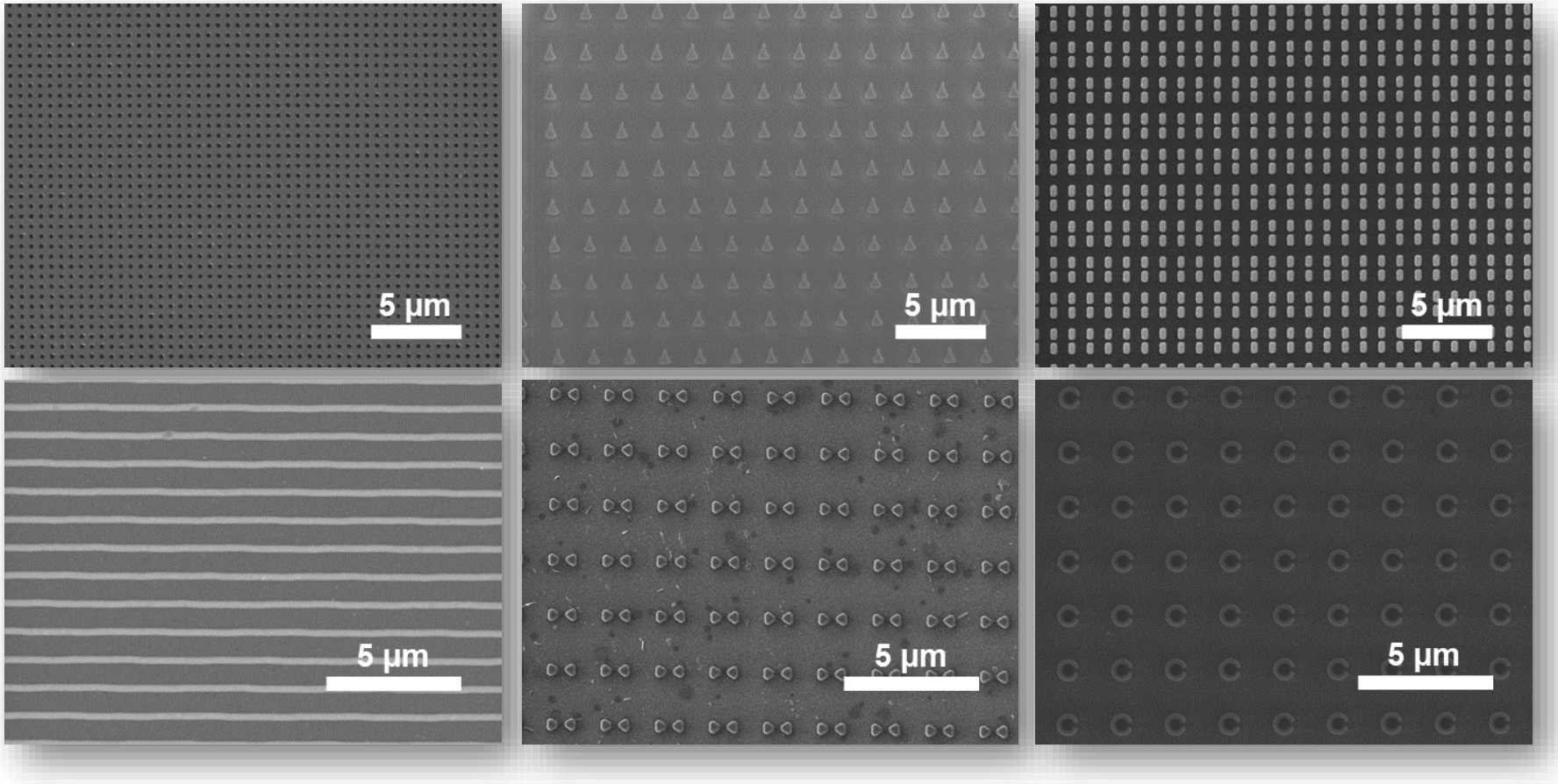
Introduction

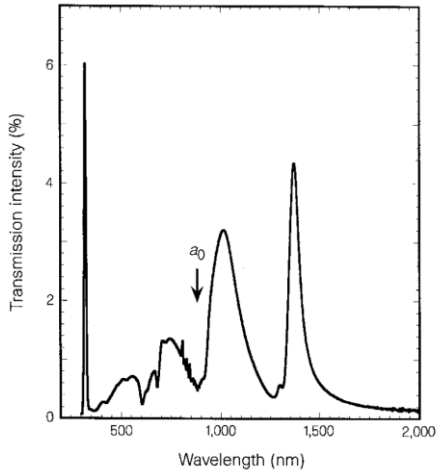
부산대학교 최준하

Electron beam lithography



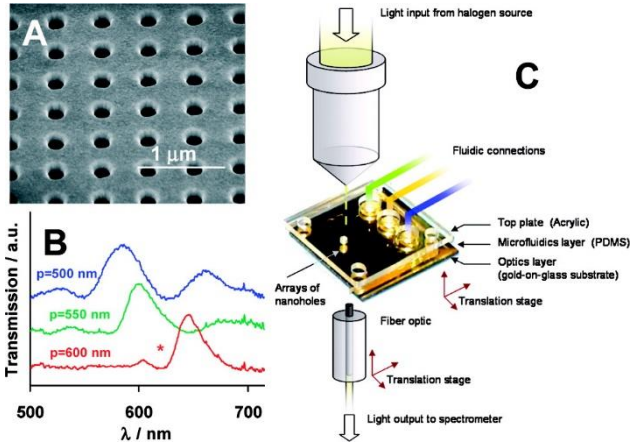
Extraordinary Optical Transmission (EOT) Sensor

Background

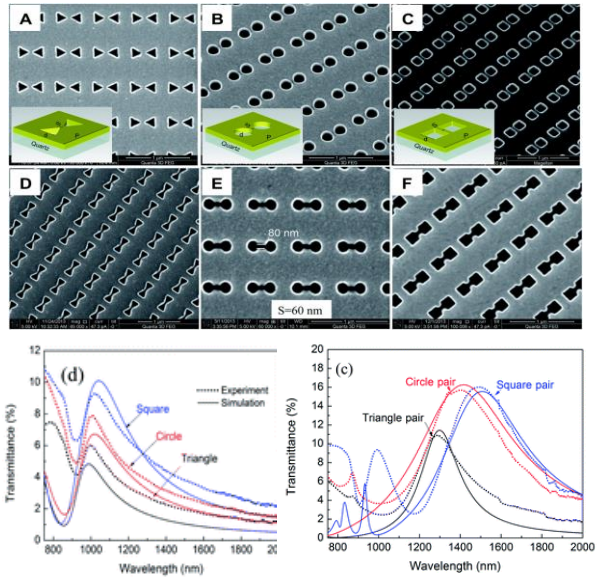


T. W. Ebbesen, et al. "Extraordinary optical transmission through sub-wavelength hole arrays," Nature 391 (1998): 667−669.

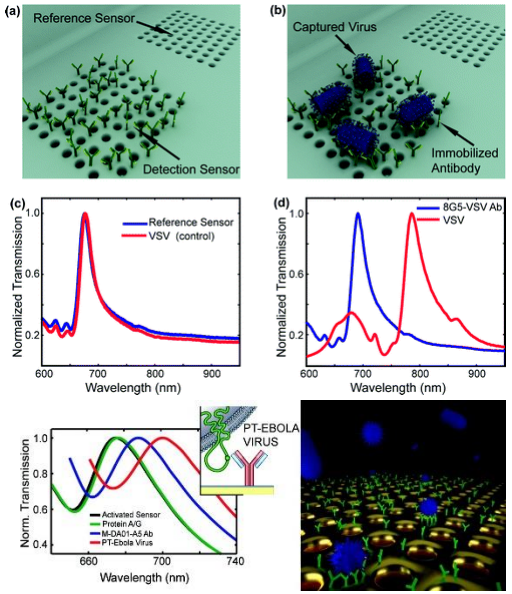
- In classical Bethe's theory, light has an extremely low transmission through subwavelength apertures.
- In 1998, Ebbesen et al. reported that extraordinary optical transmission(EOT) phenomenon, which occurs when light is transmitted through a subwavelength hole array.
- The EOT phenomenon has been investigated theoretically and experimentally in many fields.



Gordon, Reuven, et al. "A new generation of sensors based on extraordinary optical transmission." Accounts of chemical research 41.8 (2008): 1049-1057.



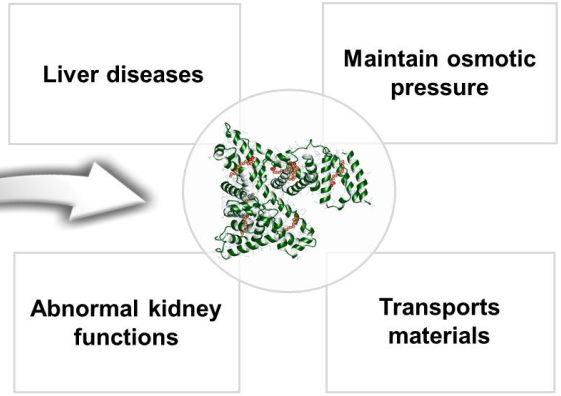
W. Yue, et al. "Enhanced extraordinary optical transmission (EOT) through arrays of bridged nanohole pairs and their sensing applications," Nanoscale 6 (2014): 7917-7923.

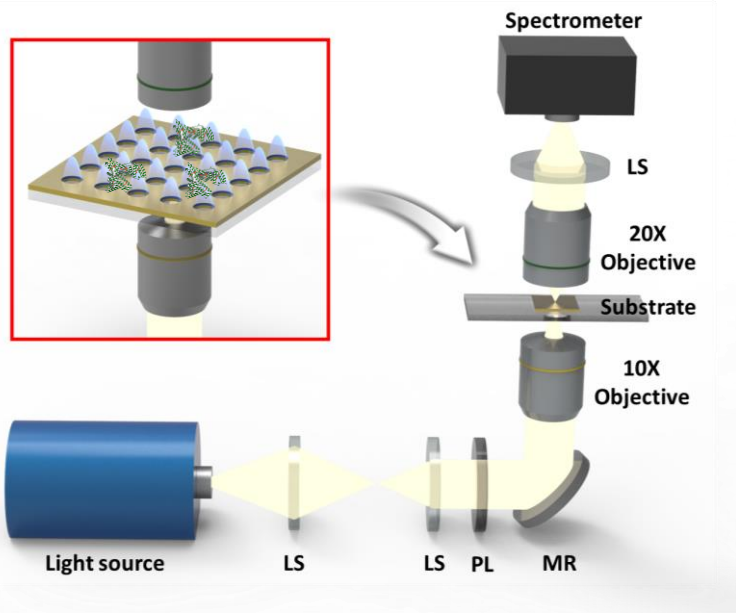


Yanik, Ahmet A., et al. "An Optofluidic-nanoplasmonic biosensor for direct detection of live viruses from biological media." Nano letters 10.12 (2010): 4962.

Extraordinary Optical Transmission (EOT) Sensor

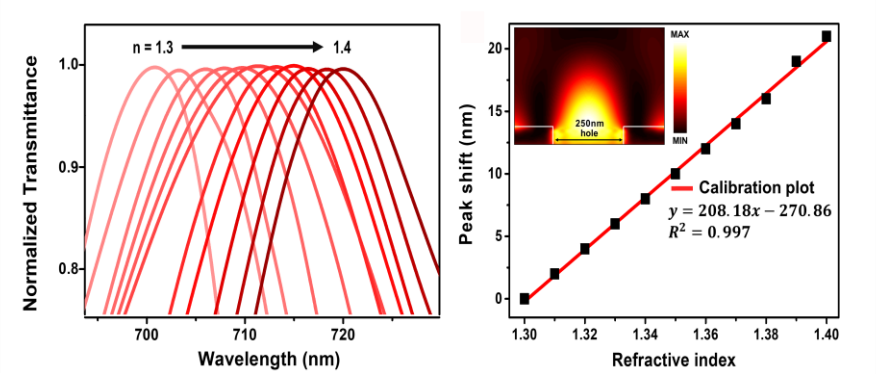
Concept of albumin detection platform





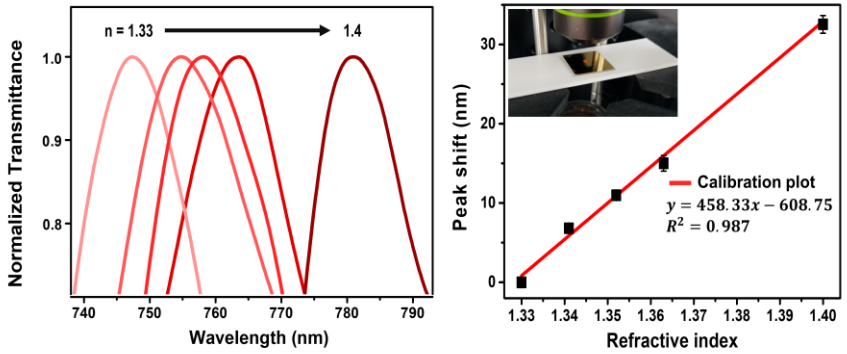
Diseases marked by low concentrations of albumin in blood (Hypoalbuminemia)

Transmittance spectra (simulation)



- The peak position is shifted from 684 nm to 705 nm.
- The sensitivity is estimated to about **210 nm/RIU**

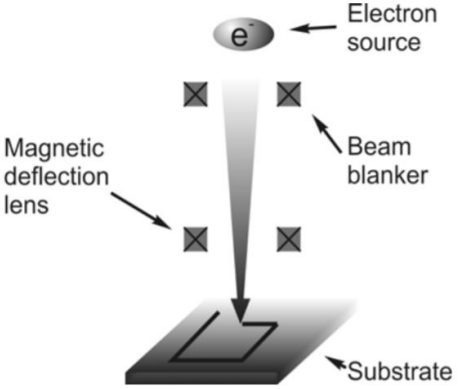
Transmittance spectra (experiment)



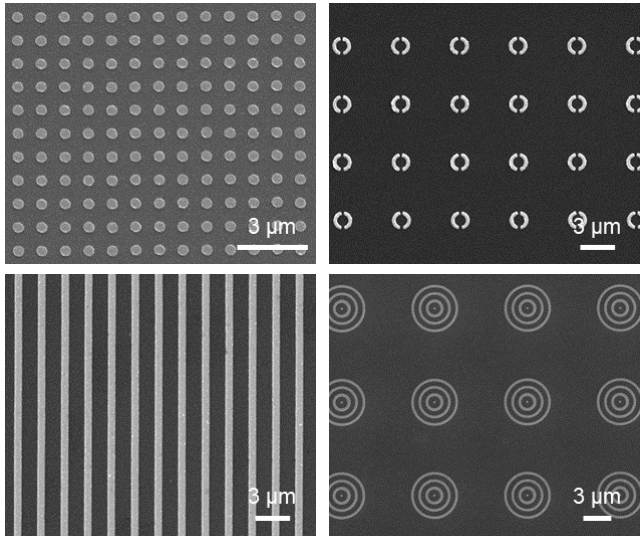
- The peak position is shifted from 747.35 nm to 779.8 nm.
- The sensitivity is estimated to about **460 nm/RIU**

Plasmonic Lithography

- Motivation



E-beam Lithography



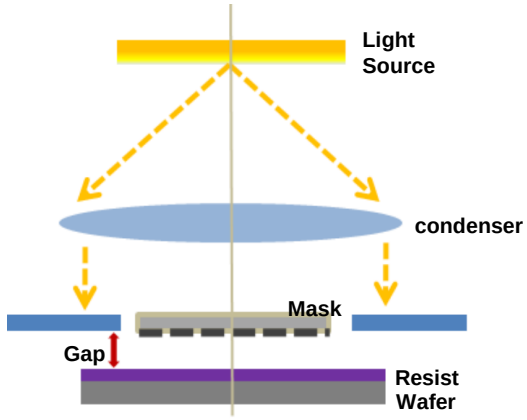
E-beam Lithography Disadvantage

- Slow to fabricate
- Expensive and complicate
- Difficult to fabricate in large area

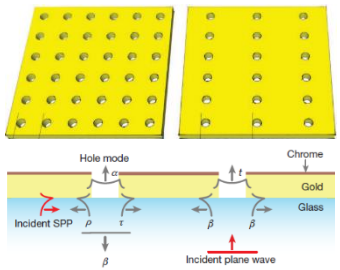
Plasmonic Lithography

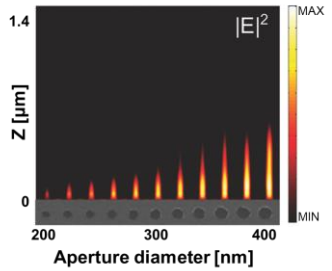
- Plasmonic Lithography

Photo Lithography



Plasmonics





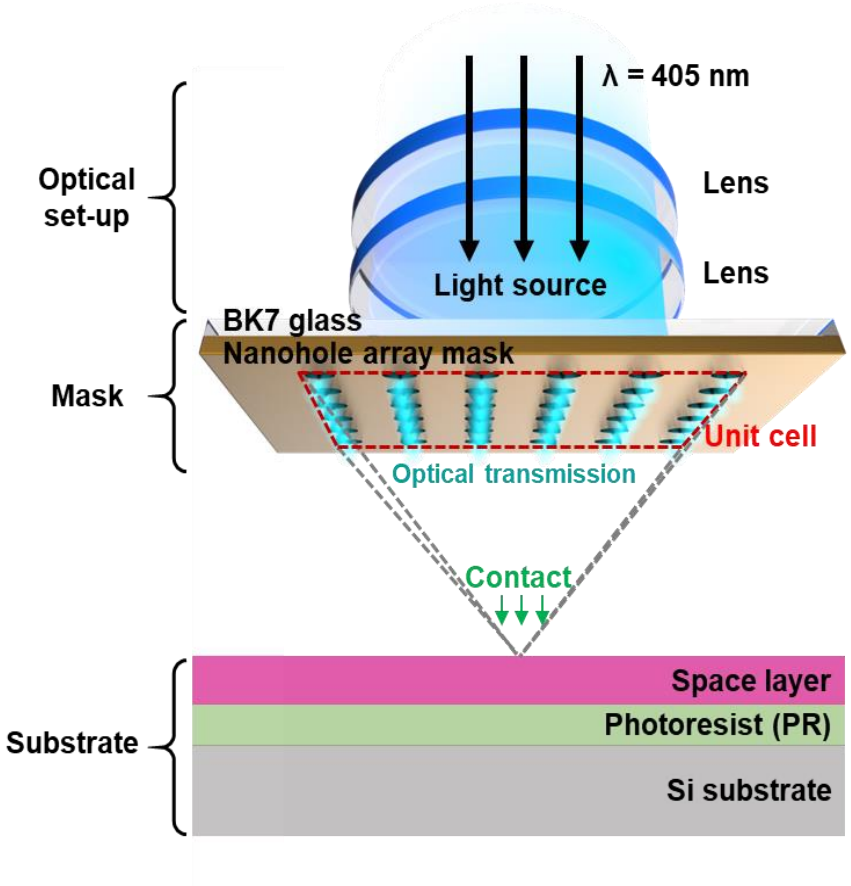
Extraordinary optical transmission (**EOT**) is the phenomenon of greatly enhanced transmission of light through a subwavelength aperture in an otherwise opaque metallic film which has been patterned with a regularly repeating periodic structure.

Van Beijnum, Frerik, et al., *Nature,* 492.7429 : 411(2012)
Choi, J. R., et al, *Advanced Optical Materials*, *2*(1), 48-55(2014)

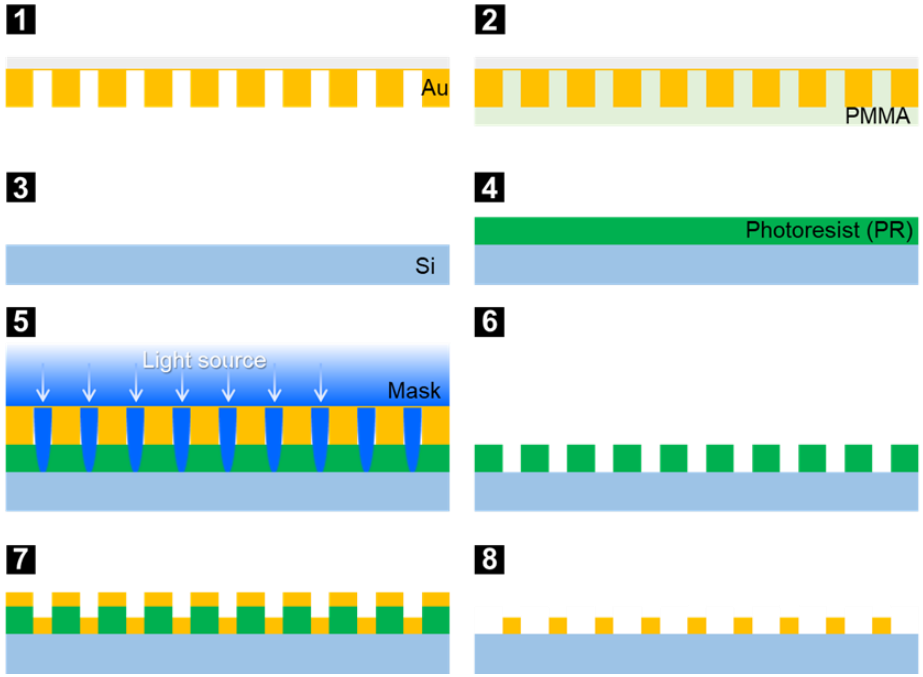
McMurray, et al., In *Biomedical engineering, trends in materials science*. InTech(2011)
Levinson, Harry J., SPIE press, 146(2005)

Plasmonic Lithography

- Schematic image and optical set-up



- Fabrication process



Laser wavelength : 405 nm

Laser Power : 40 mW

Exposure time : 5 s

Resist : Az GXR-601

Coating rpm : 6000 rpm

Developer : AZ MIF 300

Mask

1 Mask fabrication

2 Spacer(PMMA) coating

Substrate

3 Cleaning

4 PR coating

Plasmonic lithography

5 Mask alignment & Exposure

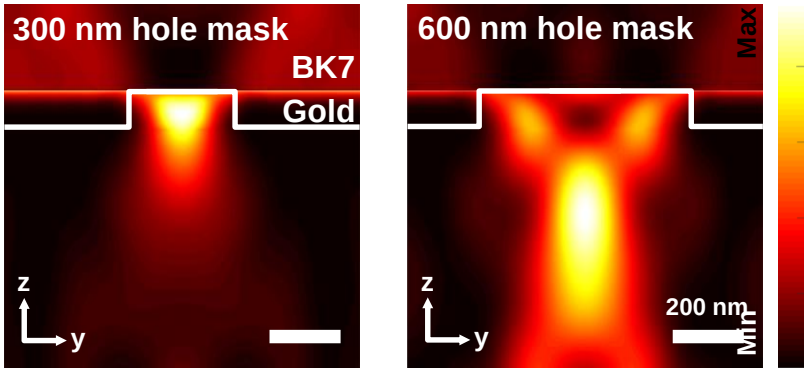
6 Develop

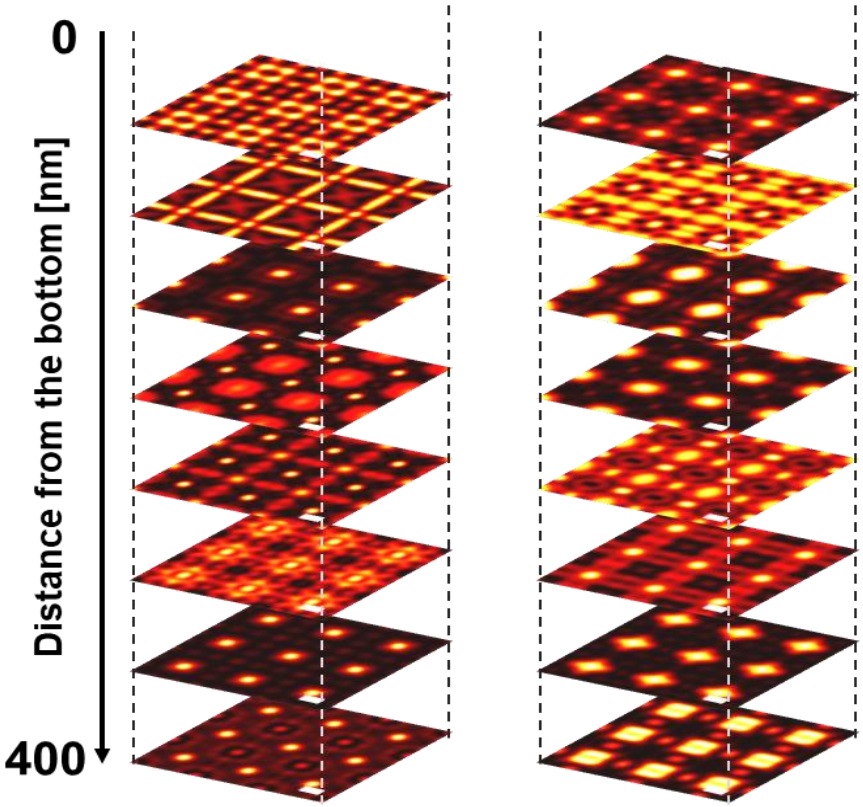
7 Au deposition

8 Lift-off

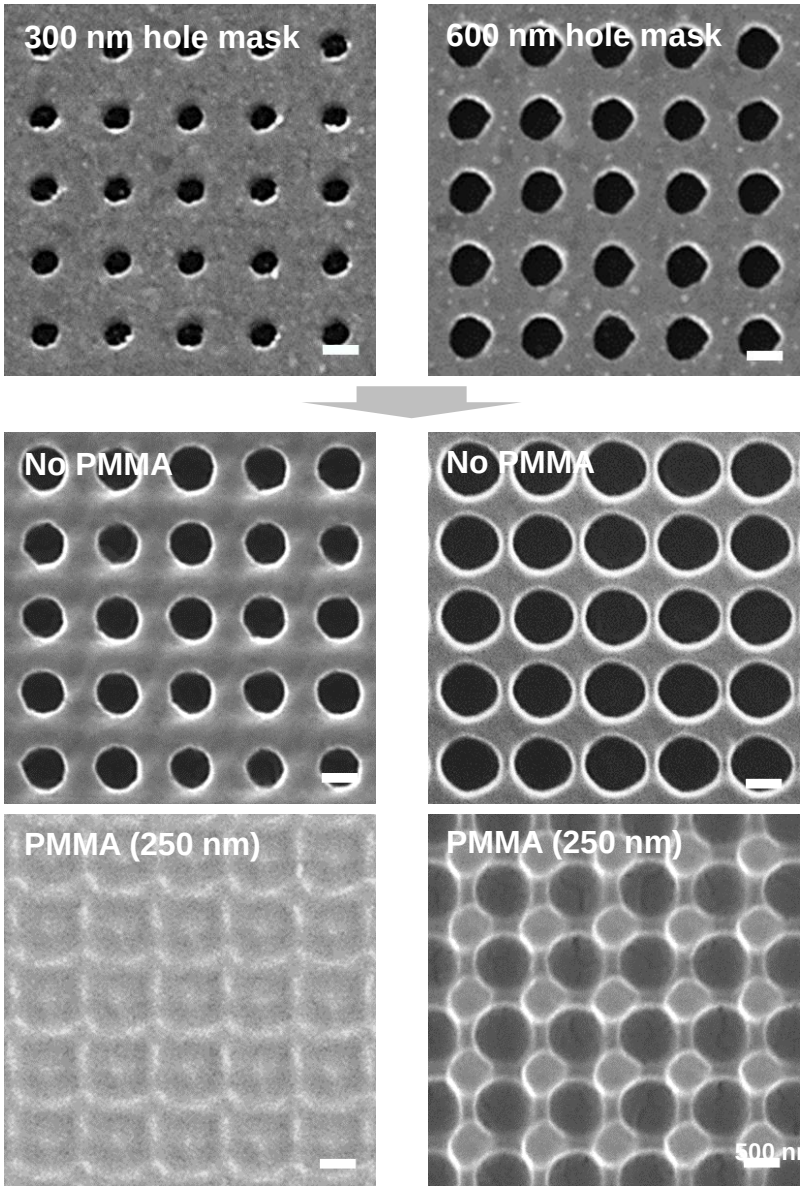
Plasmonic Lithography

- Simulation data



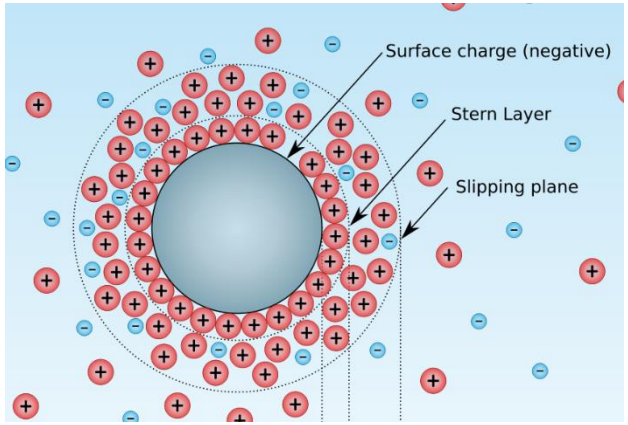


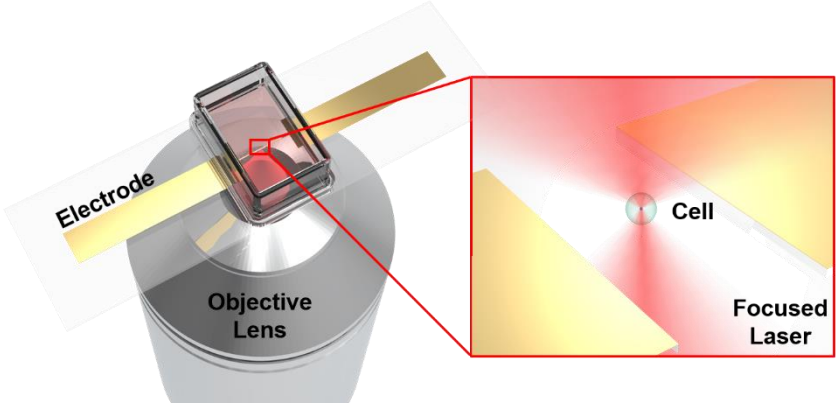
- Mask image and experimental results

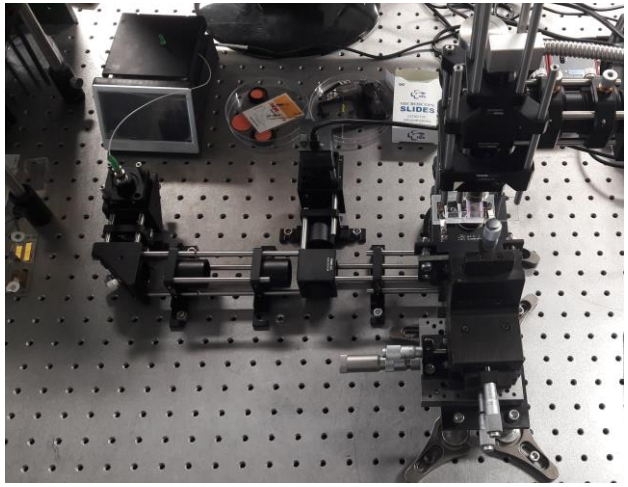


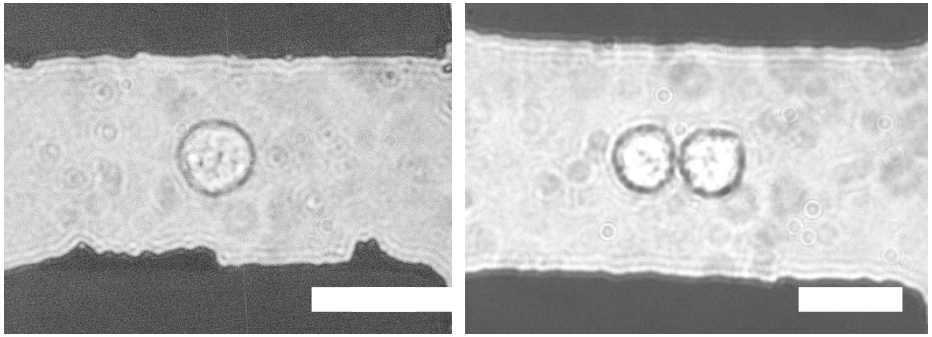
Cell capacitance

- The membrane capacitance of a specific cell is an electrical parameter related with the electrical activity and morphology of the plasma membrane.



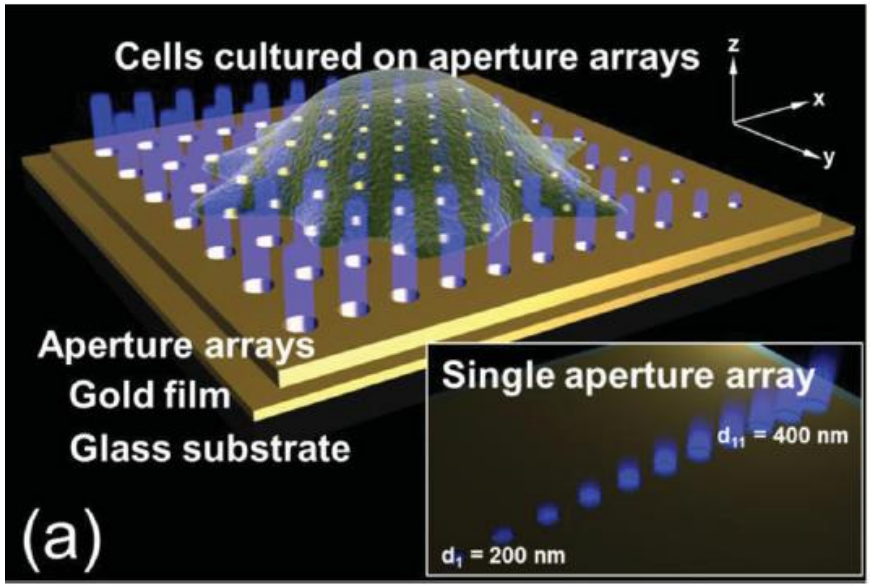


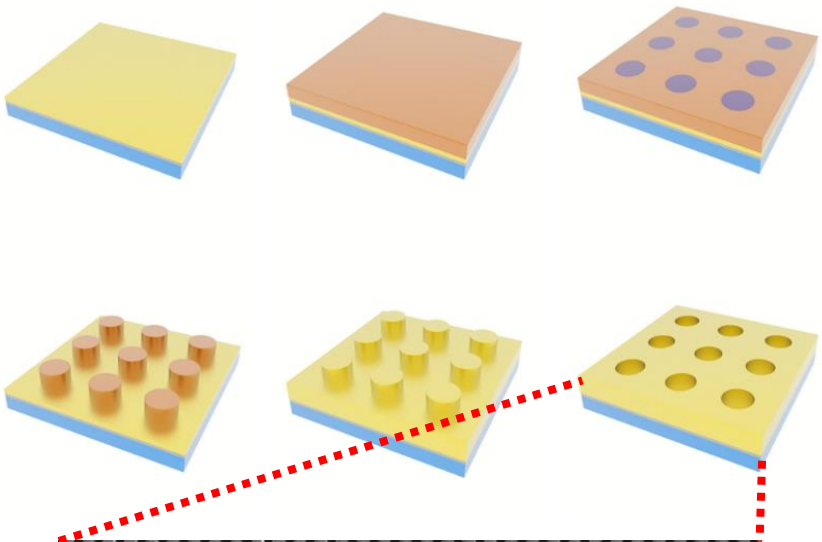


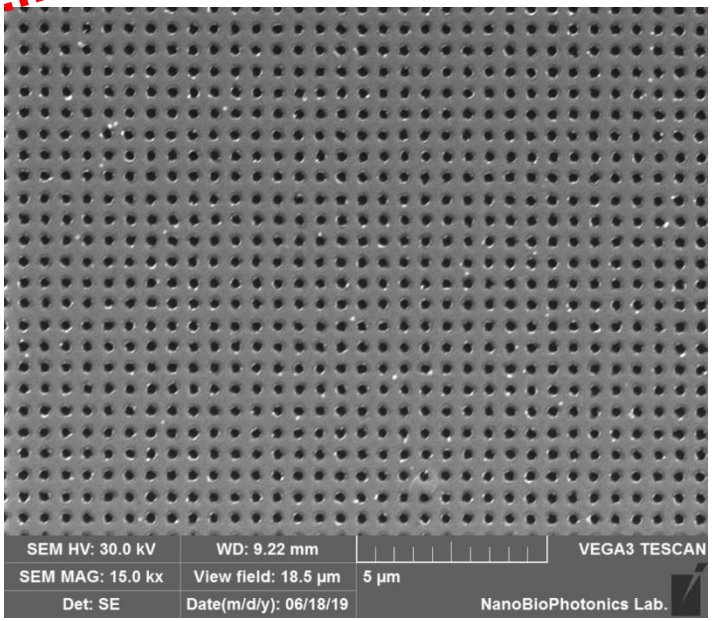


Sensitivity comparison of EOT signal according to incident light shape

EOT signal comparison according to beam shape



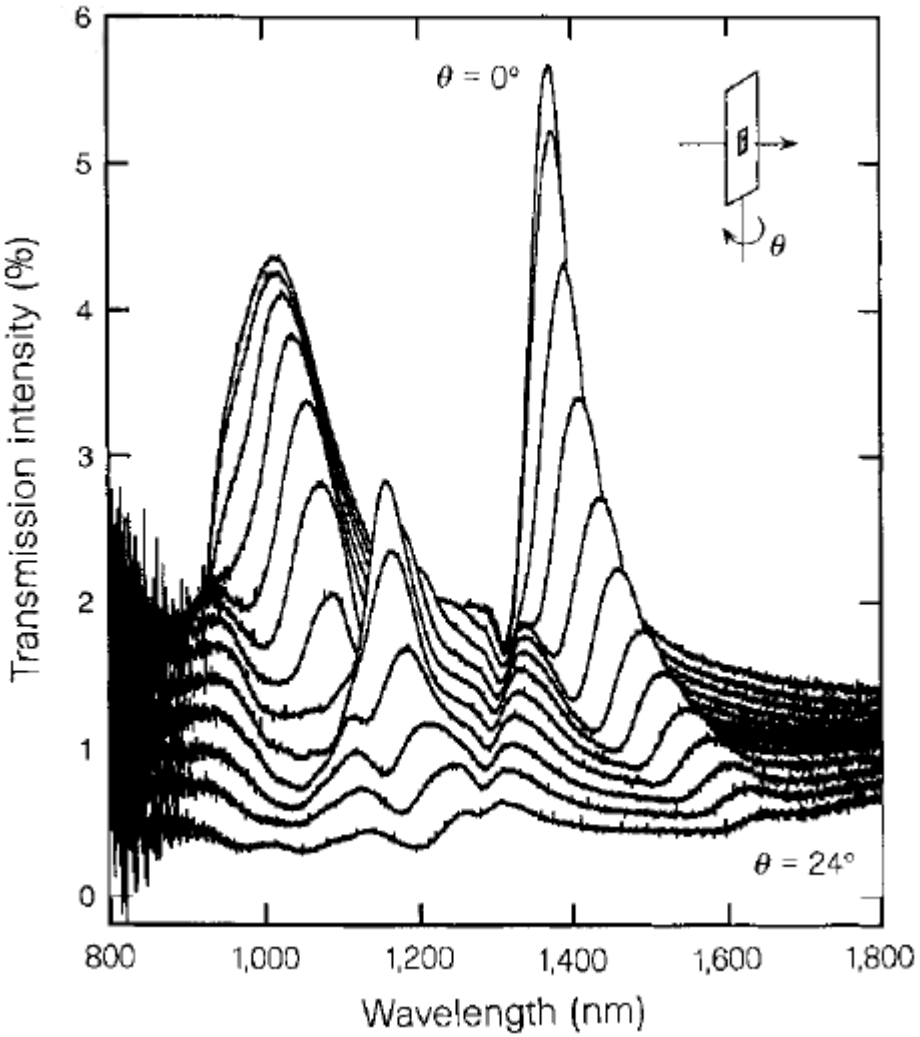




Diameter : 250nm
Periodicity : 550nm
Area : 2mm X 2mm
Deposit
- 5nm Cr
- 10nm Au
- 100nm Au_depth

EOT signal comparison according to beam shape

❖ Condition : Difference of incident angle

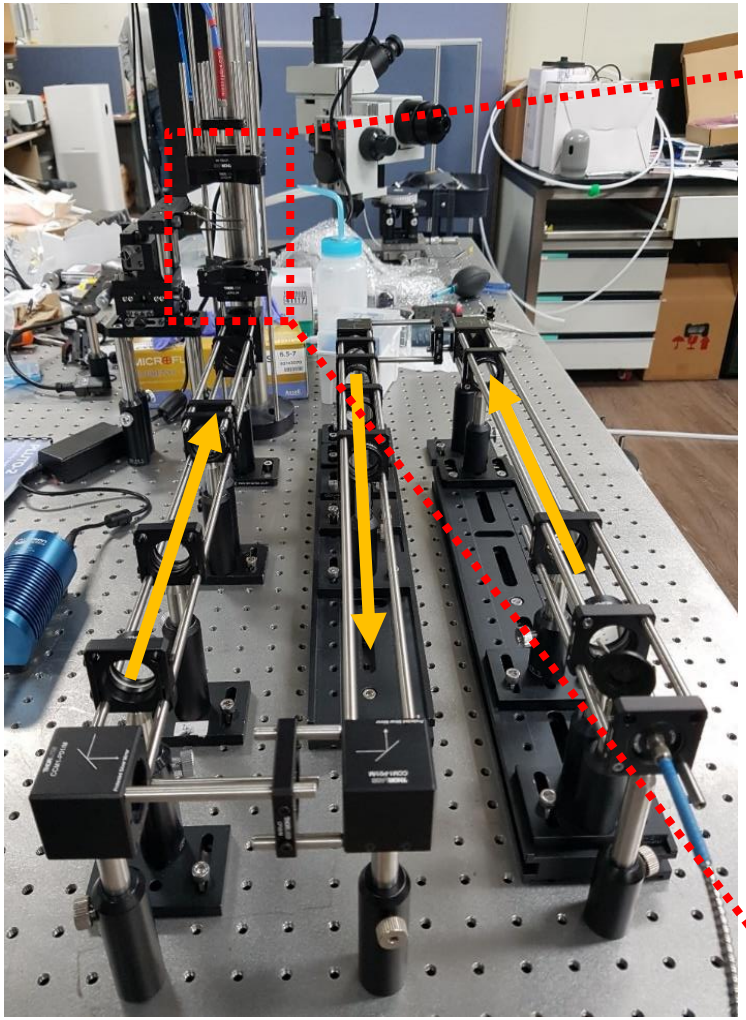


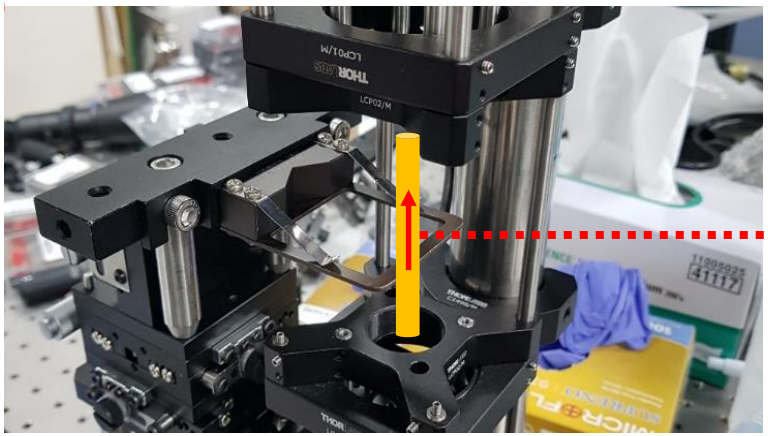
Angle makes
- Plasmonics
- Resonance
- Interference
- Diffraction

→ Other signal components

II. Metarials and Methods
Cell adhesion_in incubator

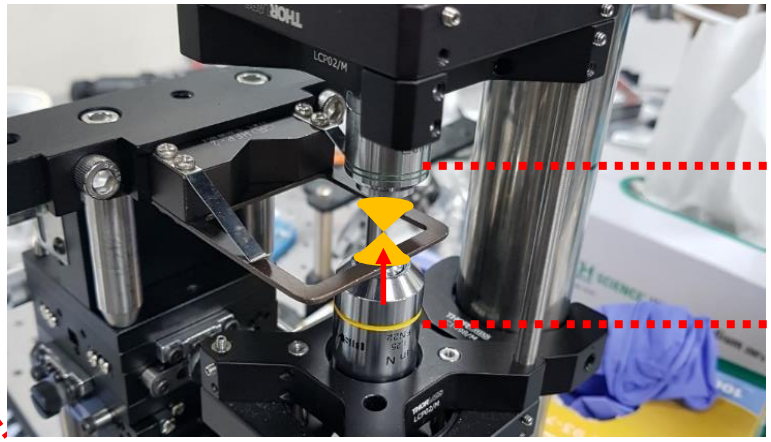
❖Condition : Collimating beam and Focusing beam





Collimating beam

Diameter
=2mm

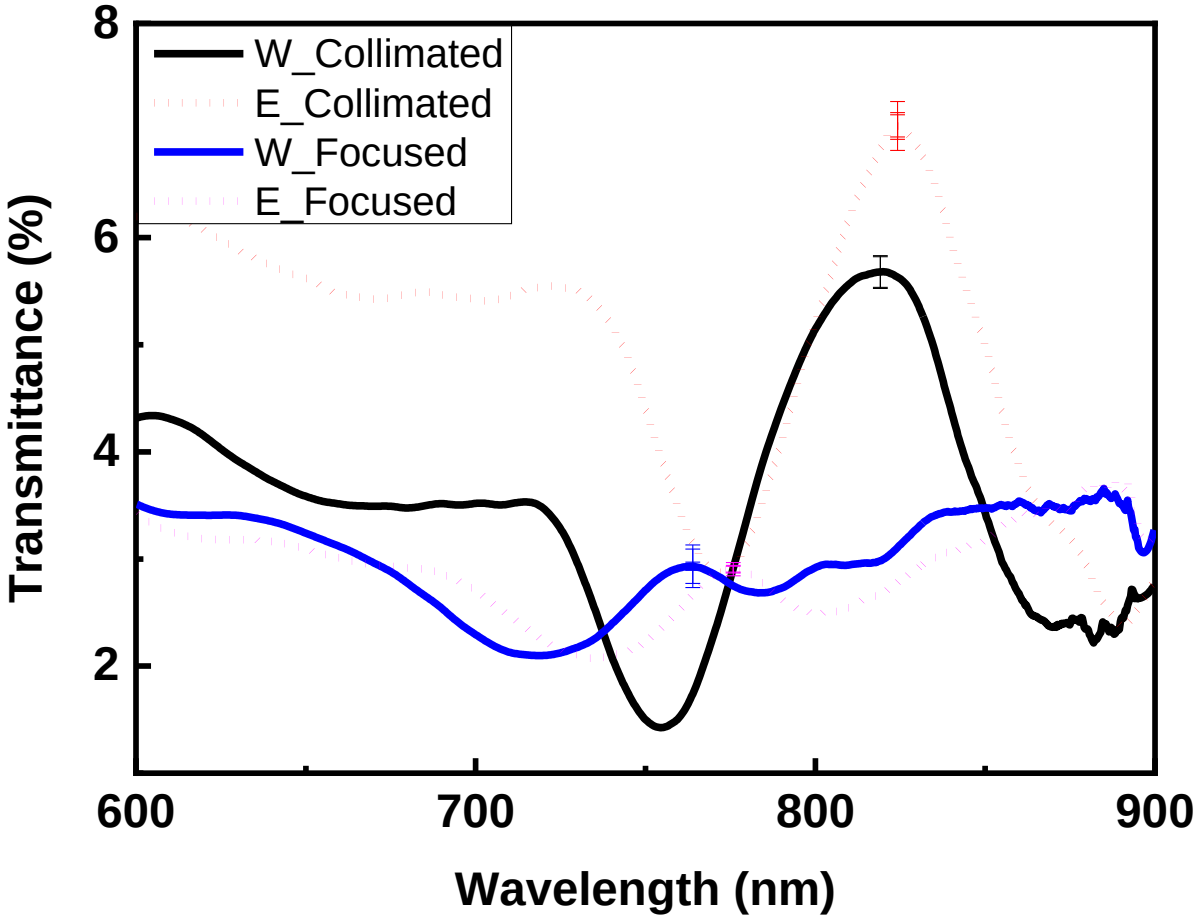


Focusing beam

NA=0.4
X20

NA=0.25
X10

Capacitance measurement



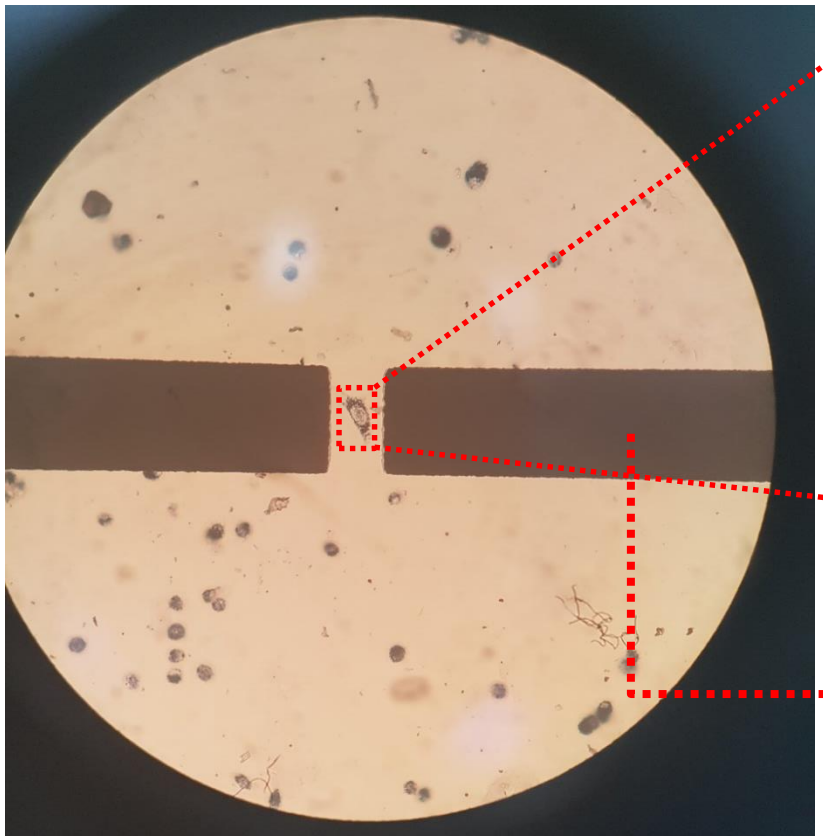
Collimating	Peak(nm)	FWHM
DI water	820.1	56.5
Ethanol	824.19	48.08
Collimating	**Height**	**PF**
DI water	3.22	57.0
Ethanol	3.70	77.0

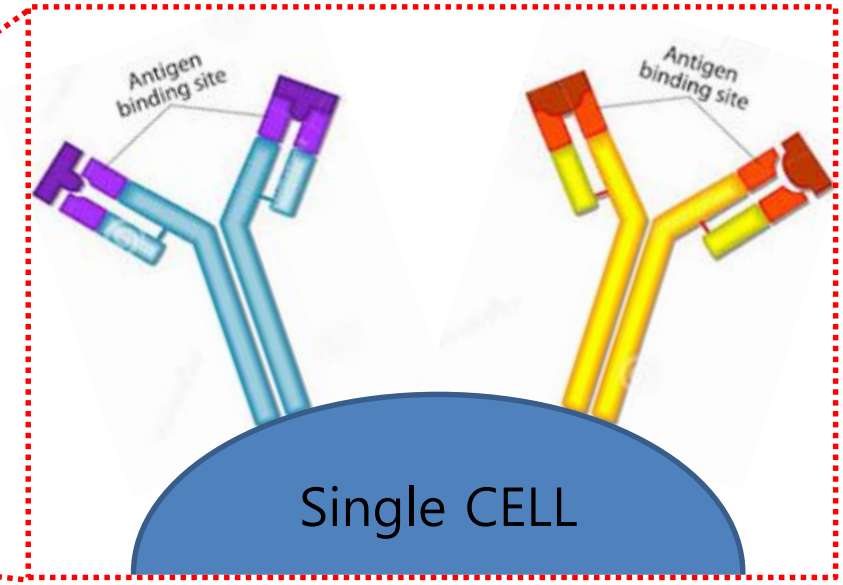
Focusing	Peak(nm)	FWHM
DI water	763.24	20.87
Ethanol	775.84	22.9
Focusing	**Height**	**PF**
DI water	0.28	13.42
Ethanol	0.42	18.34

● PF = (Height/FWHM) ×1000

Single cell optical trapping and capacitance comparison

Single cell capacitance comparison



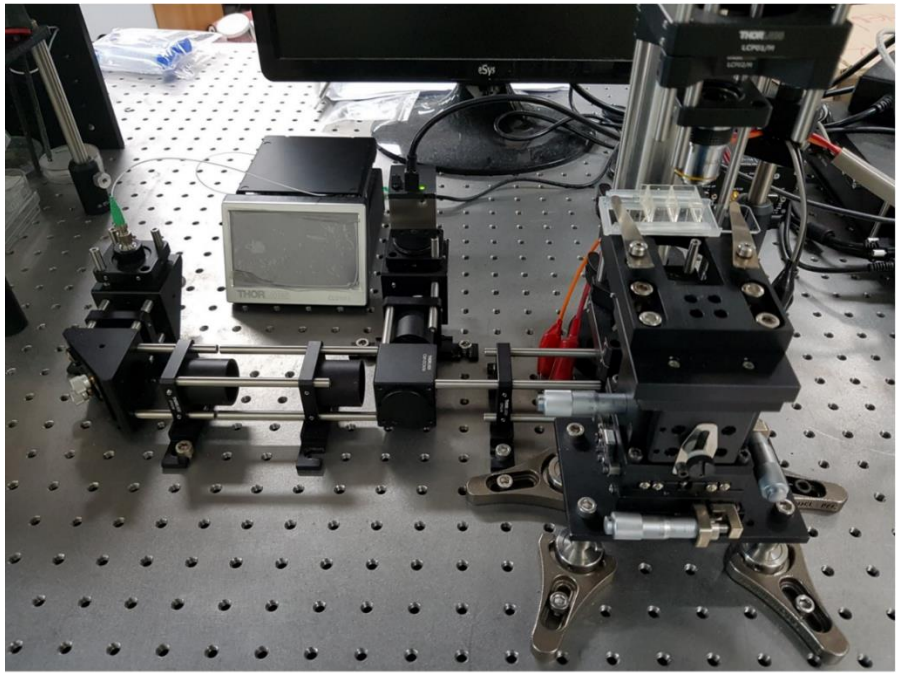


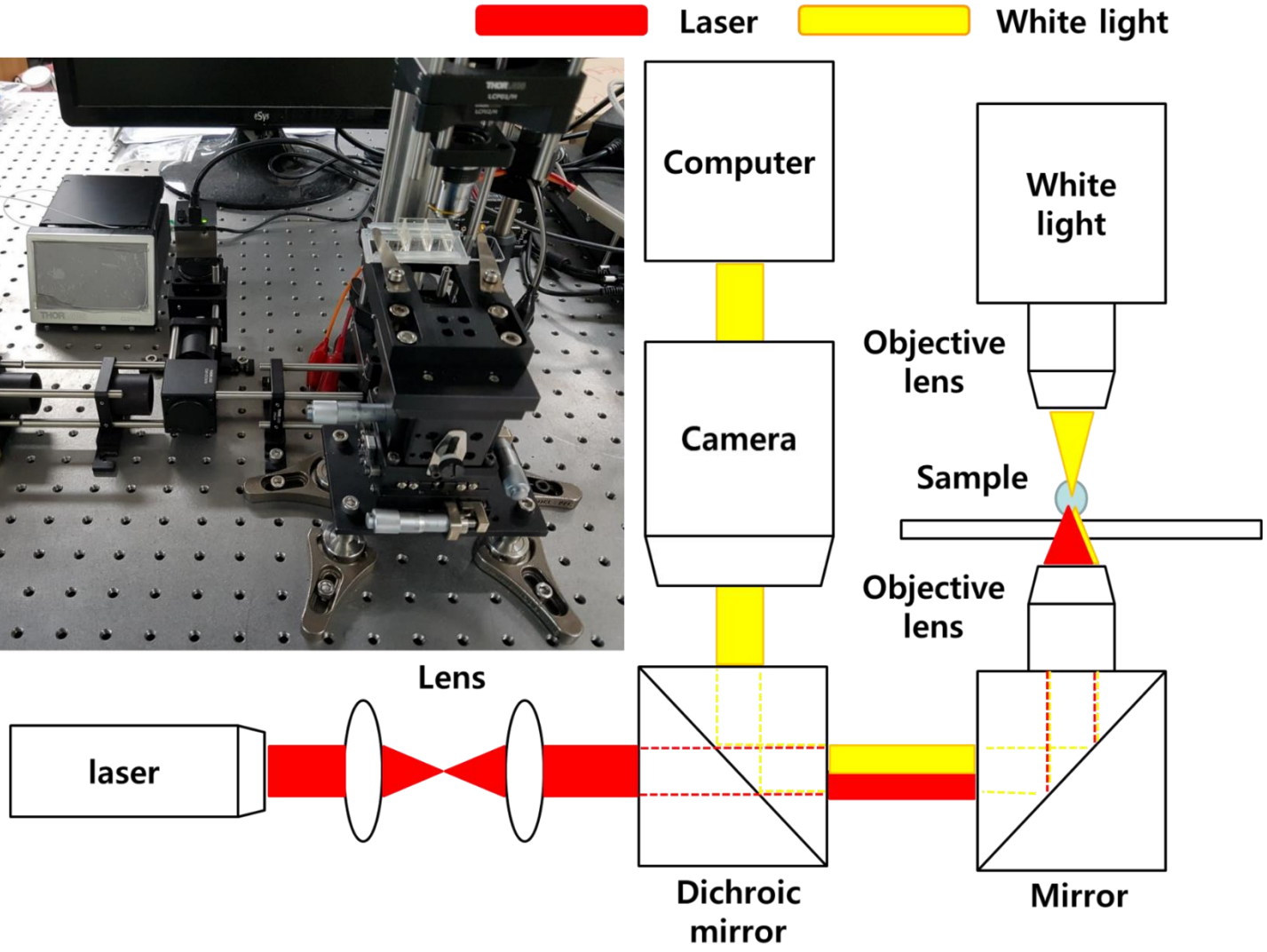
Compare antibody reaction

Electrode
_Capacitor

Optical trapping

❖Condition : Focusing beam on sample

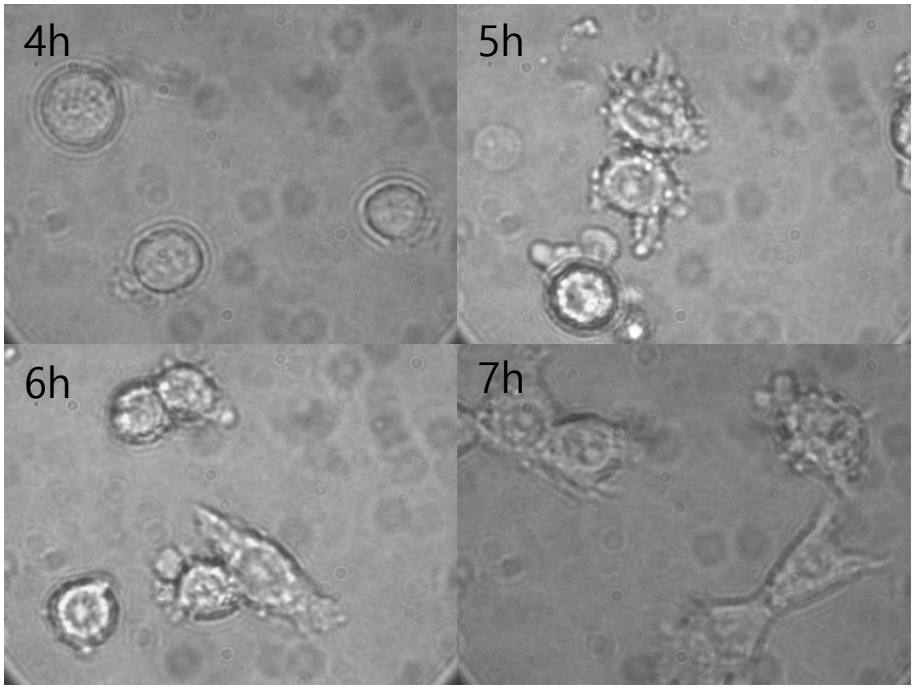




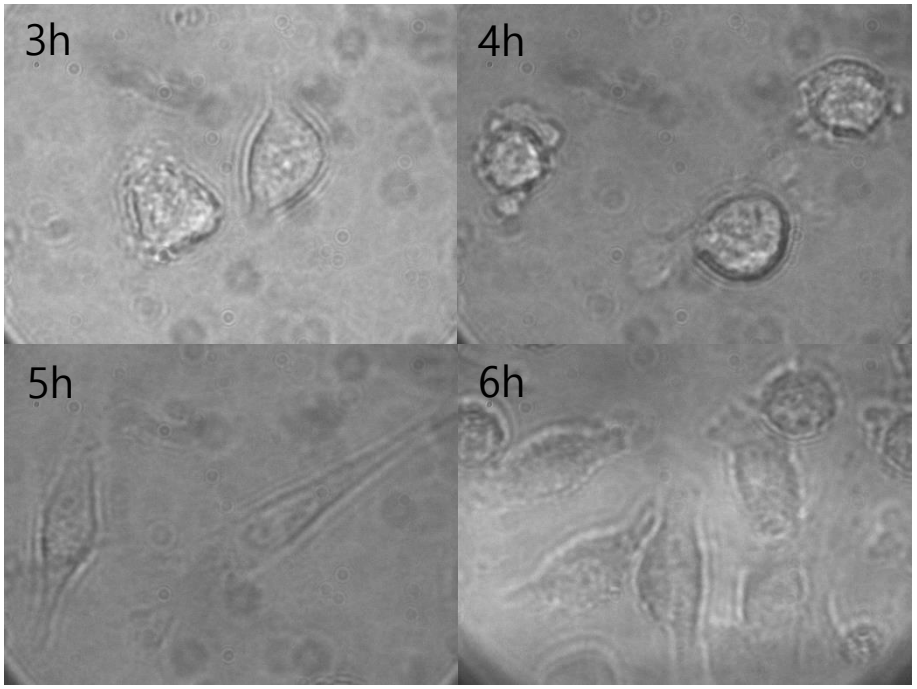
II. Metarials and Methods
Cell adhesion_in incubator

❖Condition : Bio-coating with Poly-L-Lysine

Hela cell



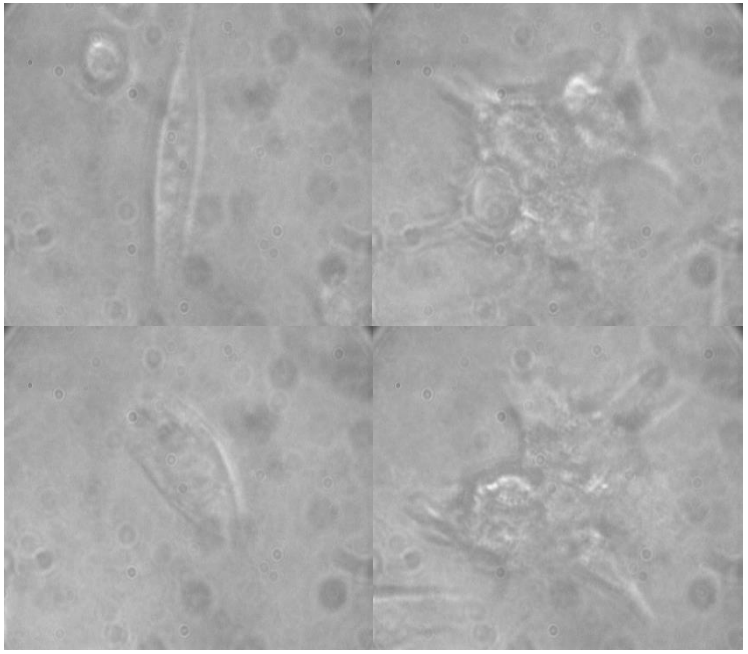
NIH3T3 cell



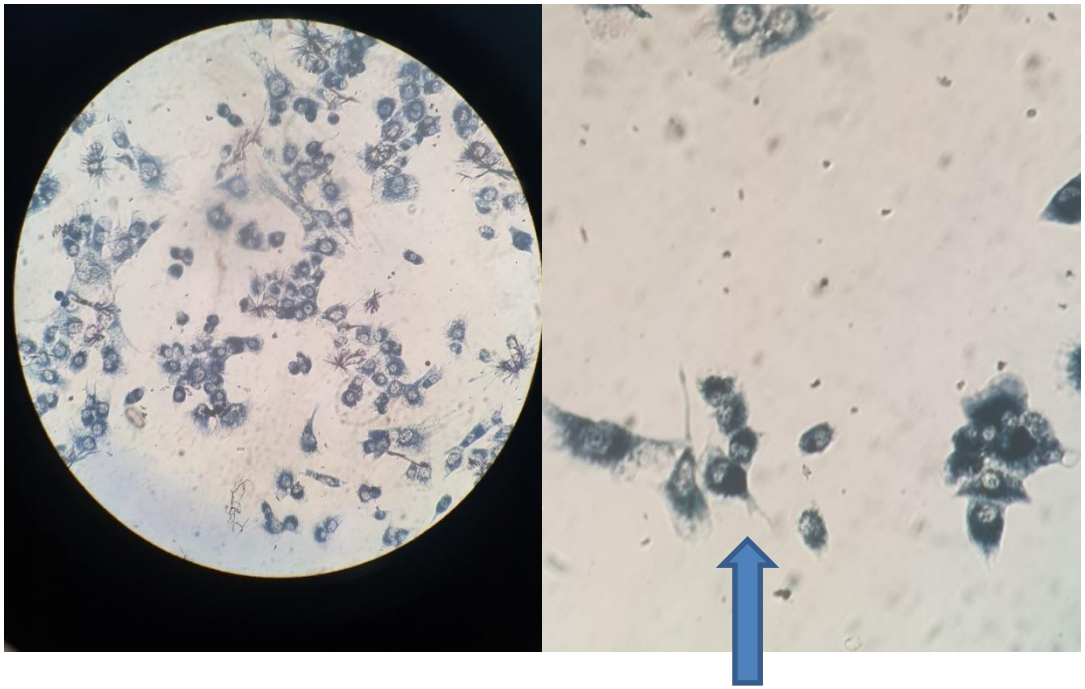
II. Metarials and Methods
Live cell confirmation

❖Condition : Bio-coating with Poly-L-Lysine

Incubating 12h



MTT reaction



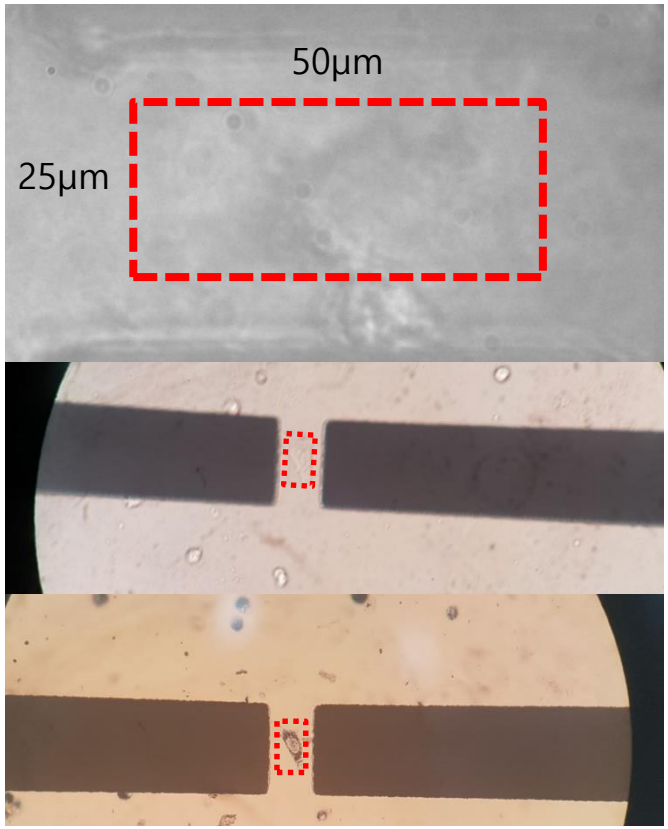
The cells were alive

MTT particles kill only live cells and dye blue.

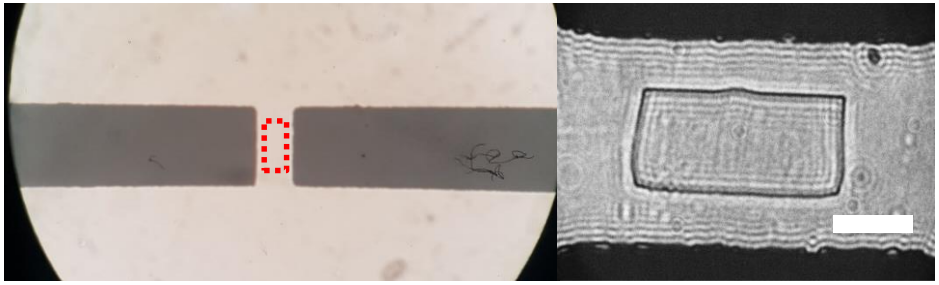
Single cell growth

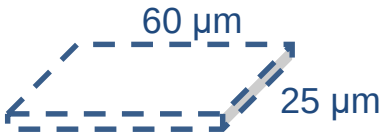
❖Condition : By optical trapping

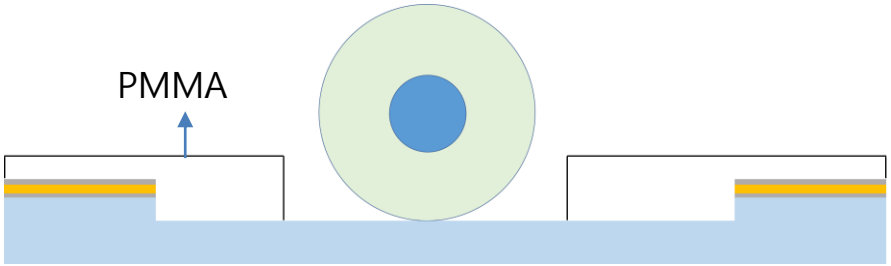
Initial model



Fix well size
60μm X 25μm

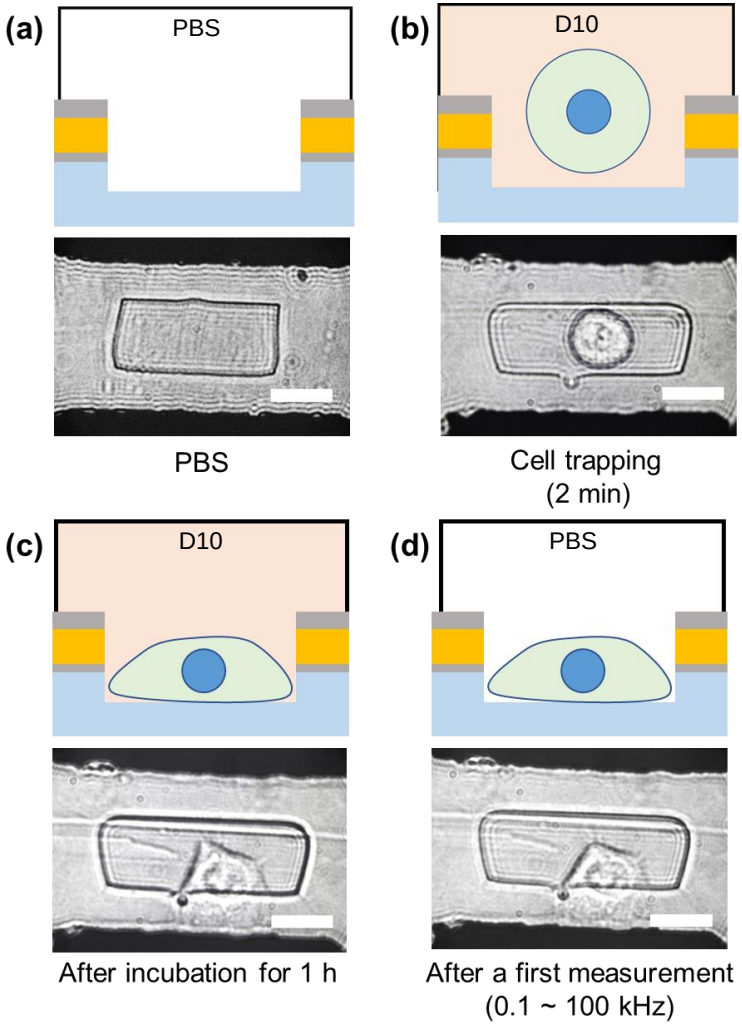


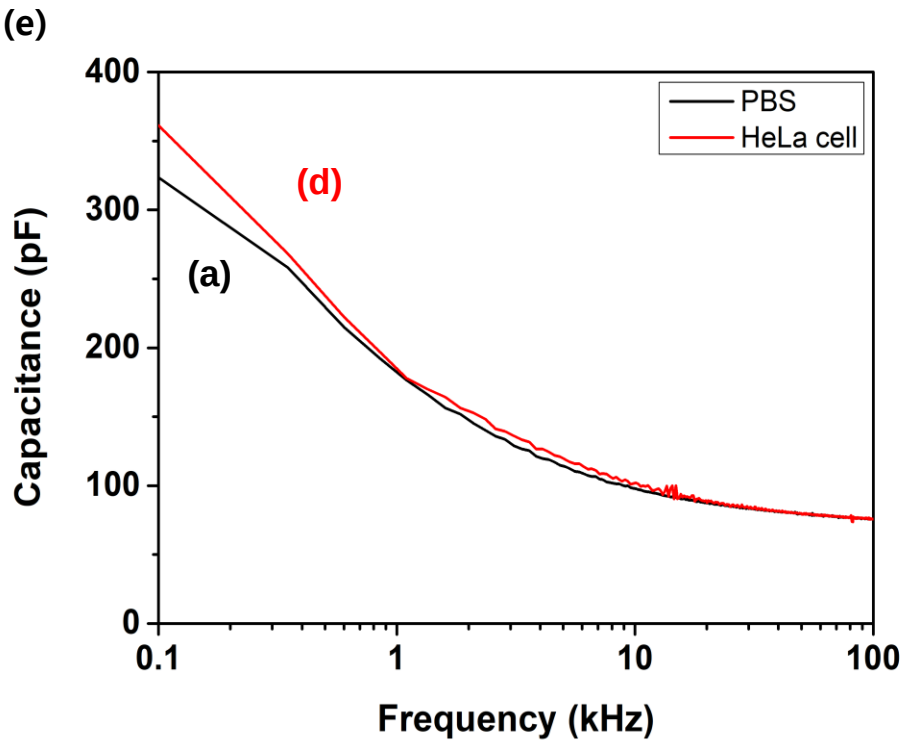




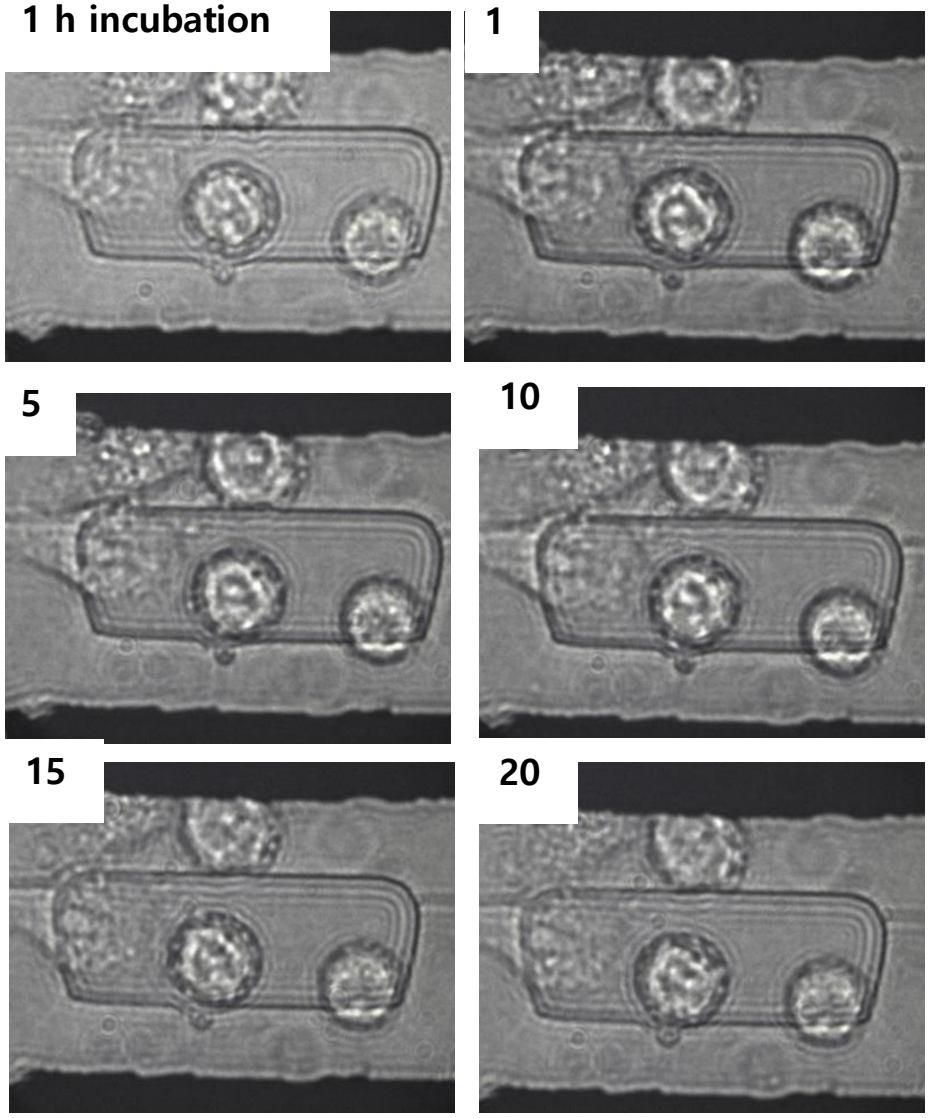
Capacitance measurement

- Objectives : Capacitance measurement of PBS media, without and with adherent HeLa cells

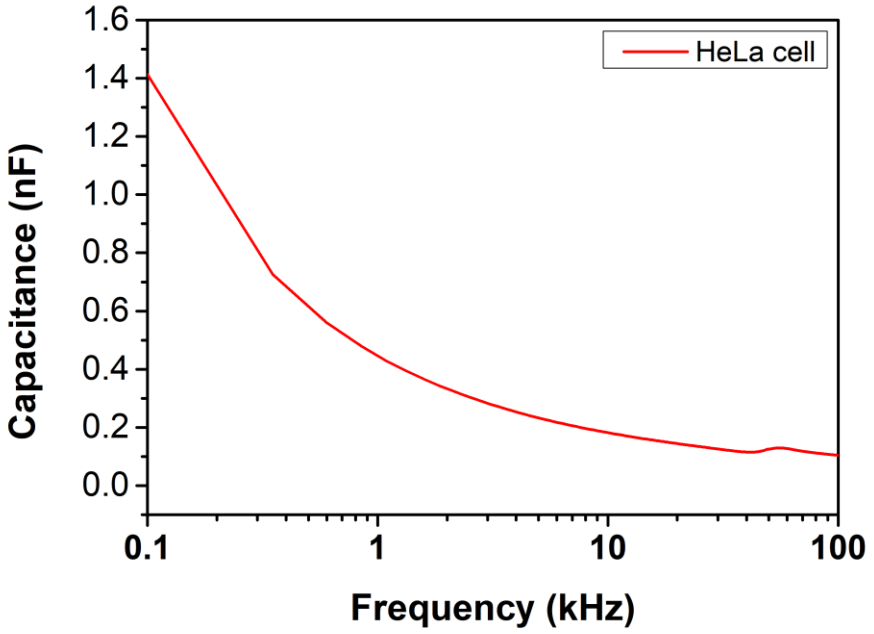




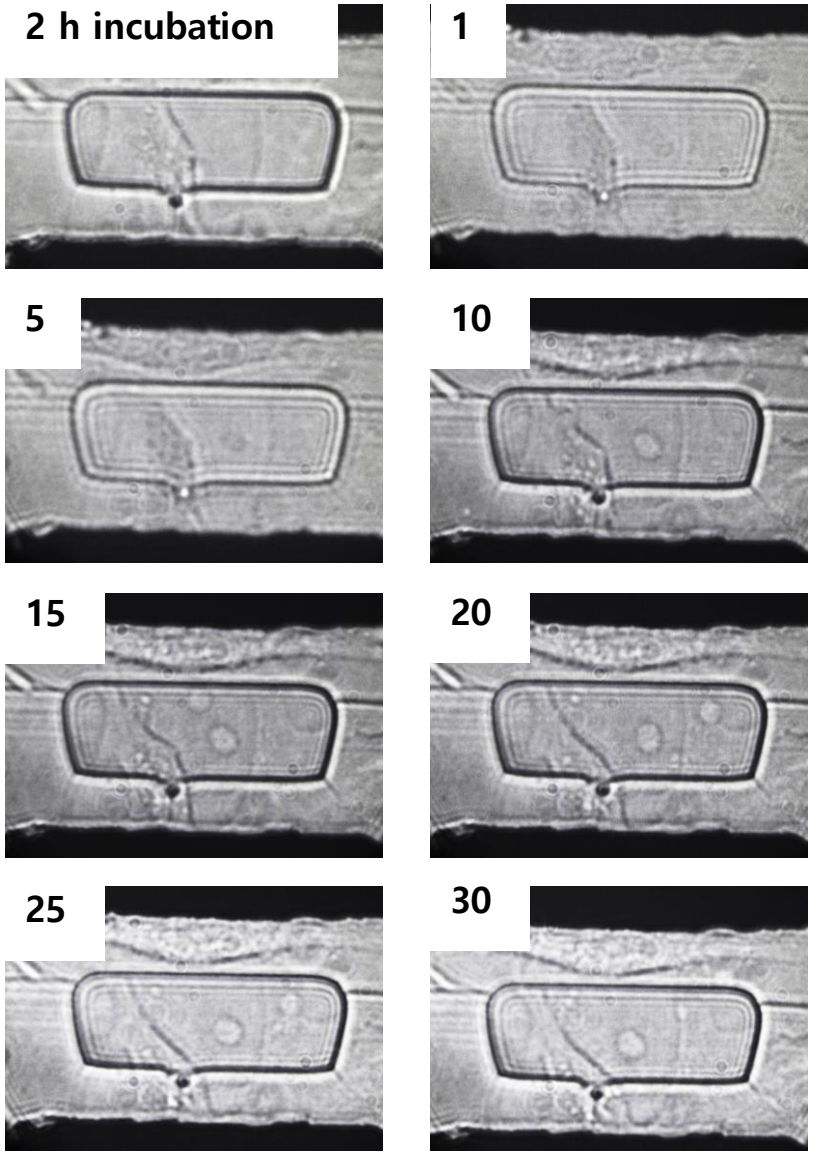
Capacitance measurement of HeLa cell



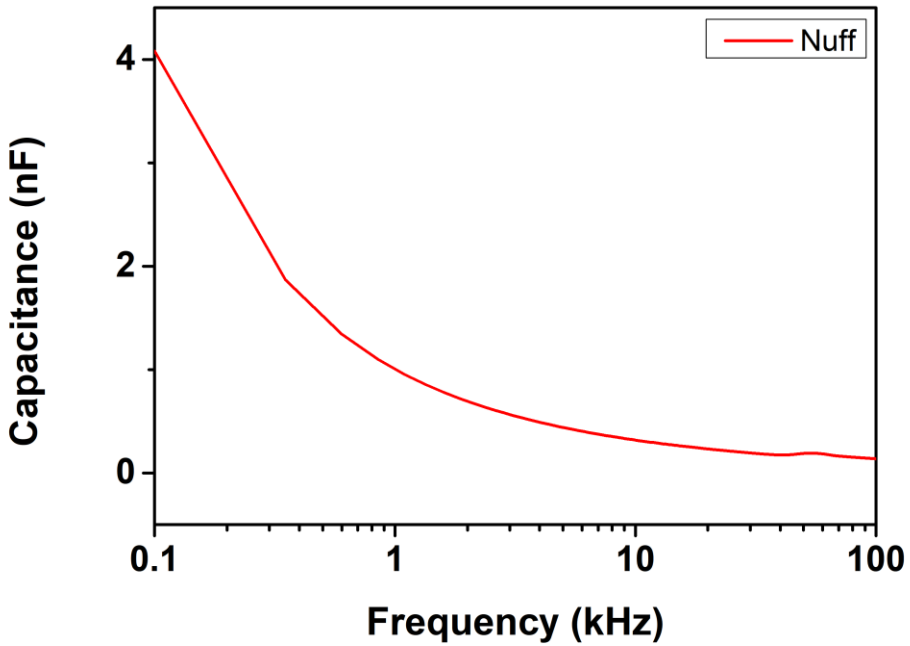
Cell : HeLa
Frequency : 0.1 - 100 kHz
Number of measurement : 20
Final state of cell : health



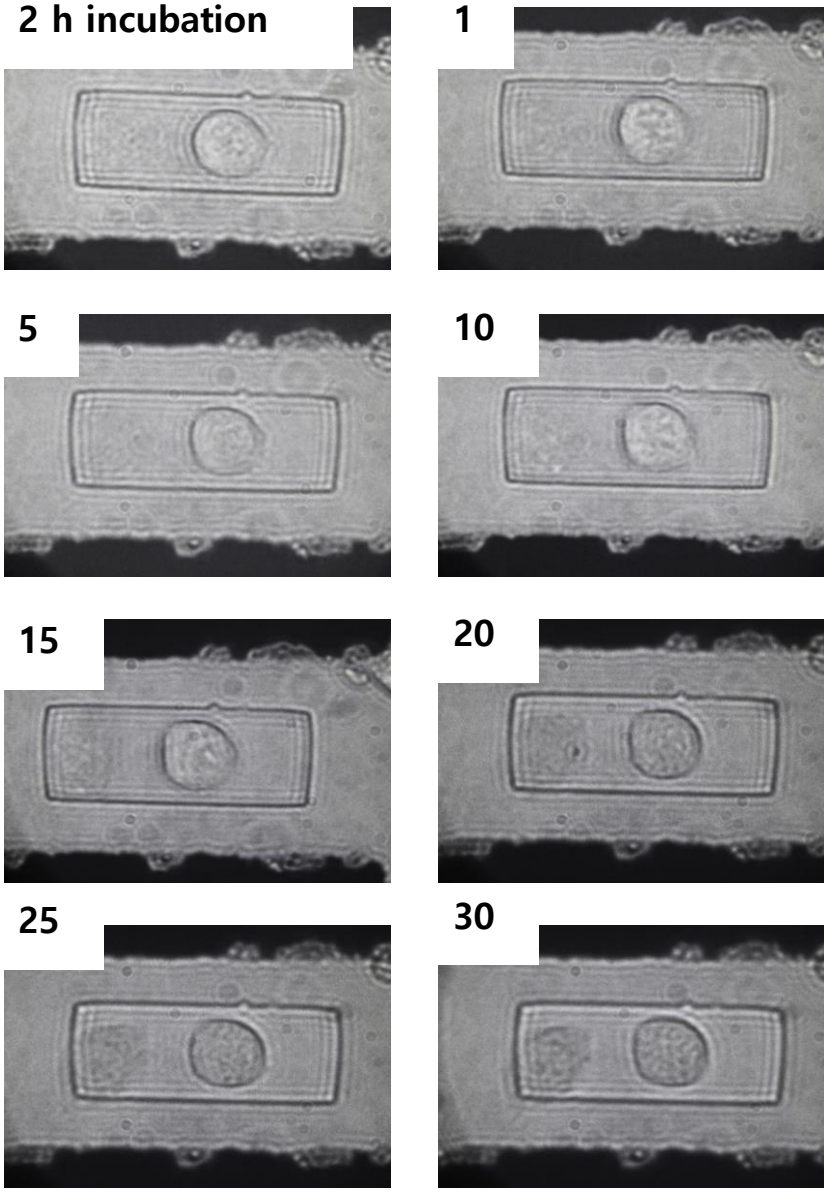
Capacitance measurement of Nuff



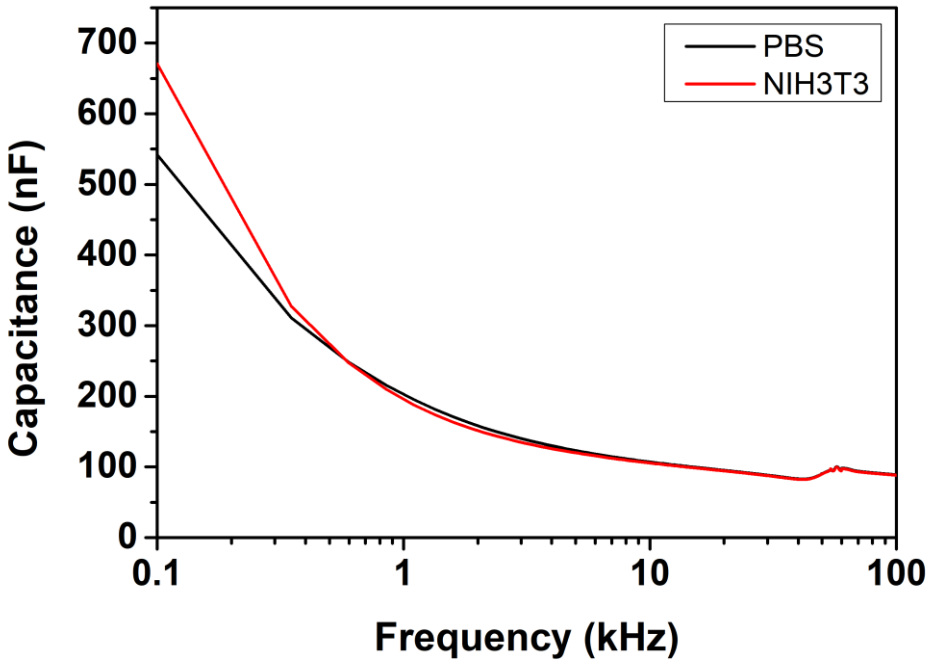
Cell : Nuff
Frequency : 0.1 - 100 kHz
Number of measurement : 30
Final state of cell : health



Capacitance measurement of NIH3T3 cell



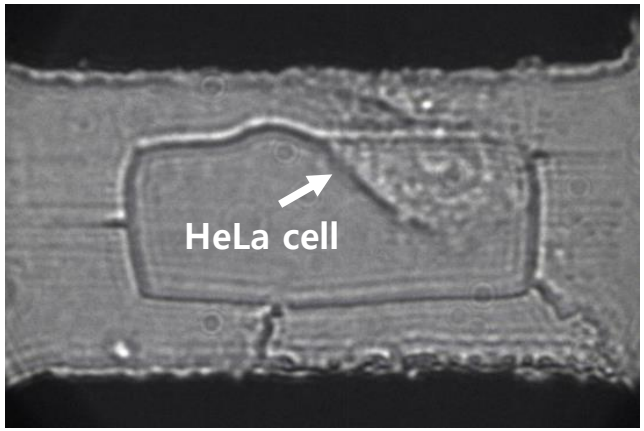
Cell : NIH3T3
Frequency : 0.1 - 100 kHz
Number of measurement : 30
Final state of cell : health



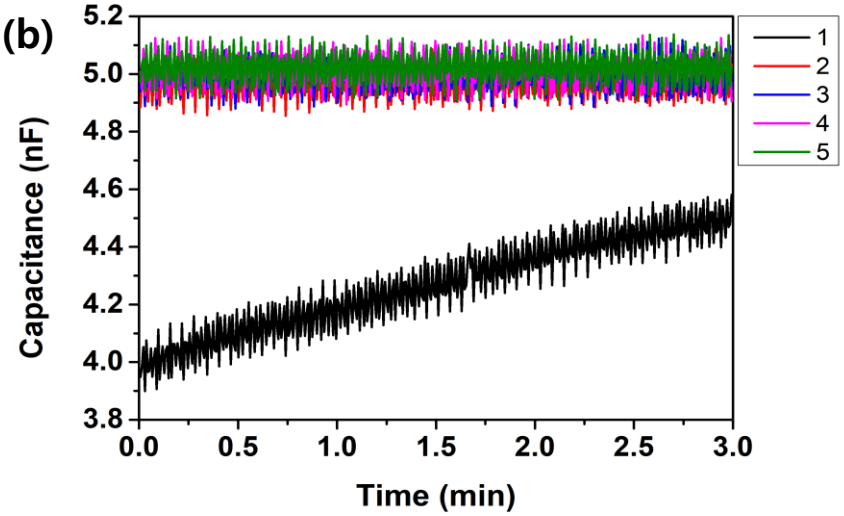
Real-time capacitance of the HeLa cell treated with folic acid (10μM)

❖Objectives : To detect endocytosis of folic acid on cell membrane using Cp sensor.

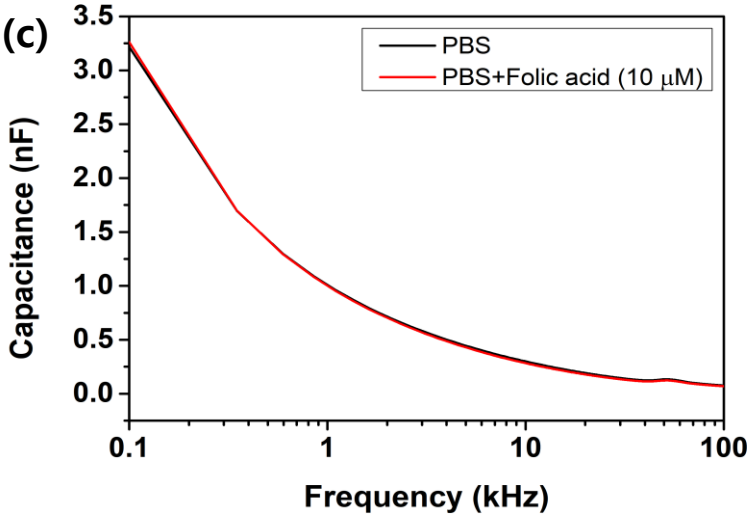
(a)



(b)



(c)



(d)