Glass Surfaces and Coatings for Biotechnology

Carlo G. Pantano
Department of Materials Science and Engineering
Materials Research Institute
Pennsylvania State University

University Park, PA, USA


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Esco
POLYSINE™
MICROSCOPE SLIDES
Precleaned
GOLD
Microscope Slides
Corning Incorporated
CORNING
40004
MICROSCOPE SLIDES
SCHOTT
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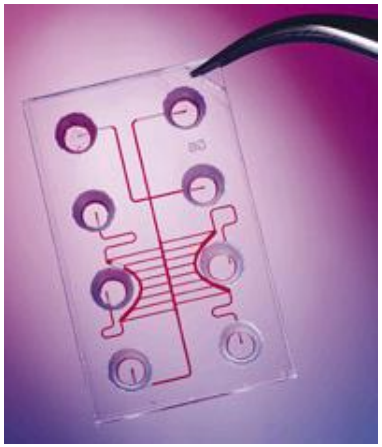
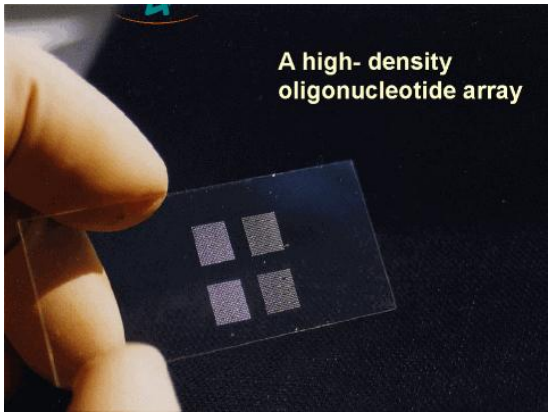
SUPERFROST® PLUS
MICROSCOPE SLIDES
Precleaned




A high- density
oligonucleotide array

Biomaterials and Bionanotechnology

lecture outline:

- relevant characteristics and properties of glass surfaces and coatings >>> introduction
- surface charge on flat glass substrates
  >>>substrates for cell transfer assays
- silane and hybrid sol/gel coatings
  >>>DNA and other microarrays
- carbon-doped "oxycarbide" glass
  >>>blood contact materials
- nanostructured coatings
  >>>engineered surfaces for biology, biomedicine and biotechnology

discussion and other applications:

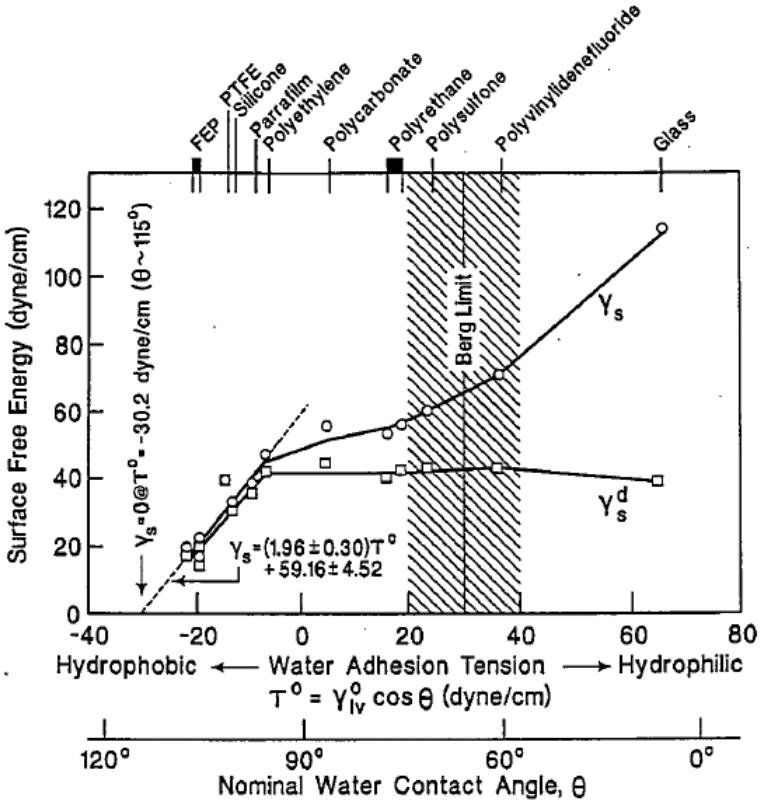
- surfaces for pharmaceutical packaging
- superhydrophobic/superhydrophilic surfaces
- bio-active glasses and toxicity

Biomaterials and Bionanotechnology

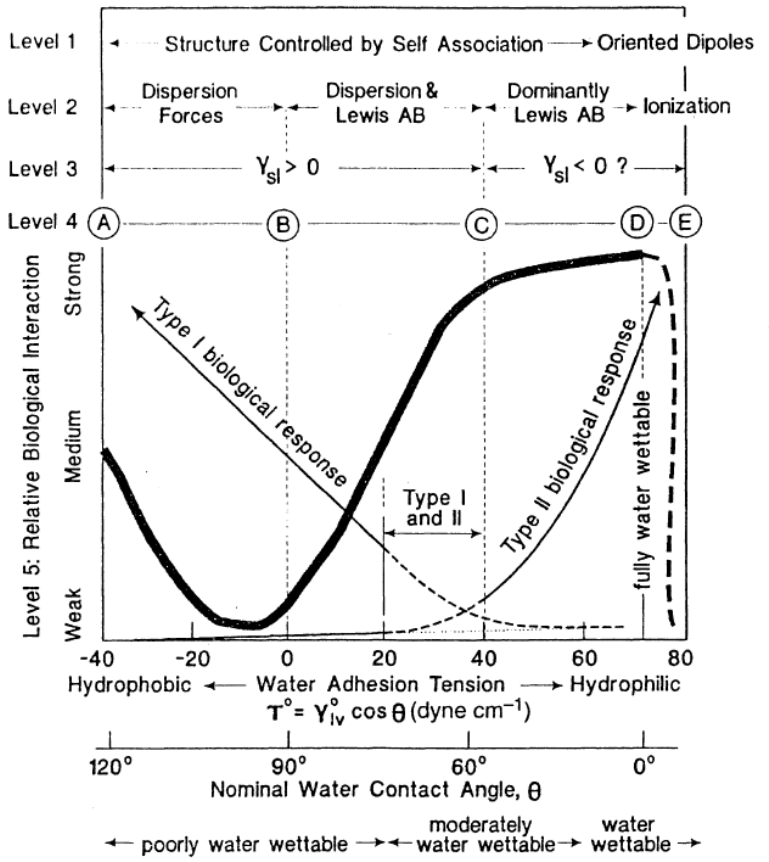
Characteristics and Properties of Glass Surfaces and Coatings

- composition
- chemical functionality
- contact angle/wettability
- surface charge and other surface forces
- porosity/roughness/specific surface
- cleanliness and chemical durability
- uniformity of ALL the above

E.A. Vogler / Adv. Colloid Interface Sci. 74 (1998) 69–117



Water in Biomaterials Surface Science



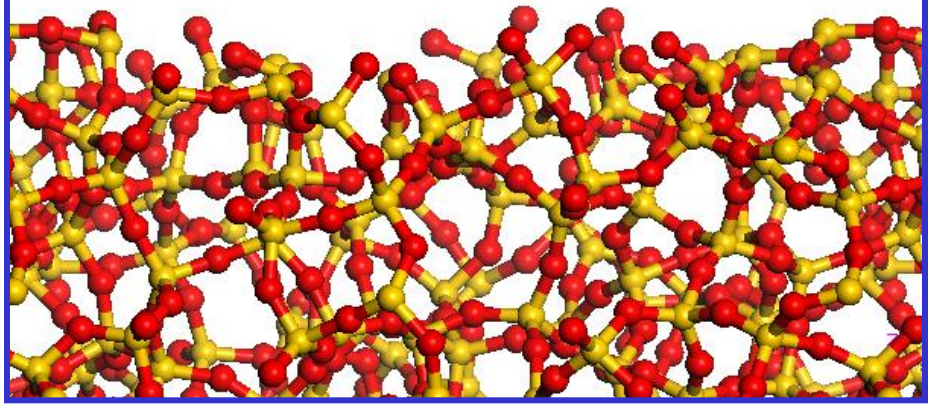
Biomaterials and Bionanotechnology

Methods of Characterization

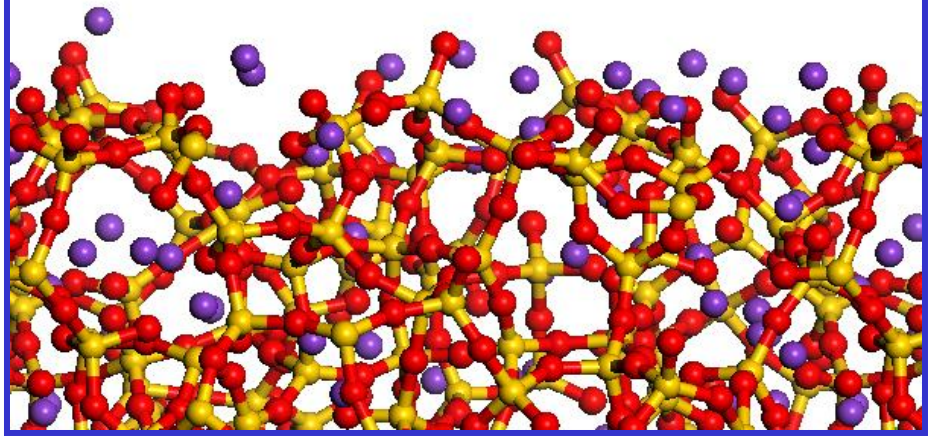
- surface composition (XPS)
- depth profiling (SIMS)
- surface roughness (AFM)
- organic adsorbates (FTIR/Raman)
- chemical structure (NMR)
- ellipsometry
- surface charge (streaming potential)
- contact angle tensiometry
- adhesion (CFM)

Glass Surface Structure Models

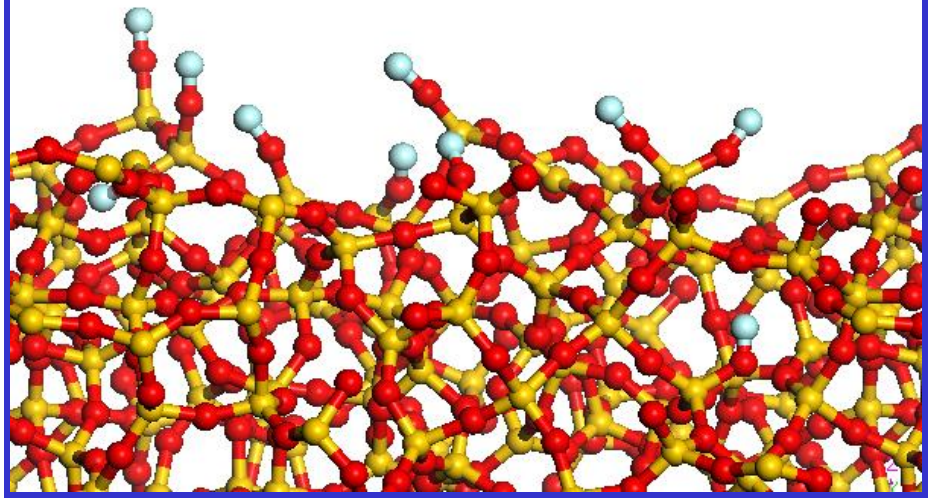
clean silica surface



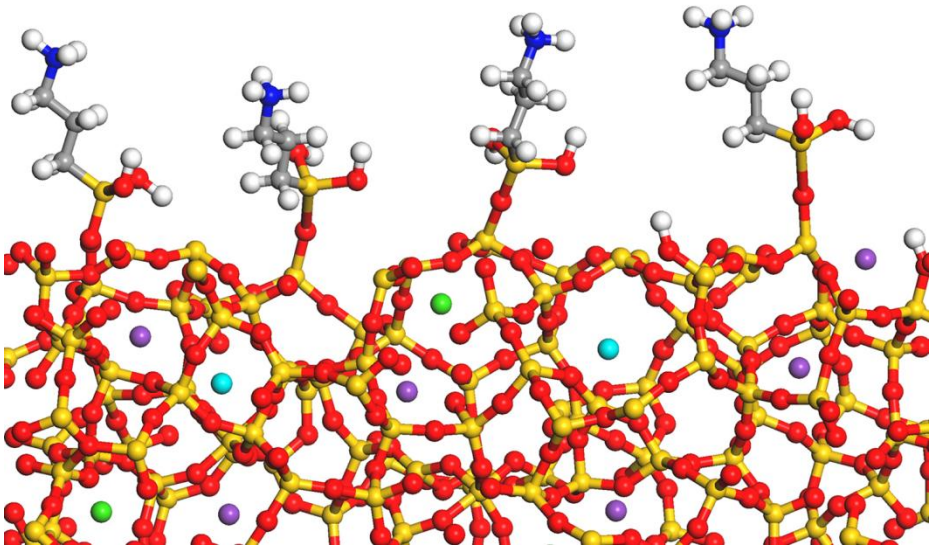
clean multi-component surface



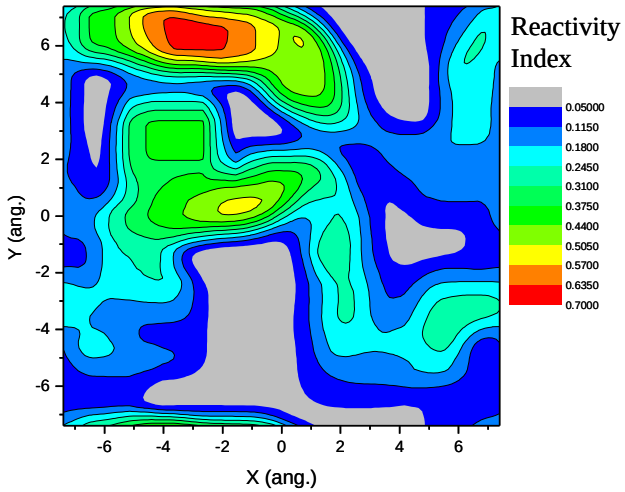
hydroxylated silica surface

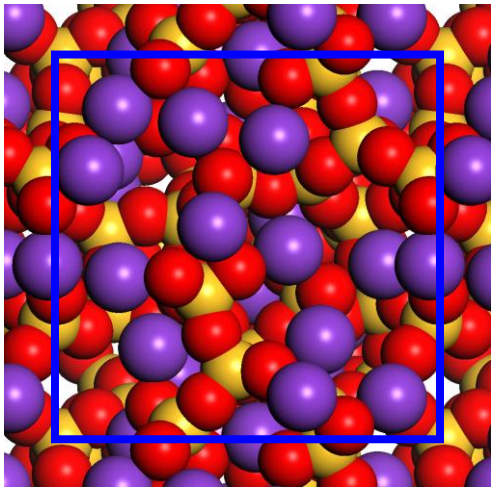


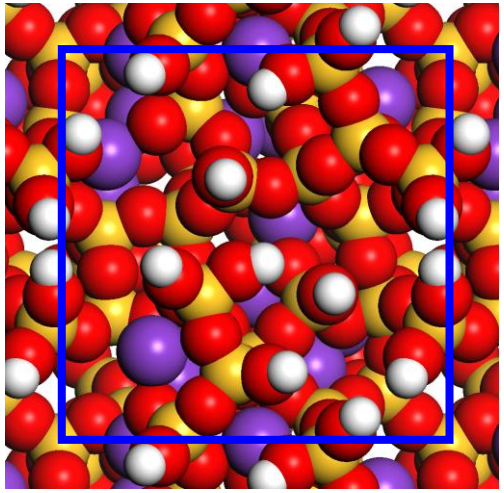
functionalized multi-component surface

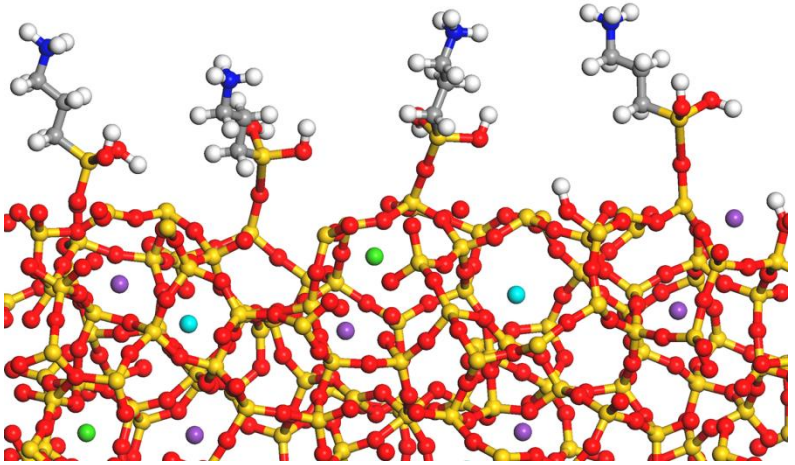


Computer simulation of glass surfaces: their atomic/nanoscale heterogeneity, hydroxlyation and organo-functionalization





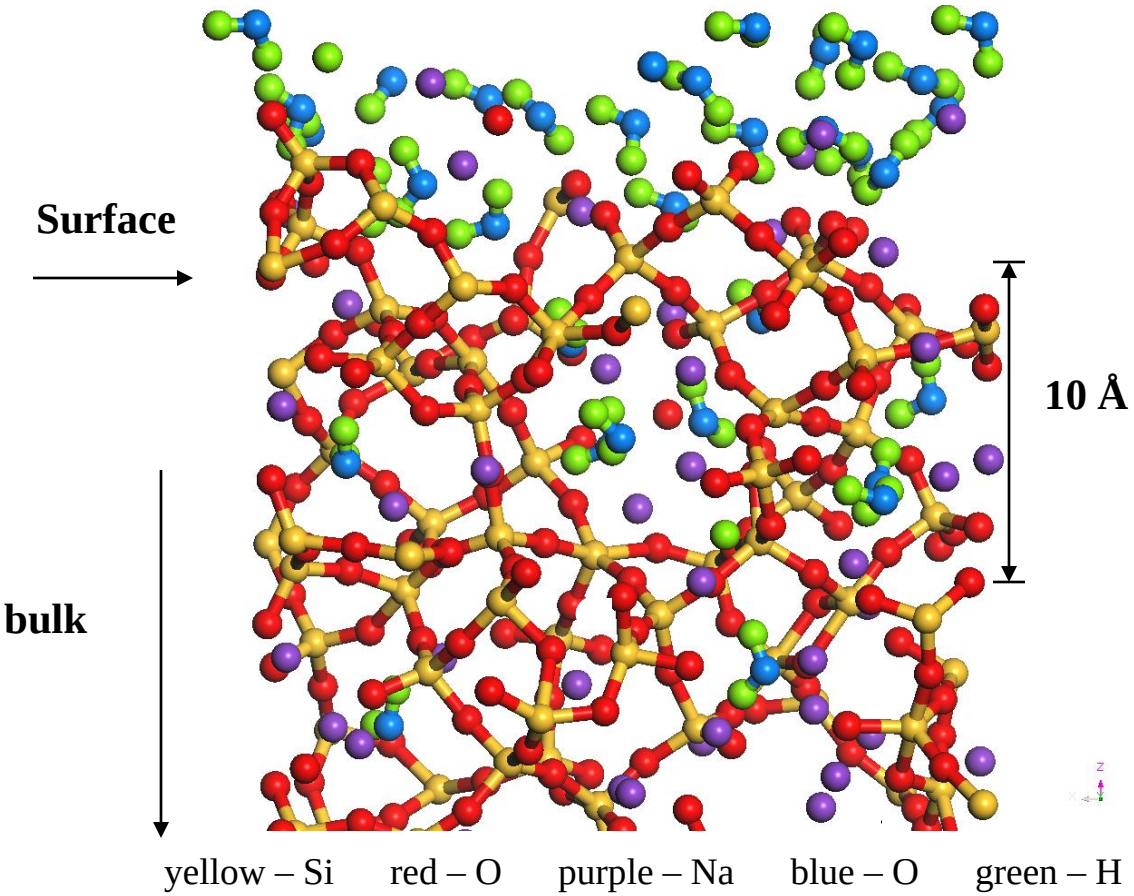




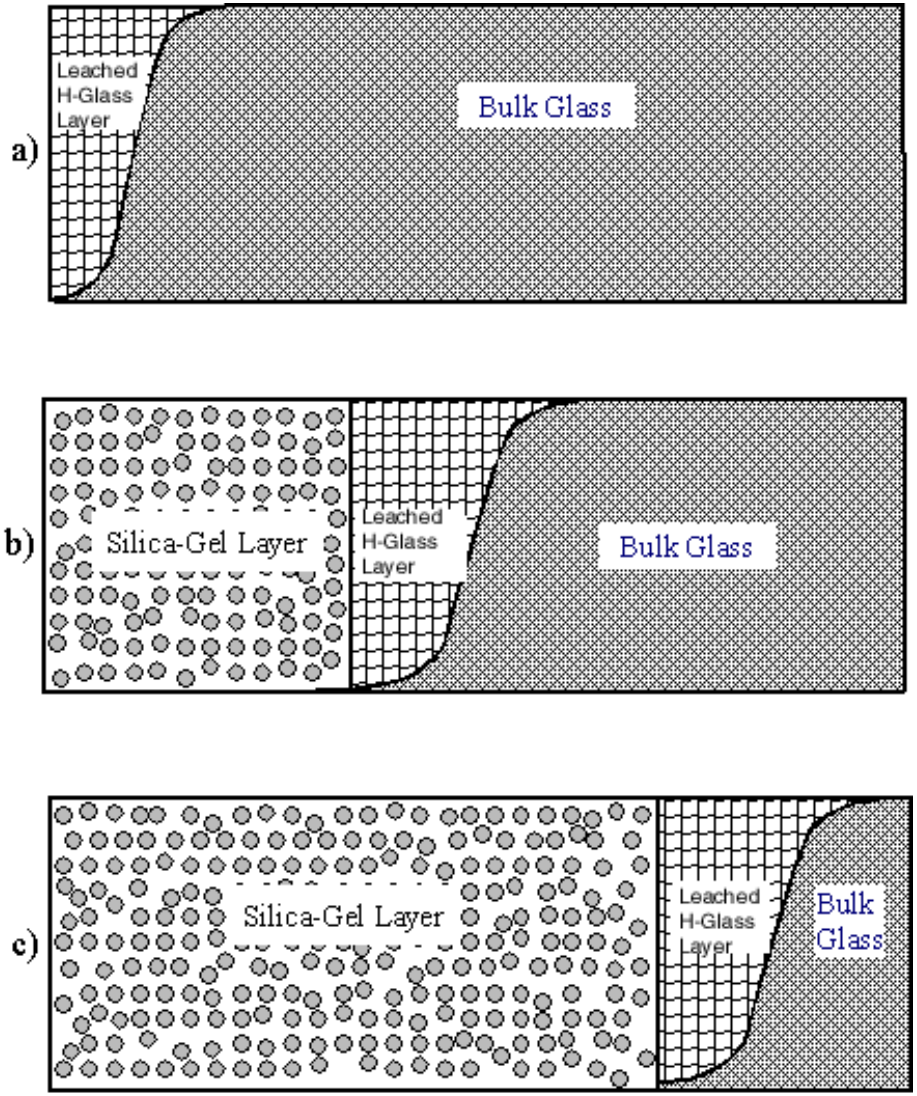
Water Molecules Adsorbing on a Simulated Sodium Silicate Glass Surface

Molecular Modeling of Water Interactions with Silica and Silicate Surfaces

Elam A. Leed and Carlo G. Pantano



Leaching and surface layer formation:



Cubic Cell (22 Å)³
800 atoms

"relaxed" from 8000 K to 300 K (in 500 ps)
"relaxed" at 300 K (100 ps)

1 Bulk Glass Structure

Removal of above periodic boundary condition……..
"relaxed" at 300 K (200 ps)

Glass "Surface" Structure

Removal of: aluminum, calcium, and sodium

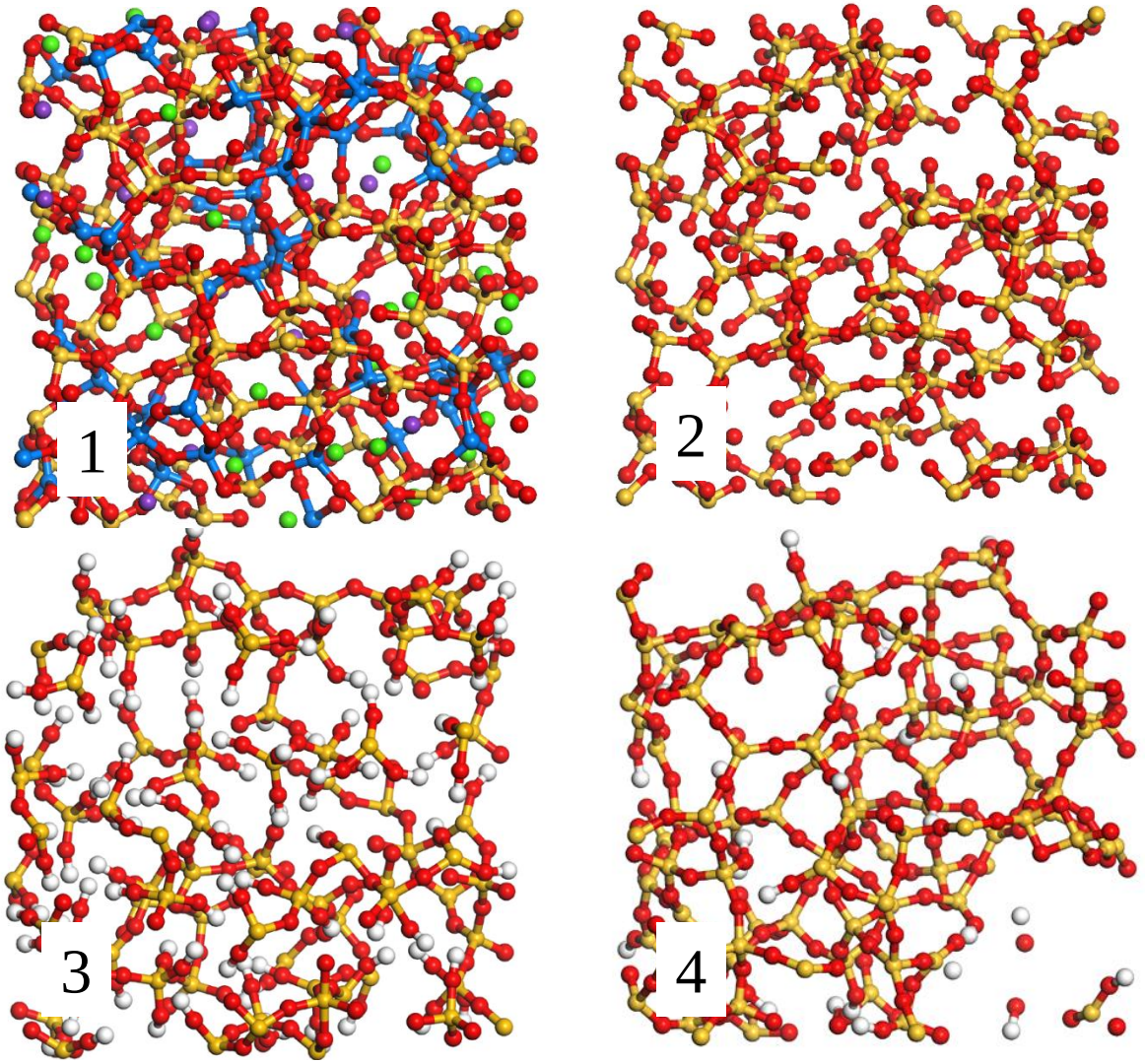
2 Simulated Surface Layer Structure

Hydroxylation (charge neut.)

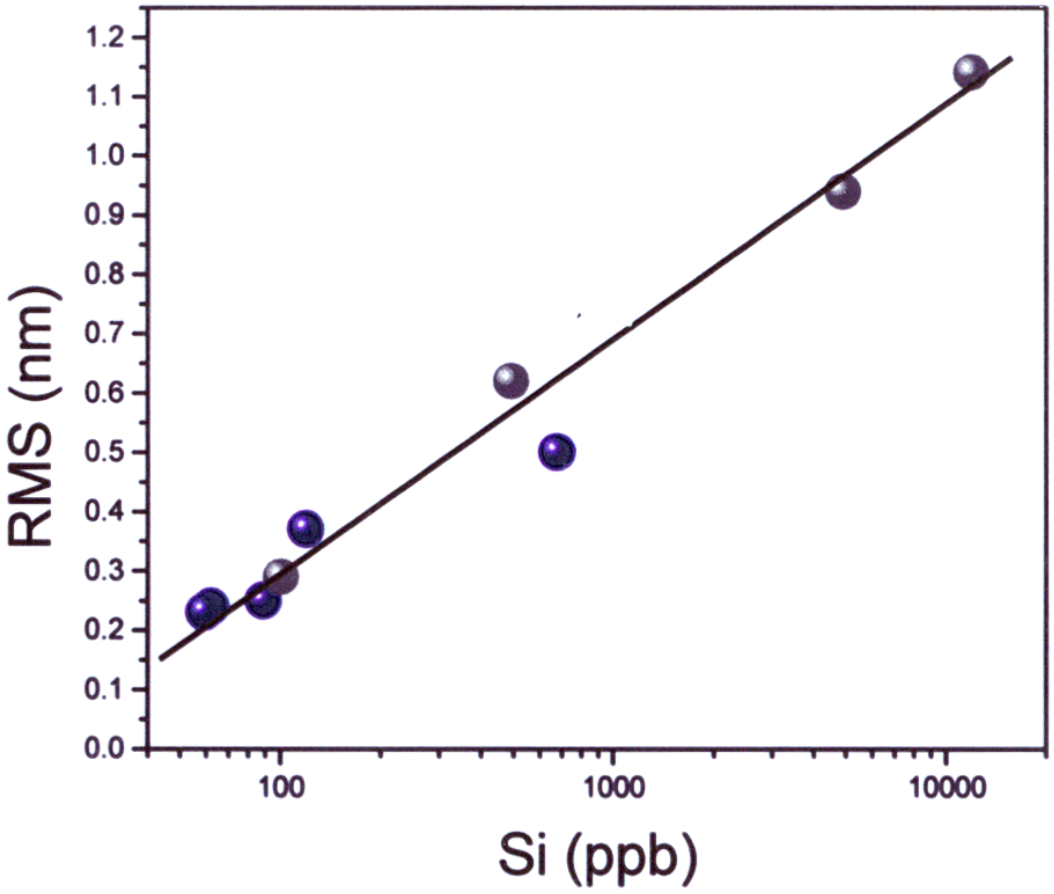
3 Hydroxylated Leached Glass Structure

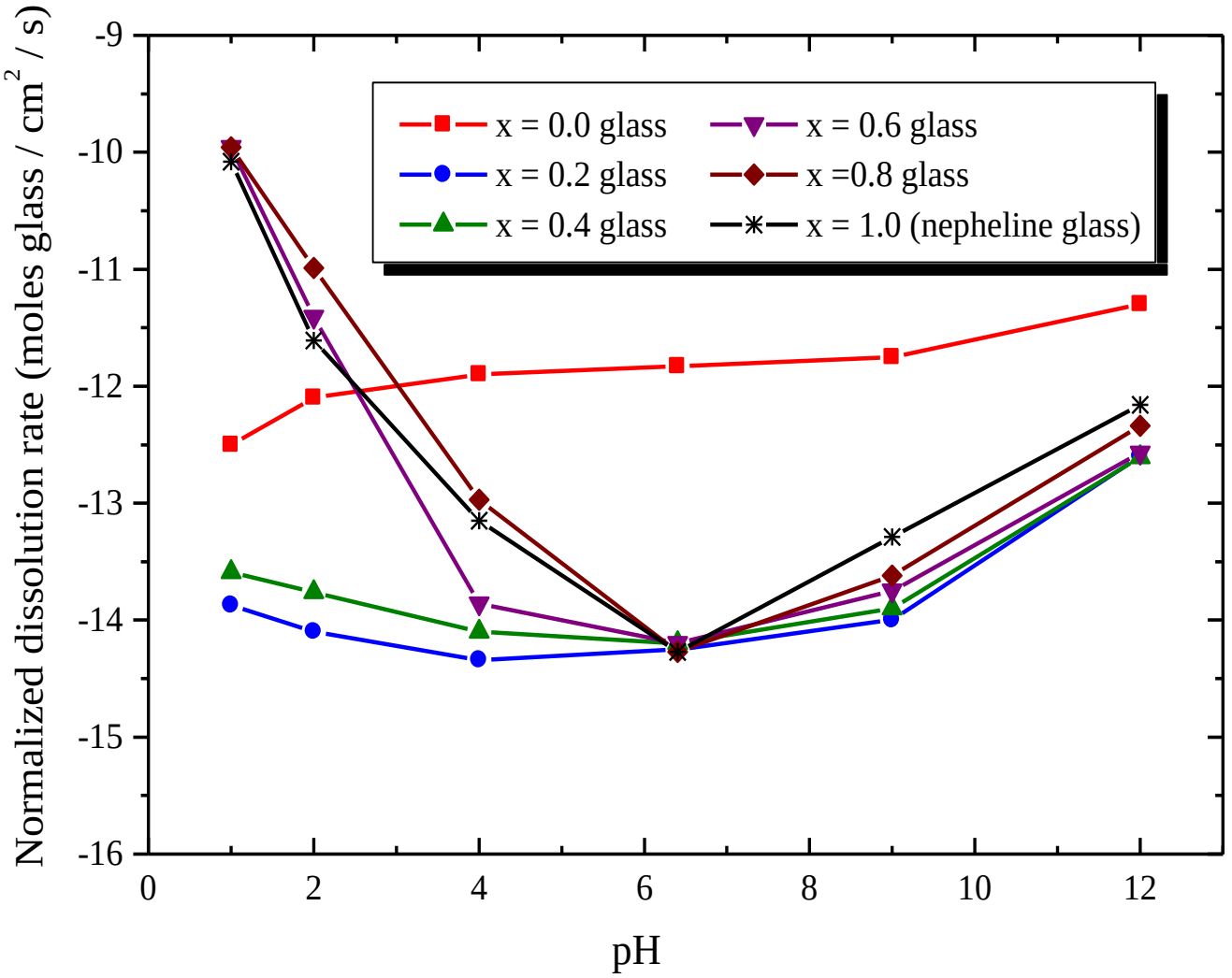
"condensed" at 300 K (200 ps) (2 OH's ~1.5 Å)

4 Leached Glass Structure



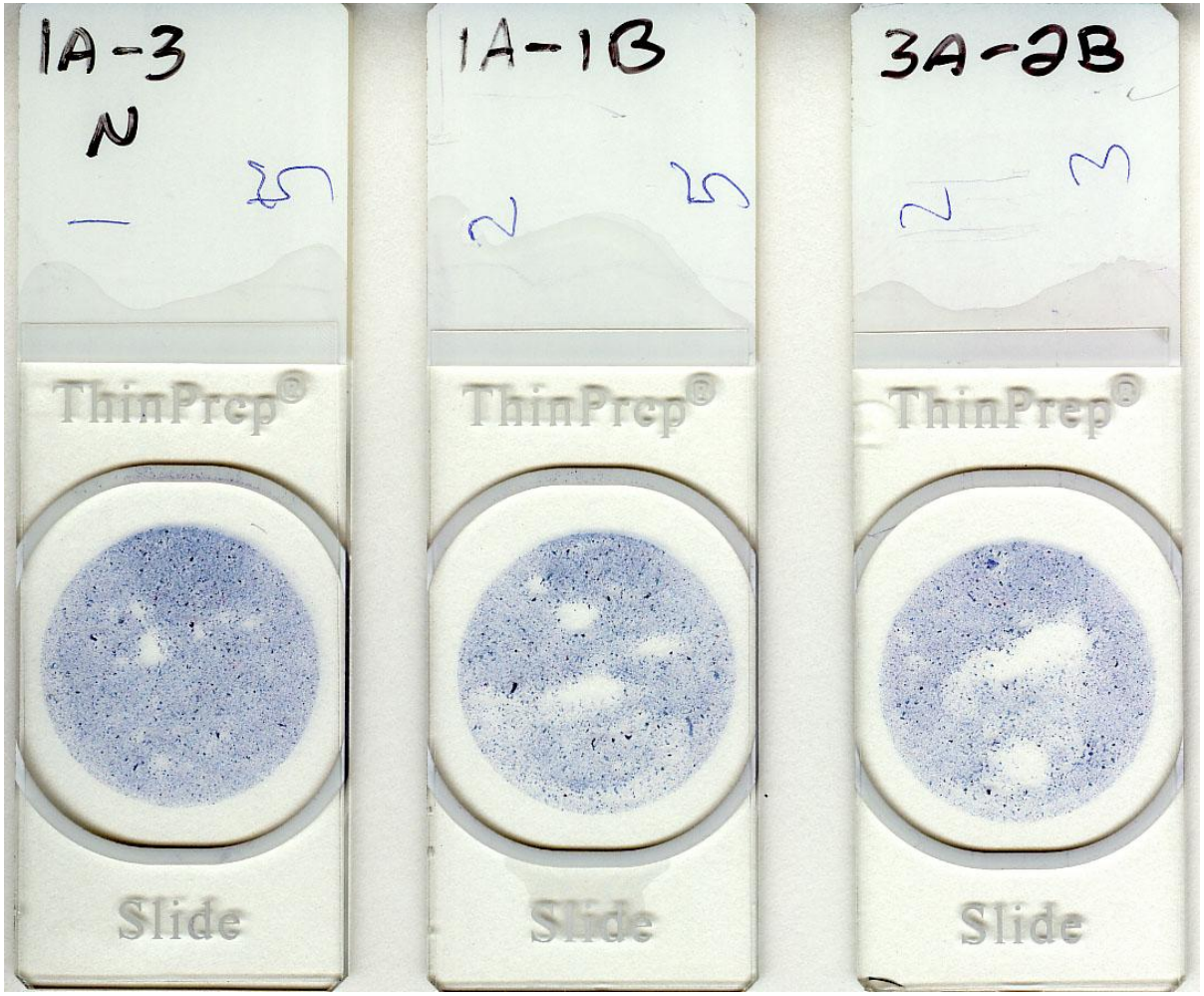
surface roughening by dissolution



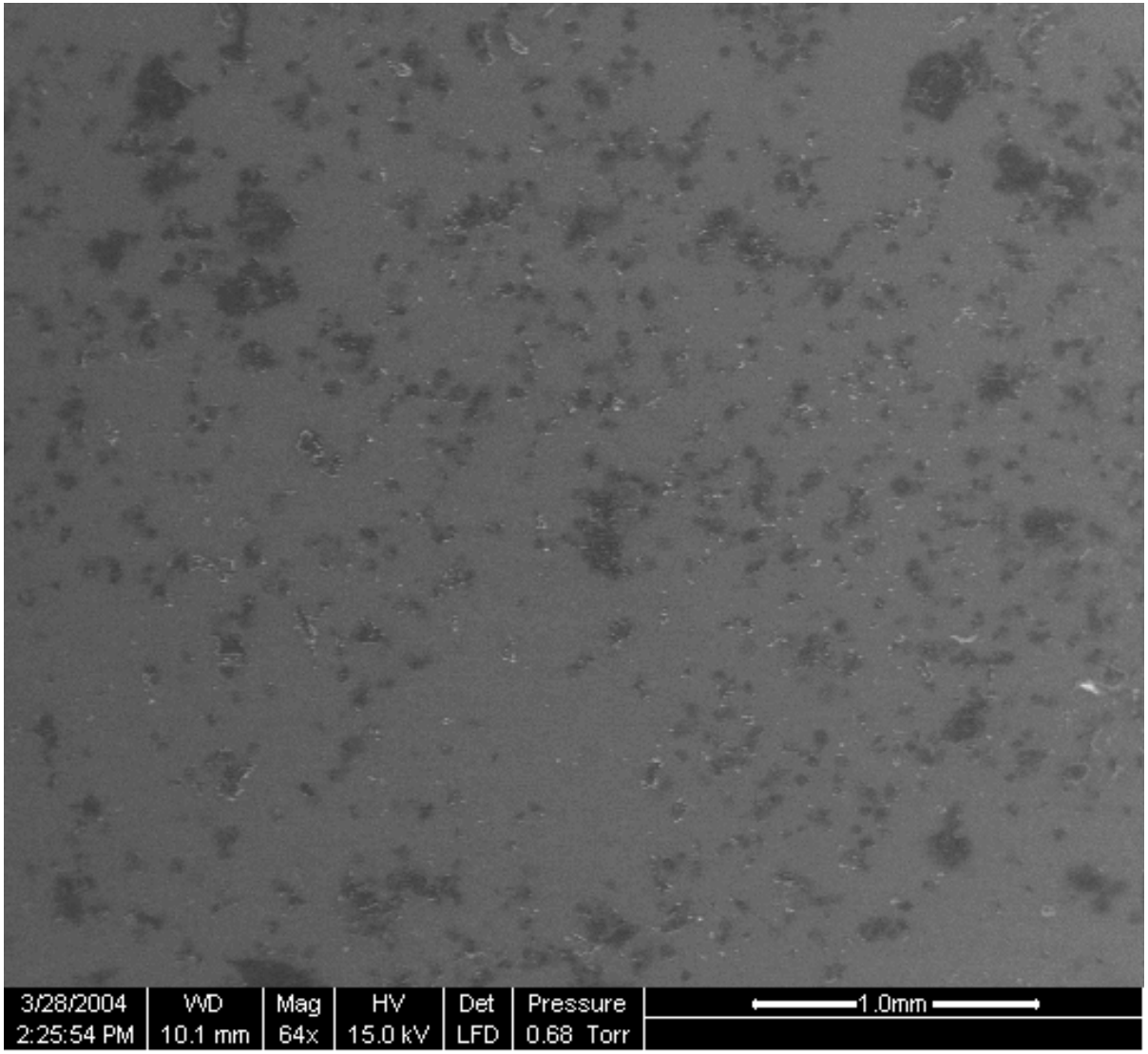


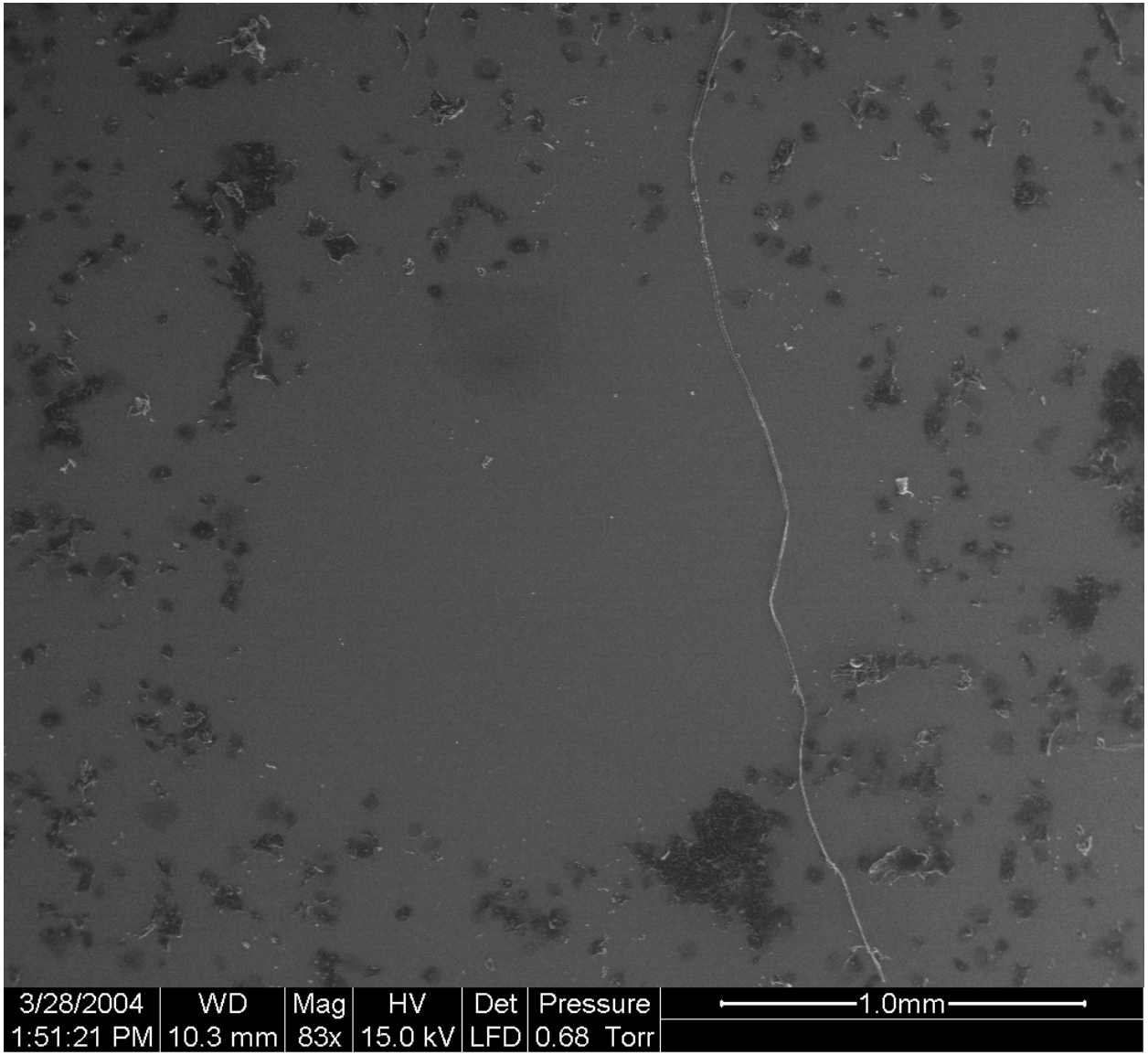
Normalized dissolution rates vs. pH for sodium-aluminosilicate glasses in the NBO glass series.

Cell Transfer for Cervical Cancer Diagnosis

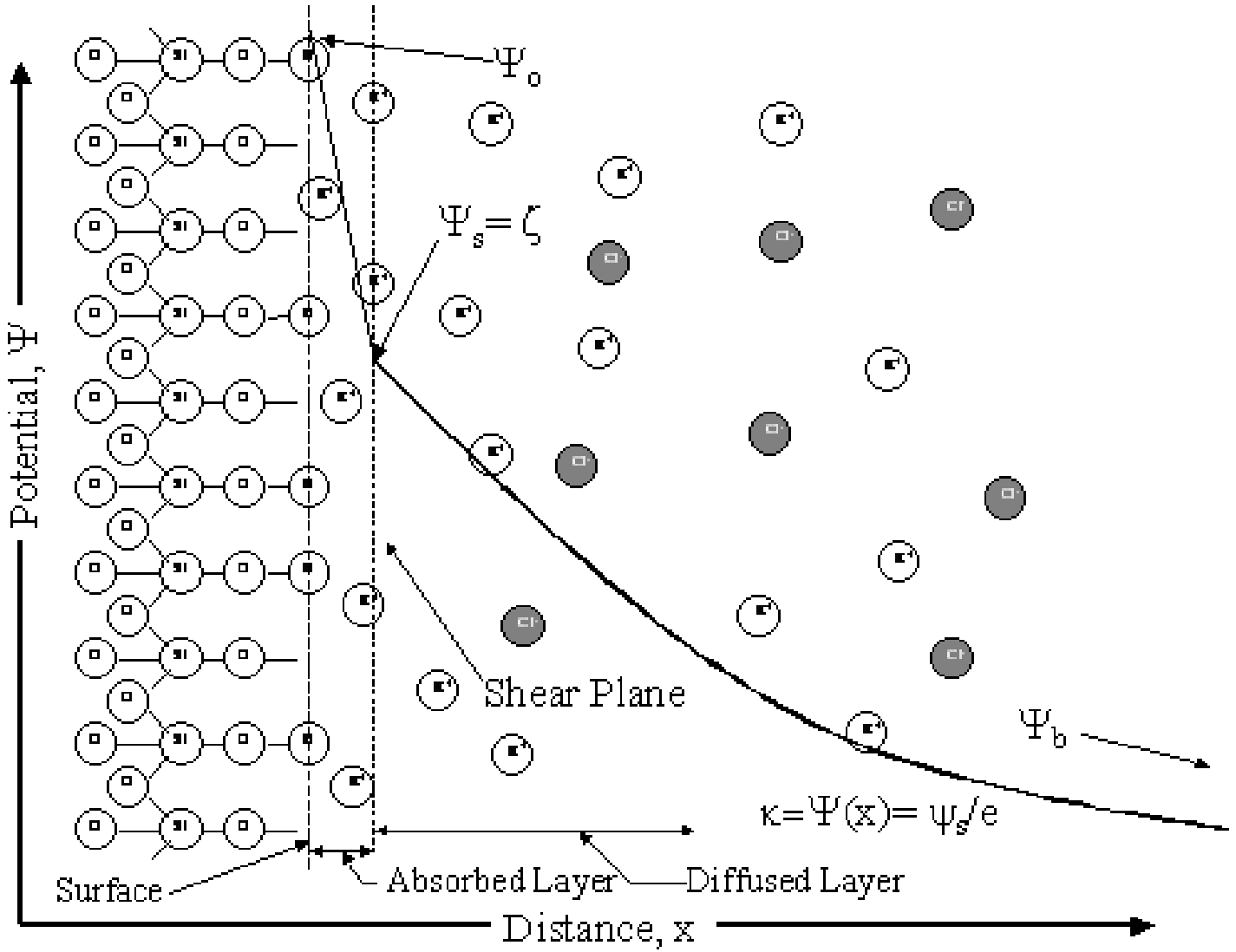


GYN cell transfer layer by SEM

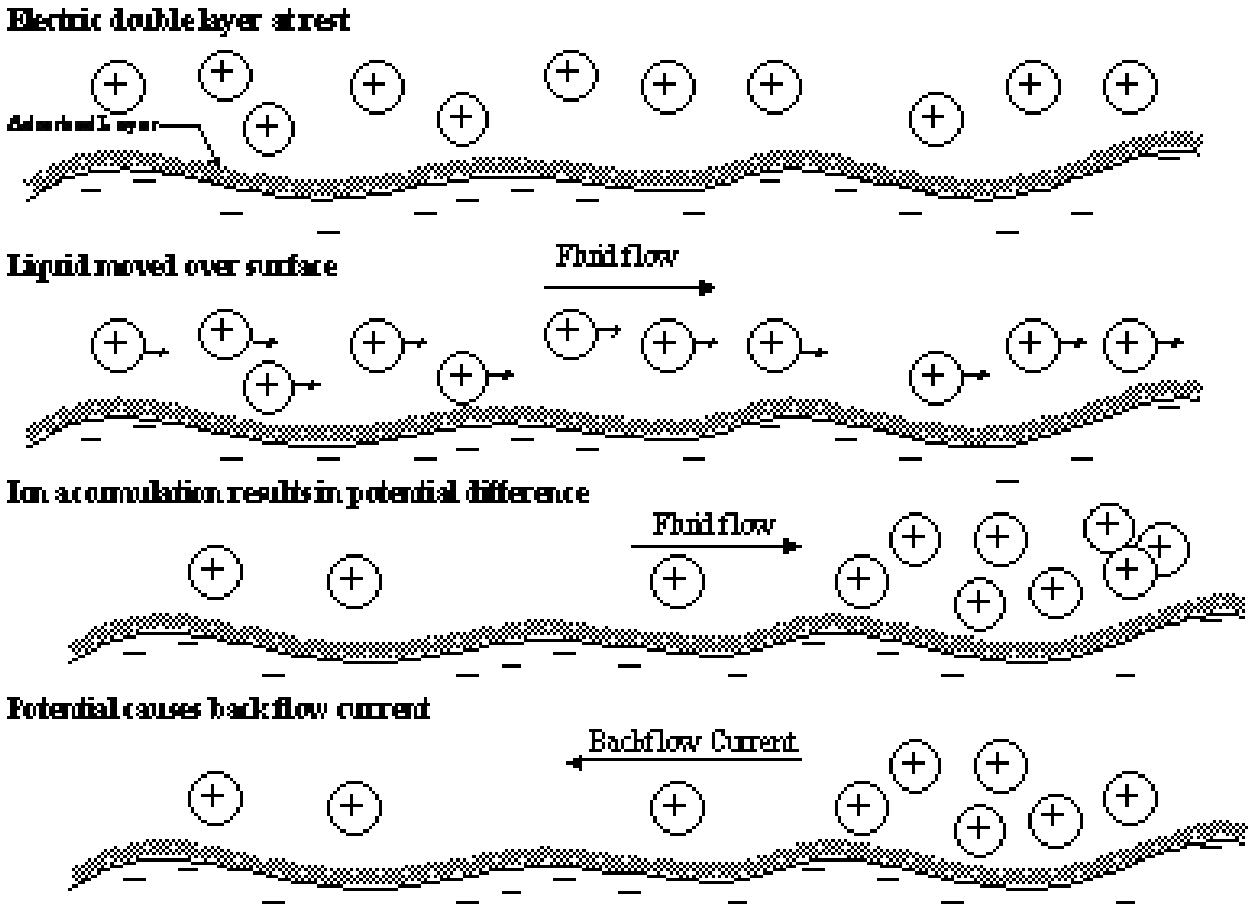



3/28/2004
1:51:21 PM
WD
10.3 mm
Mag
83x
HV
15.0 kV
Det
LFD
Pressure
0.68 Torr
1.0mm

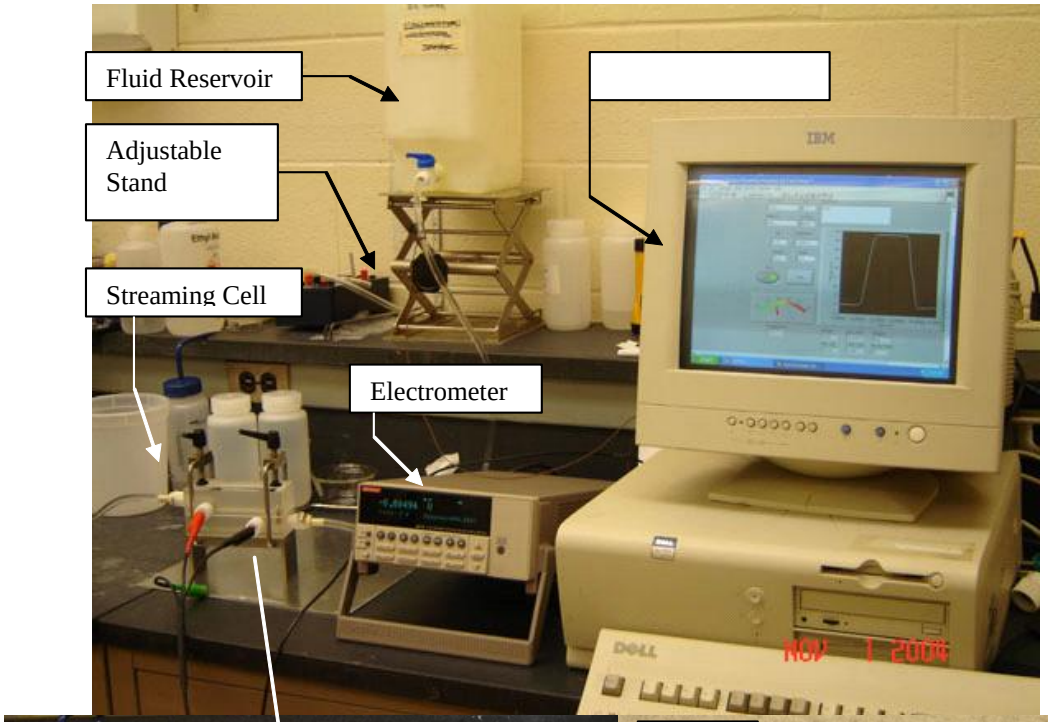
Electrical double layer at the glass-water interface

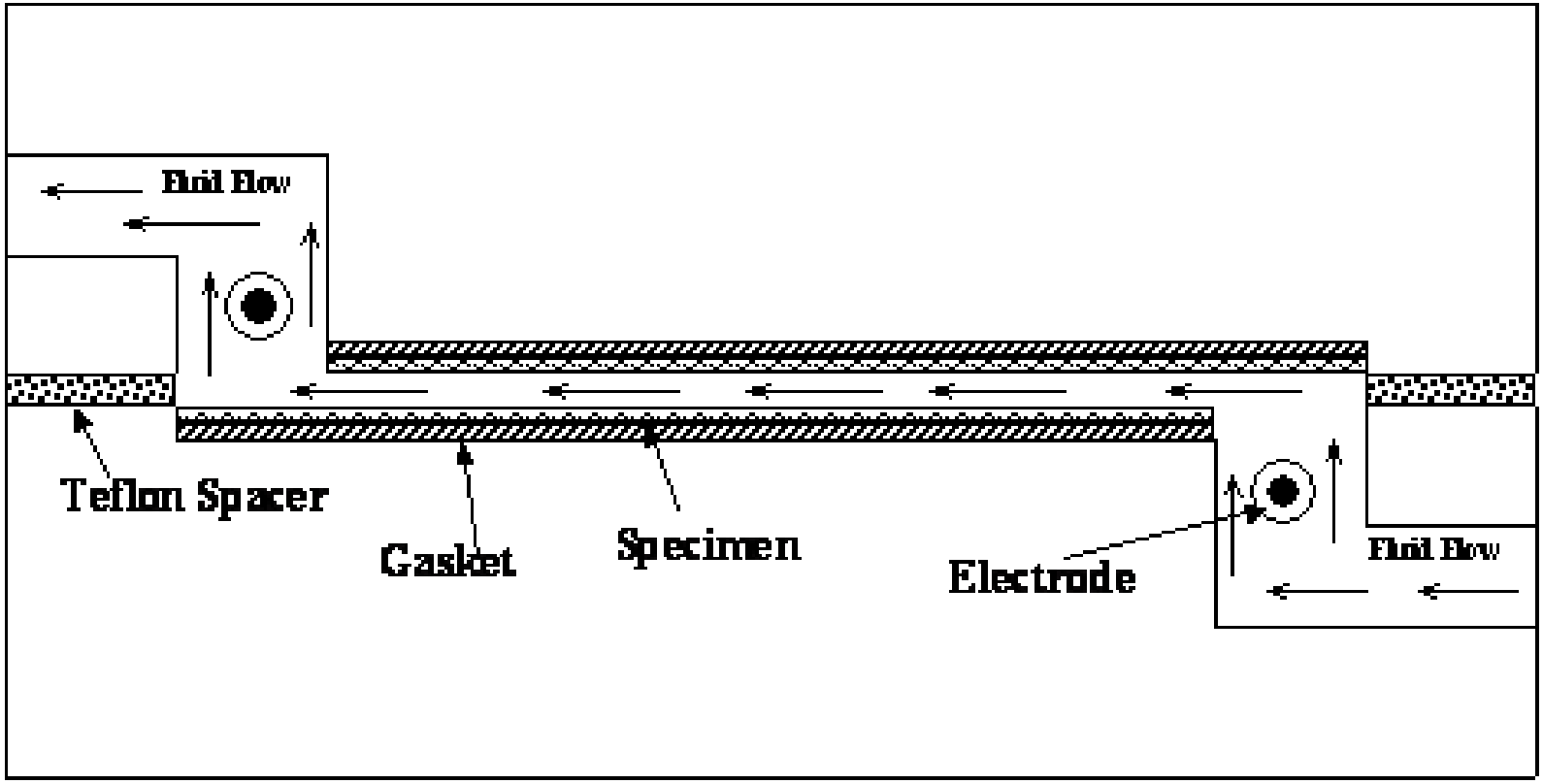


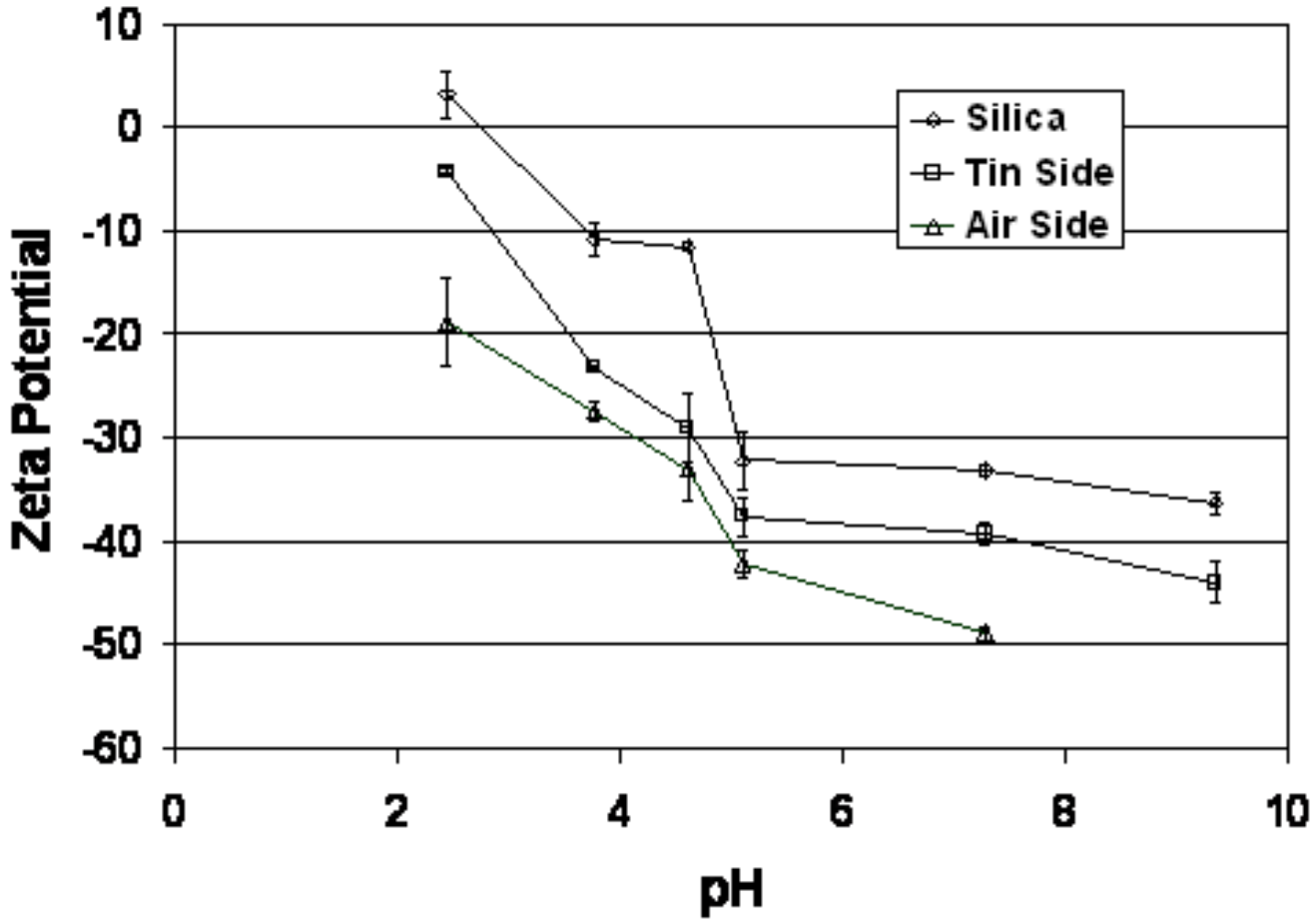
Streaming potential determination of surface charge

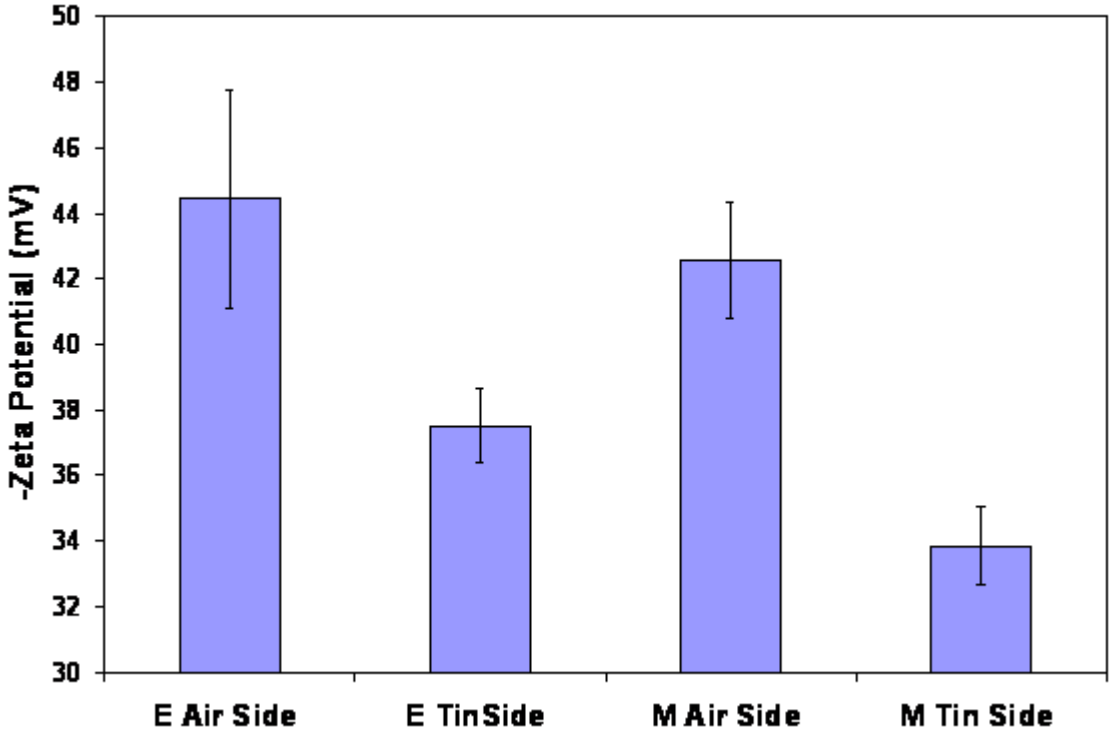


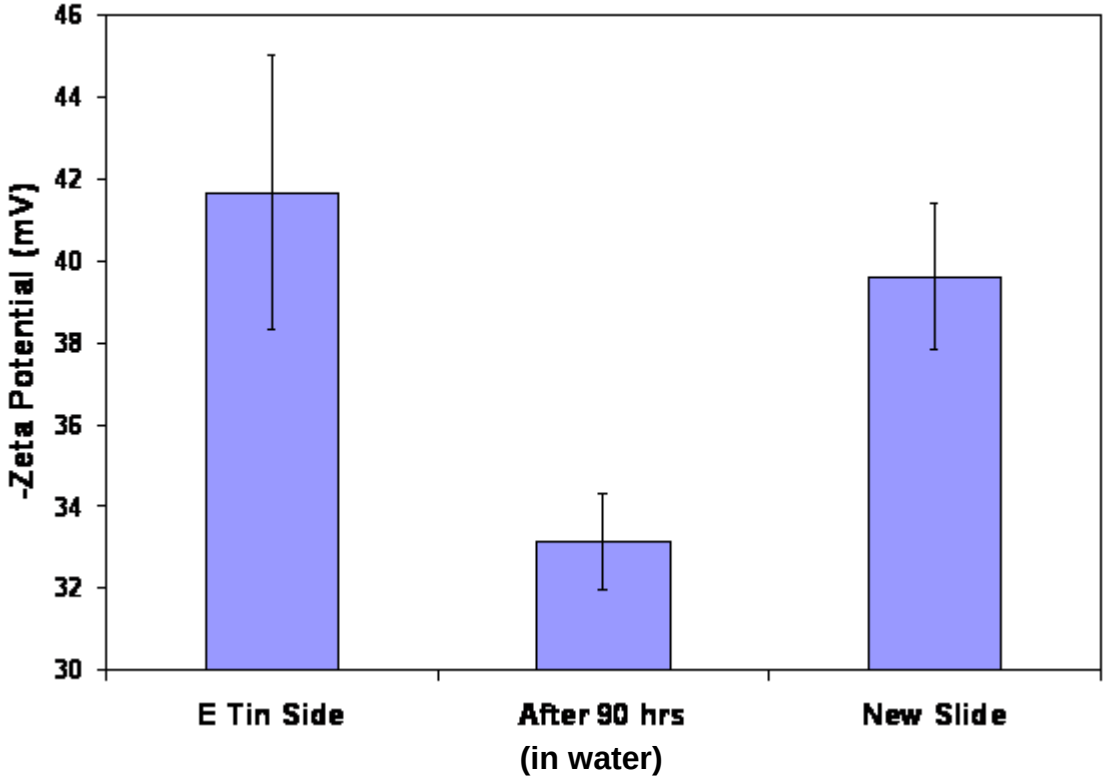
Streaming Potential System for Flat Glass

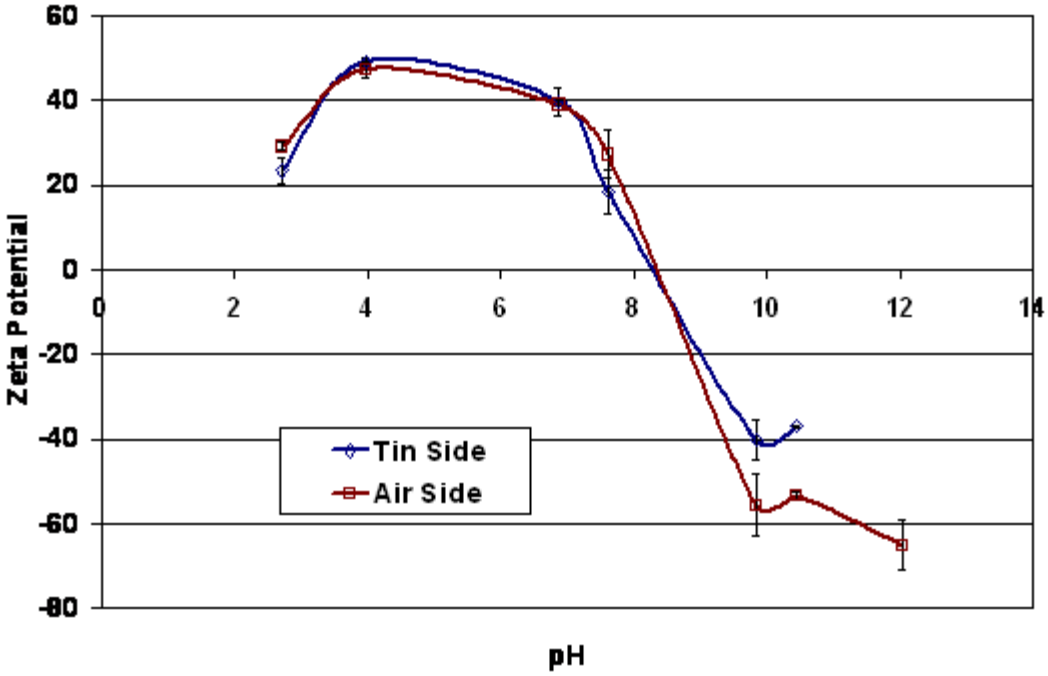



Fluid Flow
Teflon Spacer
Gasket
Specimen
Electrode
Fluid Flow


Zeta Potential
10
0
-10
-20
-30
-40
-50
-60
0
2
4
6
8
10
pH
Silica
Tin Side
Air Side


50
48
46
44
42
40
38
36
34
32
30
-Zeta Potential (mV)
E Air Side
E TinSide
M Air Side
M Tin Side

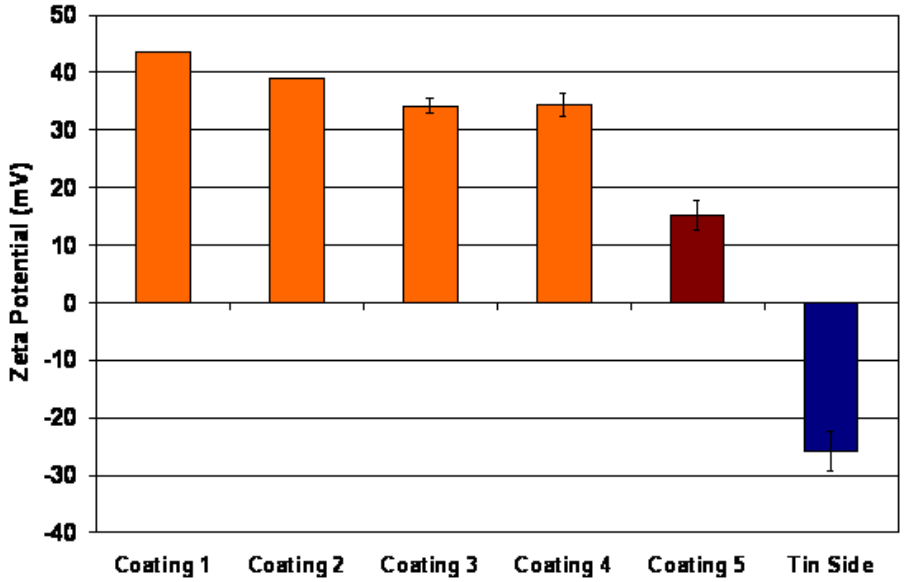

46
44
42
40
38
36
34
32
30
-Zeta Potential (mV)
E Tin Side
After 90 hrs
(in water)
New Slide



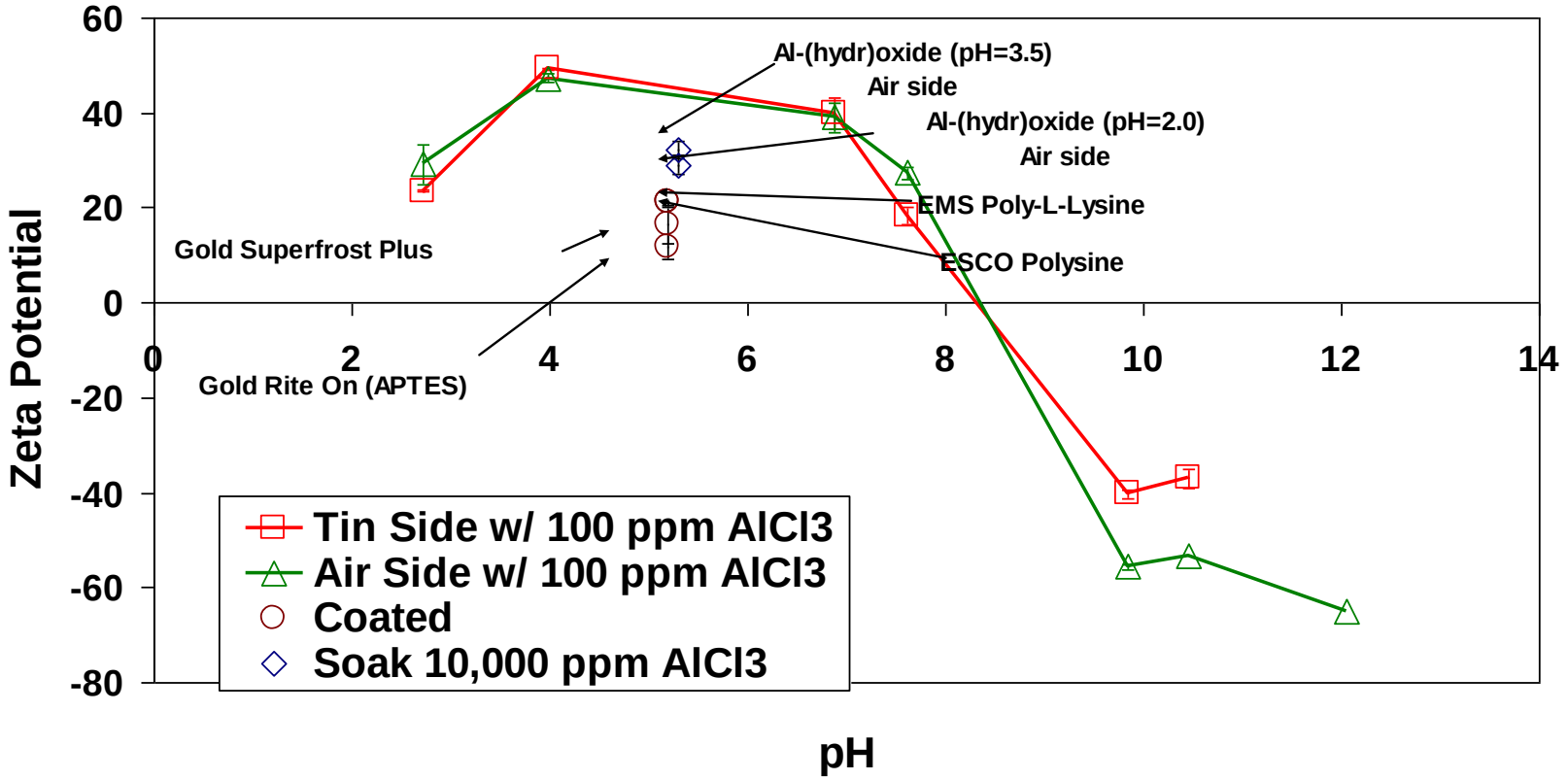
Zeta potentials determined for the air and tin surfaces of soda-lime-silicate glass slides for 10^{-3} KCl solutions **containing 100 ppm of $AlCl_3$ at different pH's.**

Surface compositions (by XPS) for the **aluminum-hydroxide sol/gel coated slides**, and the tin surface of an uncoated E slide for reference; Coating 5 was rinsed before the heat treatment.

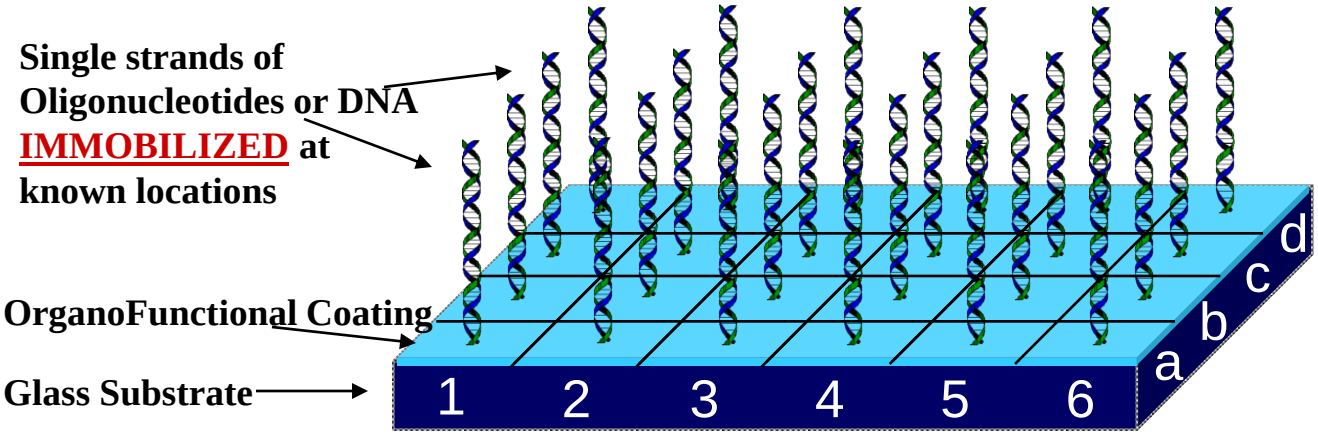
	Na	O	Sn	N	Ca	Mg	C	Cl	B	Si	Al
	(at%)	*(at%)*	*(at%)*	*(at%)*	*(at%)*	*(at%)*	*(at%)*	*(at%)*	*(at%)*	*(at%)*	*(at%)*
Coating 1	3.0	45.8	0.0	0.2	0.0	0.1	17.4	6.7	1.2	3.9	21.7
Coating 2	3.3	49.0	0.0	0.3	0.0	0.1	13.5	6.6	0.8	0.6	25.8
Coating 3	3.5	49.1	0.0	0.5	0.0	0.1	12.6	6.7	0.3	0.9	26.2
Coating 4	4.8	47.9	0.0	0.5	0.0	0.1	11.7	8.5	0.8	0.7	25.0
Coating 5	6.2	54.2	2.2	0.2	1.4	1.5	10.9	1.3	0.3	16.1	5.5
Tin Side	4.8	59.6	4.0	0.2	2.9	2.7	4.0	0.4	0.2	21.1	0.1



Coated Glass Slides– inorganic and (commercial) organic coatings



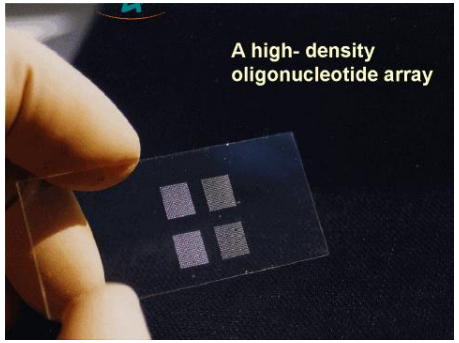
DNA Microarray: a glass-based biological sensor



glass substrates provide: chemical inertness
optical platform
low fluorescence background
flatness and smoothness
low cost!

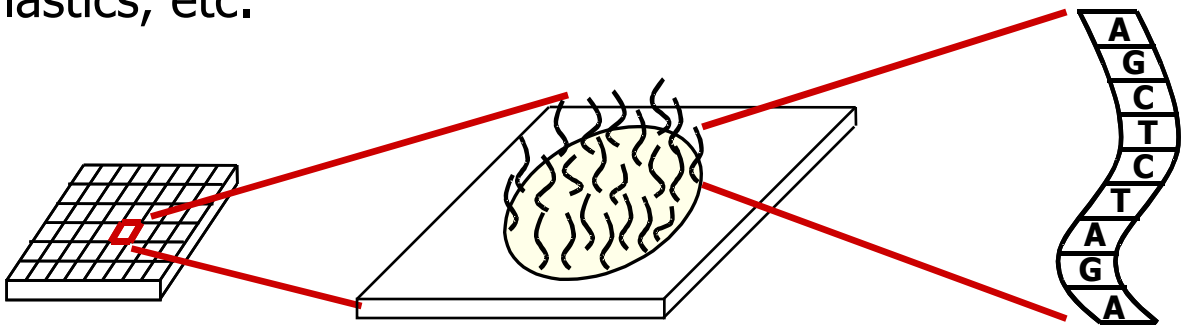
DNA Microarrays

A planar device comprised of an array of DNA single strands immobilized on the surface of an insoluble solid support.



Solid support:
Glass slides
Silicon
Plastics, etc.

Molecules:
oligonucleotides, proteins, cells or tissues



SEGMENT OF THE MICROARRAY

1x2 cm^2

# of spots = 100-500,000

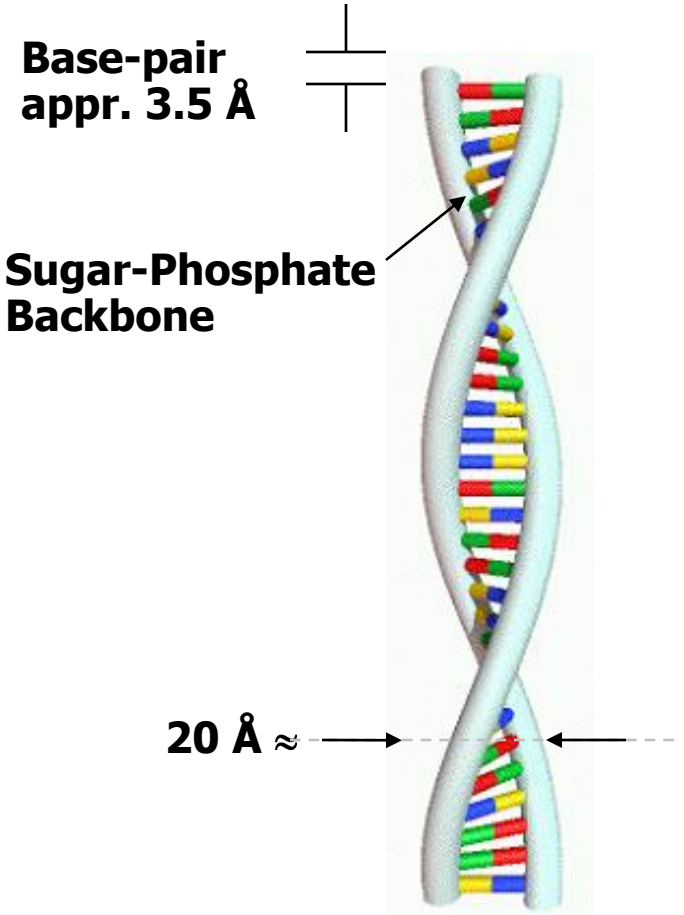
SPOT CONTAINING DNA Probes

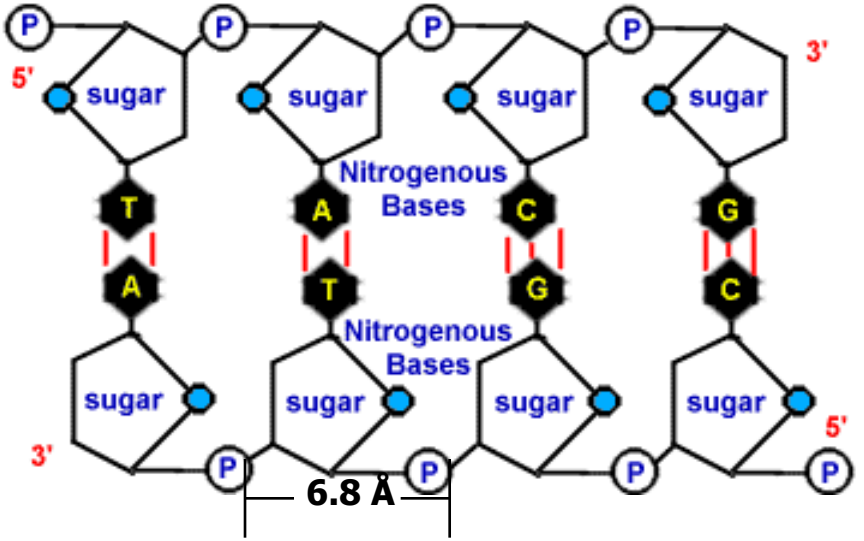
(10-250μm)

Immobilized DNA Probe

For DNA arrays:
Each spot contains
10^6 to 10^9 of
identical DNA fragments.

DNA Structure: The Fundamentals





- DNA is a linear polymer made up of a sugar and phosphate backbone with variable side groups of different nitrogen bases. (A, C, G, T)
- DNA may be *single* or *double* stranded.

- COMPLEMENTARY BASE PAIRING:

Weak H-bonding between the base pairs

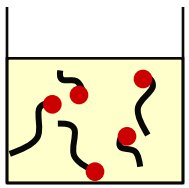
G↔C and T↔A

(HYBRIDIZATION)

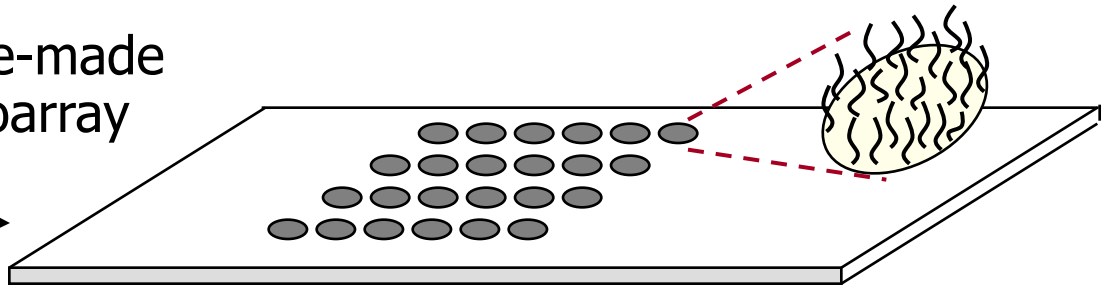
T-C-A-G-G-T-T

A-G-T-C-C-A-A

DNA Microarrays (Gene Chips for sequencing)



Apply to pre-made
DNA Microarray

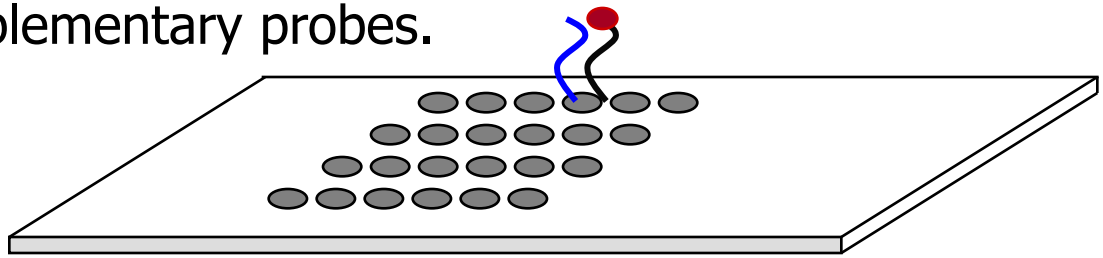


Unknown DNA solution
with fluorescent dyes.

Each spot contains identical DNA
probes of different known sequence.

Laser Confocal Scan

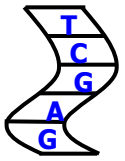
Unknown DNA molecules attach
to their complementary probes.

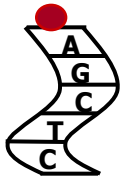


The sequence of the unknown
strand is now determined.

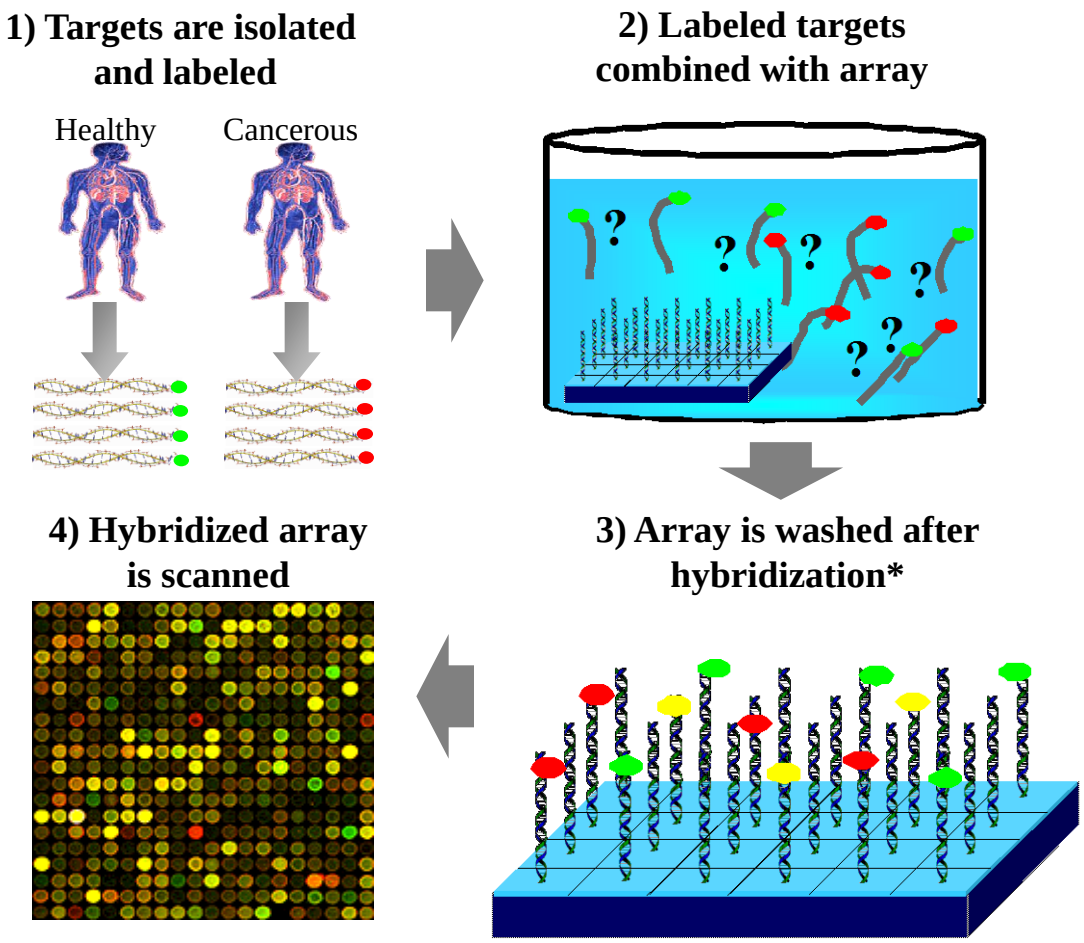
i.e.

Array
probe



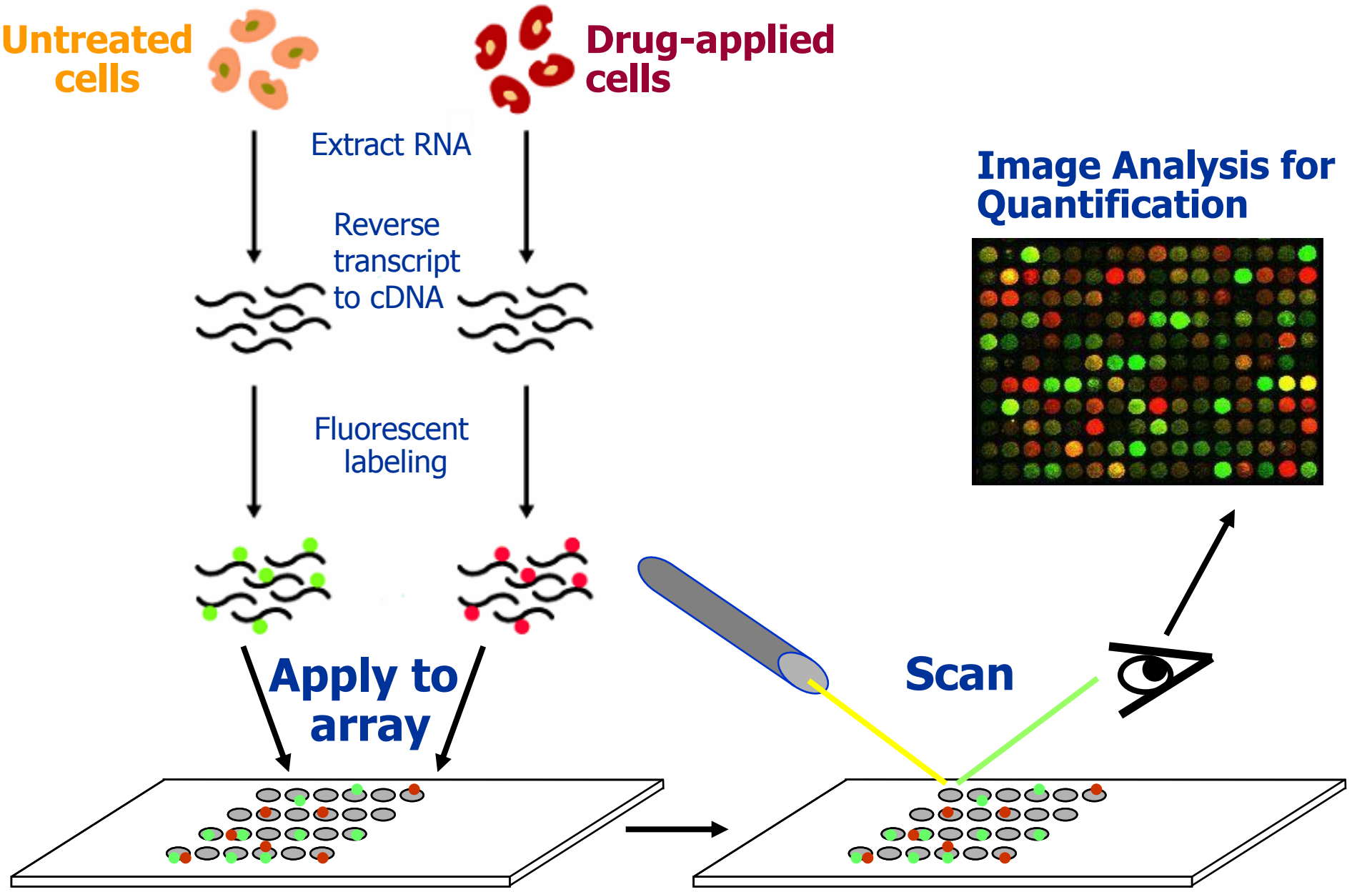


Unknown
probe

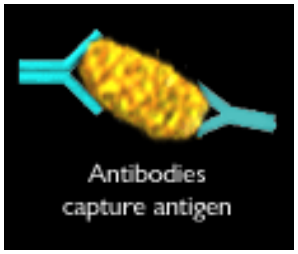


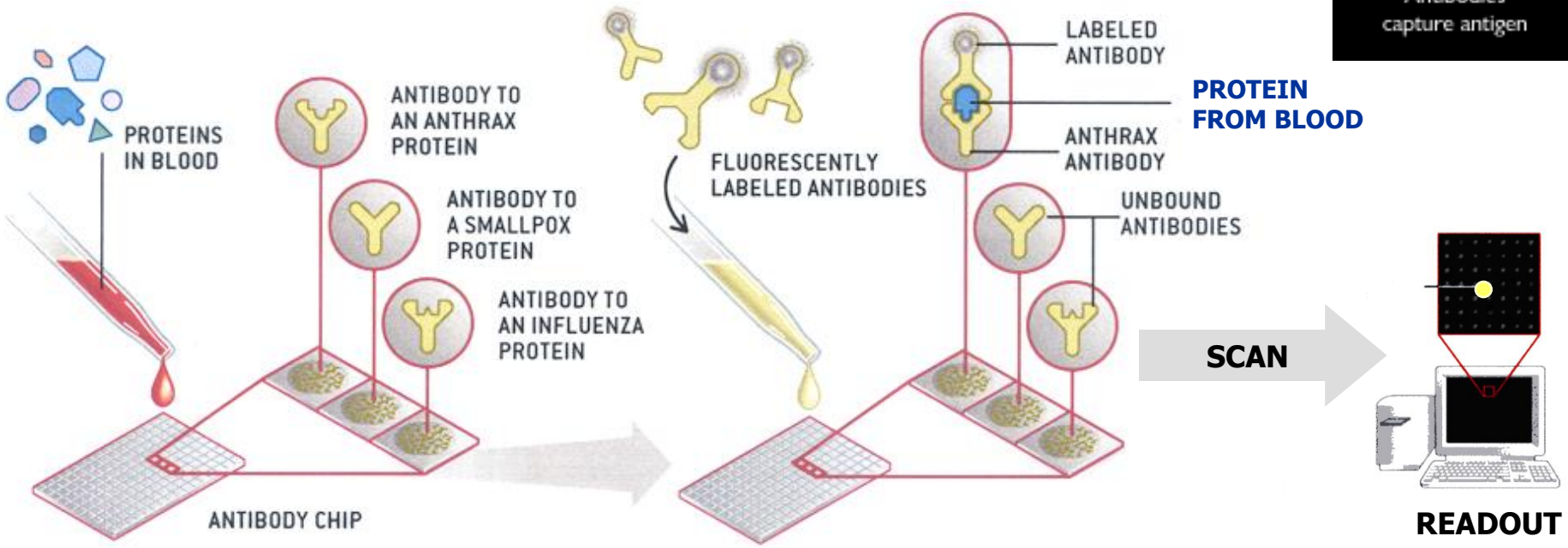
Use of Microarrays: Gene Expression Experiment

Use of Microarrays: Drug Discovery



Protein Arrays: Diagnostic Analysis





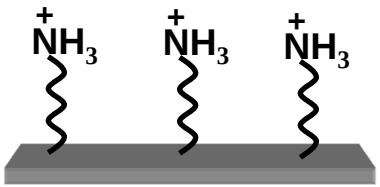
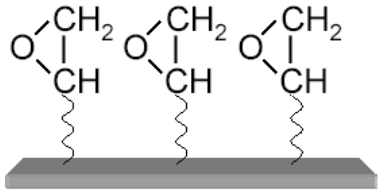
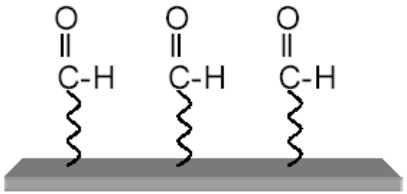
- Squares of antibodies able to bind a specific protein representing a disease-causing agent.
- Apply blood to the array of antibodies → proteins from blood attach
- Apply fluor-labeled antibodies recognizable by the attached proteins. forming a antibody "sandwich"
- Dot indicating that the patient has anthrax.

Anderson and Valkirs, Scientific American, 2002

Multiple Surface Chemistries Provide Opportunities for Immobilization of Various Probes

and in addition to DNA arrays/probes:

ELISA's
Protein arrays
Carbohydrate arrays
Chem-Bio Sensors

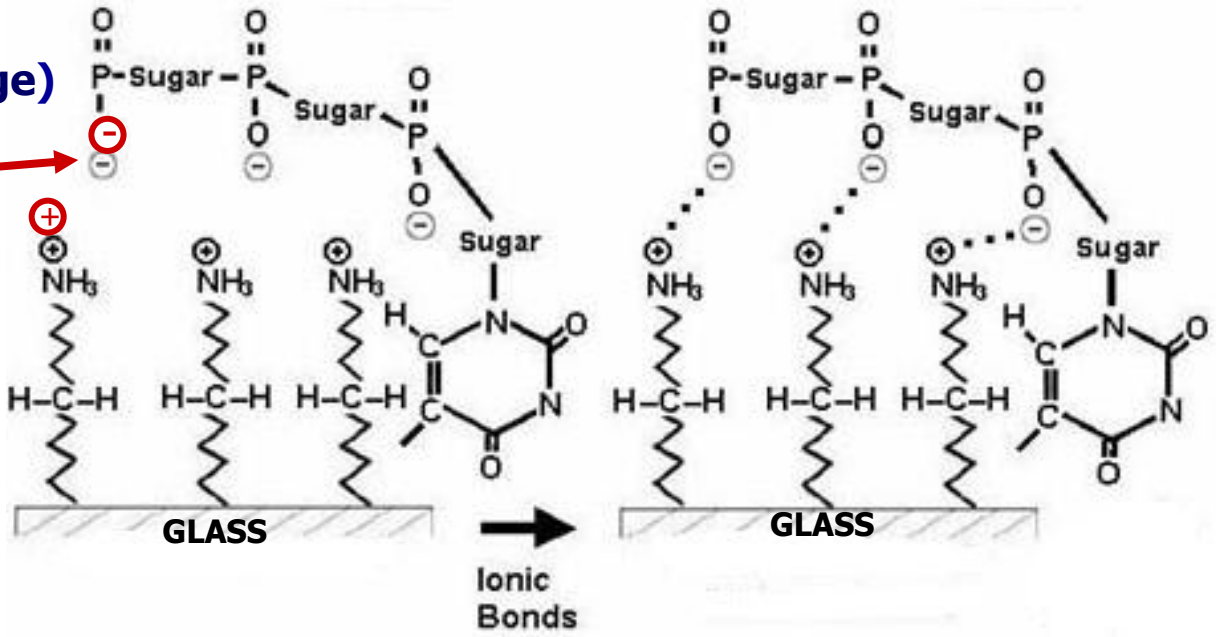
Surface Coatings	Recommended Probes
 Amino	• PCR products • Long oligos (size ≥ 50 mers)
 Epoxy	• Short and long oligos • PCR products
 Aldehyde	• Peptides • Short and long NH_2-modified oligos • NH_2-modified PCR products • Antibodies

Immobilization of Unmodified DNA to glass substrates

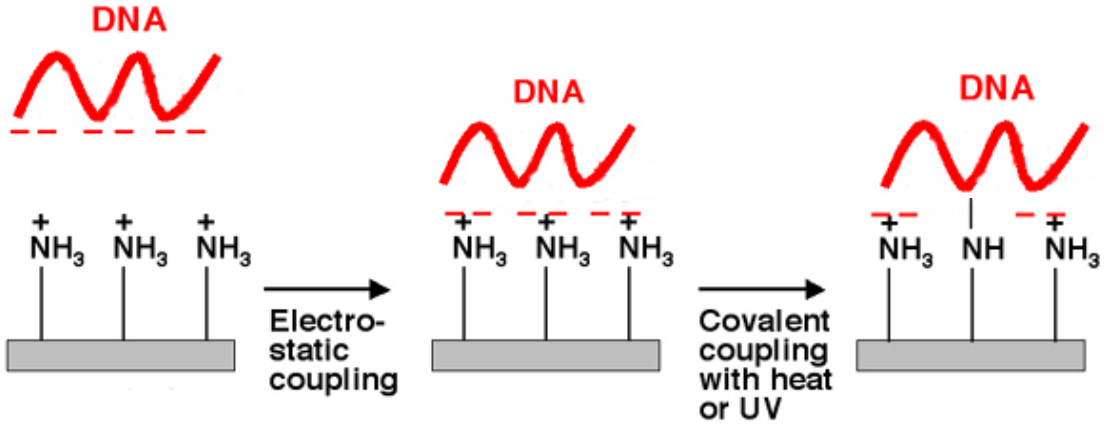
Phosphate-Sugar DNA backbone (carries negative charge)

electrostatic attraction

functional amine group-NH_3^+

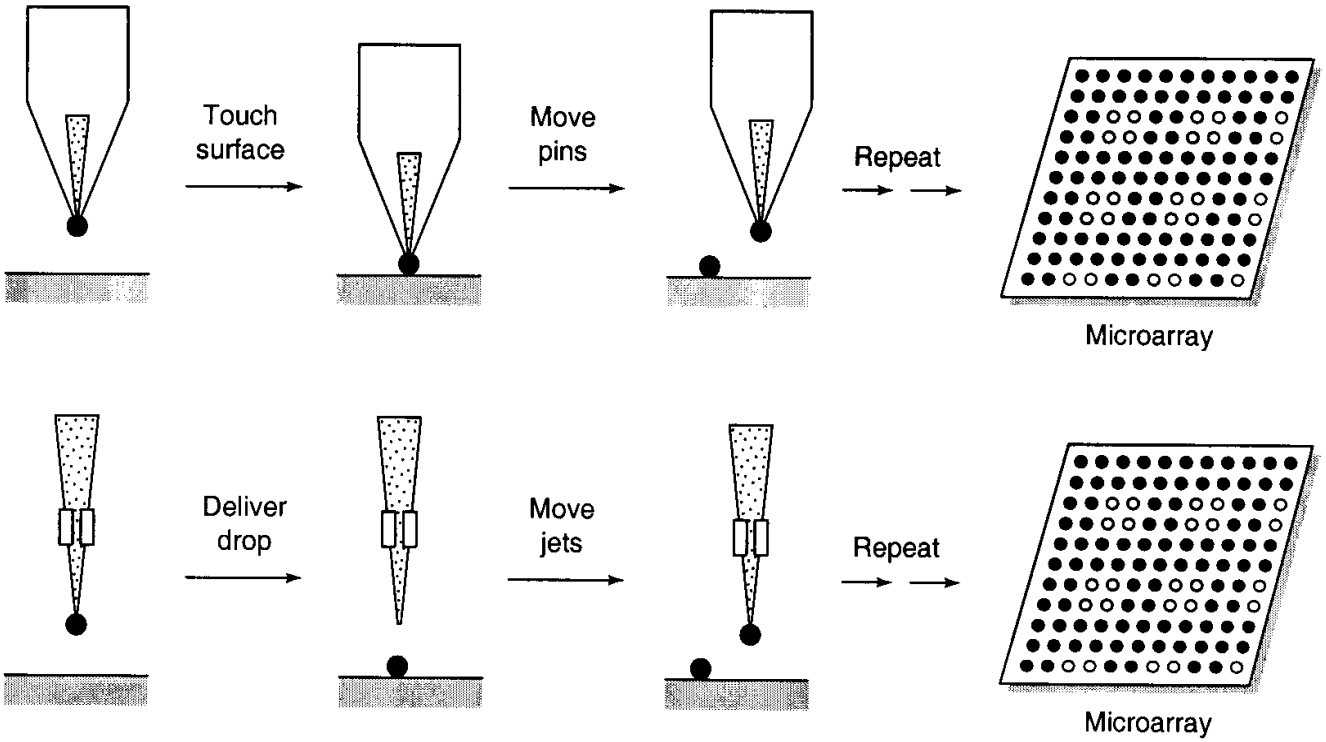


Unmodified DNA strands carry intrinsic $(PO_4)^{3-}$ groups; glass surfaces functionalized with protonated amino groups (NH_2) can be used for their initial immobilization.



Physical Deposition of Modified and Unmodified DNA

Microspotting (Shalon ad Brown, Stanford, 1995)



Because of the ease of use and affordability, microspotting has become the most common microarray technology for basic research.

Physical Chemistry/Engineering of the Microspotting Process