Analysis of Microscale Transport for BioMEMS

Introduction

- Microfluidics
- Fluid mechanical characteristics of microfluidics system
- Basic principles of microfluidics
- Two common methods by fluid actuation through microchannel
- Electrothermal simulation

Microscale

- The surface force becomes much pronounced compared to the body force because of its small size, i.e. extremely large surface-to-volume ratio

- The condition of channel wall flowing fluid extremely influences fluid stream.

Microfluidics

- Microfluidics is a mulitidisciplinary field comprising physics, chemistry, engineering and biotechnology that studies the behavior of fluids at the microscale and mesoscale.

- Technology that determine installation methods to operate and control the fluid flows, heat transfer and mass transfer.

Fluid mechanical characteristic of microfluidics system

- Flow in microfluidic system be performed by various driving force
- Driving force
  - -Pressure gradient
  - -Surface tension
  - -Gradient of surface tension
  - -Electric filed
  - -Magnetic filed
  - -Centrifugal force

Basic principles of microfluidics

- The flow of a fluid through a microfluidic channel can be characterized by Reynolds number, defined as

$$\mathrm{Re} = \frac{\rho u l}{\mu}$$

l : length scale
μ : viscosity
ρ : the fluid density
u :the average velocity of the flow

Boundary condition

- No-slip boundary condition
- Slip boundary condition

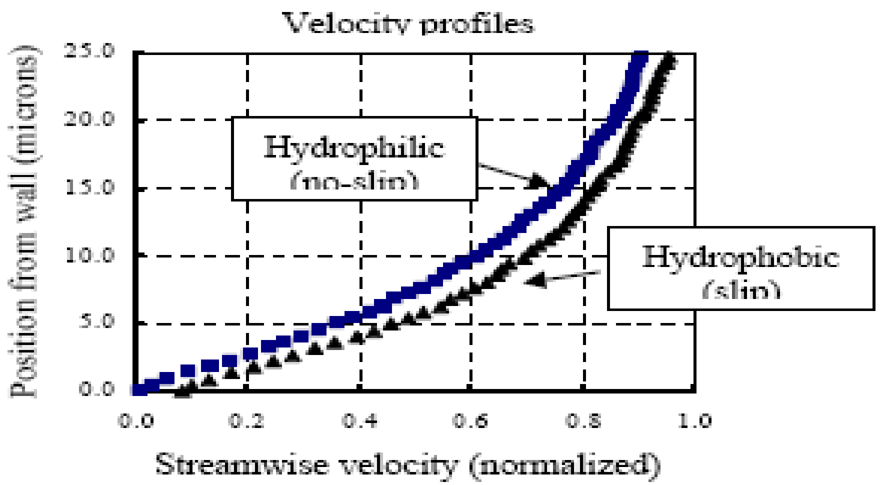

Fig.1. Velocity profiles for flow over a hydrophilic(square) and hydrophobic(triangle) microchannel surface.

Two common methods by fluid actuation through microchannel

- Pressure driven flow
- Electrokinetic flow

Pressure driven flow

- One of the basic laws of fluid mechanics for pressure driven laminar flow, the so-called no-slip boundary condition, states that the fluid velocity at the walls must be zero.

- This produces a parabolic velocity profile within the channel.
  -the parabolic velocity profile has significant implications for the distribution of molecules transported within a channel.

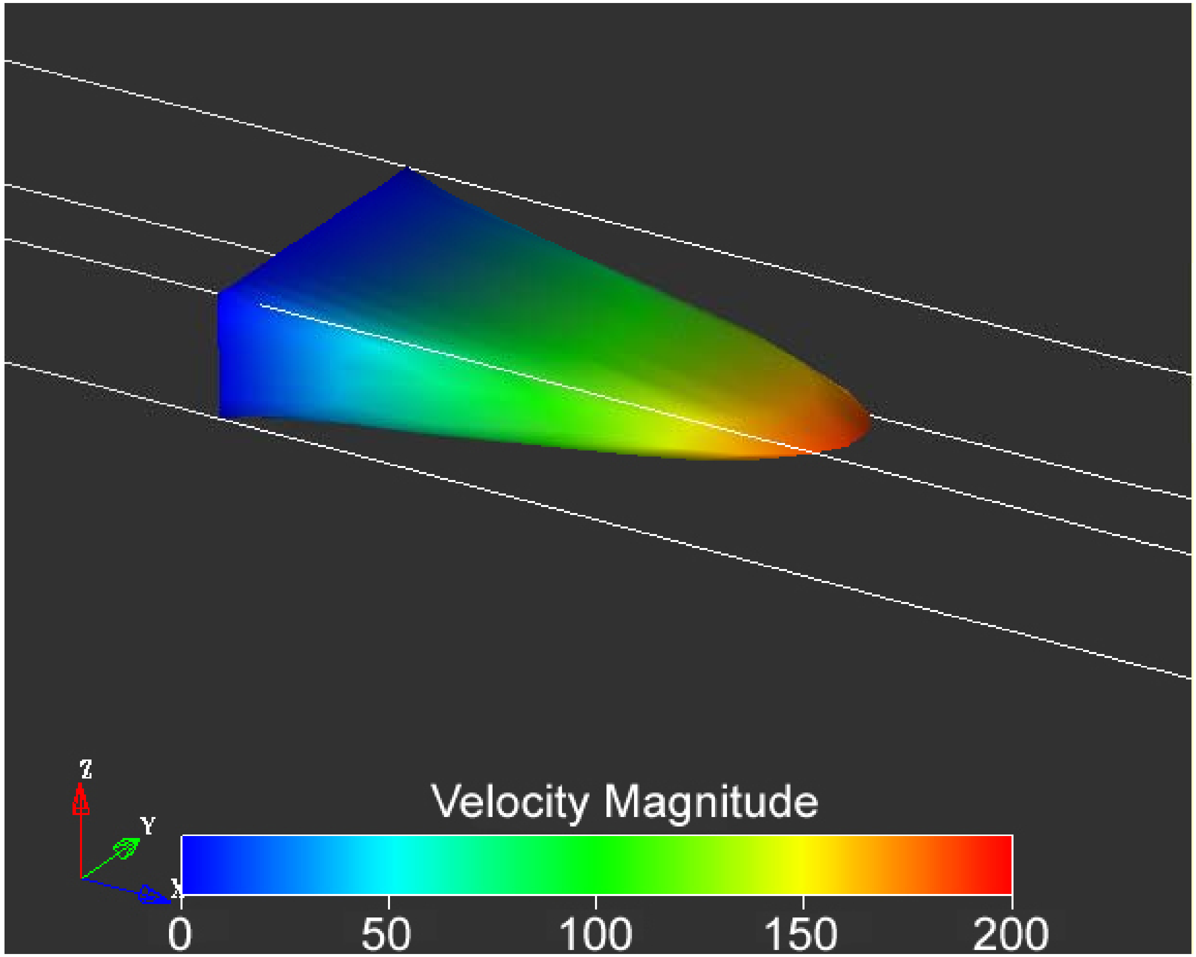

Fig.2. Velocity profile in a microchannel with pressure dirven flow.

Elecrokinetic flow

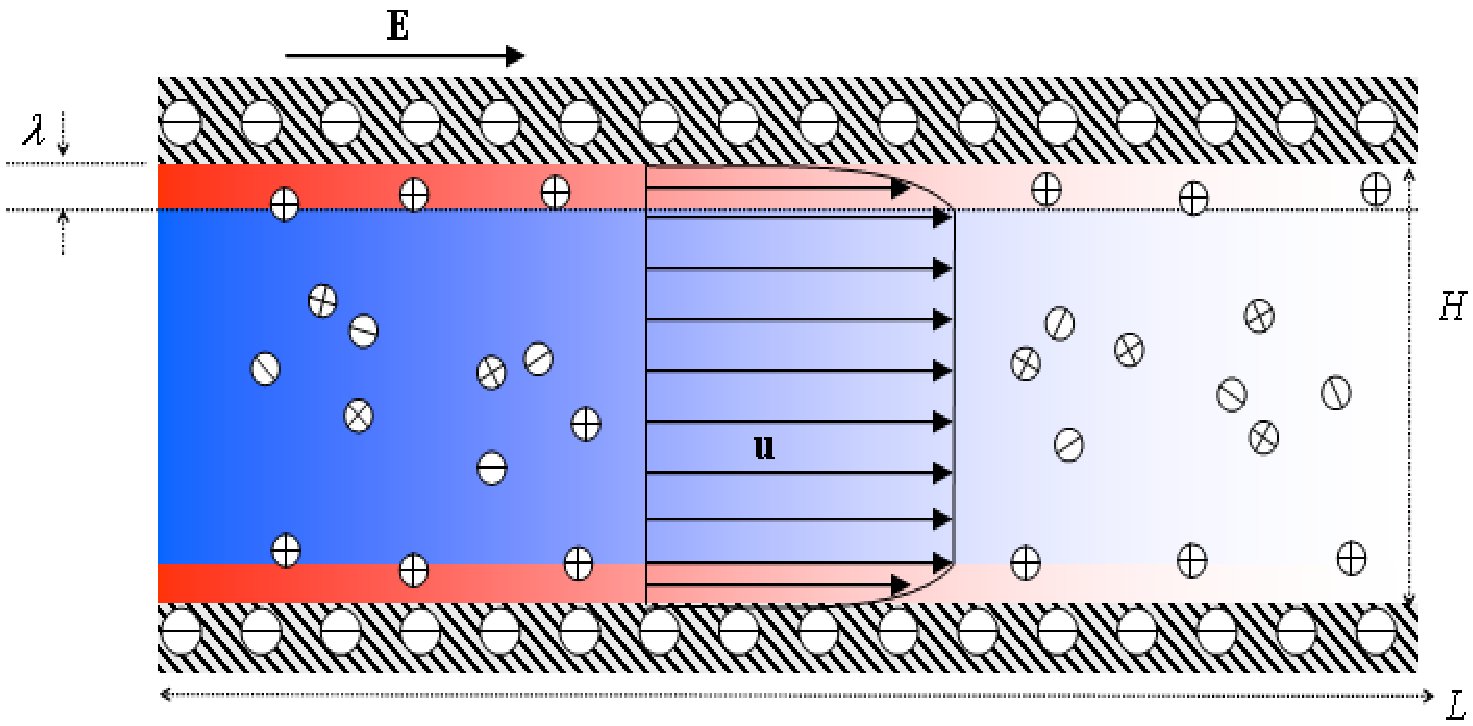

Fig.3. Elecroosmotic flow developed in microchannel, channel size, H and L are much larger than the thickness of eletrical double layer: λ .

Elecrokinetic

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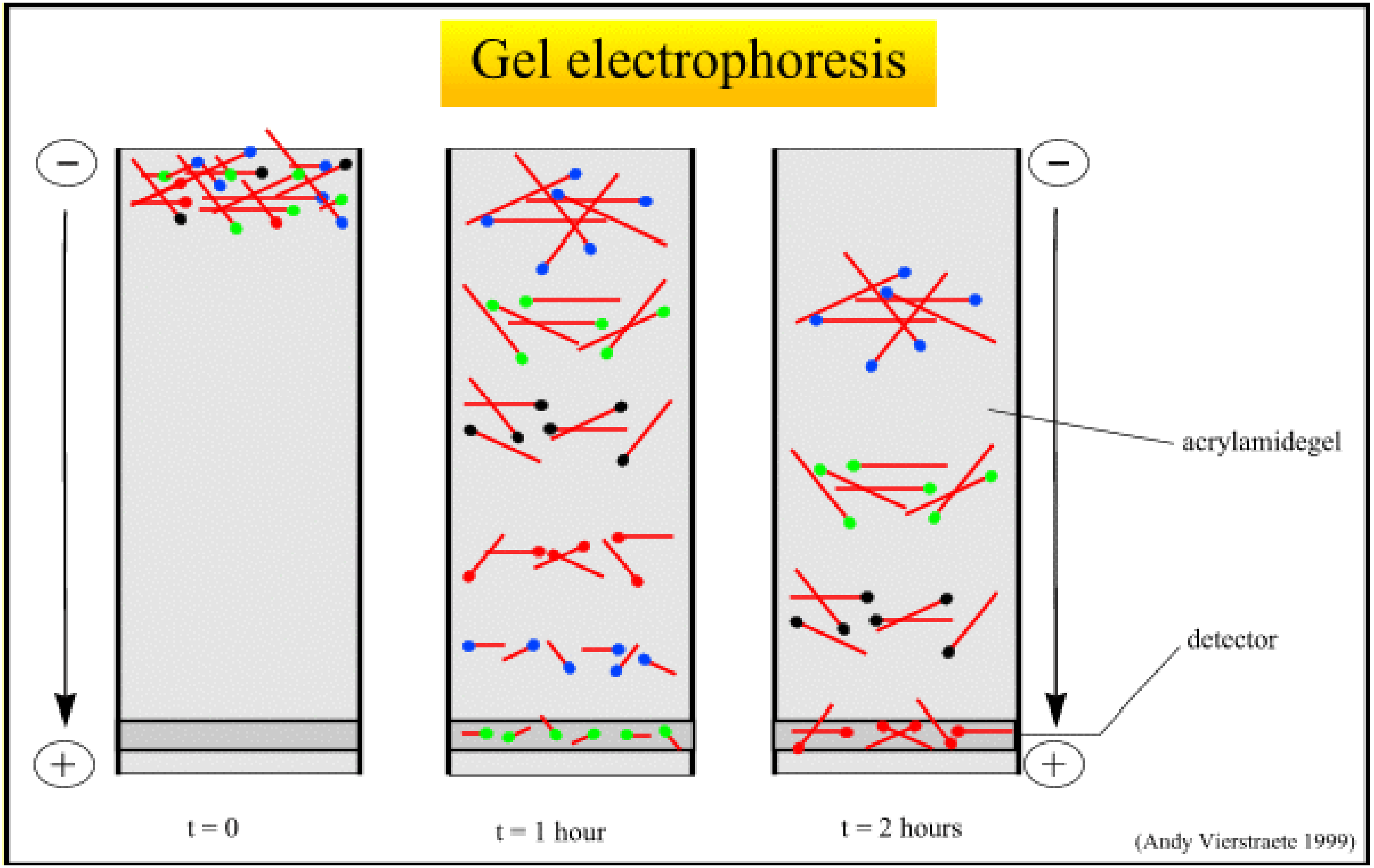

Fig.4. The separation of the molecules with electrophrosis.

- AC electrokinetics are advantageous over DC electrokinetic
  - Minimize electrolysis
  - Operate at lower voltages(1～20V)

- AC electrokinetics can be classified into three broad areas
  - Dielectrophoresis(DEP)
  - Electrothermal forces
  - AC electroosmosis

Dielectrophoresis

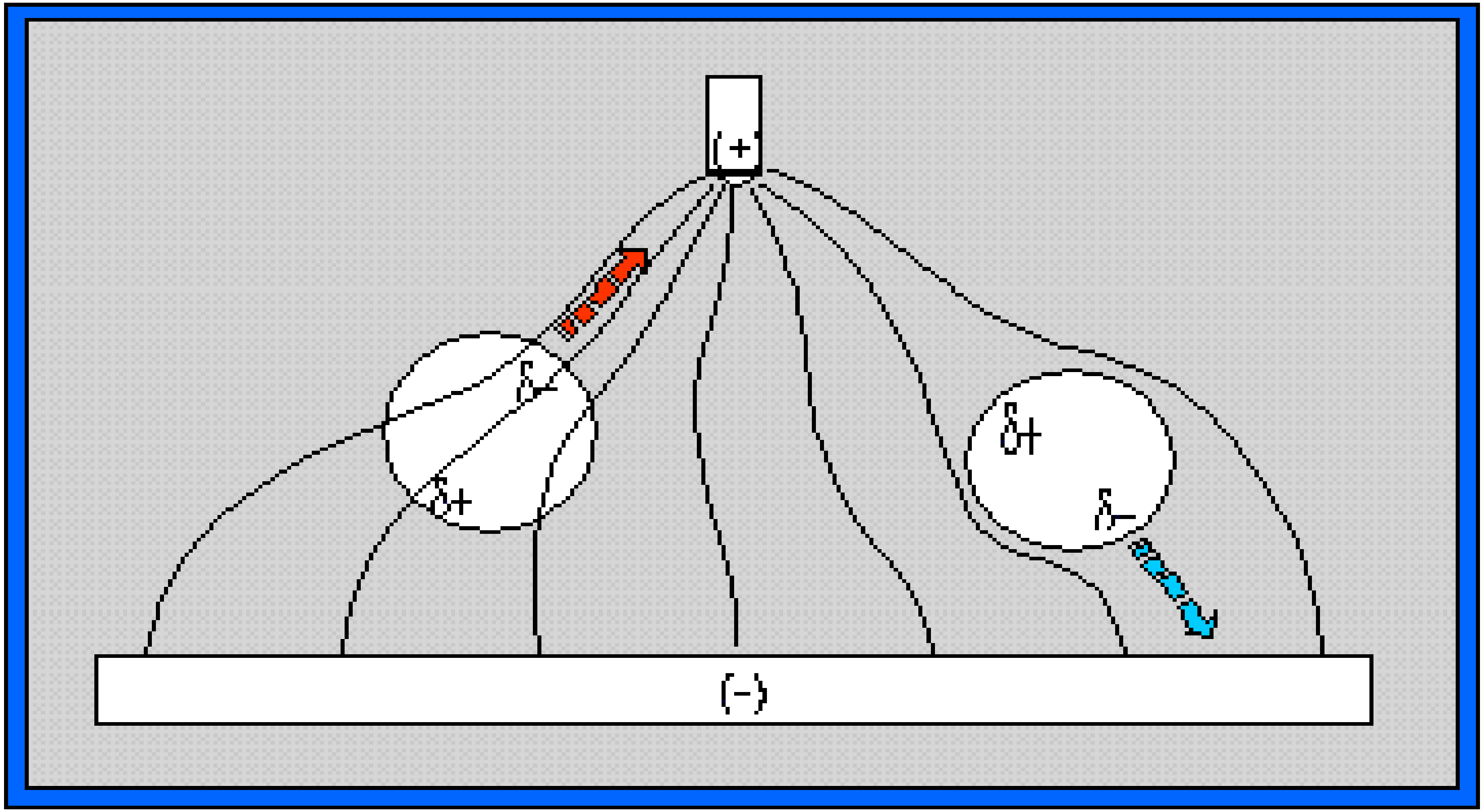

Fig.5. Two different particles in a non-uniform electric field.

AC electroosmosis

- It arise when the tangential component of the electric filed interacts with a filed-induced double layer along a surface.

Electrothermal forces

- Transport enhancement for small proteins may be most successful through electrothermally-driven flow
- A non-uniform electric filed produces uneven Joule heating of the fluid, which gives rise to nonuniformities in conductivity and permittivity
- These interact with the electric filed to generate flow

Immunoassays

- Immunoassys is a technology for identifying and qu
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  - W
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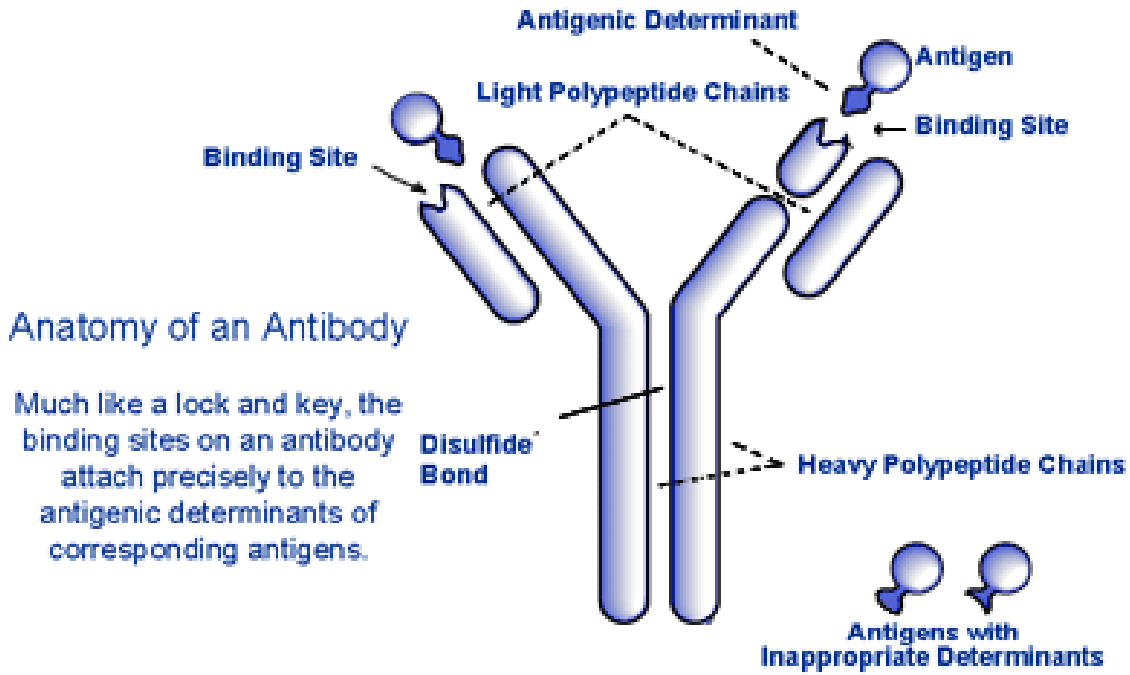

Fig.6. Interaction between an antibody and an antigen.

Immunosensor

- Sensors in which a ligand immobilized within a microchannel binds analyte flowing through the channel for the propose of detection of that analyte
- Immunosensors are potential utility as specific, simple, direct detection means and provision of reduction in size, cost and time of analysis comparing with conventional immunoassay

AC electrokinetics for microfluidic immunosensor

- A technique is proposed to enhance microfluidic immuno-sensors
- These sensors can be limited in both response time and sensitivity by the diffusion of analyte to the sensing surface

- **The sensitivity and response may be improved by using AC electrokinetically-driven microscale fluid motion to enhance antigen motion towards immobilized ligands**
  - Electrothermal effects can produce swirling flow patterns that carry sample past binding surface

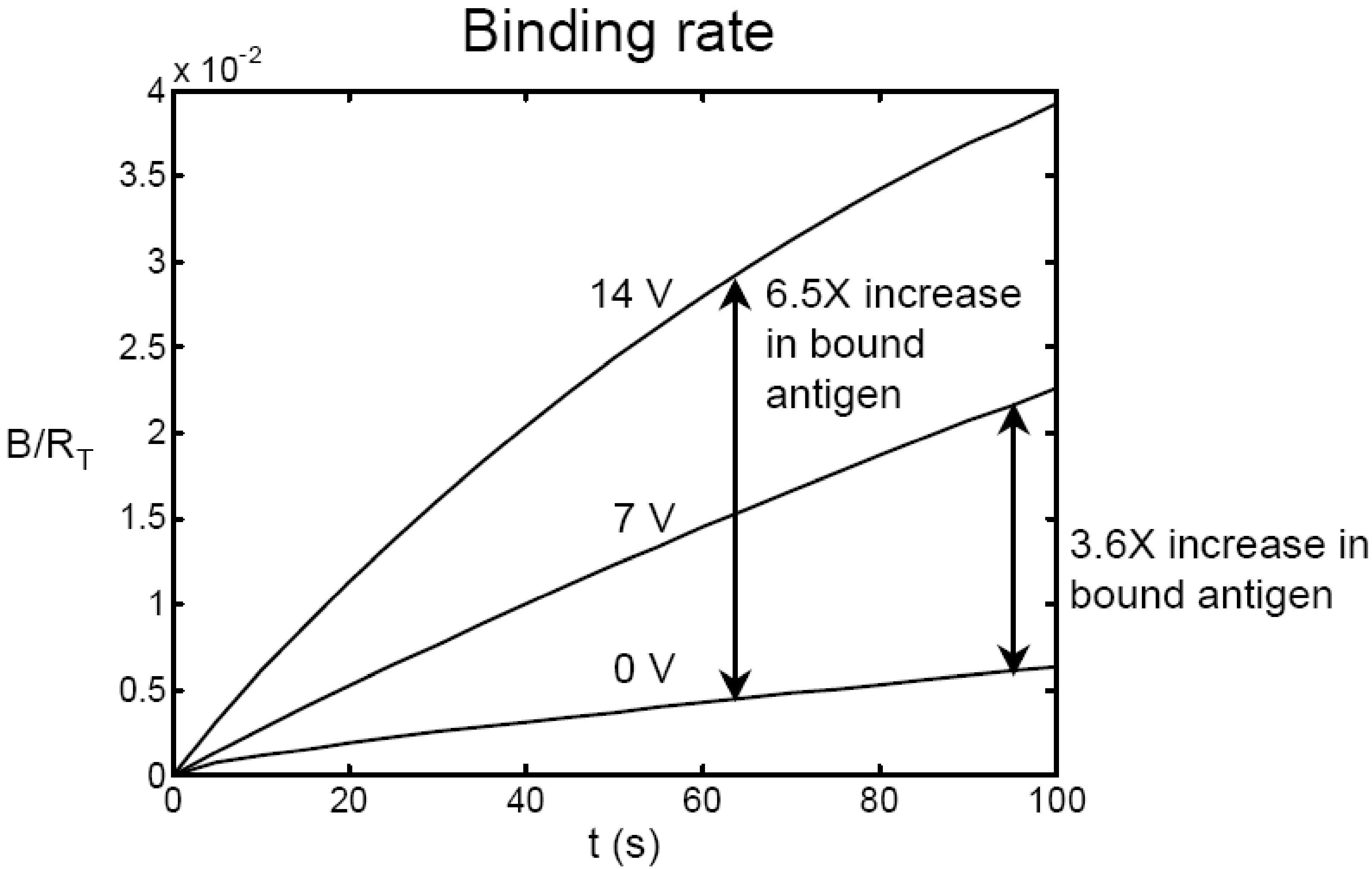

Fig.7. binding curves for non-enhanced (0V) and enhanced (7V&14V) transport.

Simulation results

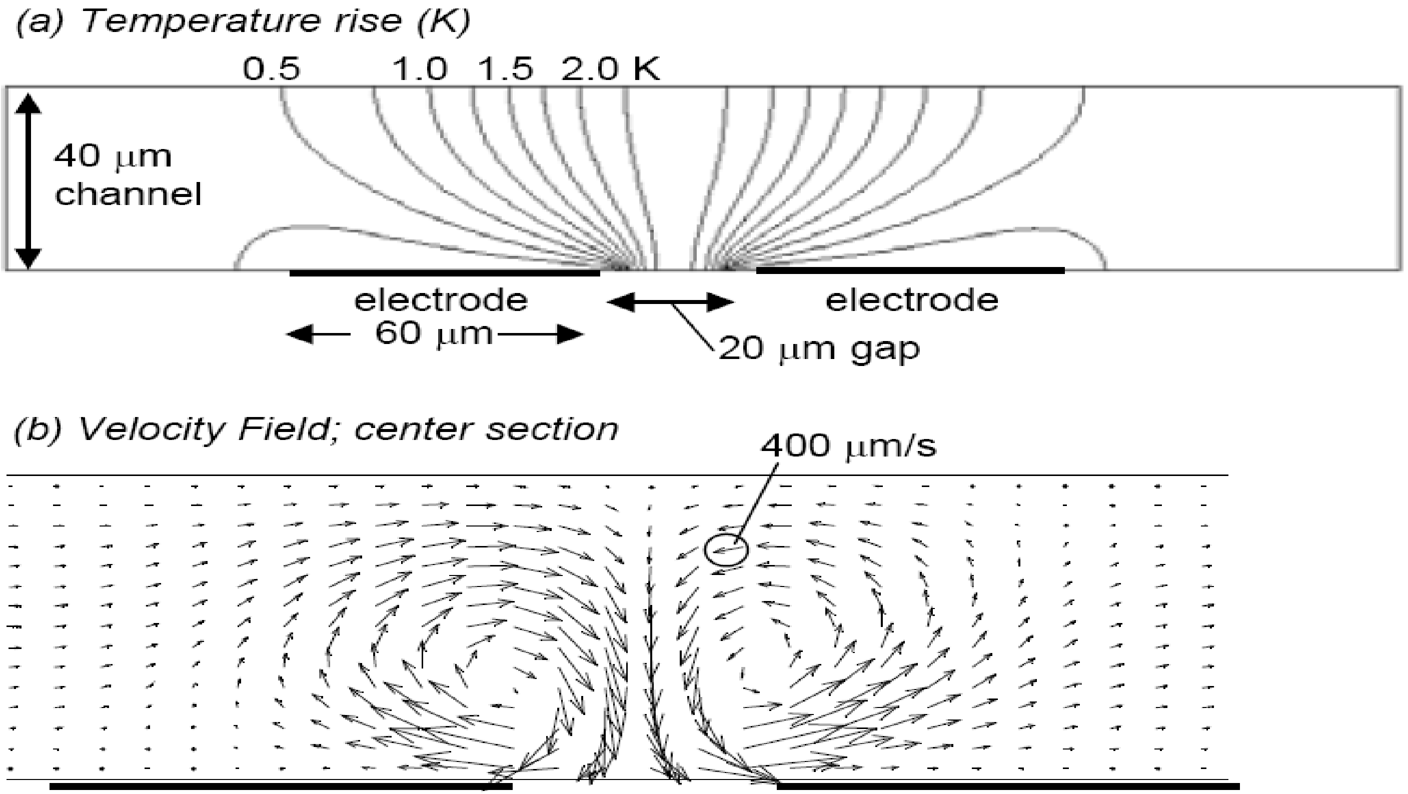

Fig.8. simulation of electrothermally-driven flow in a 40 channel using FEMLAB software
(a) Non-uniform temperature distribution created by Joule heating, and
(b) Electrothermally-driven motion.

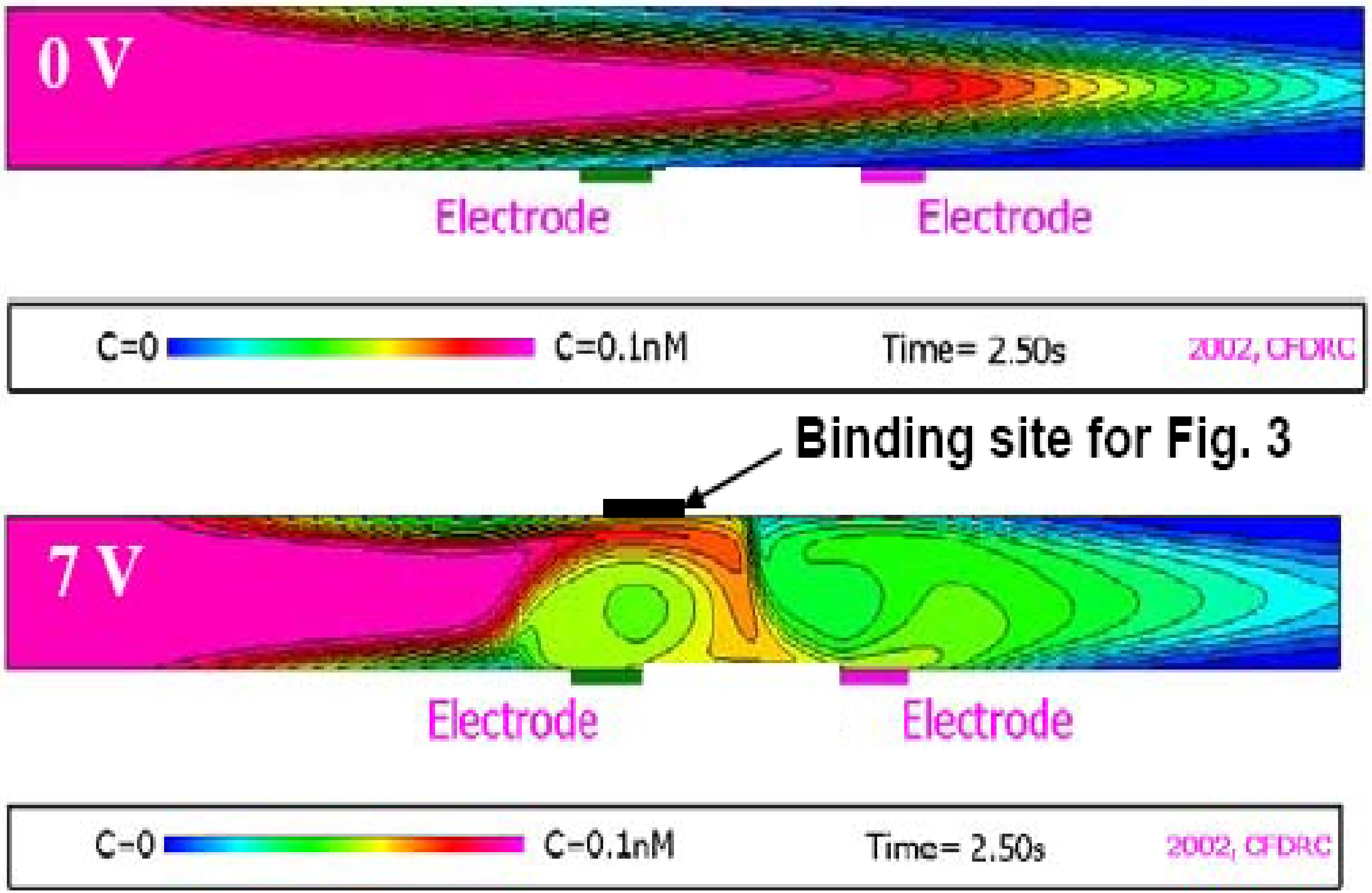

Fig.10. Concentration plots of electorthermally modified channel flow with applied voltage of 0V and 7V.

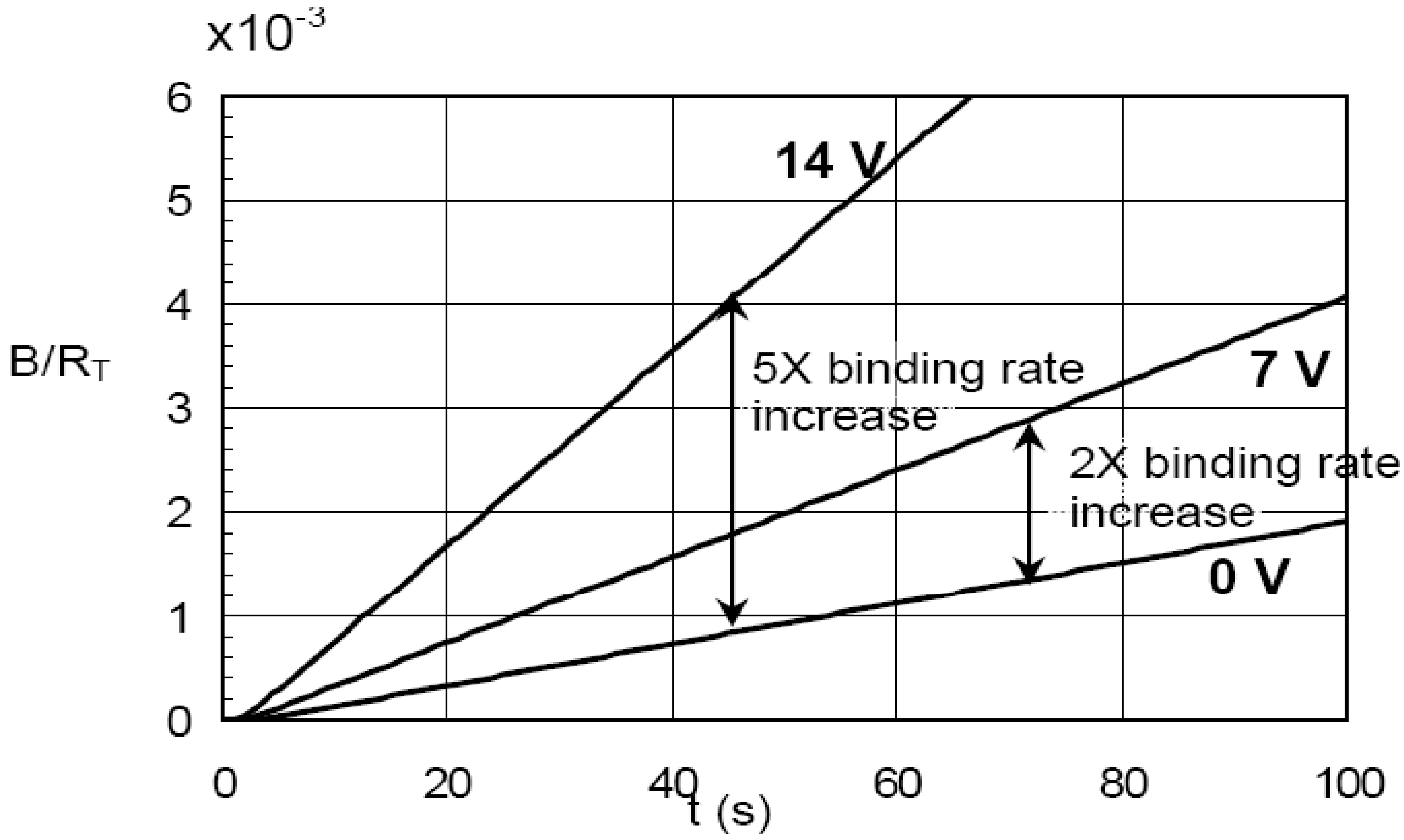

Fig.11. Microchannel enhancement. Unmerical simulation of mormalized bound concentrationFor microchannel assay.

Summary

- Microfluidic systems for manipulating fluids in the micro scale are widely used in scientific areas ranging form chemistry, biology to material science
- By designing a microchannel electrode system that takes advantage of electrothermal effects, cross-stream transport of an antigen and hence binding can be enhanced.