Microfabricated Interdigitated Microelectrodes-Based Electrical/Electrochemical Impedance for Biological Detection

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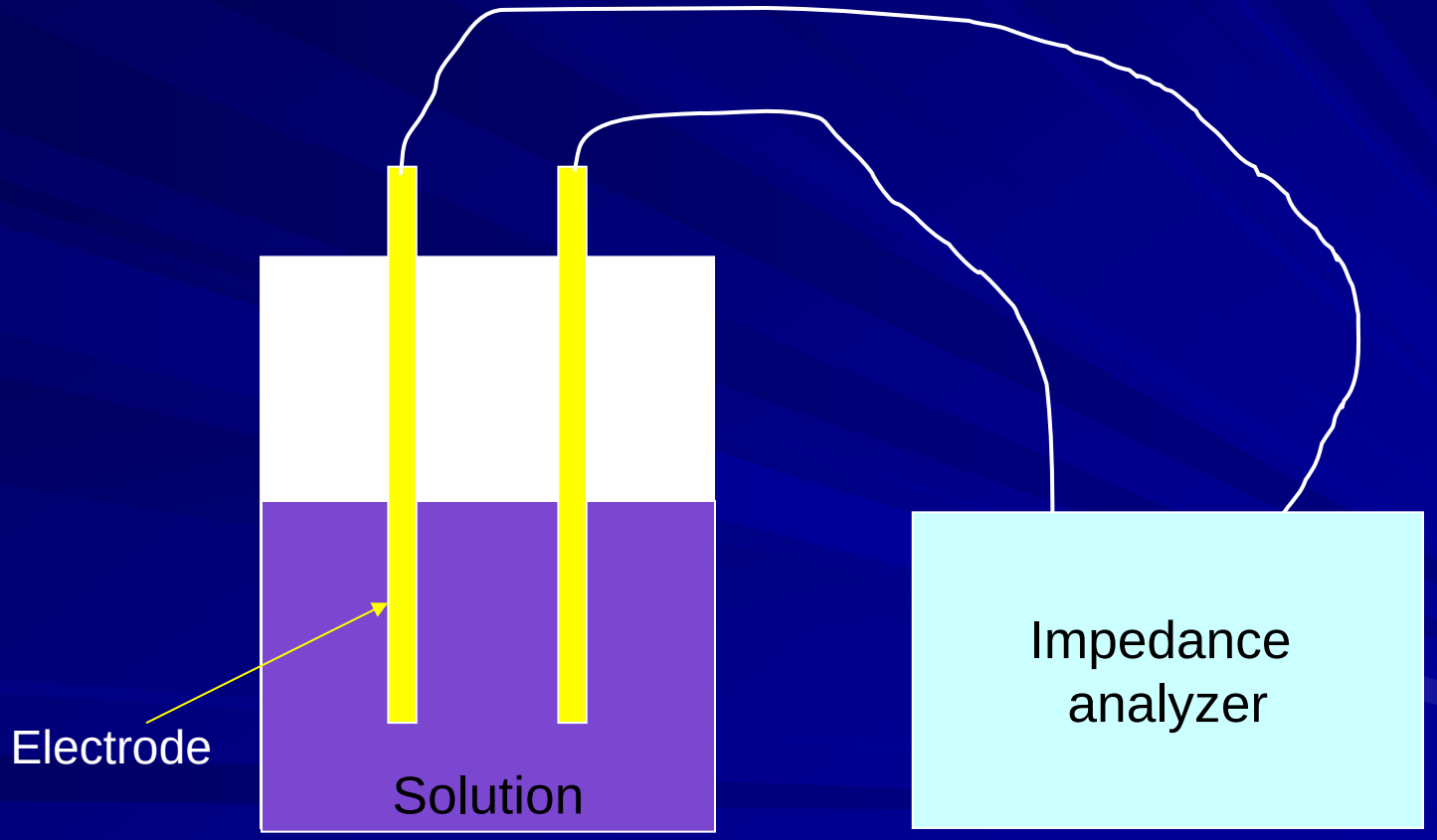
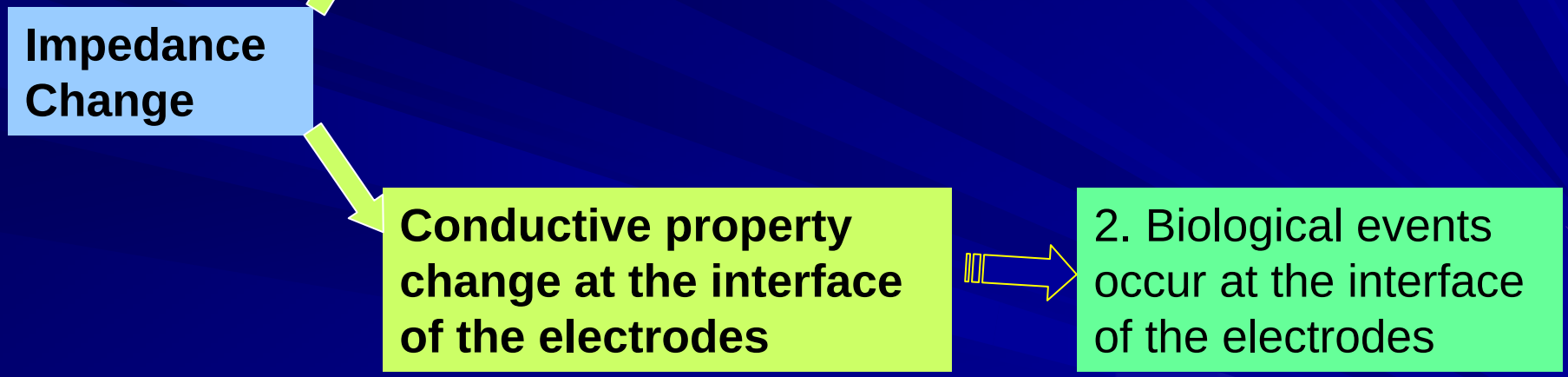
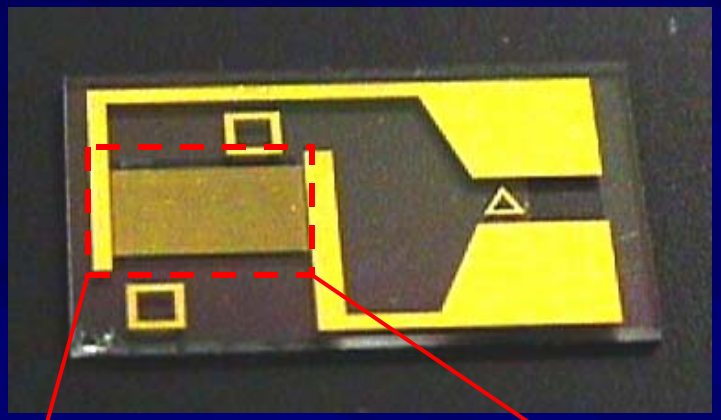
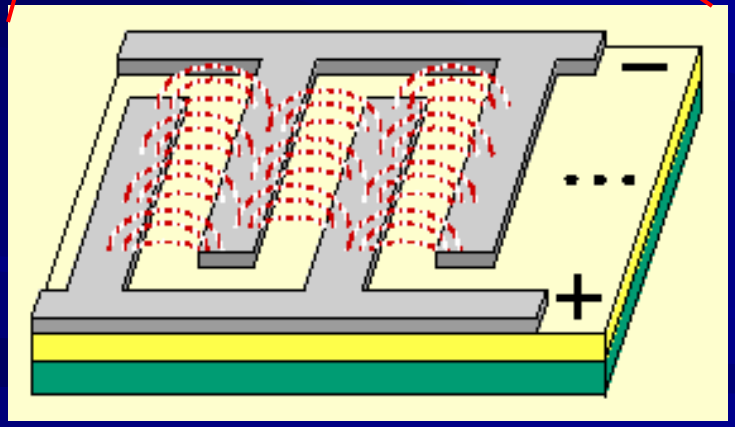
- ***Impedance*** **is a measurement of the ability of a circuit or electrical element to resist the flow of AC electrical current.**




Impedance Change
Conductive property change in the solution
1. Biological events occur in the solution.
Conductive property change at the interface of the electrodes
2. Biological events occur at the interface of the electrodes

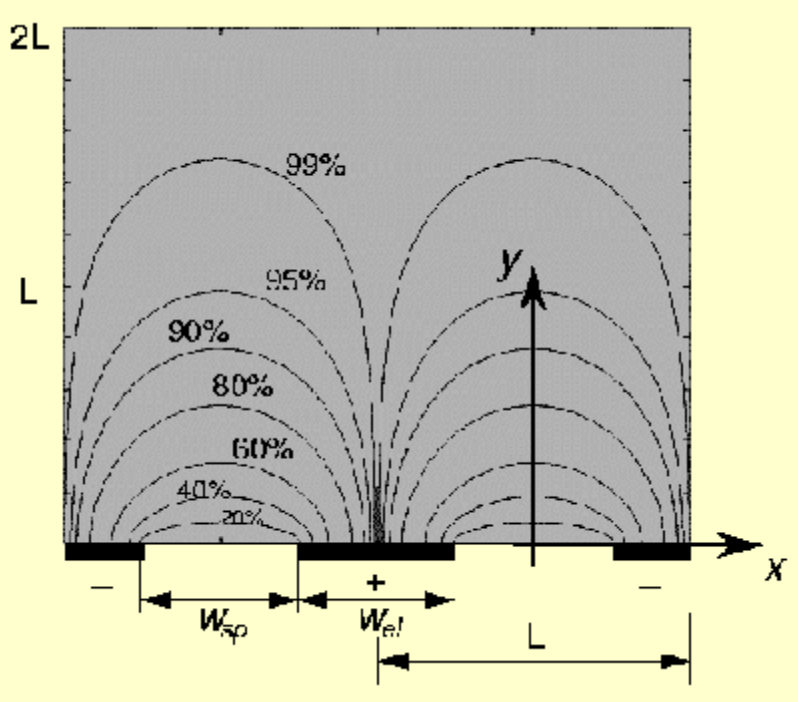
Interdigitated Array (IDA) Microelectrodes



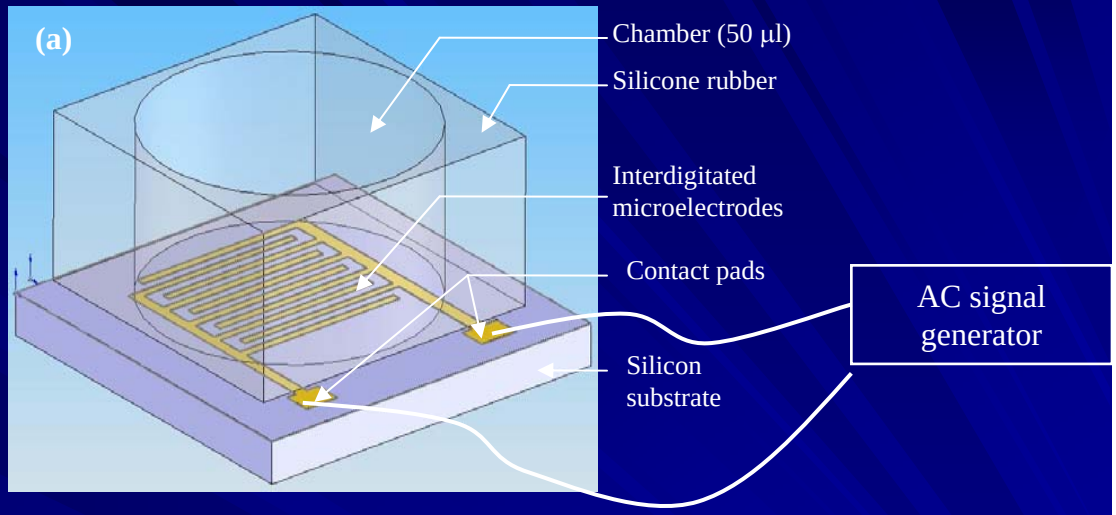


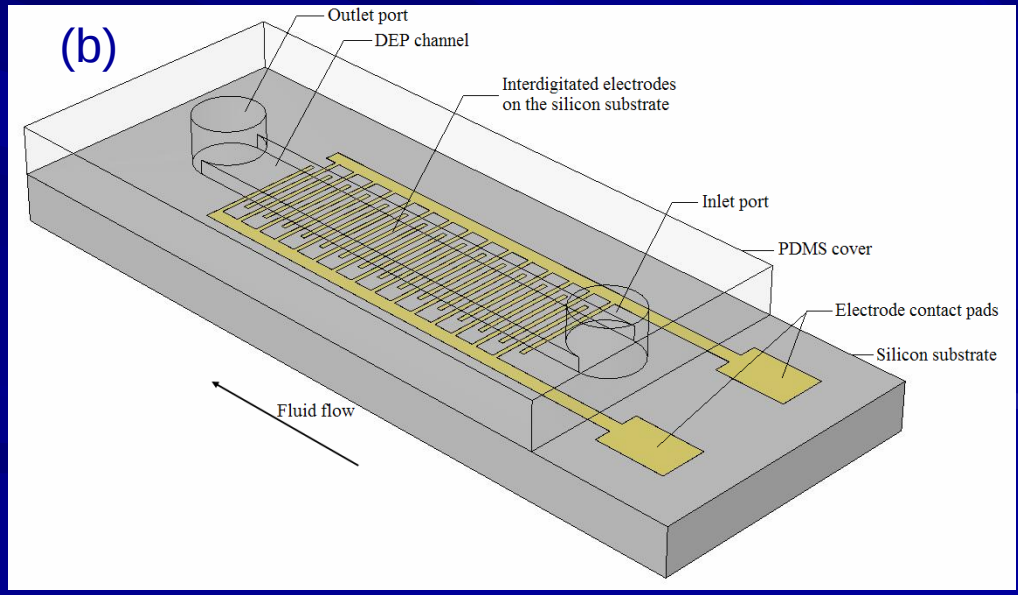
- Low ohmic drop
- High signal-to-noise ratio
- Rapid attained steady state
- Improved sensitivity
- Small testing volume
- Reproducible fabrication

- **Two-electrode system**
- **Multiple electrode pairs**
- **Progressively shorter electrode distance**
- **Large electrode surface area**

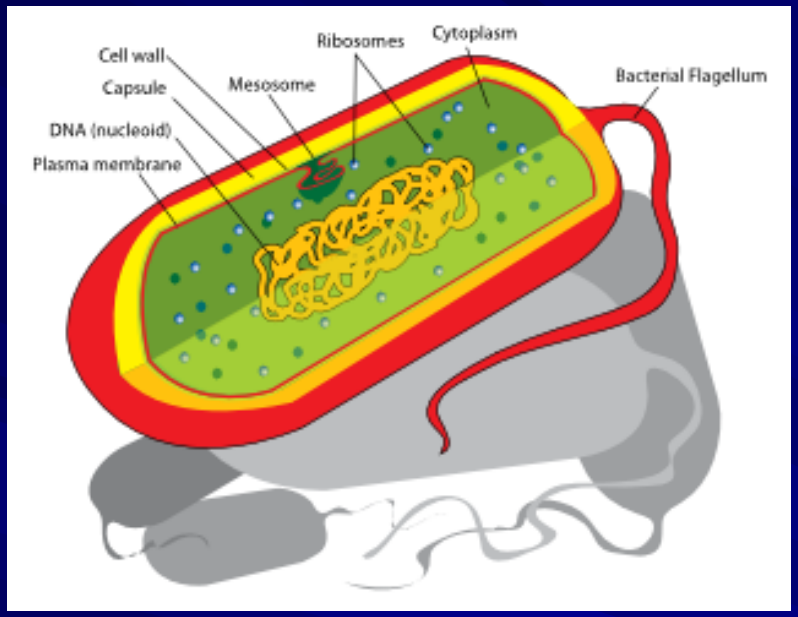


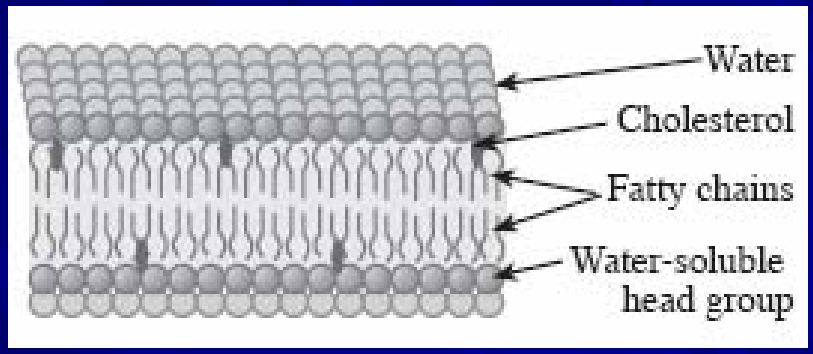
Van Gerwen P, et al. Sens. Actuators B, 1998; 49, 73-80





Impedance of biological cells





- The cell membrane consists of a lipid bilayer containing many proteins. It is highly insulating. The conductivity is around 10^{-7} S/m.
- The inside of a cell contains many dissolved charged molecules. The conductivity of the interior of a cell can be as high as 1 S/m.

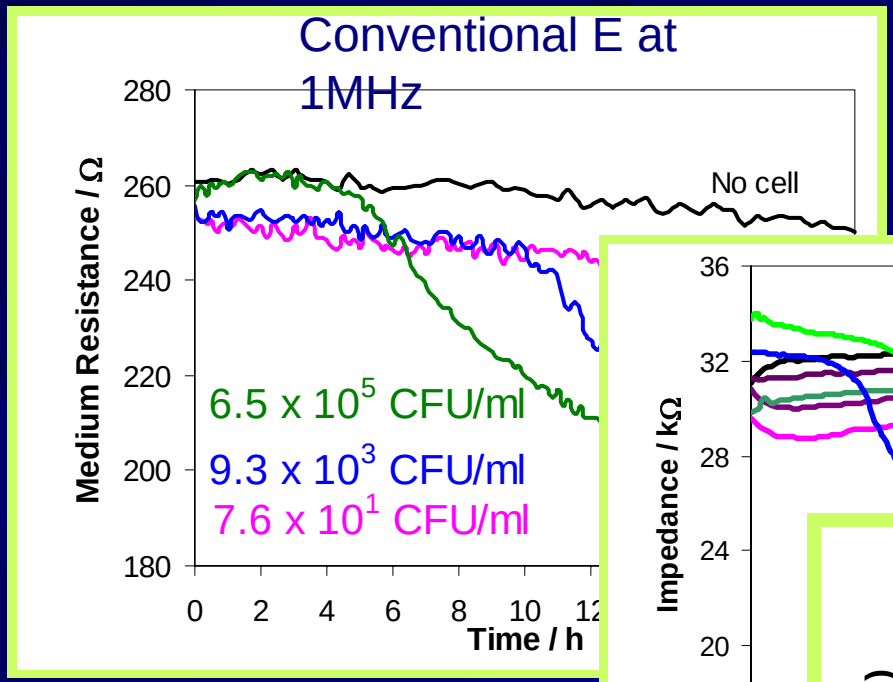
Mechanisms for impedance detection of biological cells

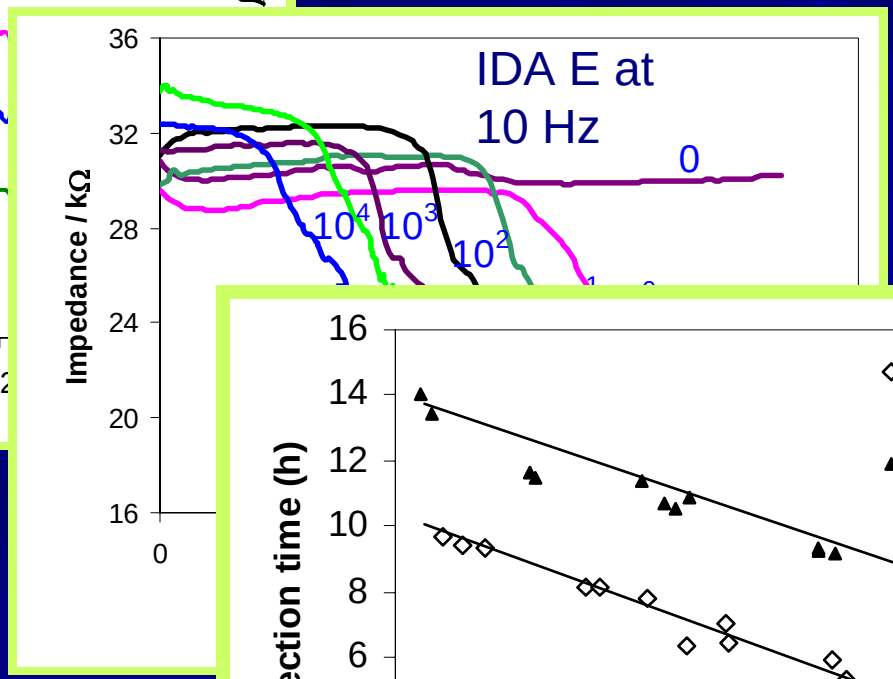
(i) Making use of the metabolic activity of biological cells. This is represented by **impedance microbiology**, which is based on the measurements of the change in electric impedance in a medium or a reactant solution resulting from the bacterial metabolism.

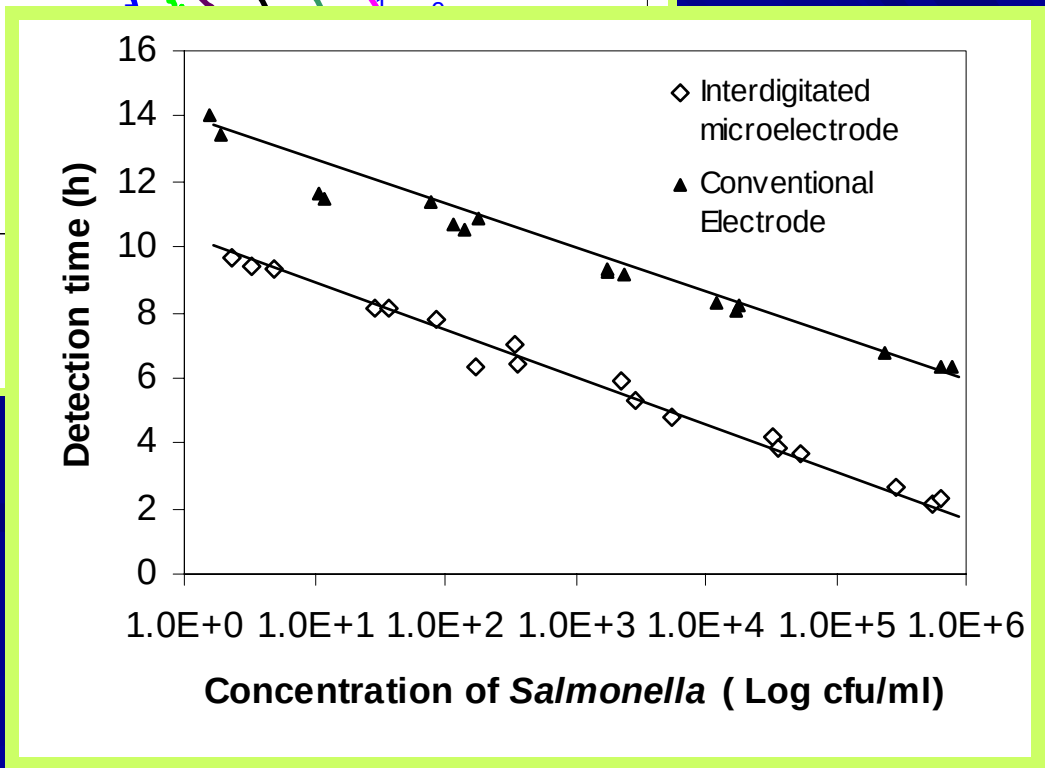
(ii) Making use of the insulating properties of the cell membrane. **–Label free biosensor**.

(iii) Making use of the highly ionic cytoplasm of the cells. **– cell lysis or ion release**

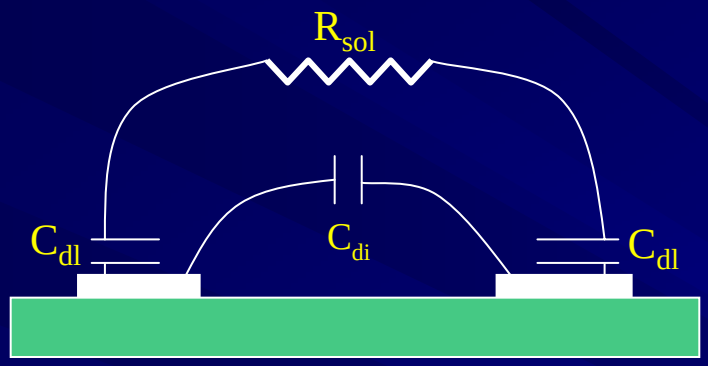
(i) Impedance detection based on bacterial metabolism

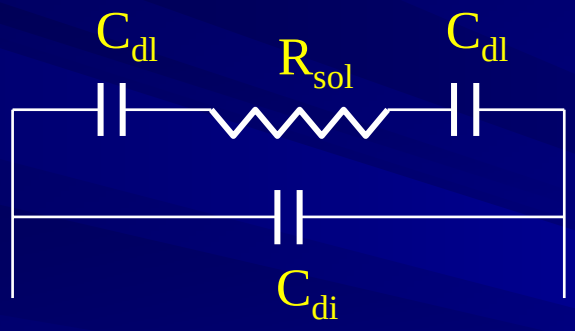


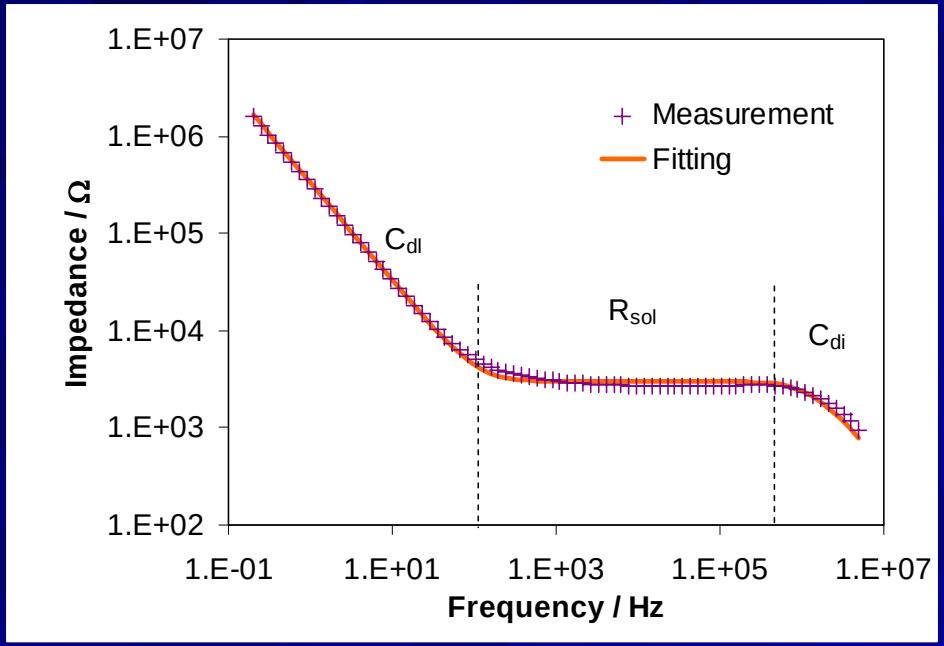




Equivalent Circuit of the Microelectrode Systems

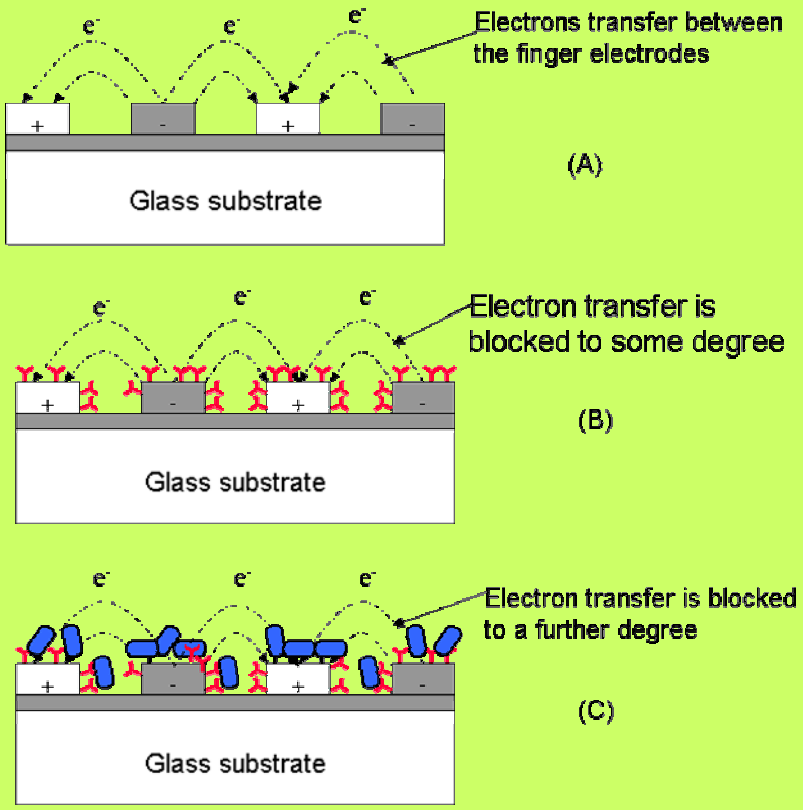


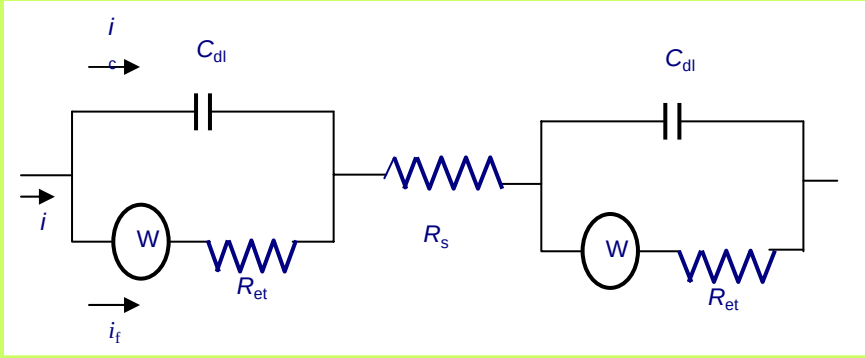


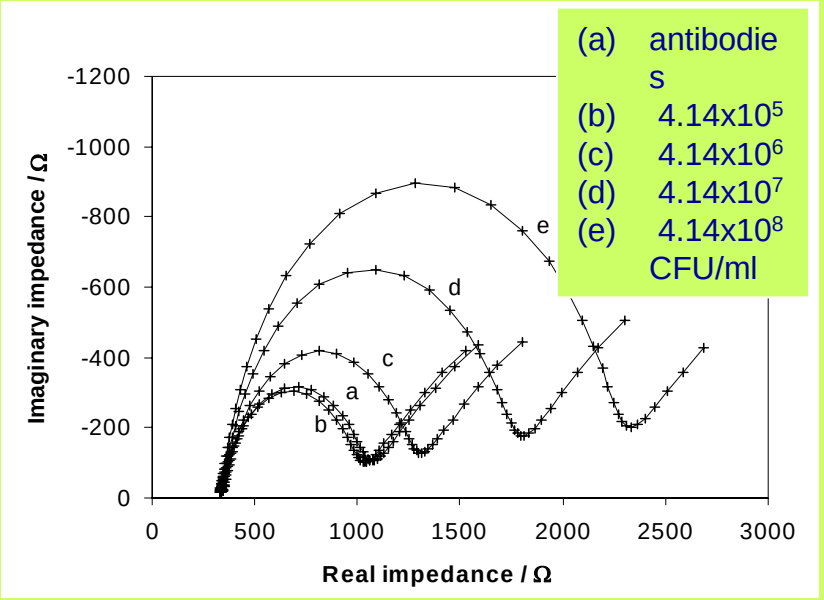


	C_{dl} / nF	R_s / Ω	C_{di} / pF
Before bacterial growth	397.2 ± 33.2	349.6 ± 16.0	45.3 ± 1.7
After bacterial growth	528.2 ± 73.7	365.1 ± 25.2	44.6 ± 2.8
Change	33%	4.4%	1.5%

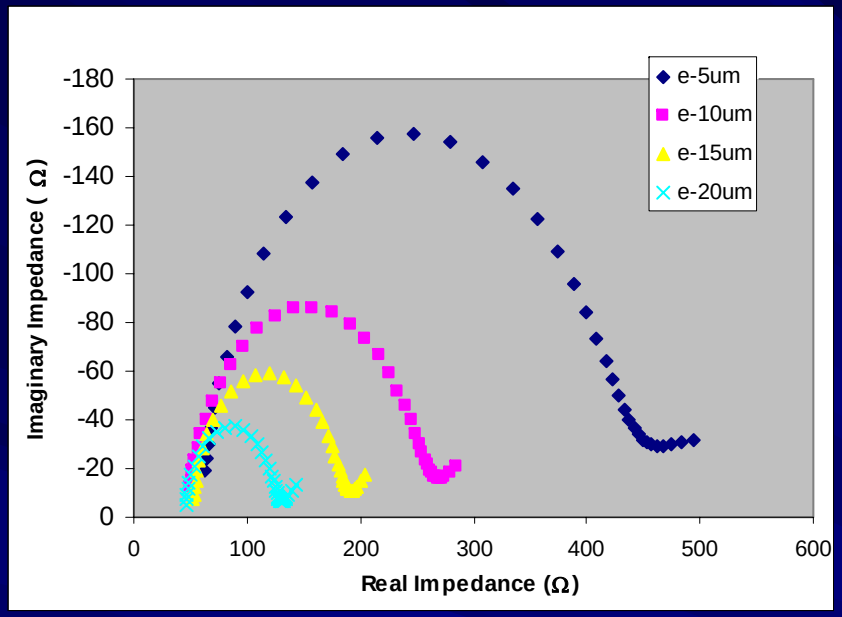
(ii) Label-free impedance biosensor

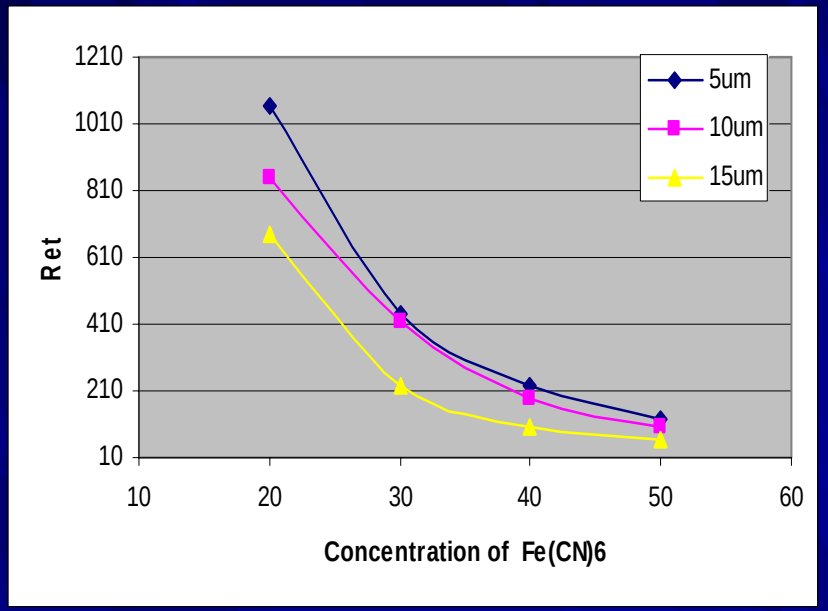


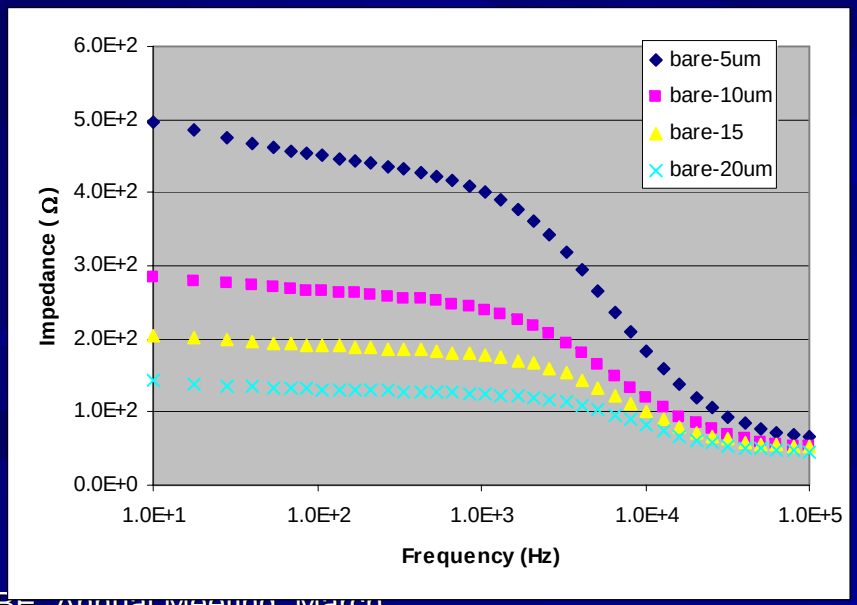


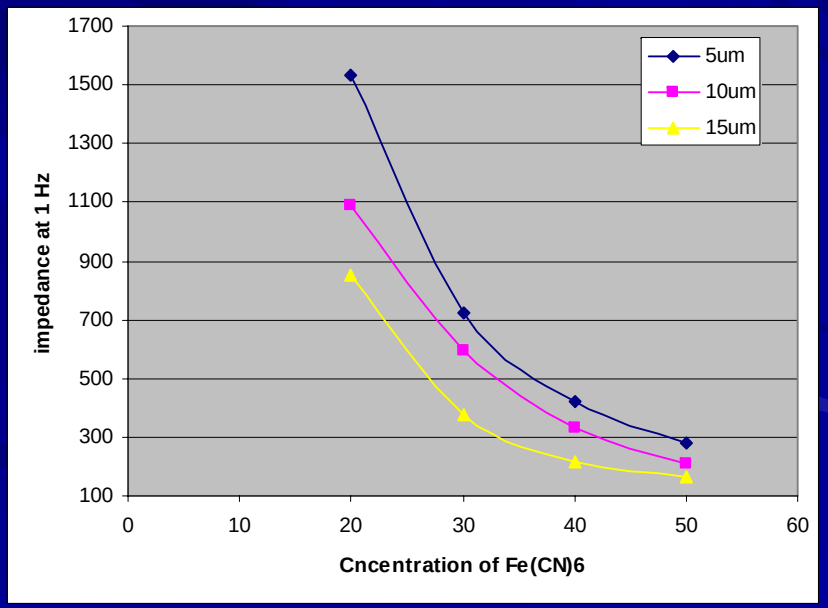


IDA electrodes size effect







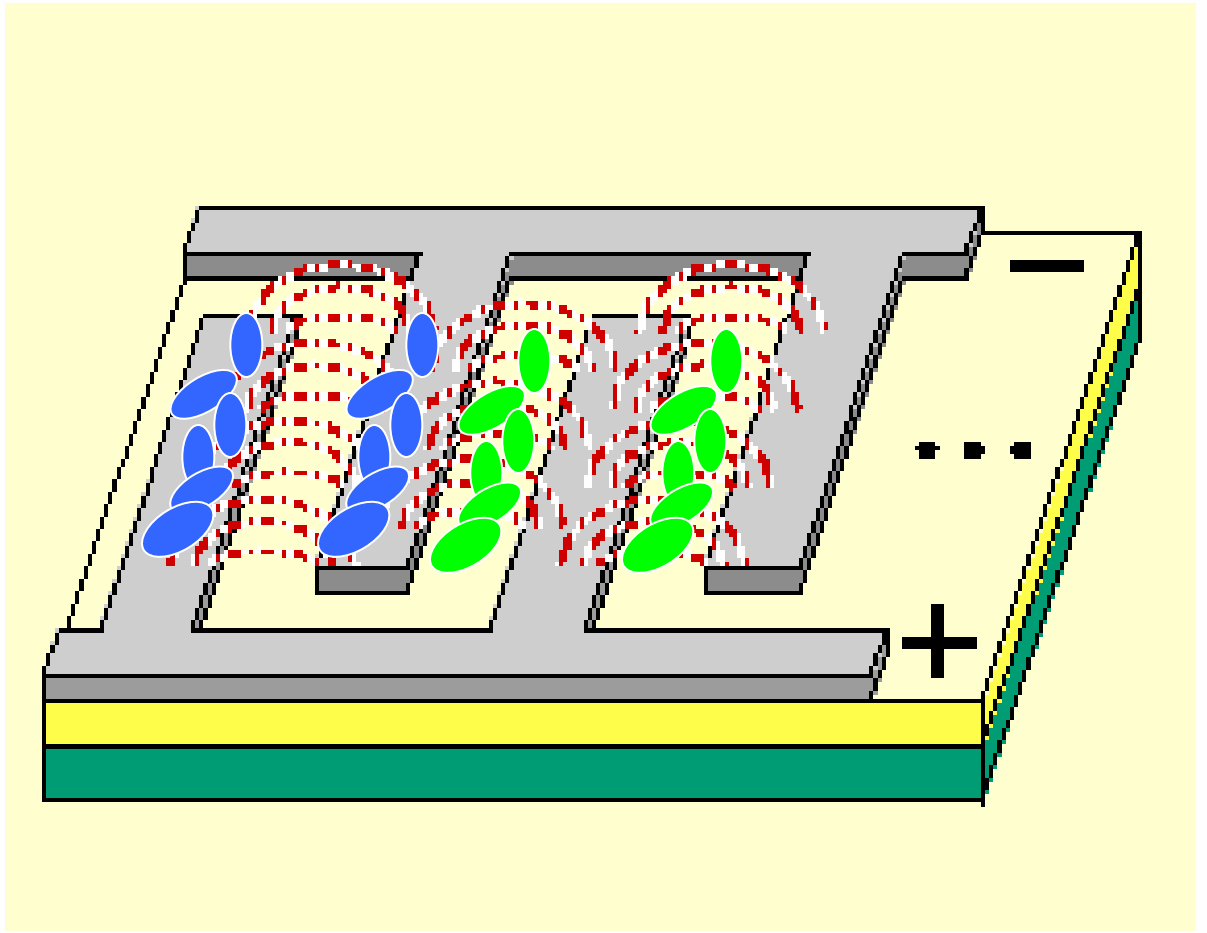


Manipulating bacterial cells on sensor surfaces

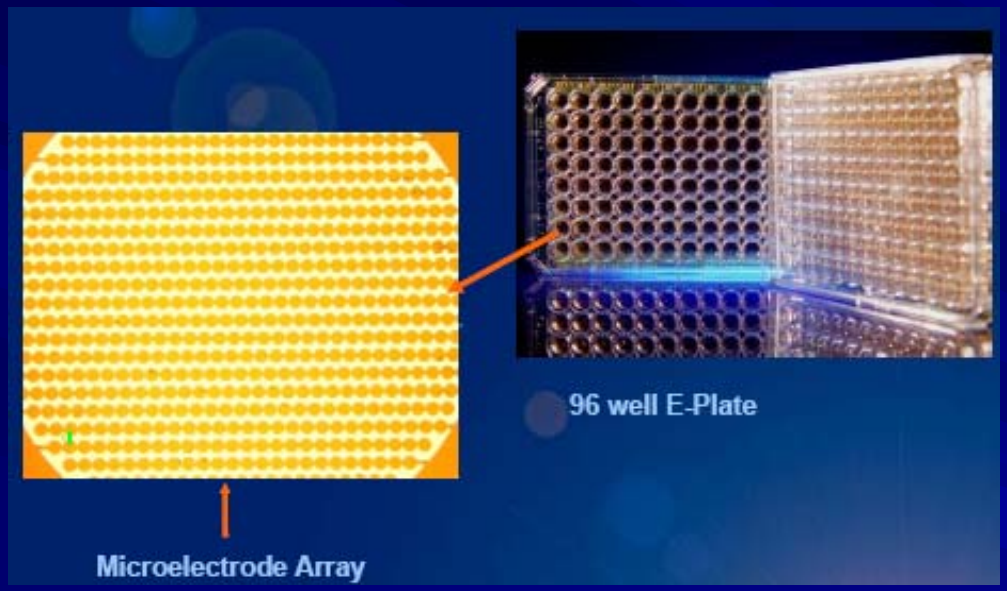
electrode

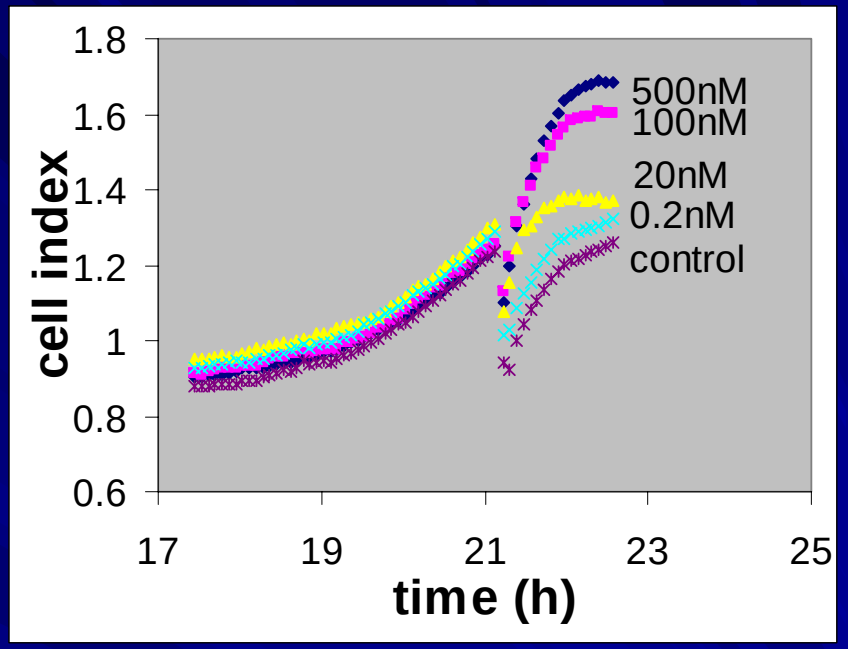
No DEP

0 Hz

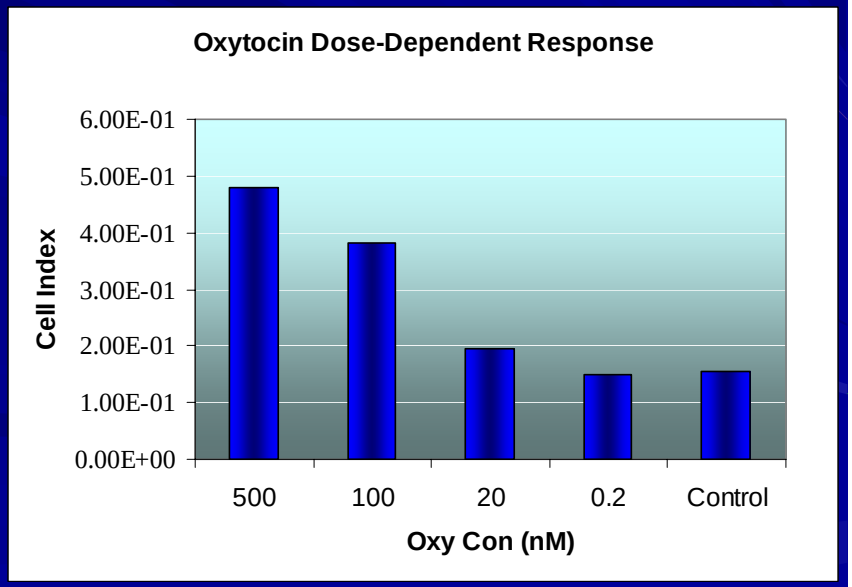


High throughput E-plates for label free cell-based drug screening

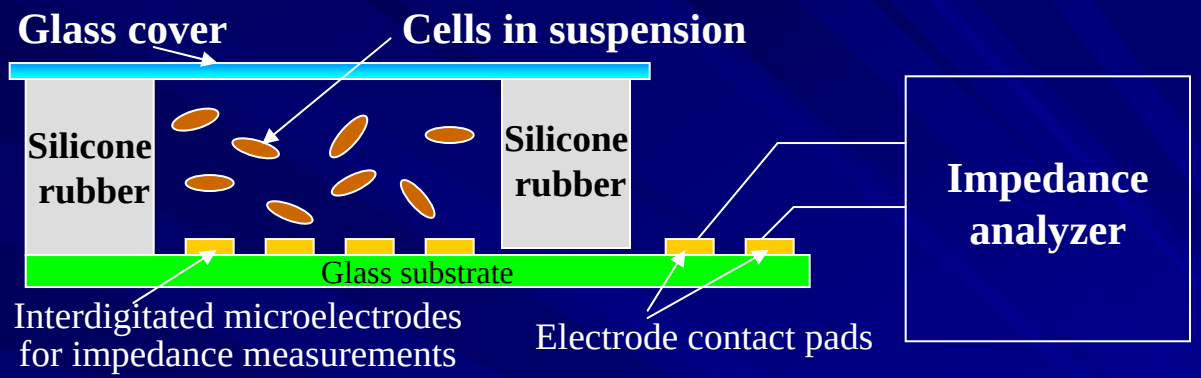


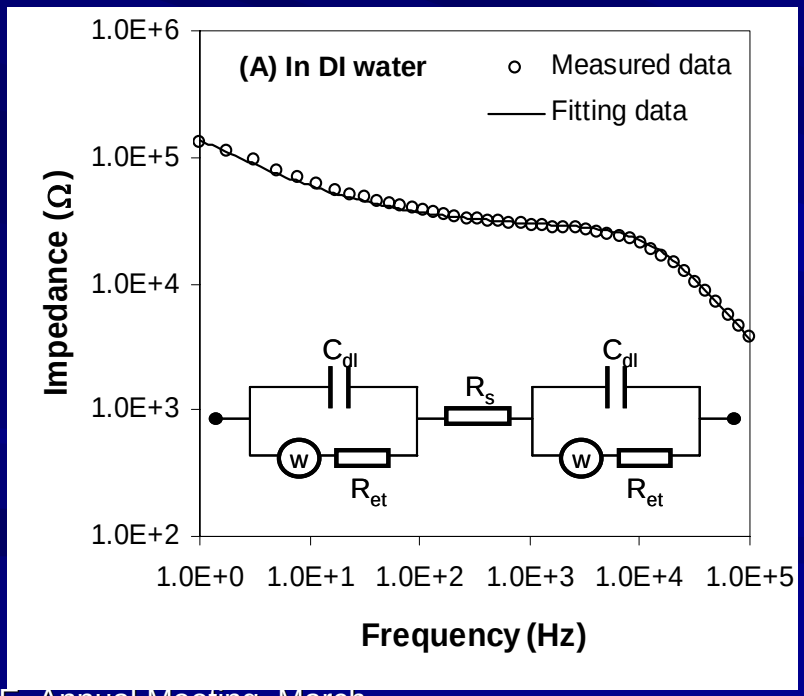


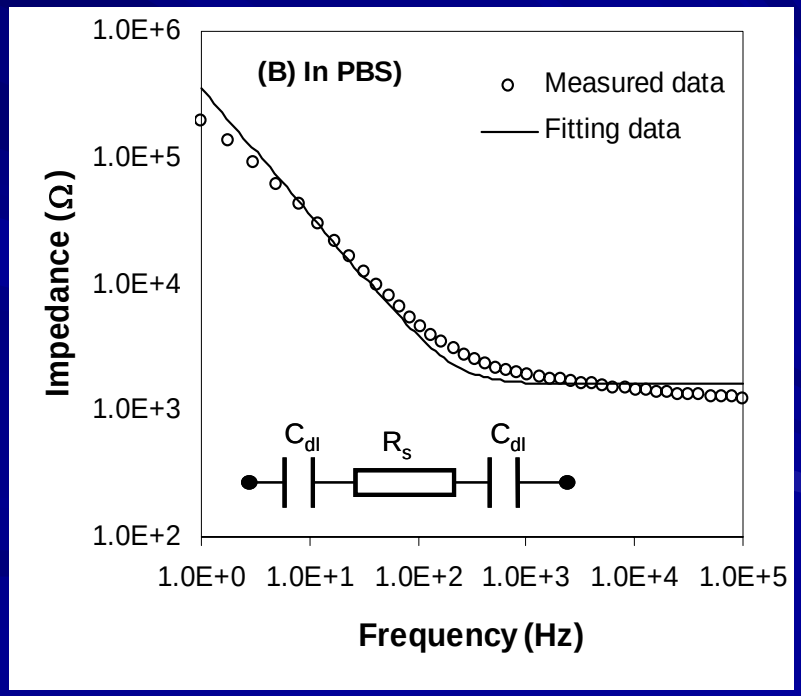
CHO Cells Over-Expressed Oxytocin Receptor - Oxytocin Treatment

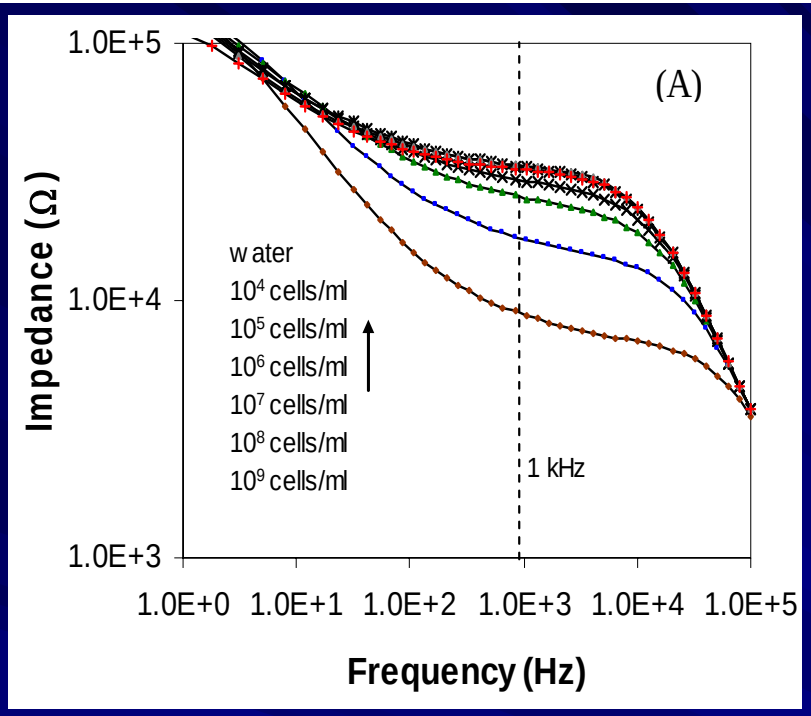


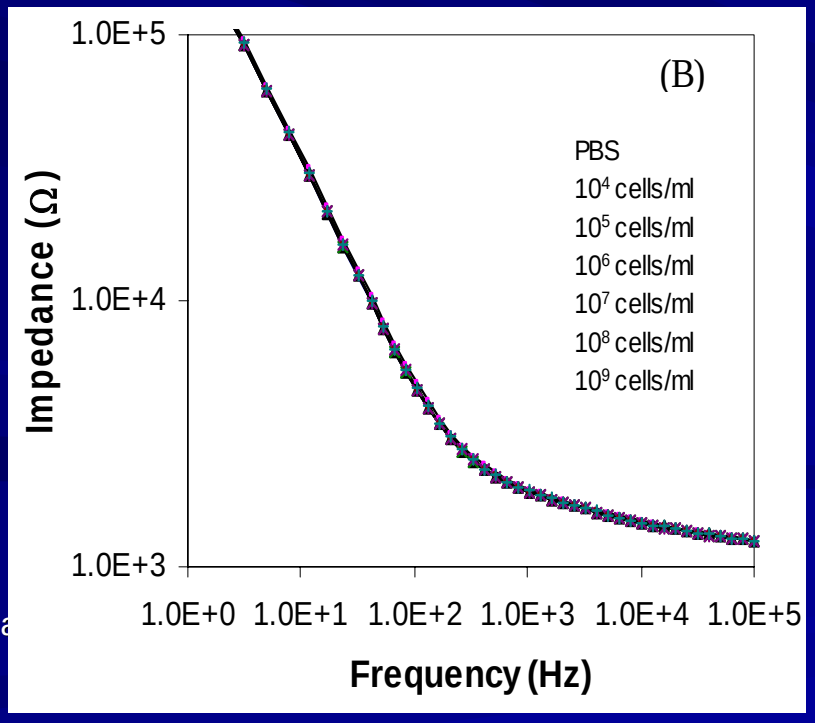
(iii) Impedance detection based on ion release from bacterial cells

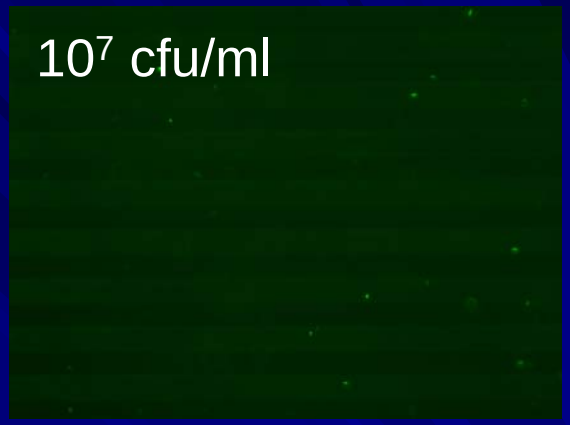


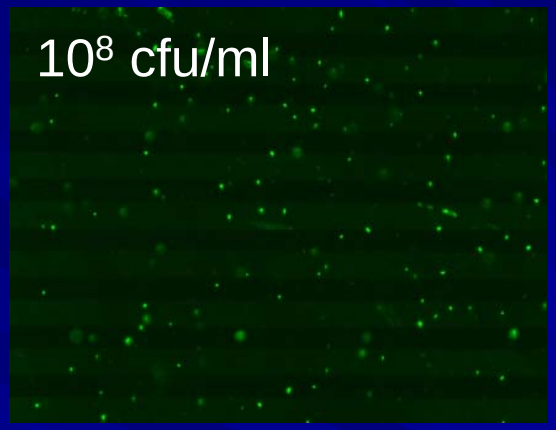


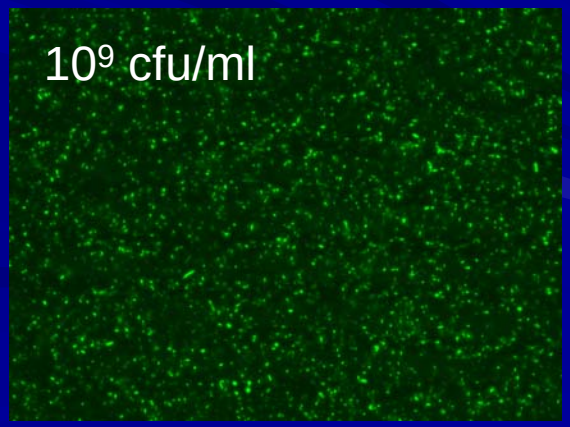


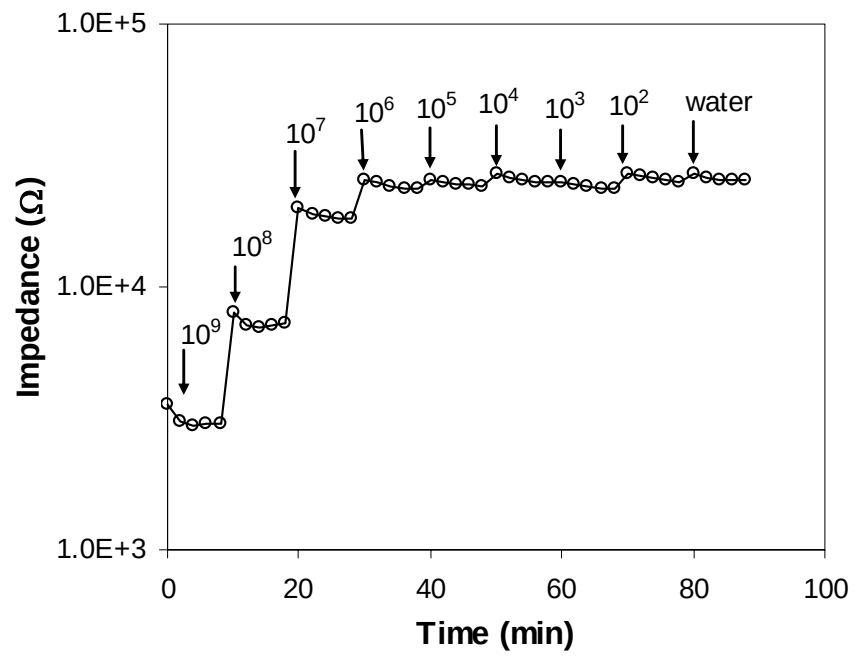

(A)
1.0E+5
1.0E+4
1.0E+3
Impedance (Ω)
water
10^4 cells/ml
10^5 cells/ml
10^6 cells/ml
10^7 cells/ml
10^8 cells/ml
10^9 cells/ml
1 kHz
1.0E+0 1.0E+1 1.0E+2 1.0E+3 1.0E+4 1.0E+5
Frequency (Hz)

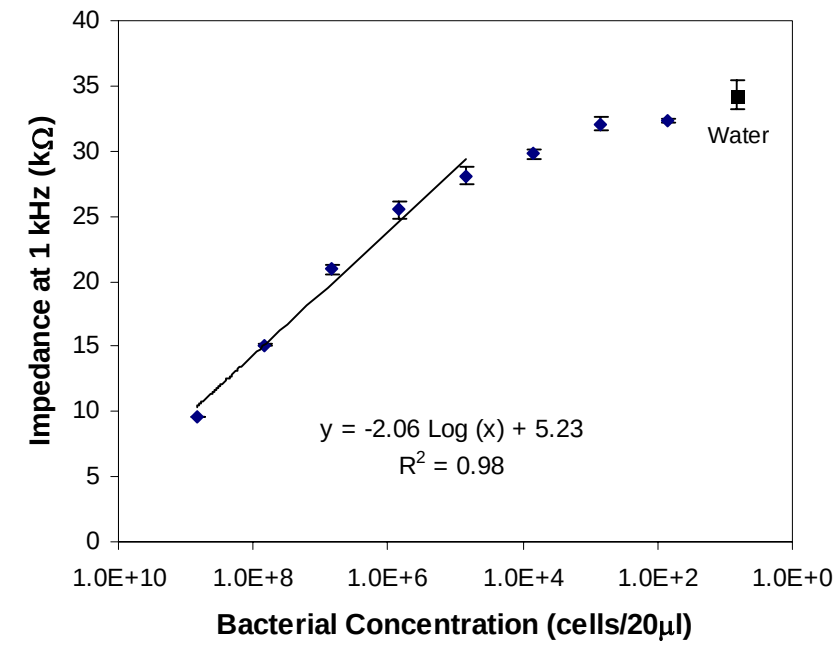

(B)
1.0E+5
1.0E+4
1.0E+3
Impedance (Ω)
PBS
10^4 cells/ml
10^5 cells/ml
10^6 cells/ml
10^7 cells/ml
10^8 cells/ml
10^9 cells/ml
1.0E+0 1.0E+1 1.0E+2 1.0E+3 1.0E+4 1.0E+5
Frequency (Hz)

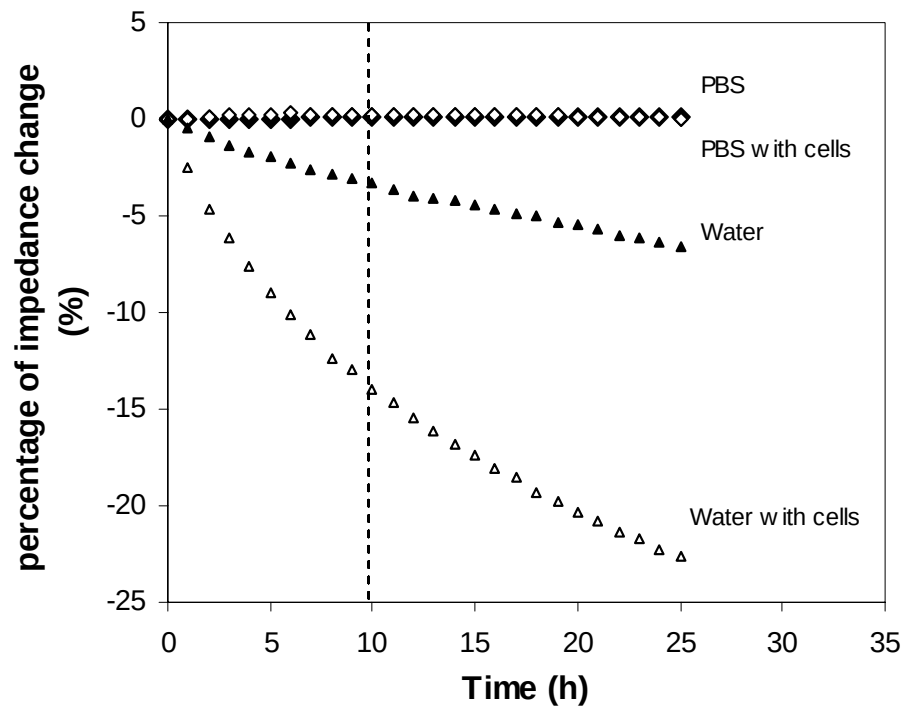

10^7 cfu/ml


10^8 cfu/ml


10^9 cfu/ml


1.0E+5
1.0E+4
1.0E+3
Impedance (Ω)
0
20
40
60
80
100
Time (min)
10^9
10^8
10^7
10^6
10^5
10^4
10^3
10^2
water


40
35
30
25
20
15
10
5
0
Impedance at 1 kHz (kΩ)
1.0E+10
1.0E+8
1.0E+6
1.0E+4
1.0E+2
1.0E+0
Bacterial Concentration (cells/20μl)
Water
y = -2.06 Log (x) + 5.23
R2 = 0.98


5
0
-5
-10
-15
-20
-25
percentage of impedance change (%)
0
5
10
15
20
25
30
35
Time (h)
PBS
PBS with cells
Water
Water with cells

Acknowledgement

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Thank you !