Smooth Enucleation by Hydraulic Force Control Using Magnetically Driven Microtool

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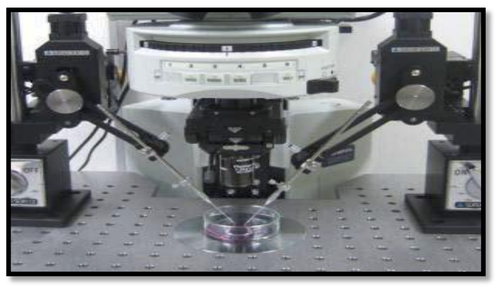
マイクロロボットで流体力を制御し,卵子が高速かつスムーズに切れた！

1. Background

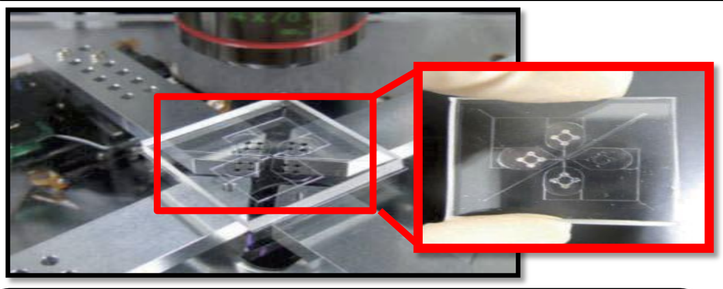
Conventional cell manipulation



Mechanical robot arm operations

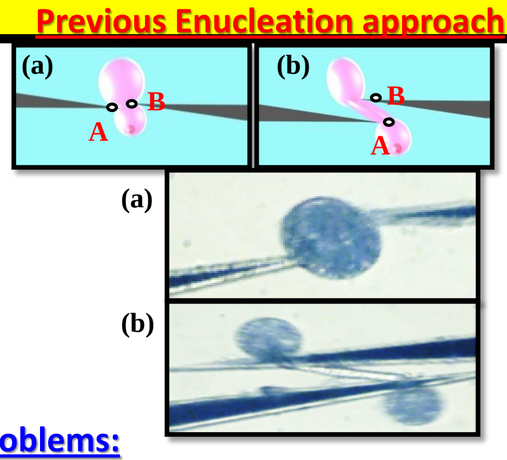
Problems:
1. Reproducibility 2. Contamination 3. Success rate 4. Productivity 5. Operability

On-chip microrobot based manipulation



ADVANTAGES OF THE ON-CHIP ROBOT
1. MINIATURIZATION
2. CONFINED SPACE OPERATIONS
3. AUTOMATION

Previous Enucleation approach



Problems:
1. Misalignment 2. Continuous process 3. Volume control

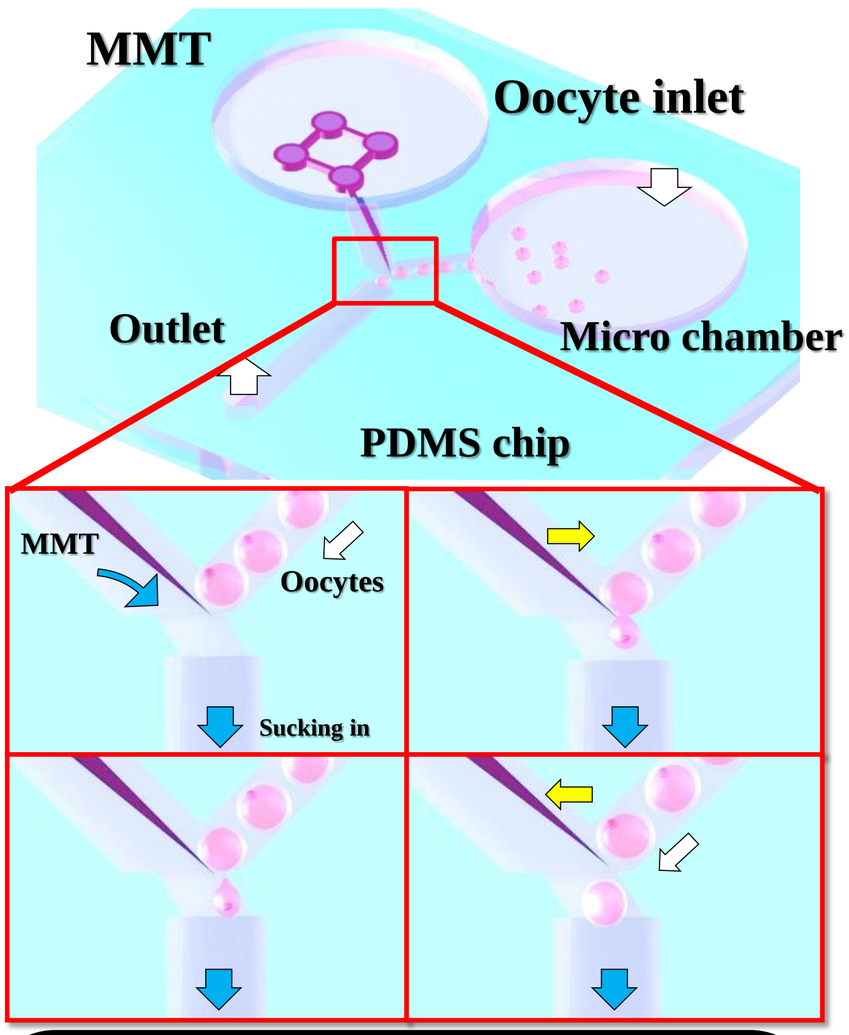
Riblet MMT

(a) SEM image of after wet etching

(b) SEM image of Si-Ni hybrid MMT

Fluid friction reduction of microrobot by riblet surface

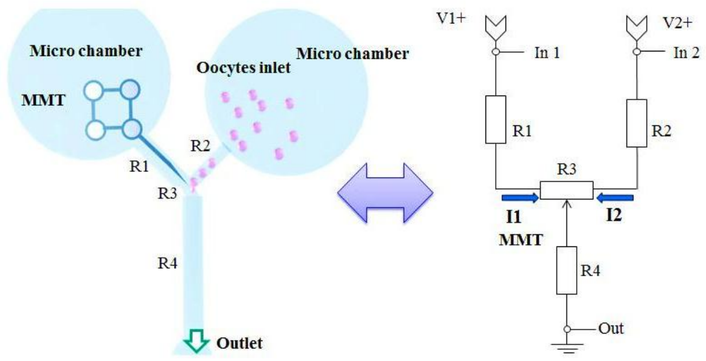
2. Concept



Oocyte Enucleation Process
- Blue arrows: Flow direction
- Yellow arrow: MMT moving direction
- White arrows: Oocyte moving direction

3. Methods

The electric circuit analogy

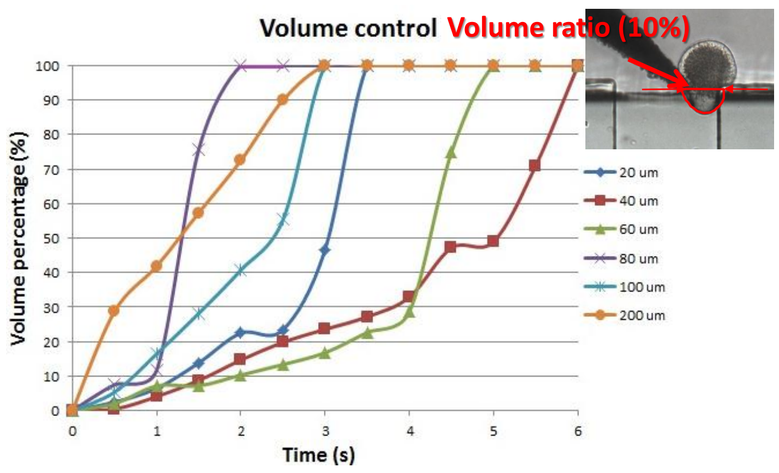


Oocyte is regularly 100μm in diameter,
To balance the pressure.
Oocyte inlet micochannel width: 150 μm, height: 300 μm, length: 1mm. R1= R2 → R2: width: 300 μm, height: 300 μm, length: 2.343 mm

$$R_h \cong \frac{8\eta L}{r_h^2 A} \qquad r_h \cong \frac{2A}{P}$$

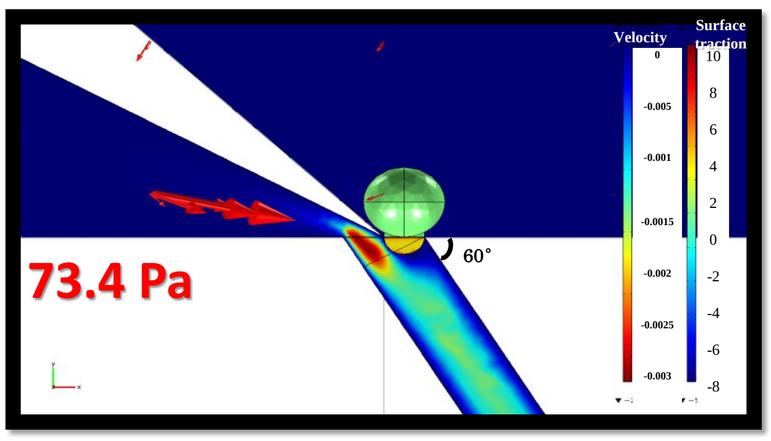
R_h: hydraulic resistance
H: viscosity coefficient
L: the length of the microchannel
A: the cross-sectional area of the channel
r_h: the hydraulic radius of the channel
A: the cross-sectional area of the channel
P: the length of the perimeter of the channel

Cutting volume control

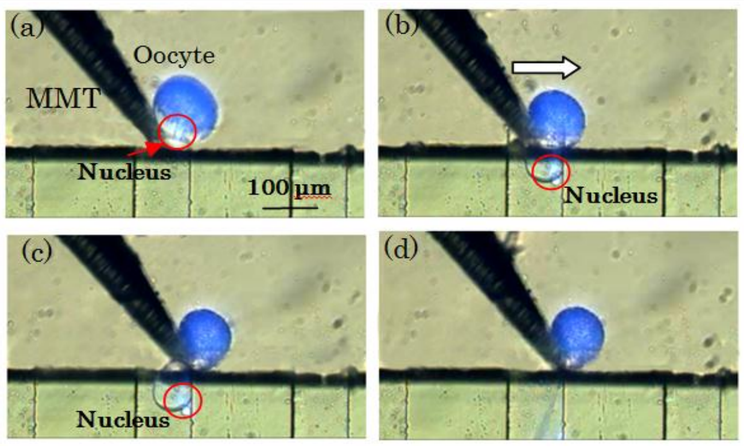


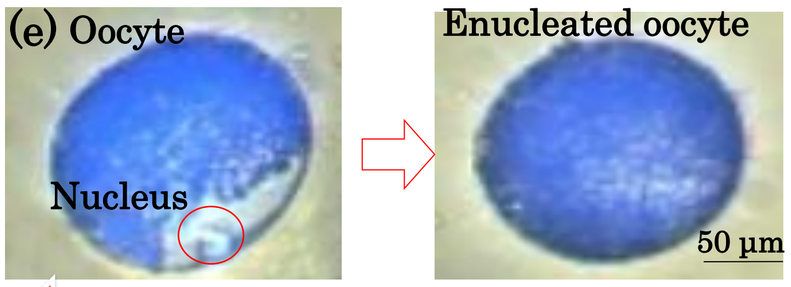
FEM Simulations

Object surface: Surface traction (force/area), y component (Pa) Arrow: Velocity field
Slice: Velocity field, y component (m/s)



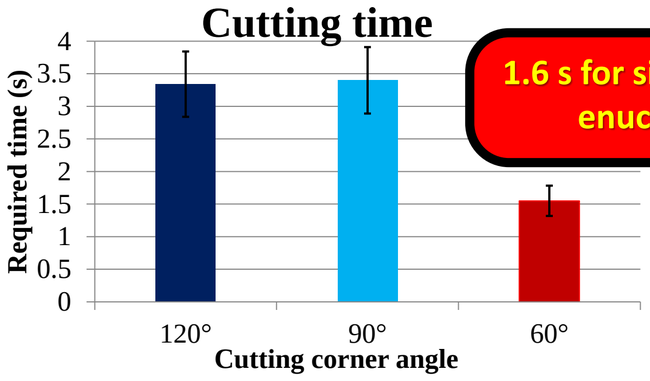
4. Experiments





Oocyte Enucleation Process

Enucleation time evaluation



1.6 s for single oocyte enucleation

5. Conclusions and future work

1. The volume of the enucleated part is controllable.
2. The incision of enucleated oocyte is smooth and neat.

6. References

1. M. Hagiwara et al., “On-chip magnetically actuated robot with ultrasonic vibration for single cell manipulations”, Lab on a Chip, vol. 11, pp.2049-2054, 2011.

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