Advanced 15
Future Works in Micro-Nano Mechatronics

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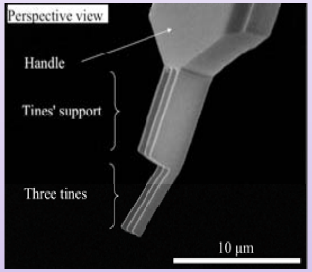
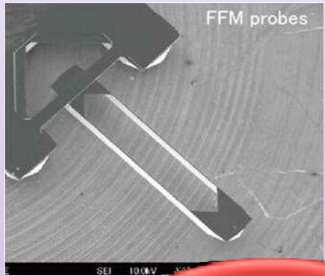
Technologies for Micro-Nano Mehcatronics

Micro-Nano fabrication

- MEMS
- NEMS
- Machining
- Assembly
- Optics/Imaging

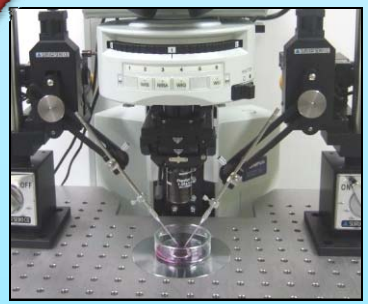


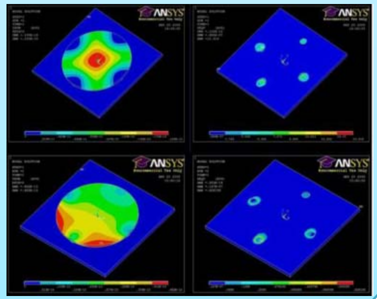


Micro-Nano Mechatronics

Robot technology

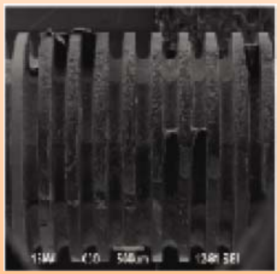
- Sensors
- Actuators
- Control theory
- Dynamics

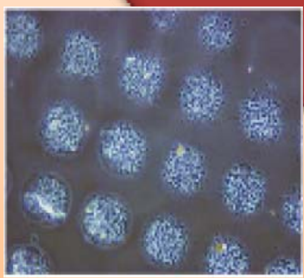




Micro-Nano Materials

- Tribology
- Energy
- Synthesis

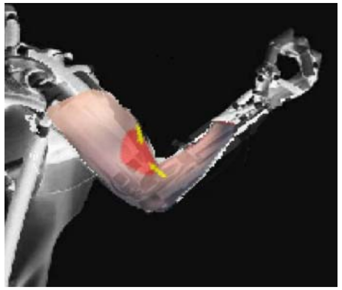




Future Works

Performance

- Automation
- Speed
- Sensitivity
- New technology



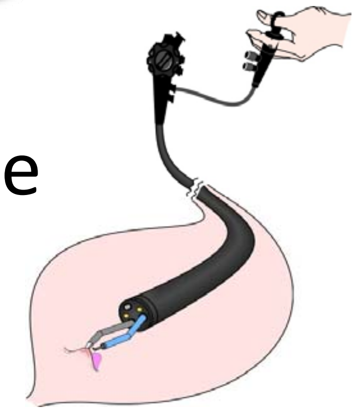
Education

- Standardization
- Professional development
- Interdisciplinary study

Micro-Nano
Mechatronics

Practical use

- Cost
- Applications
- Cooperation

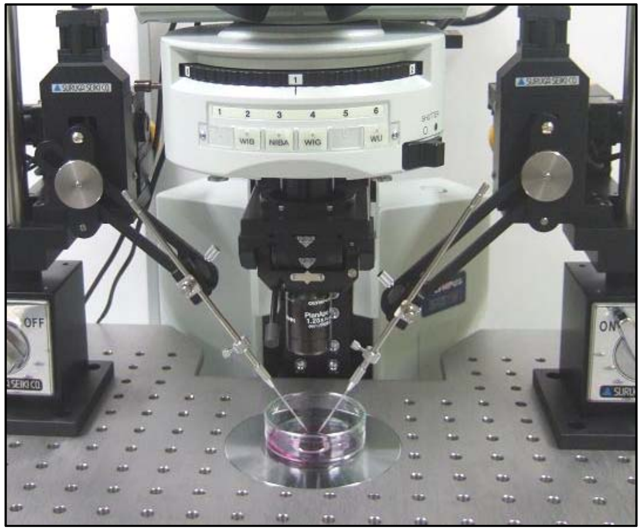


Performance

Hi-Speed, Hi-Accuracy, and Hi-Power Microrobot

Conv. Cell Manipulation

Manual operation by mechanical manipulator

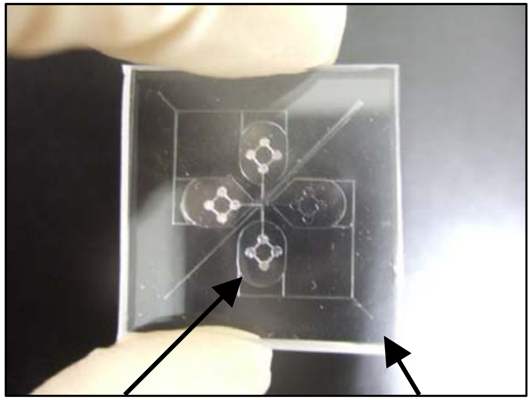


PROBLEMS

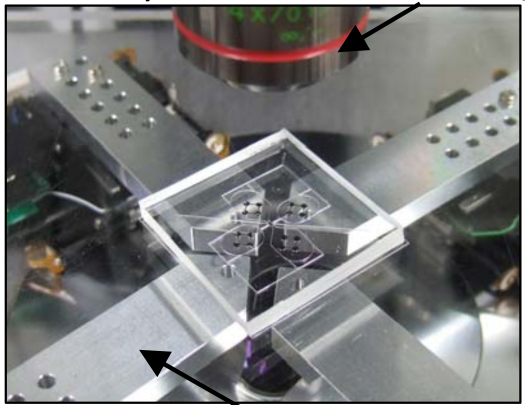
1. Tech. difficulty 2. Repeatability
3. Success rate 4. Productivity
5. Contamination

Cell Manipulation by Microrobot

On-chip microrobot



Drive system



Advantages of on-chip robot

- **Minituarization** → **High throughput, Low cost**
- **Closed environment** → **Prevent contamination**
- **Automation** → **Repeatability, Success rate, Productivity**

Actuation principle

→ Magnetic force by permanent magnet

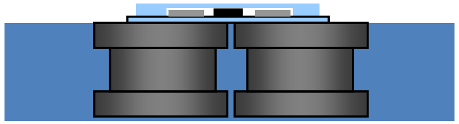
(Magnetically Driven Microtool: MMT)

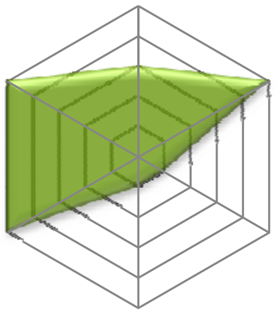
・Noncontact, high power output, low cost

Magnetic Actuators

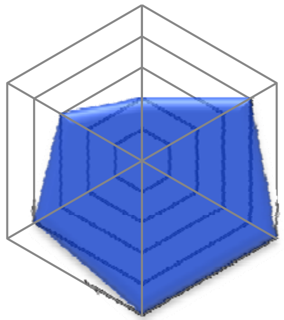
Electromagnetic coil	Helmholtz coil	Permanent magnet

Electromagnetic coil

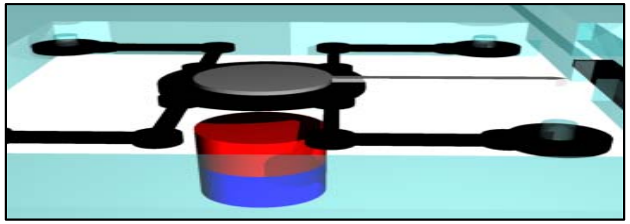


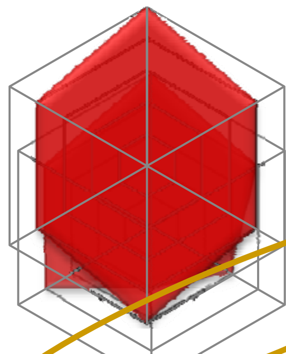


Helmholtz coil

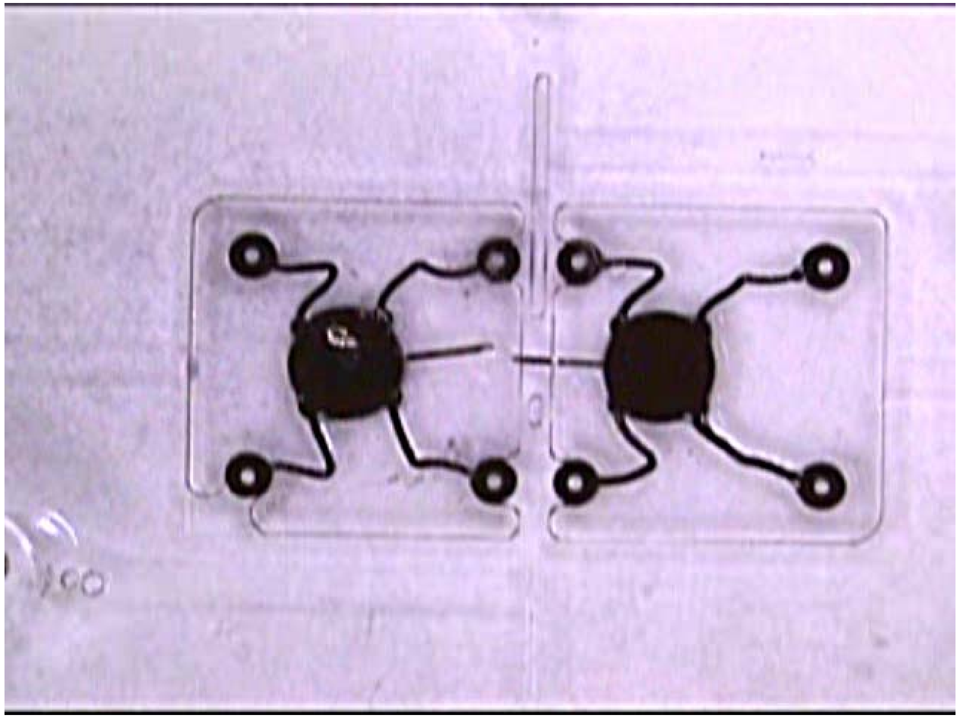


Permanent magnet

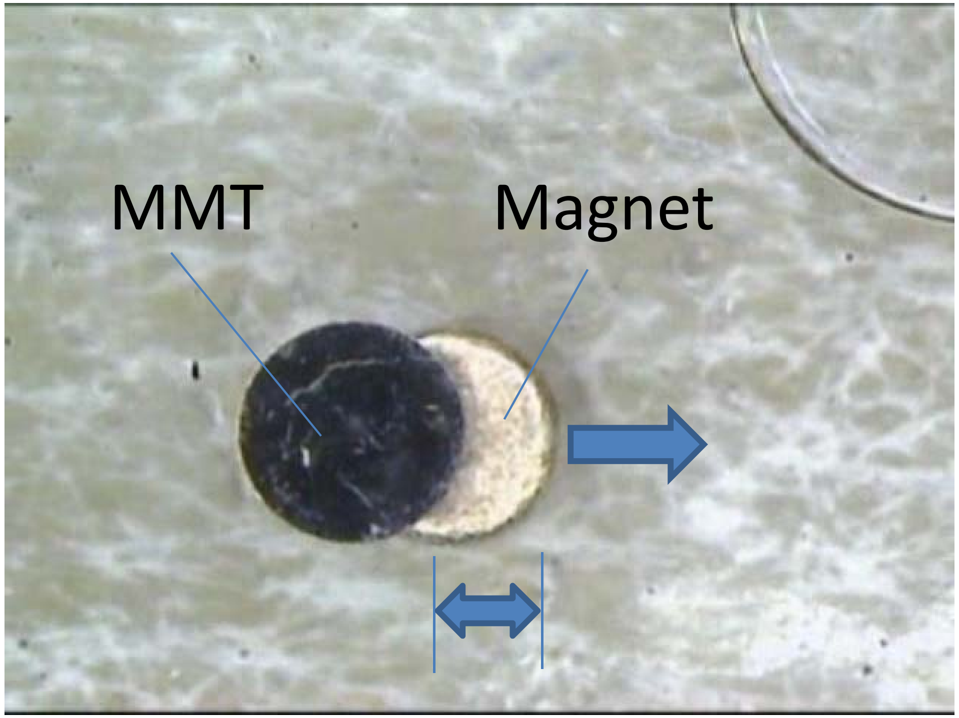




Dead Band

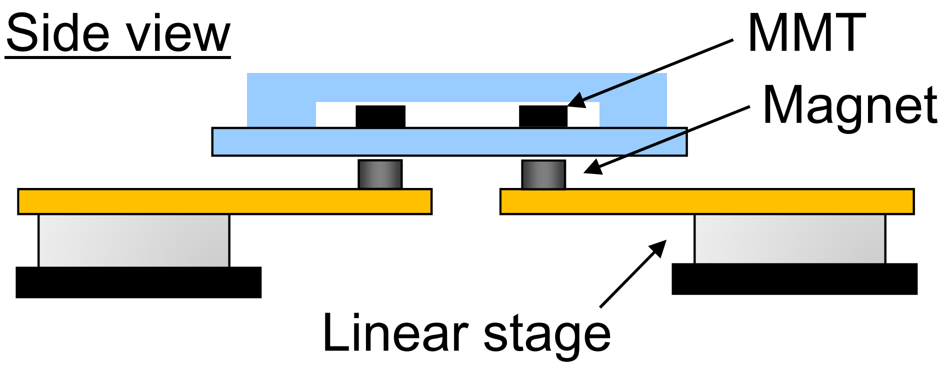


1 mm



1 mm

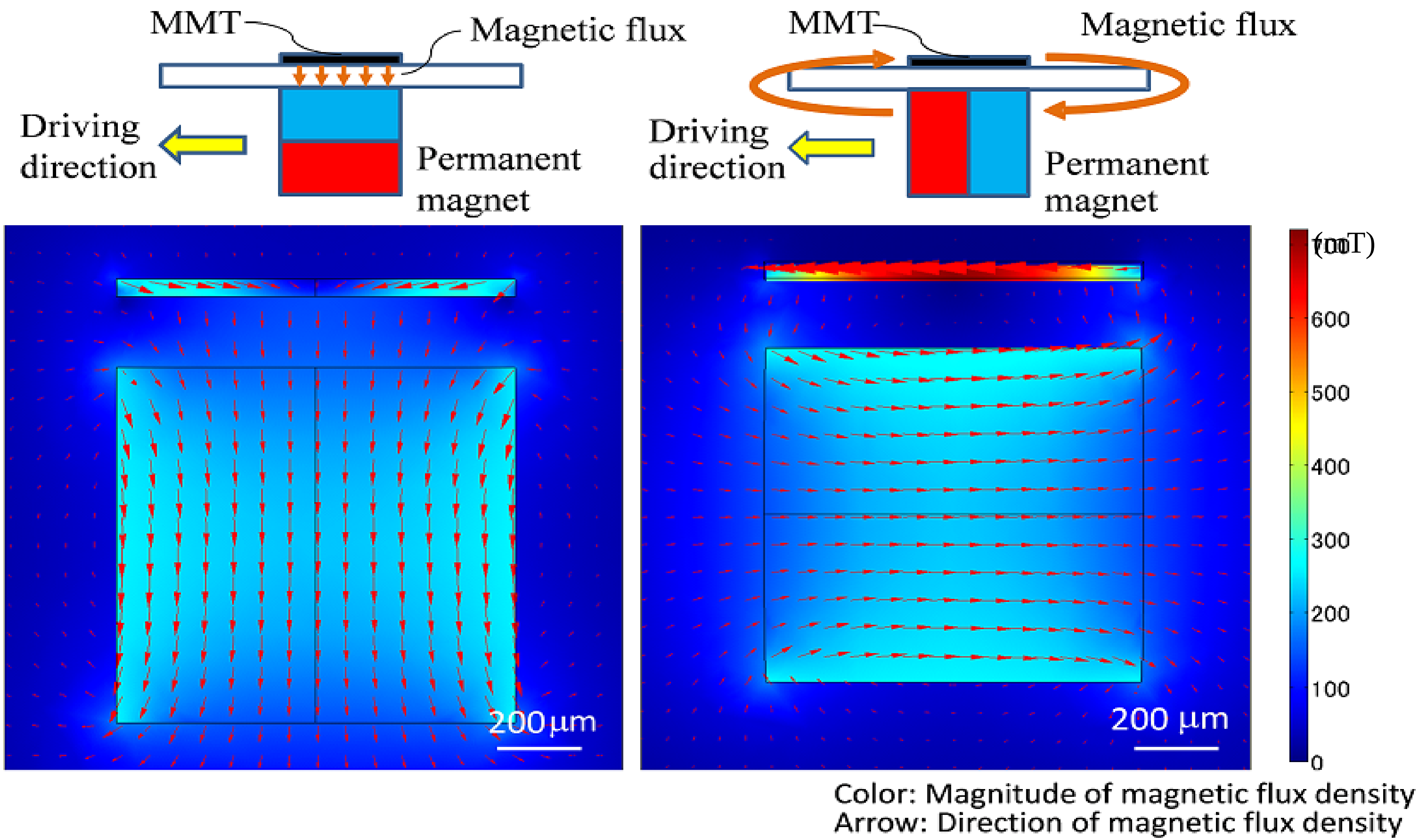
Ref: F. Arai et al. IEEE MEMS 2010 Conference (2010)



There is area called Dead band where an MMT is not actuated

Deteriorate the MMT positioning accuracy
Makes MMT automation difficult

HPD: Horizontal Polar Drive

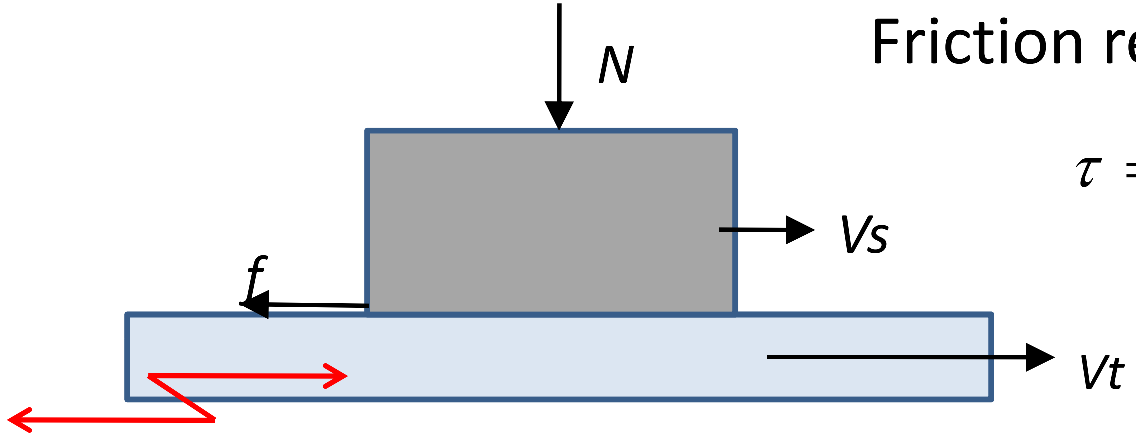


(a) Conventional Drive

(b) Horizontal Polar Drive

Ref: M. Hagiwara et al. Applied physics letters (2010)

Friction Reduction by Ultrasonic Vibration

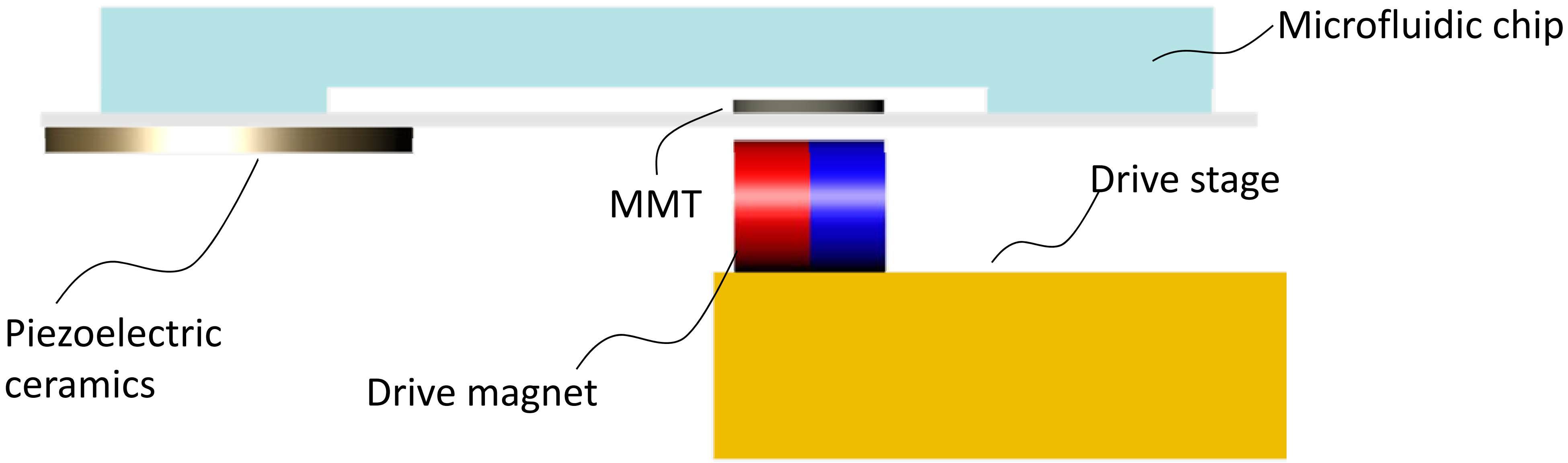


Ref: V. C. Kumar et al. Tribology International (2004)

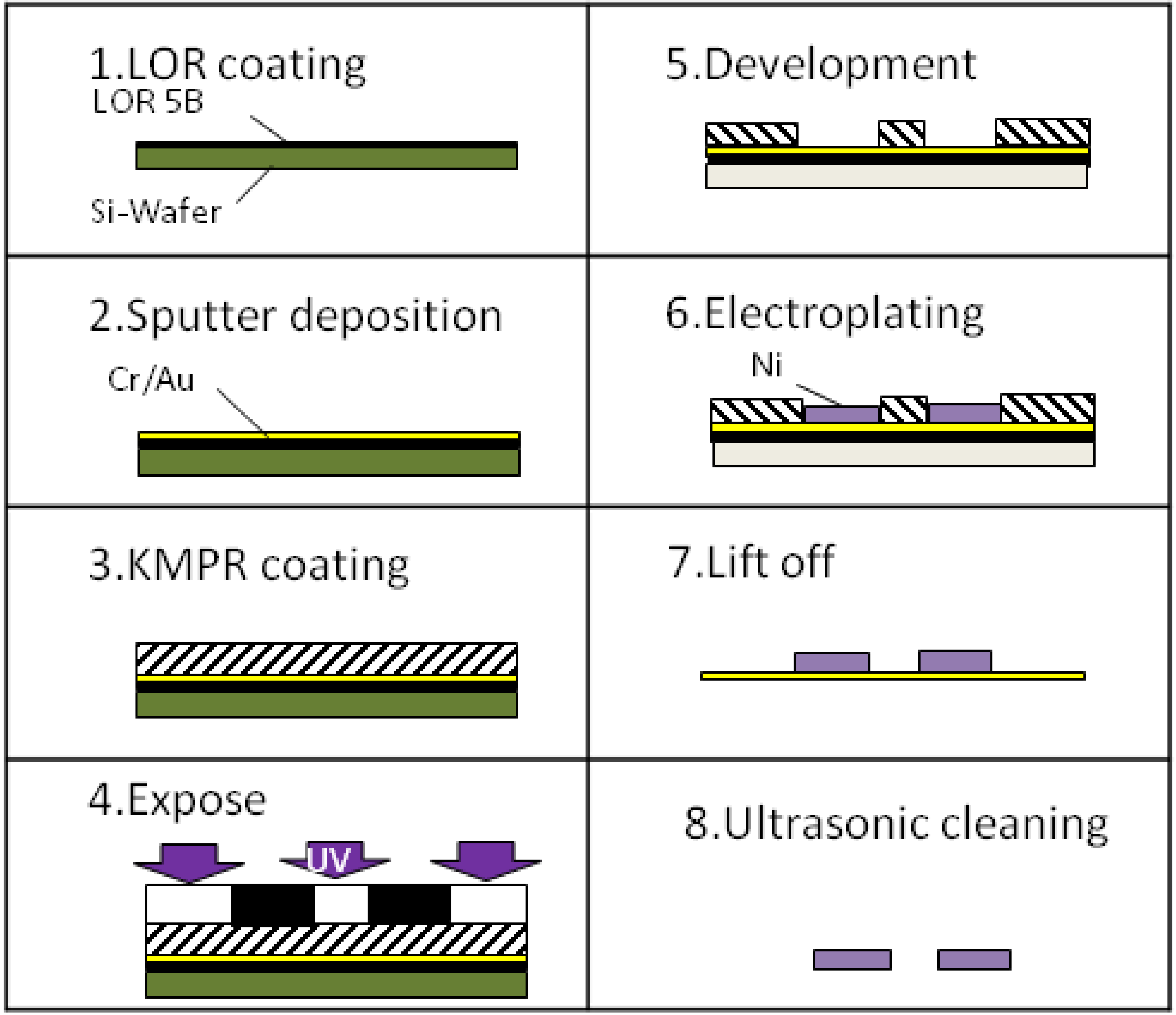
Friction reduction ratio:

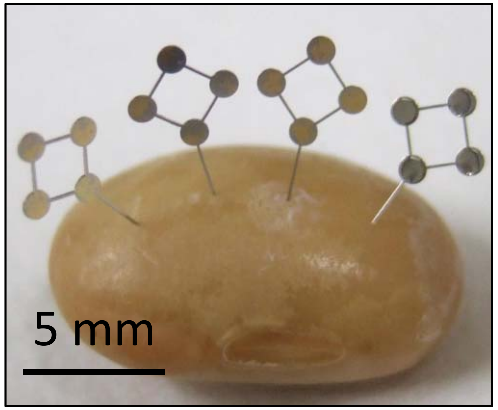
$$\tau = F_0 / F_a = \frac{\pi}{2\sin^{-1}\frac{V_s}{a\omega}} \approx \frac{\pi}{2}\frac{a\omega}{V_s}$$

a: amplitude of vibration
V_s: velocity of the sliding object
ω: frequency



MMT Fabrication



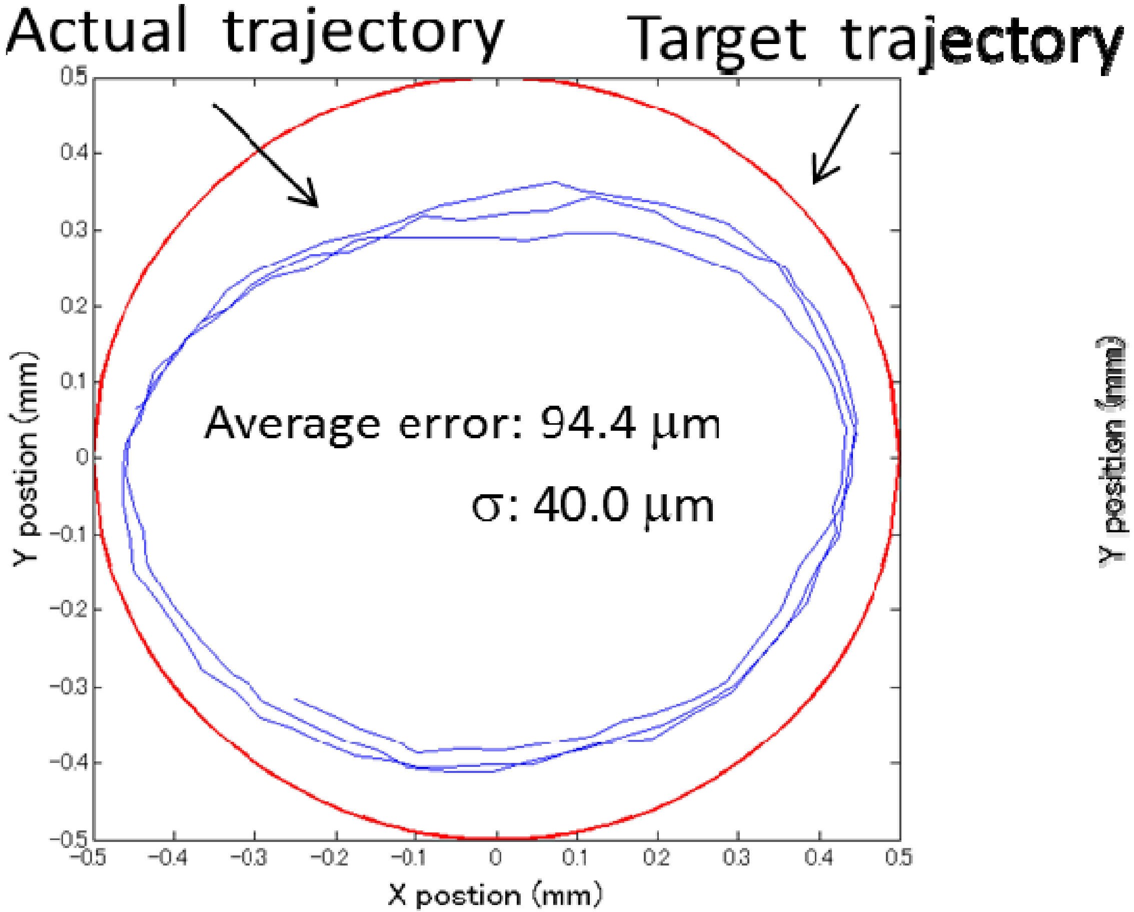


Young's module:
Oocyte 20 kPa
Ni 50 GPa

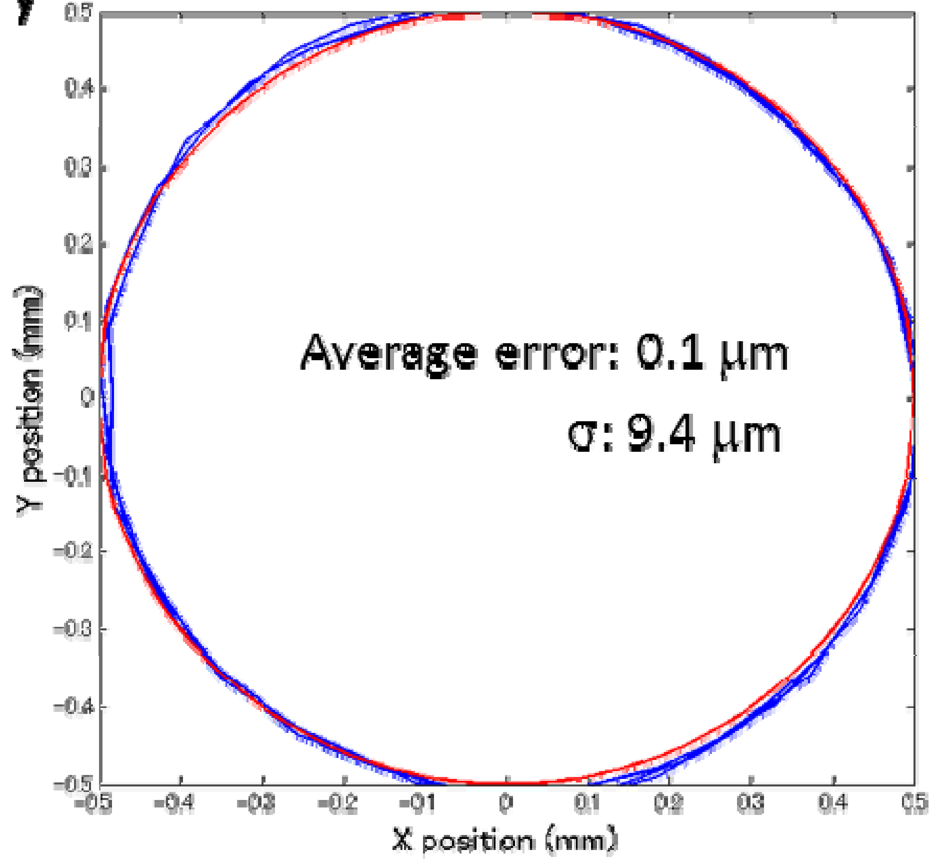
Ni has enough hardness to cut oocyte

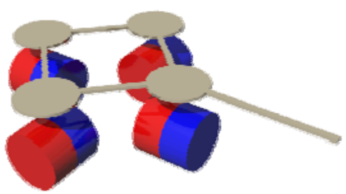
Evaluation of Ultrasonic Vibration

Without vibration

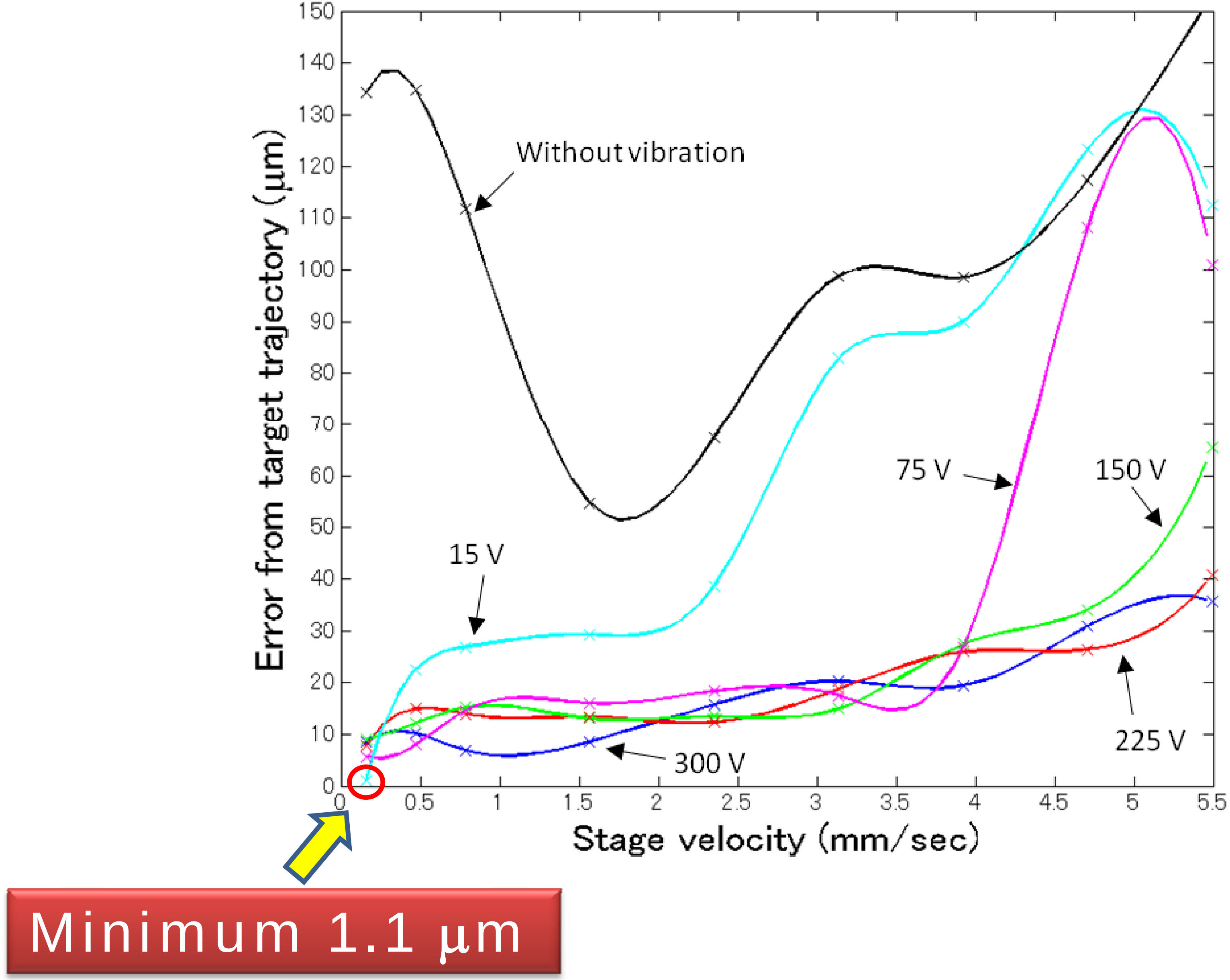


With vibration



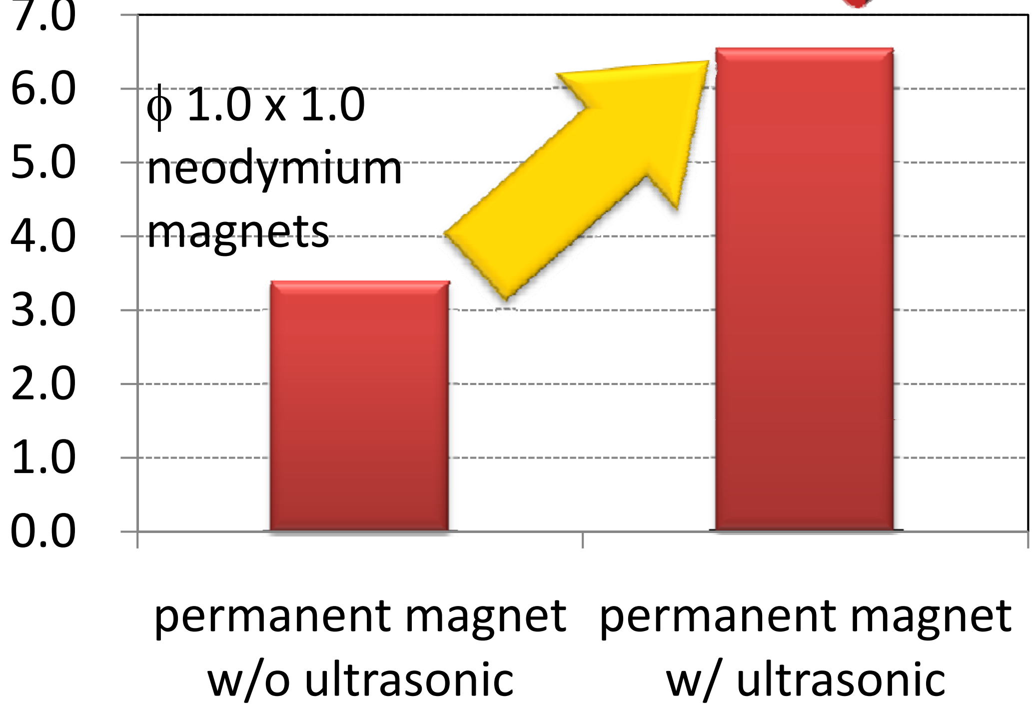


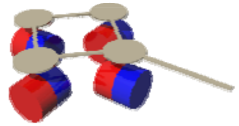
Evaluation of Ultrasonic Vibration

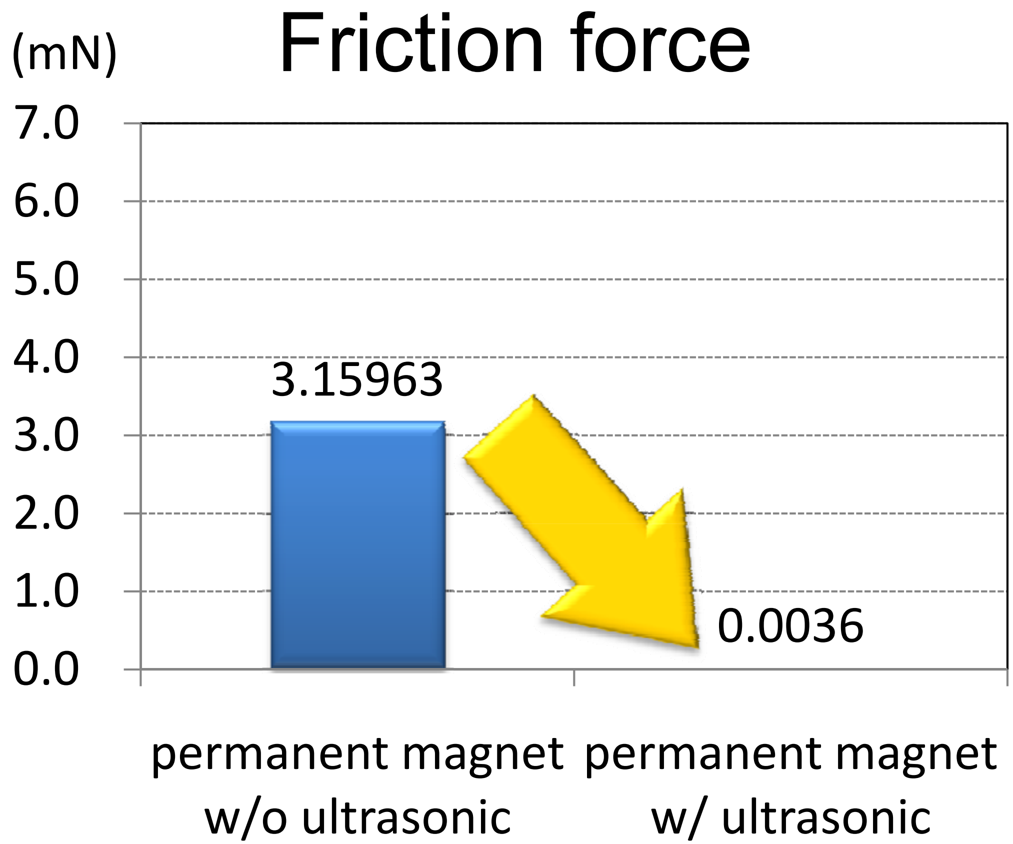


Ref: M. Hagiwara et al. MEMS (2011)

Force Comparison







From Kumar's analysis and Force balances

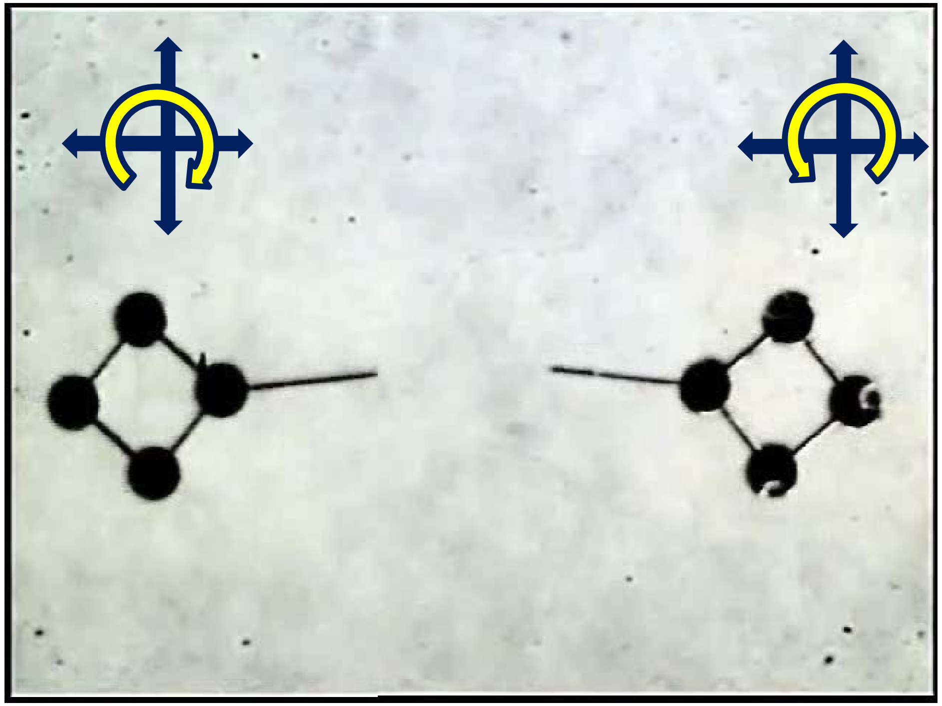
$$F_0 / F_a \approx \frac{\pi}{2} \frac{a\omega}{V_s}$$

$$F_{OUT} = F_{Drive} - F_0$$

$$F'_{OUT} = F_{Drive} - F_a$$

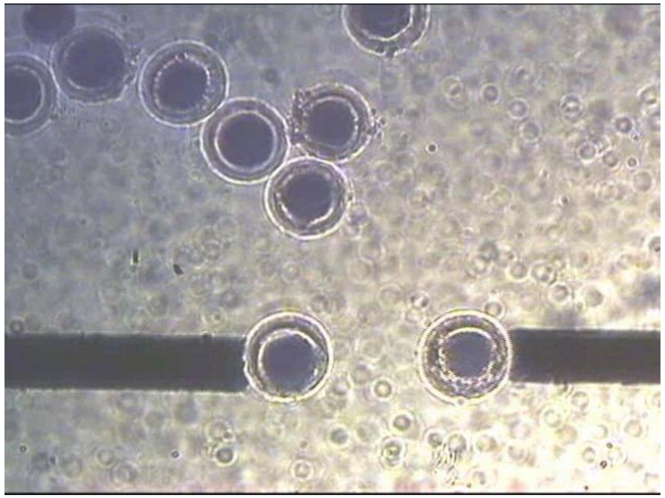
F0: friction force without vibration
Fa: friction force with vibration
a: amplitude of vibration
Vs: velocity of the MMT
ω: angular frequency
Fout: output force
Fdrive: x c.omponent of magnetic force

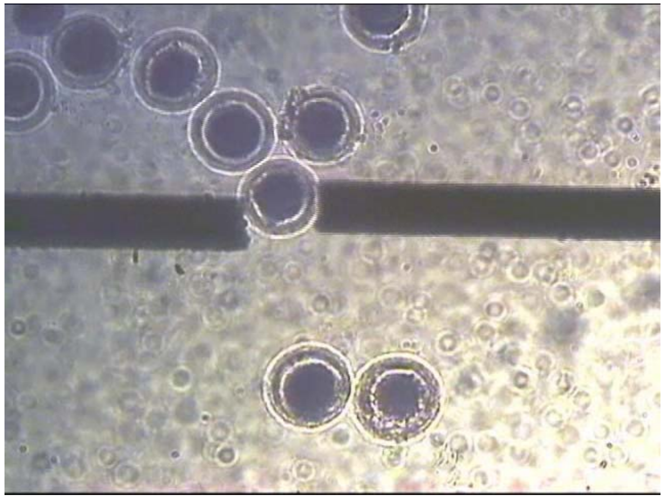
Precise Cell Handling

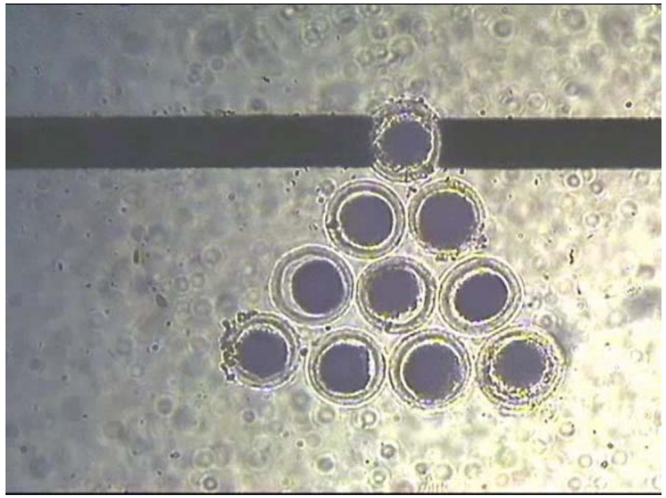


3DOF-robot-arm x 2

100 μm

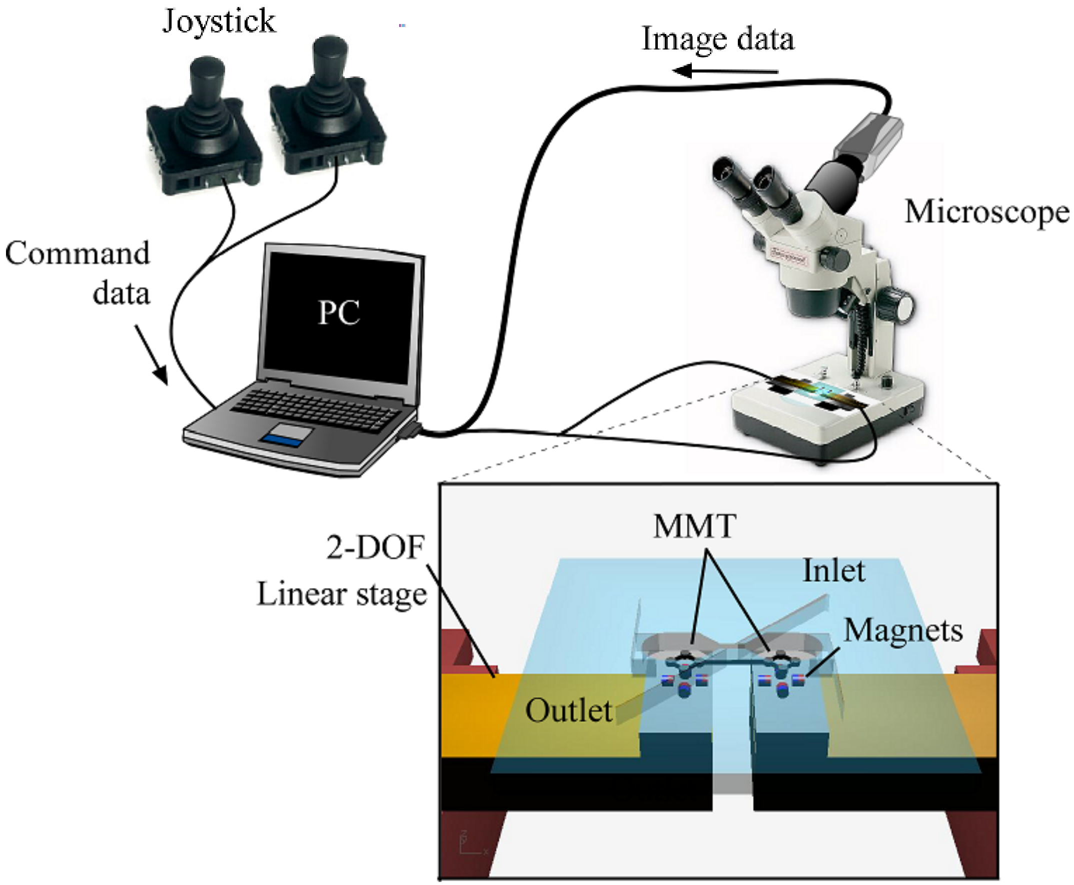




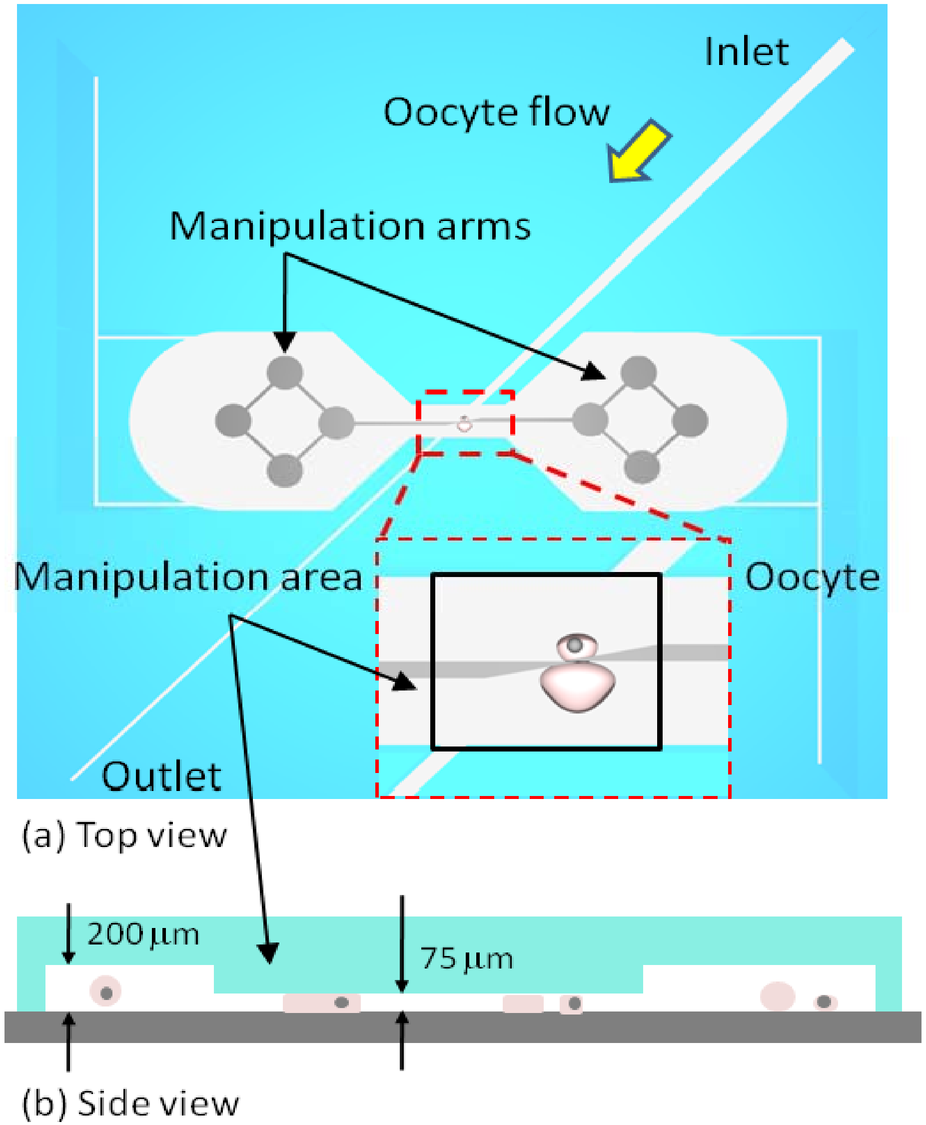


Enucleation of Oocyte Process

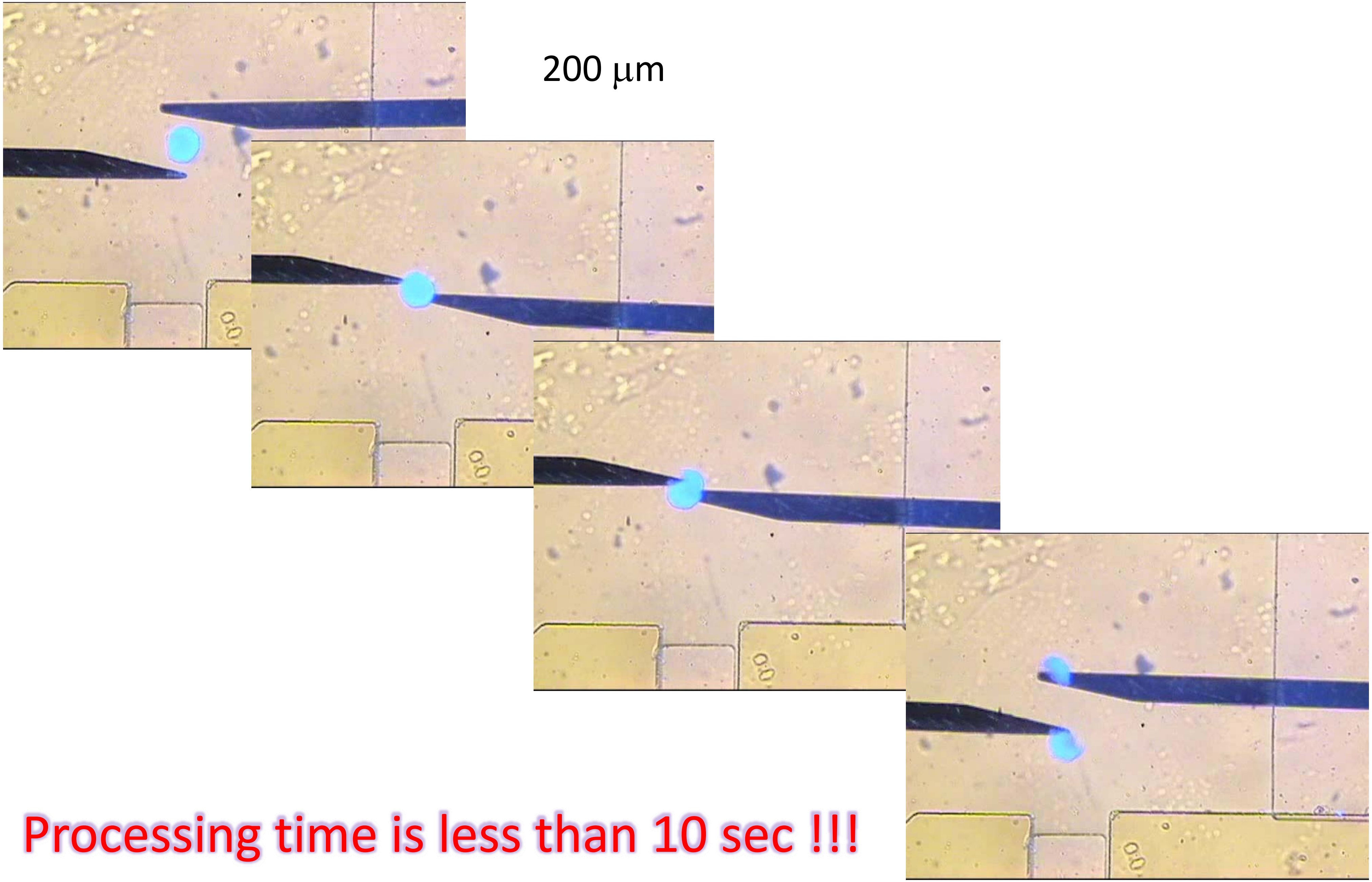
【Experimental setup】



【Design of microfluidic chip】



Application to Enucleation



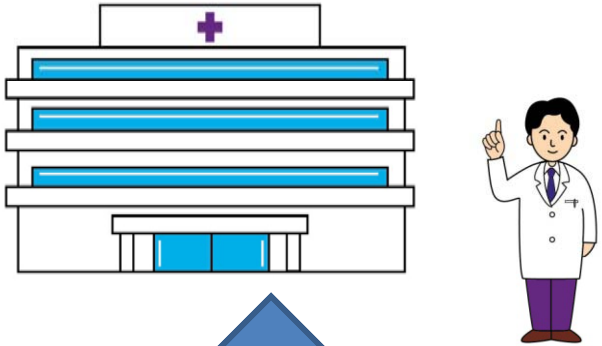
Processing time is less than 10 sec !!!

Practical use

Toward Practical Use

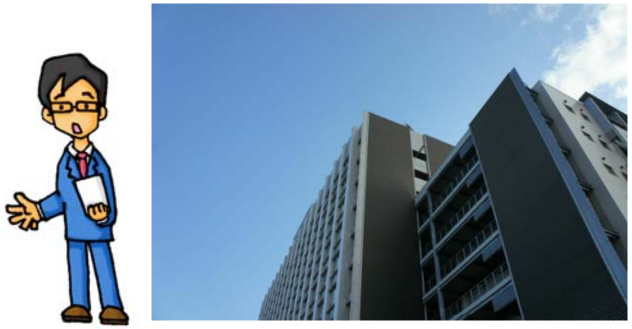
Application field

e.g., hospital



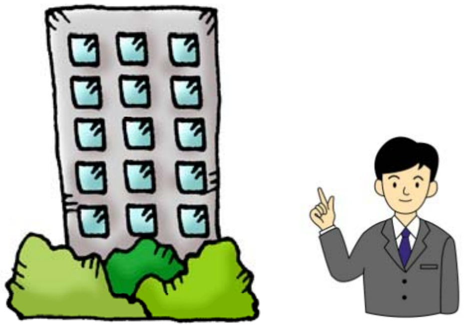
Collaborative research

University



Products, Devices

Company



Technology transfers

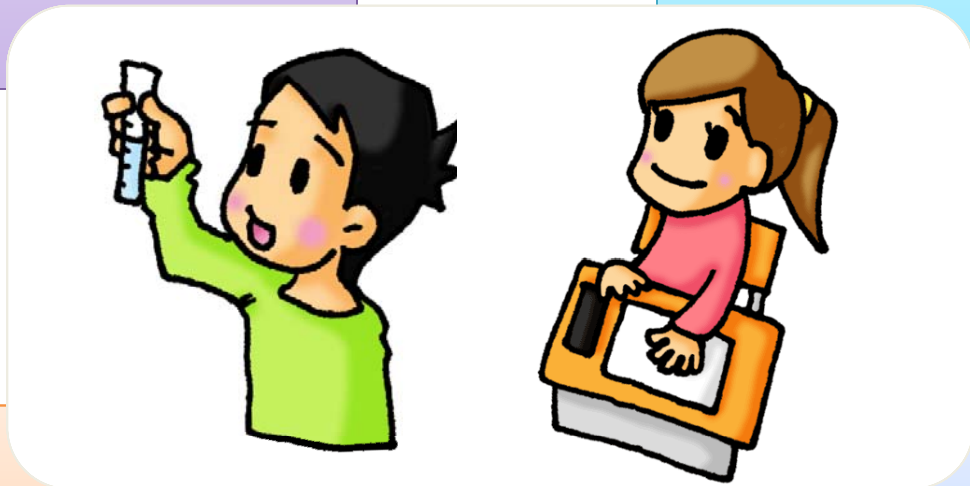
- One and only technology
- Innovative technology

Education

Education on Micro-Nano Mechatronics

Basic study
- Mechanical Engineering
- NEMS/MEMS
- Electronics
- Robotics

Advanced study
- Hands-on training
- System Integration
- Patent/Paper
- Presentation



Interdisciplinary study
- Biology, Tissue Engineering
- Medical, Welfare
- Science

Globalization
- Conference/Symposium
- Journal
- Overseas Study

References

1. M. Hagiwara, T. Kawahara, L. Feng, Y. Yamanishi, F. Arai:
On-Chip Dual-Arm Microrobot Driven by Permanent Magnets for High-Speed Cell Enucleation,
Proc. of the 24th IEEE Int. Conf. on Micro Electro Mechanical Systems (MEMS), pp.189-192, 2011.

2. M. Hagiwara, T. Kawahara, Y. Yamanishi, and F. Arai:
Driving Method of Microtool by Horizontally-arranged Permanent Magnets for Single Cell Manipulation,
Applied Physics Letters, Vol. 97, No. 013701, pp. 1-3, 2010.