Spring 2005

UNIVERSITY OF CALIFORNIA
College of Engineering

Department of Bioengineering

BioE 121 Introduction to Micro and Nanobiotechnology:
BioMEMS

Midterm Exam

Name:
Student ID#:

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Your Signature _____

Problem 1 (20 points) _____

Problem 2 (20 points) _____

Problem 3 (20 points) _____

Problem 4 (20 points) _____

Problem 5 (20 points) _____

Extra Point (20 points) _____

TOTAL (120 points) _____

Problem #1. (20 points) Design and Fabrication of Different DNA Sensors

(a) (5 points) Explain five different DNA sensors: explain mechanisms and describe advantages and disadvantages of each DNA sensor

(b) (5 points) Show the fabrication step of a magnetic (MR) DNA sensor

(c) (5 points) Show the design and fabrication steps of electrochemical DNA sensor with amplification strategies by using nanoparticles.

(d) (5 points) Most variation in a genome arises from substitutions of individual nucleotides, called single-nucleotide polymorphisms (SNPs). Explain the detection mechanism of SNPs using electrochemical DNA sensor.

Type of sensor	Advantages	Disadvantages

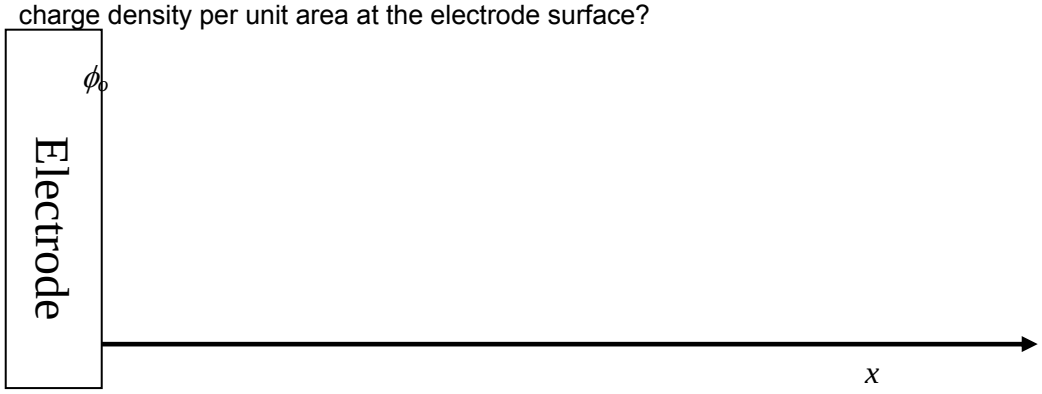
Problem #2. (20 points) Double Layer & Electrokinetics

(a) (10 points) High salt concentrations can effectively screen charge in physiological situations. Human blood has a NaCl content of about 0.150 M. Calculate the Debye screening length (κ^{-1}) in 0.150 Molar solutions of (i) NaCl, (ii) $CaCl_2$. What does this tell you about electrostatic attraction between two charged proteins in-vivo?

(b) (10 points) For a symmetric electrolyte the electric field within the 1D diffuse double layer next to a charged surface can be represented by the following function:

$$\frac{d\phi}{dx} = -\left(\frac{8kTn^0}{\varepsilon\varepsilon_0}\right)^{1/2} \sinh\left(\frac{ze\phi}{2kT}\right)$$

Use the Gauss law to calculate the solution phase charge density per unit area if the potential at the surface (x = 0) is held at ϕ_0. Hint: As x -> ∞ , $d\phi/dx$ -> 0. How does this differ from the charge density per unit area at the electrode surface?

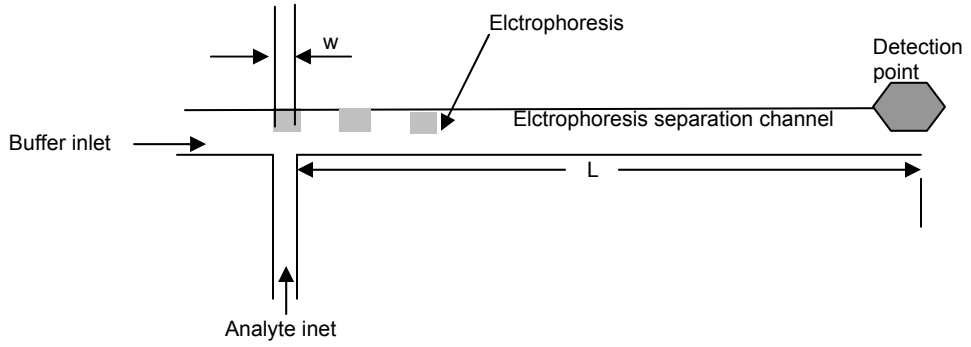


Problem #3 (20 points) Electrokinetics

(a) (5 points) Draw the velocity profile for pressure driven flow and electro osmotic flow inside an electrophoretic separation chamber. Which one is better and why?

(b) (10 pints) Protein A & B are to be separated and the protein A has a mobility (μ_i) of 1.000×10^{-8} $m^2/v \cdot s$ and the protein B has a mobility of 1.010×10^{-8} $m^2/v \cdot s$. The electrophoresis potential strength is V=200 kV. Given L=1cm calculate the electrophoretic velocity of each species.

(c) (5 points) Is this channel long enough for separation if w = 20 μm



Problem #4 (20 points) Patch-clamp Array Chip

In order to reduce the cost and time of drug discovery, microfabricated patch-clamp chip is developed by using Si-based microfabrication technology as shown in Fig. 4.

(a) (10 points) How many lithography steps are used in this process flow? Discuss the purpose of each lithography step.

(b) (10 points) Show your own optimized design and fabrication steps to reduce the manufacturing cost and time for drug discovery system applications. You can choose any technology or materials: no restrictions.

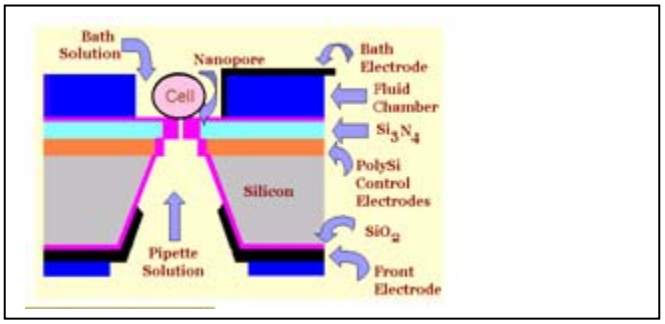


Fig. 4

Problem #5. (20 points) Basic SUMMiT Process

a. (10 points). Show the cross sectional fabrication steps of figure 1 (include deposition and etching methods)

b. (10 points). Show the cross sectional fabrication steps of figure 2 (include deposition and etching methods). In this case, you can use answer of part (a) and show only few different steps.

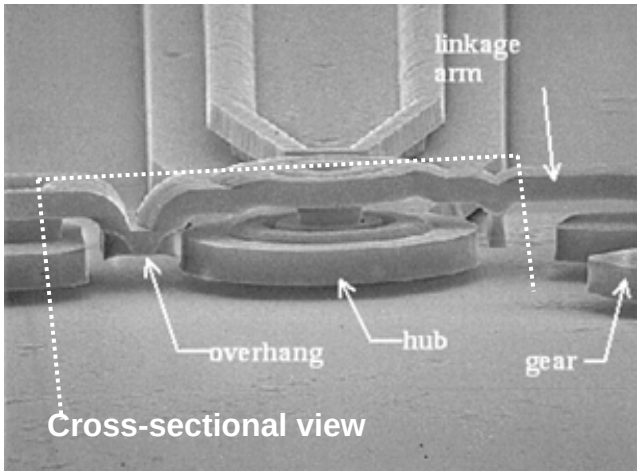


Figure 1

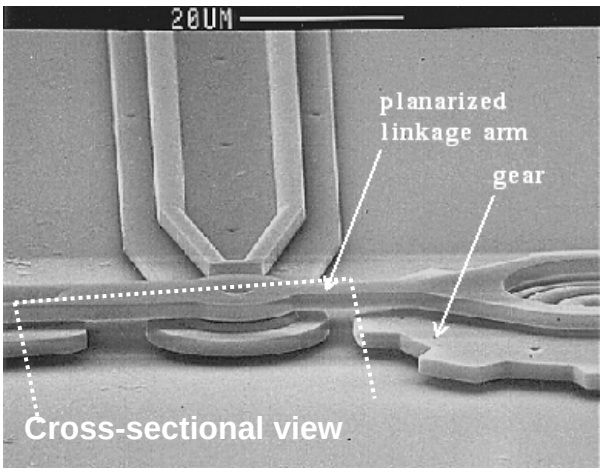


Figure 2

Extra Points (20 points) Dielectrophoretic lab-on-a-chip

Show a design of dielectrophoretic/electrophoretic lab-on-a-chip that has a capability of cancer cell separation, cell lysing, cell counting, and the detection cancer markers.

a) (5 points) Show a flow chart of integrated systems.
b) (5 points) Show a top view of microfluidic channels, chamber, location of cell separation, lysing, counting, and detection sites.
c) (5 points) Show fabrication steps with cross sectional views of chambers, location of cell separation, lysing, counting, and detection sites.
d) (5 points) Write down the details of processing steps.