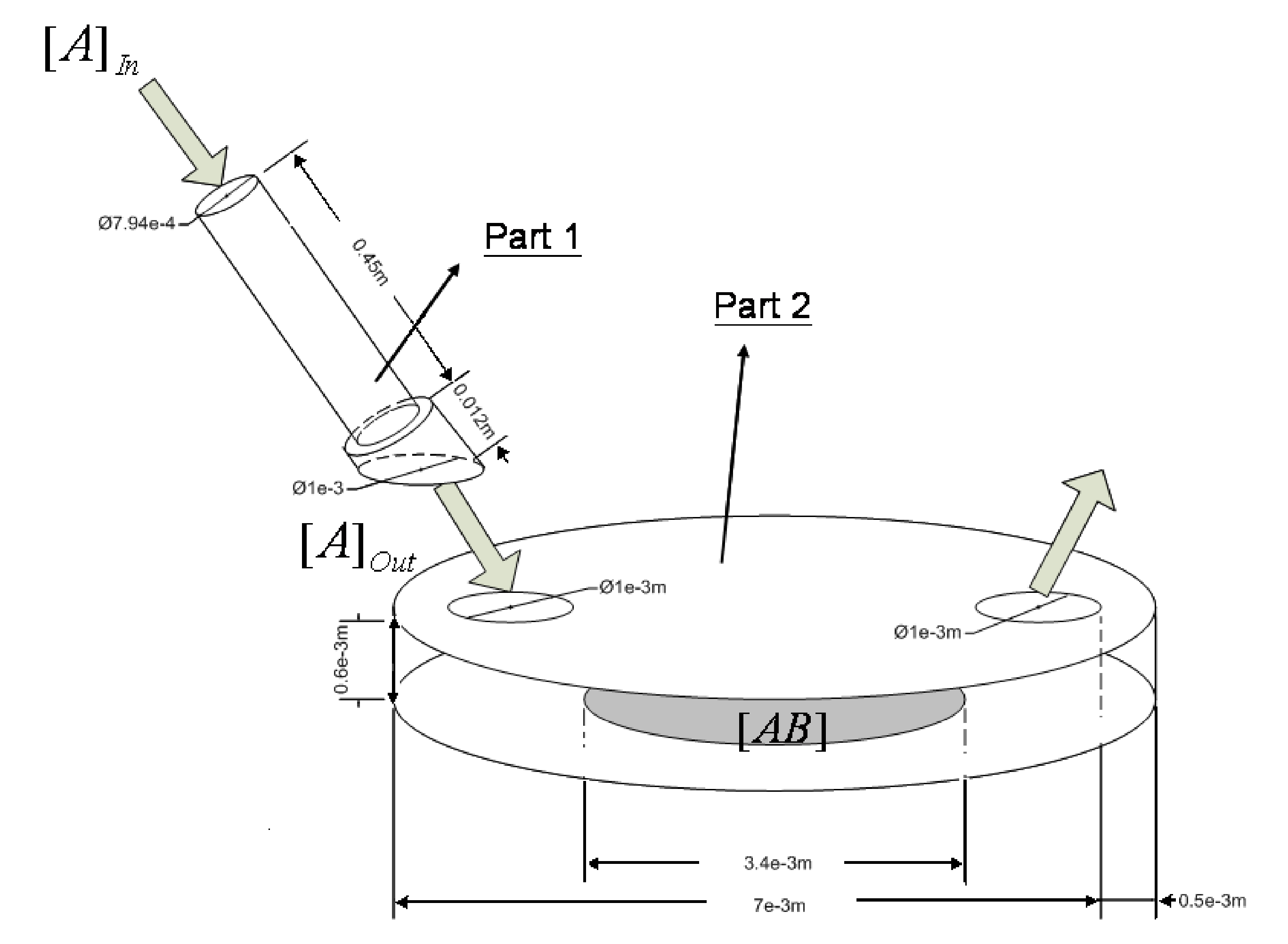
Data processing

Quartz Crystal Microbalance

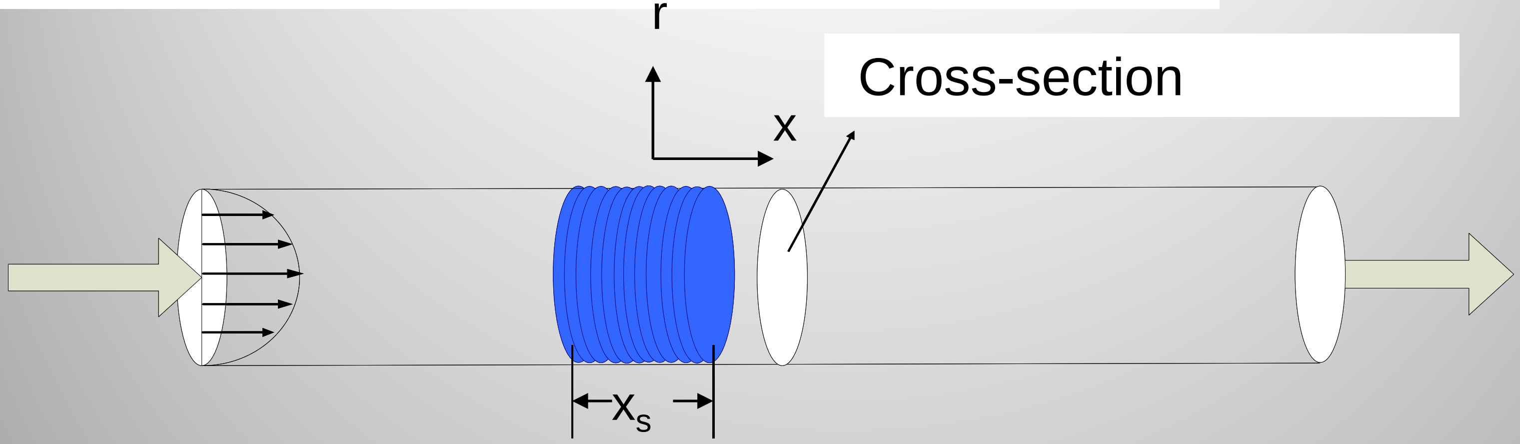
Experiment Equipments

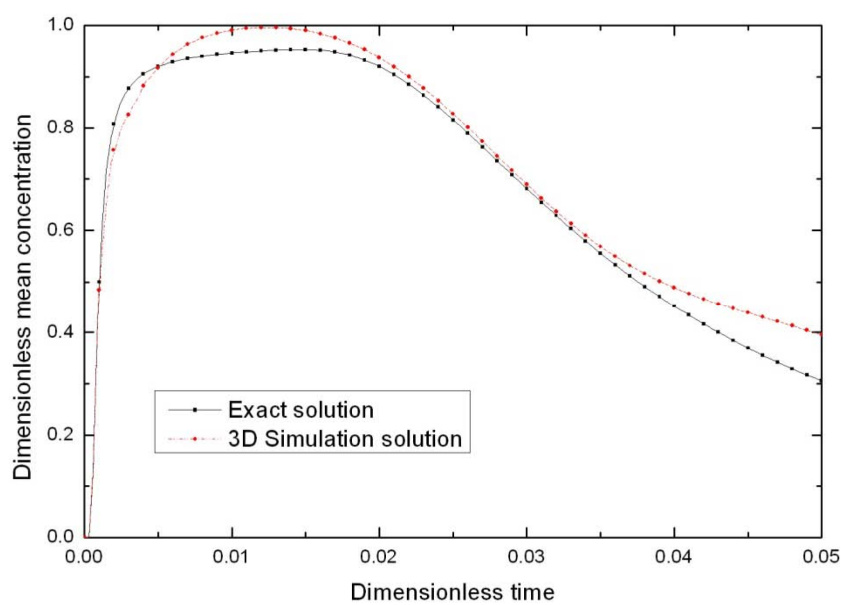


Simulation Process



Exact Analysis of Unsteady Convective Diffusion (1970, W. N. Gill, and R. Sankarasubramanian)





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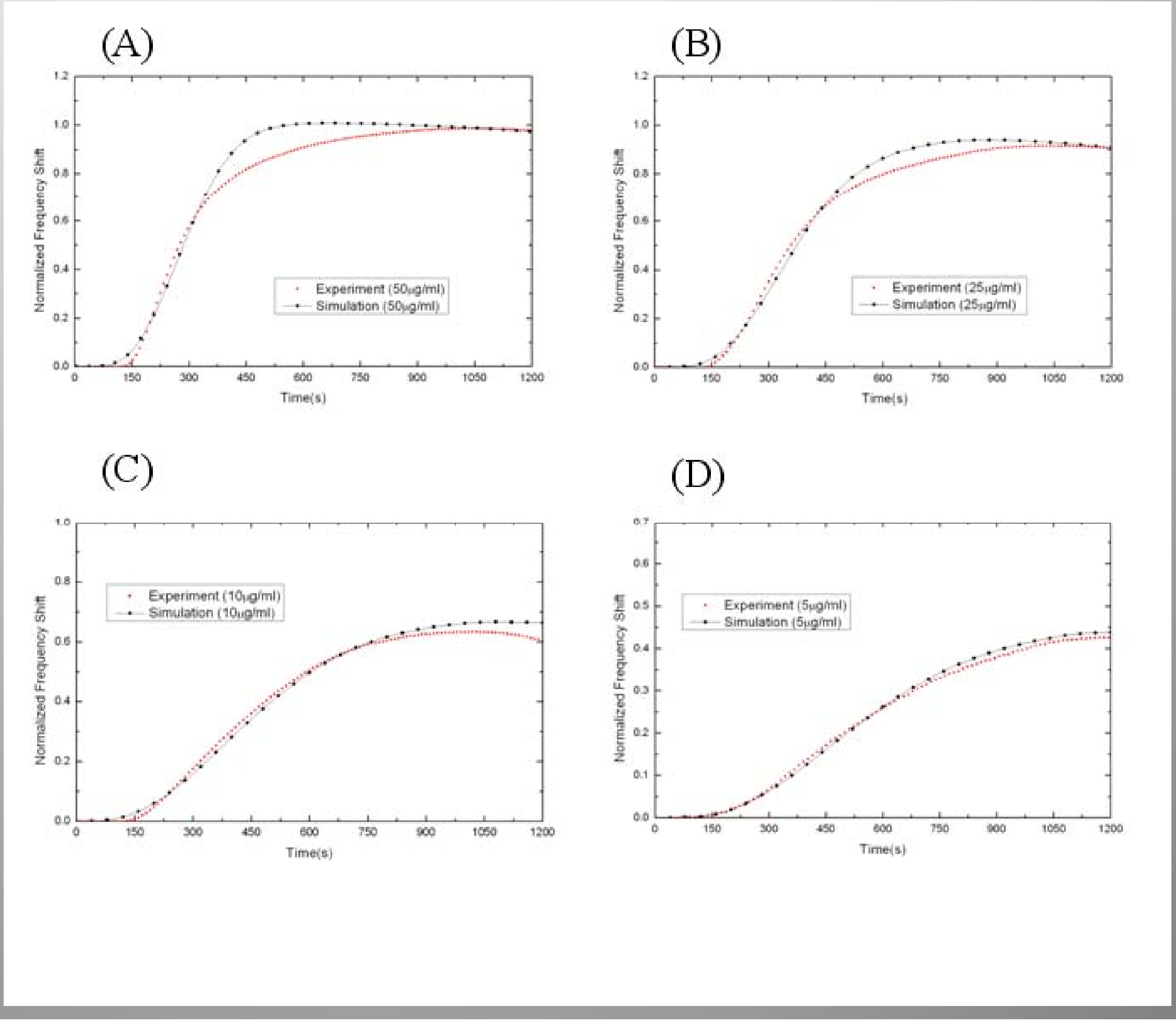
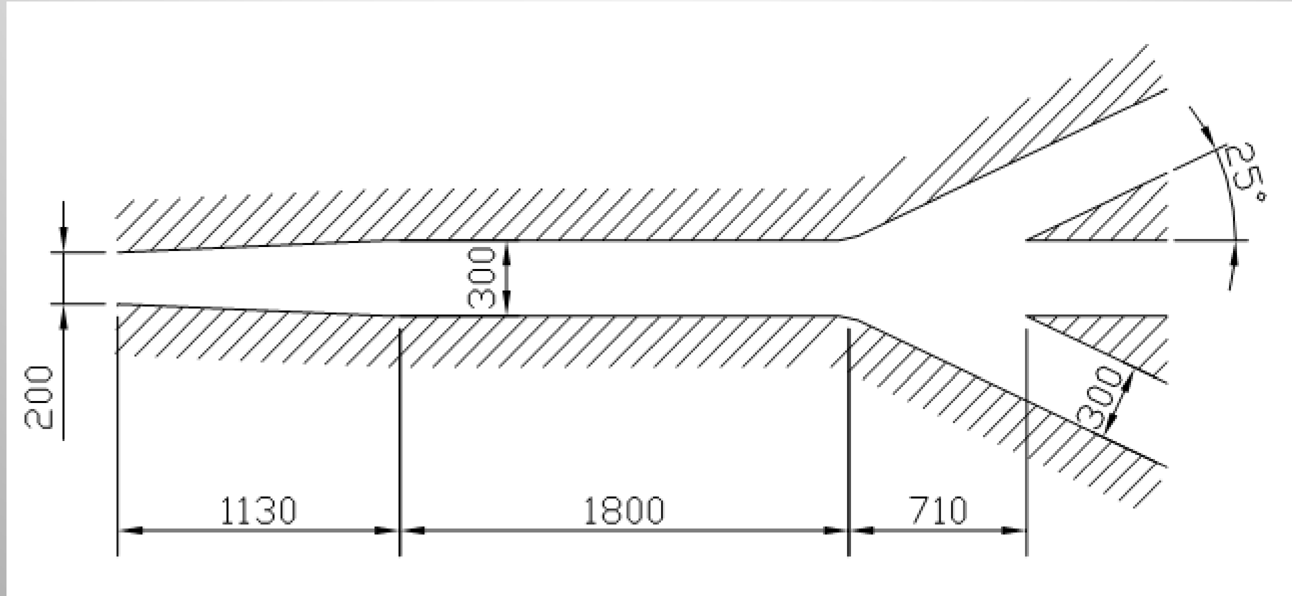
Comparison between Experiment and Simulation Results

Sample of 500μl



Two dimensional Simulation for The Microseperator



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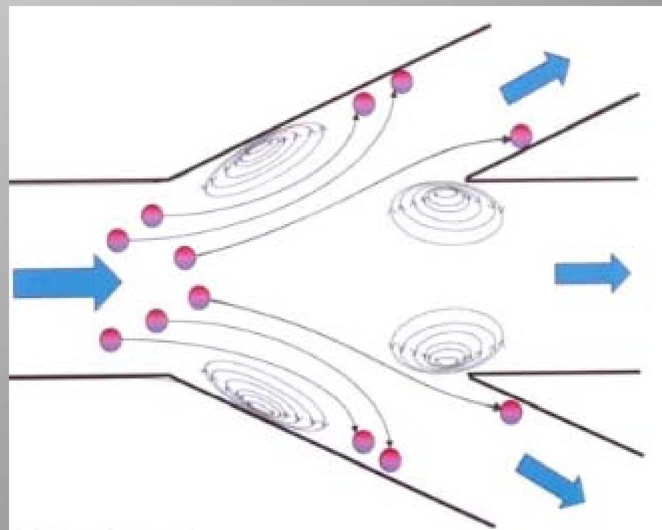
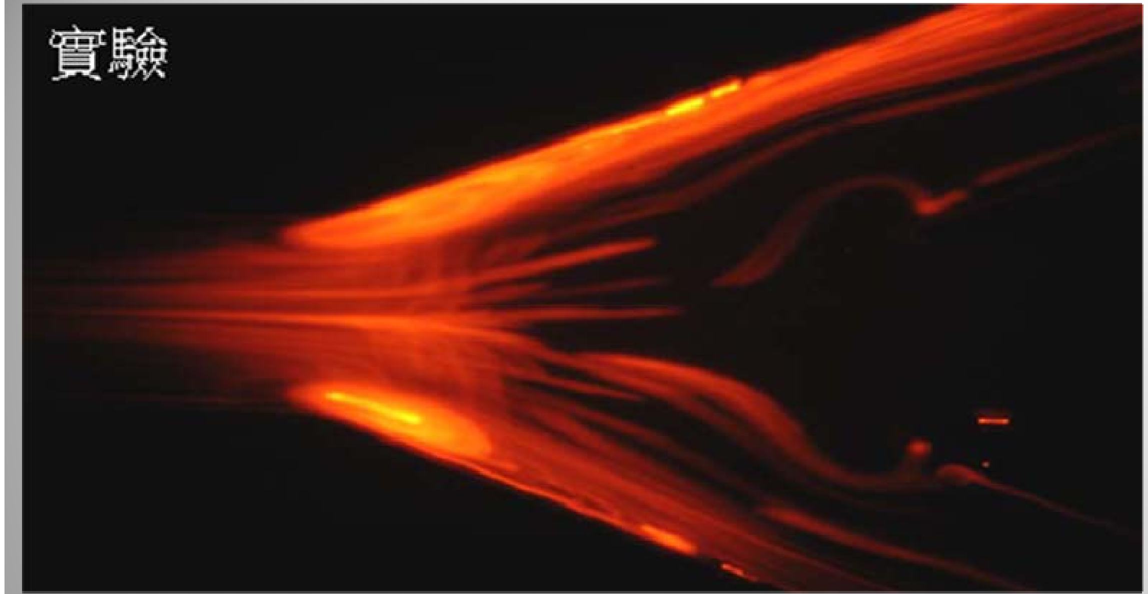
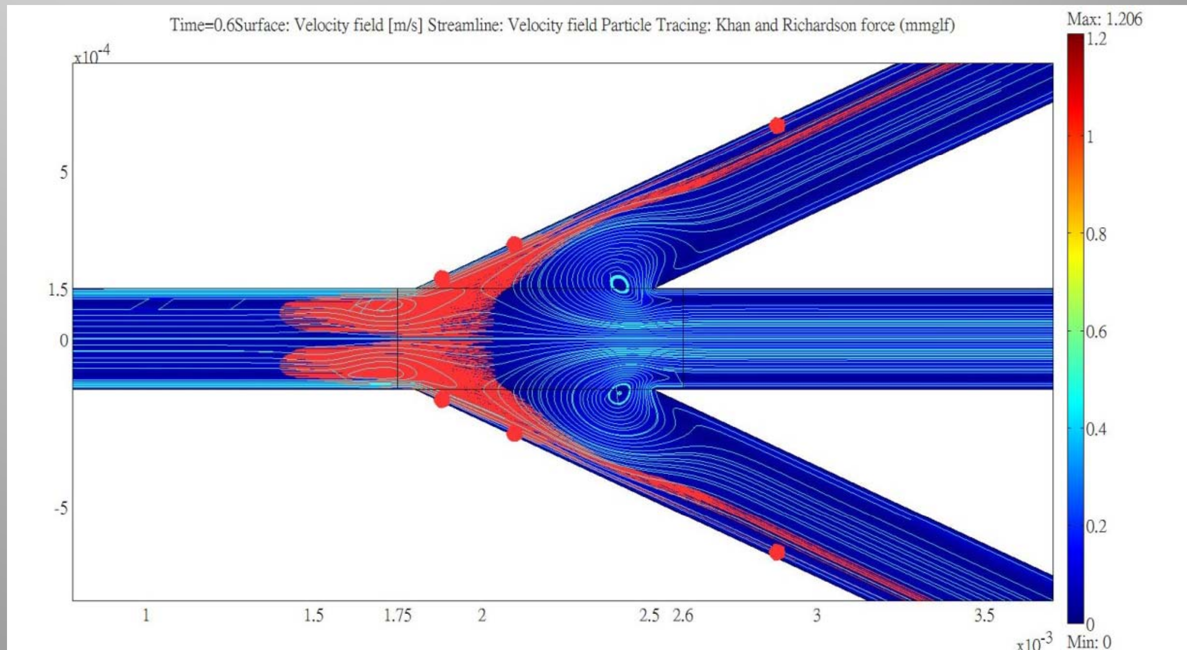


IV. Microseperator



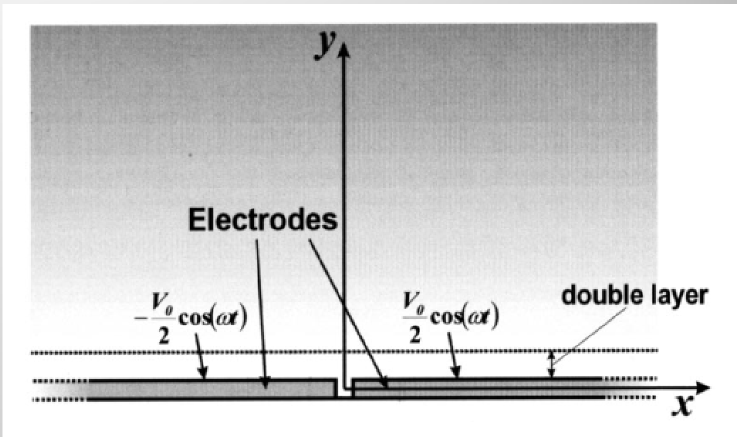
Comparison between Experiment and Simulation Results

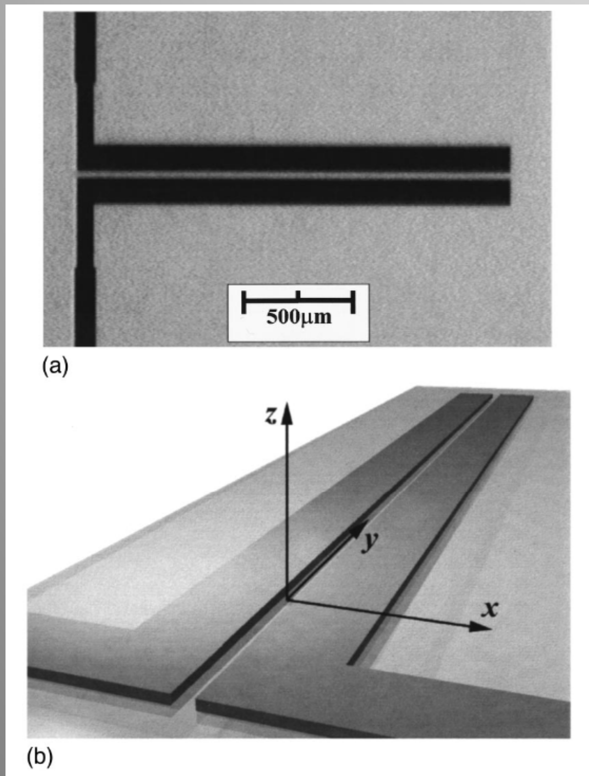


AC electroosmotic theory

A. González, A. Ramos, N. G. Green, A. Castellanos, H. Morgan, "Fluid flow induced by nonuniform ac electric fields in electrolytes on microelectrodes. II. A linear double-layer analysis, 2000

N. G. Green, A. Ramos, A. González, H.Morgan, A. Castellanos, “Fluid flow induced by nonuniform ac electric fields in electrolytes on microelectrodes. I. Experimental measurements”



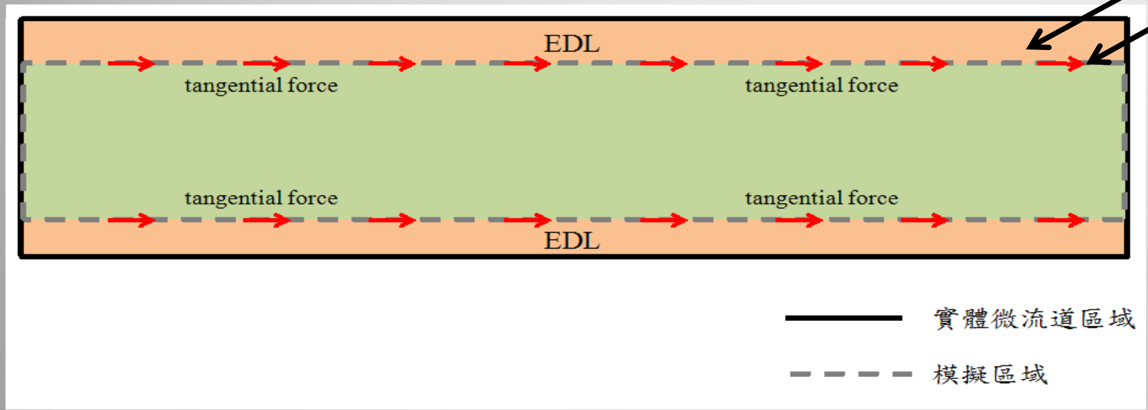


基本假設

- 流道長度遠大於流道寬度，因此可將問題簡化為2D問題
- 定義電極擺放於x=0之位置，且電極對稱y軸
- 由於電極寬度遠大於電極間之距離，因此可假設x向為一 半無限域問題。
- 流道內注入之電解液為一對稱電解液
- 所有電極階為理想極化 (ideally polarizable)，即可忽略自由電子由電極移動至電解液中
- 電極表面電位固定，且外加之AC電壓值相當小，其解可近似於一線性解；由於外加電壓相當小，因此假設外加電壓不影響表面電位。

V. AC electroosmosis

Simulation of AC electroosmosis



no slip condition
slip condition

$$U = -\frac{\varepsilon}{4\eta}\Lambda\frac{\partial}{\partial x}\left(\left|\Delta V^{2}\right|\right)$$

N.G. Green, A. Ramos, A. Gonzalez, H. Morgan and A. Castellanos , "Fluid flow induced by nonuniform ac electric fields in electrolytes on microelectrodes. III. Observation of streamlines and numerical simulation," *Physical Review E*, 66, 026305 (2002)

Simulation process

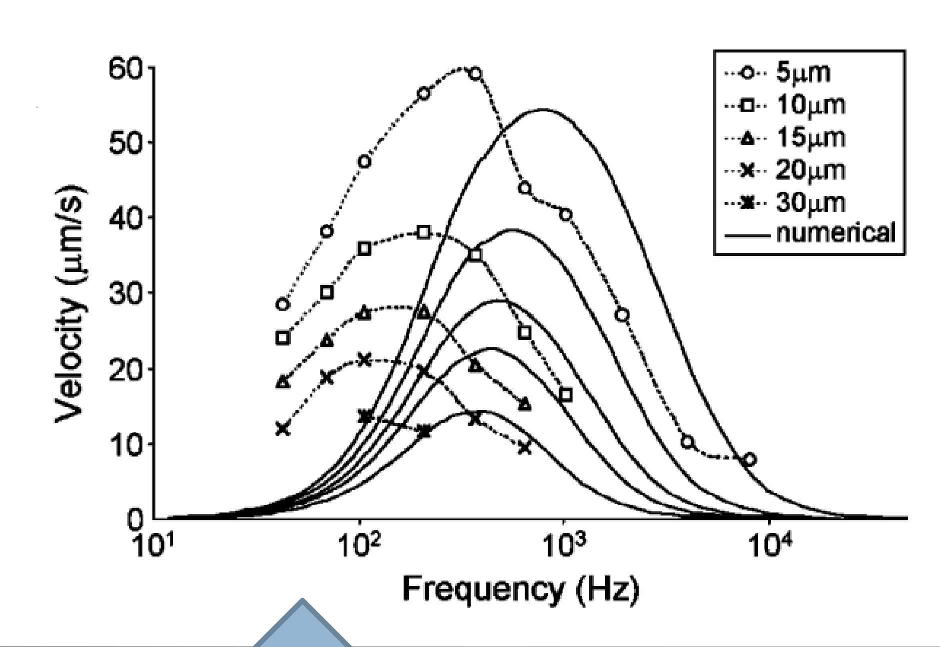
Electric field → Velocity field → Concentration field

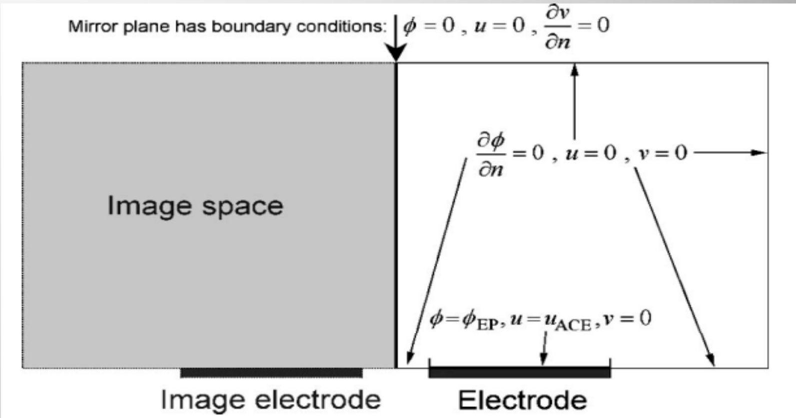
Velocity field ⇩ Micropump

Concentration field ⇩ Micromixer

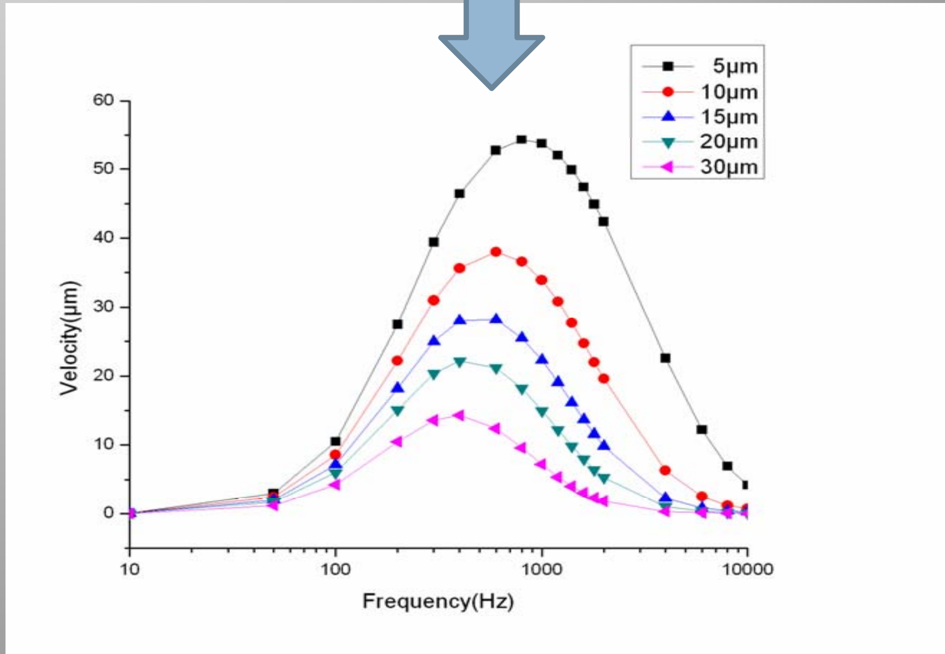
Simulation of AC electroosmosis

V. AC electroosmosis





simulation results



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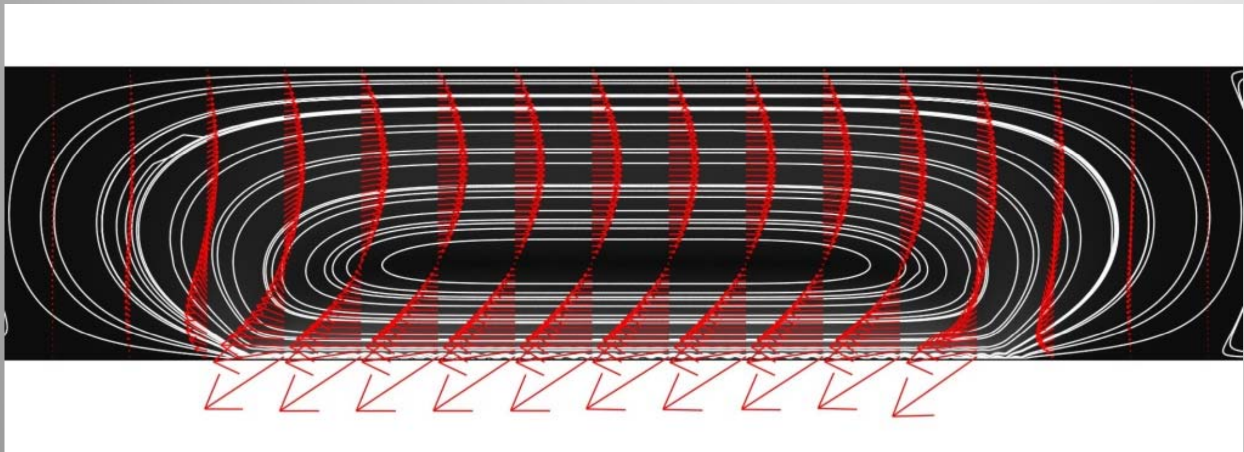
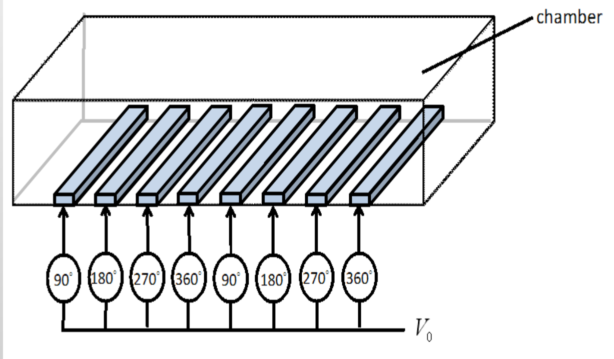
Simulation of TW electroosmosis

TWEO simulation results



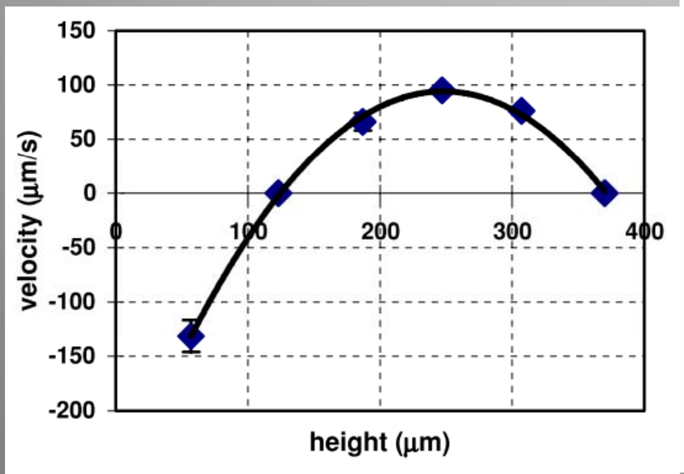


chamber length $5mm$

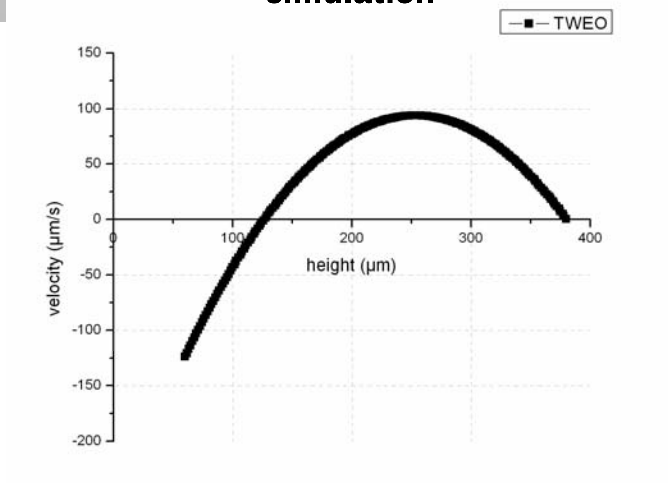
chamber height $380\mu m$

electrode length $10\mu m$

experiment



simulation



H. Yang, H. Jiang, A. Ramos,P. Garcia-Sanchez, "AC electrokinetic Pumping on symmetric electrode arrays," *Microfluid & Nanofluid*, (2009)

Thanks for your listening !!