直接外部駆動機構を用いた単一浮遊細胞の機械特性計測

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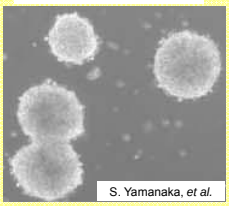
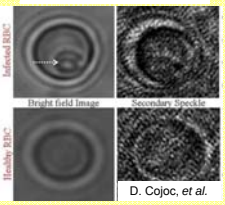
単一浮遊細胞の機械特性計測

Background

iPS cells



Red blood cells



The measurement of mechanical property of single floating animal cells(iPS cells, RBC and so on) is needed in bioscience.

Conventional cellular force measurement

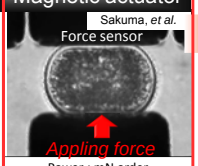
AFM

Power : nN order
Resolution : Å order
Target : Adhered cell

Optical tweezers

Power : pN order
Resolution : nm order
Target : Floating cell

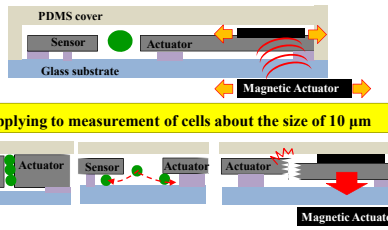
Magnetic actuator



Power : mN order
Resolution : nm order
Target : Floating cell (100 μm)

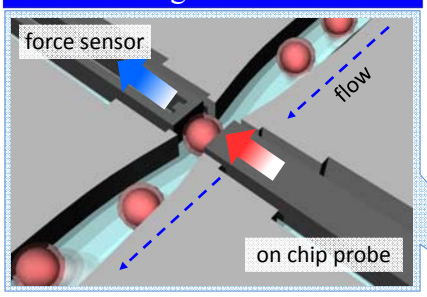
For the quantitative evaluation of these cells…
- Target : **Small (～20 mm)** and **floating cells**
- Power : **nN order**

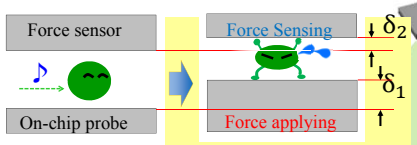
Problem



Concept of measurement system

Sensing mechanism



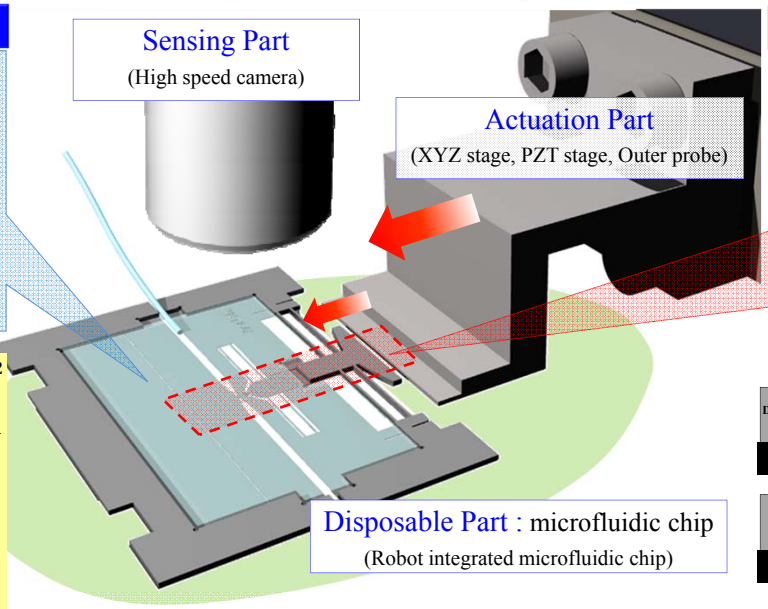


cellular force : $F_{cell} = k\delta_2$

k represents the spring constant of the force sensor. k is confirmed by the eigen frequency. it is obtained from the impulse response with Fourier Transformation.

deformation ratio : $\varepsilon_{cell} = (\delta_1 - \delta_2)/d_{cell}$

d_{cell} represents the diameter of the cell.



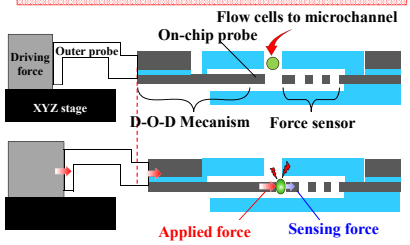
Actuation mechanism

Direct-Outer-Drive(DOD)

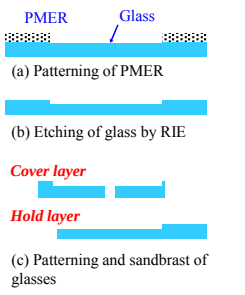
(1) Direct transmission of the displacement and the power from outer actuator
→ On-chip probe takes over its precision and accuracy over outer actuator

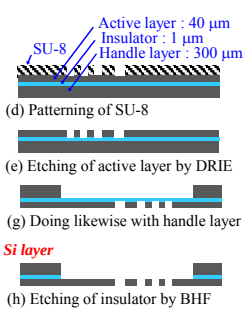
(2) Driving on-chip probe with only one direction force we want to work
→ Any thickness of silicon is available.

(3) Selectivity of the source of outer driving force
→ Optimal conditions are selected



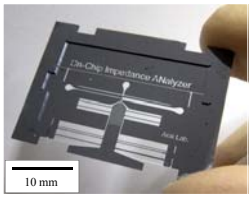
Fabrication



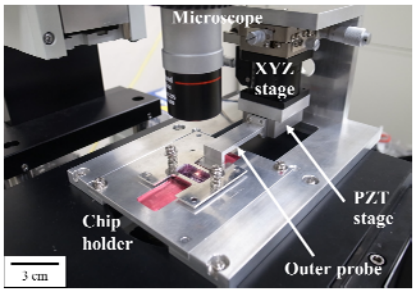


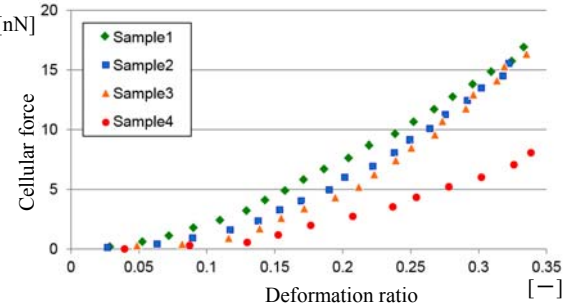
Packaging

(i) Packaging of Si and glass layers with mechanical clamp

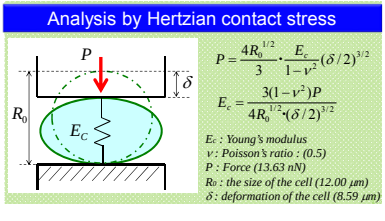


Experiment





Analysis by Hertzian contact stress



$$P = \frac{4R_0^{1/2}}{3}\cdot\frac{E_c}{1-\nu^2}(\delta/2)^{3/2}$$

$$E_c = \frac{3(1-\nu^2)P}{4R_0^{1/2}\cdot(\delta/2)^{3/2}}$$

Ec : Young's modulus
ν : Poisson's ratio : (0.5)
P : Force (13.63 nN)
R0 : the size of the cell (12.00 μm)
δ : deformation of the cell (8.59 μm)

The Young's modulus of MDCK cell was estimated by the deformation of the cell and the displacement of force sensor(theoretical spring constant: 1.72 nN/μm)

mean: 421 Pa

Conclusion

The Young's modulus of MDCK cell was estimated about 421 Pa by using on-chip cellular measurement

Reference

Measurement of Mechanical Property of Floating Cell Using On-chip Robot with Direct-Outer-Drive Mechanism 3P2-G06, 2014 Robomech 26th

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BIO Assembler