Basic 4
Micro-sensor

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History_1

1962 [Anisotropic wet etching]

1967 Oscillation gate transistor

[Sacrificial etching]

1968 [Anodic bonding]

Fundamental technologies

1970 Micro-electrodes

1973 Pressure sensor、

ISFET (Ion Senstitive FET)

Advent of Micro-sensor

History_2

1975 Integrated Gas Chromatography

1979 Integrated Pressure Sensor

1982 [LIGA process]

1986 Mass-flow-controller

1987 Micro-gear

1988 Micro-motor driven by electrostatic force

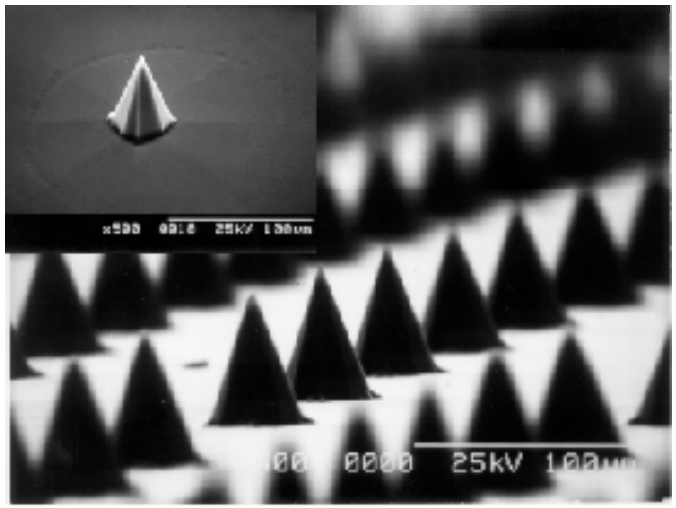
1991 ～

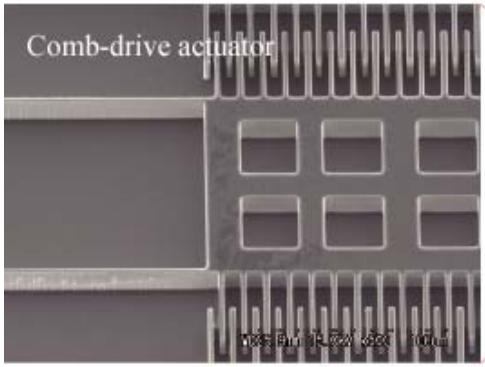
Acceleration sensor,
Gyro sensor,
Infrared sensor

Integration of Micro-sensor

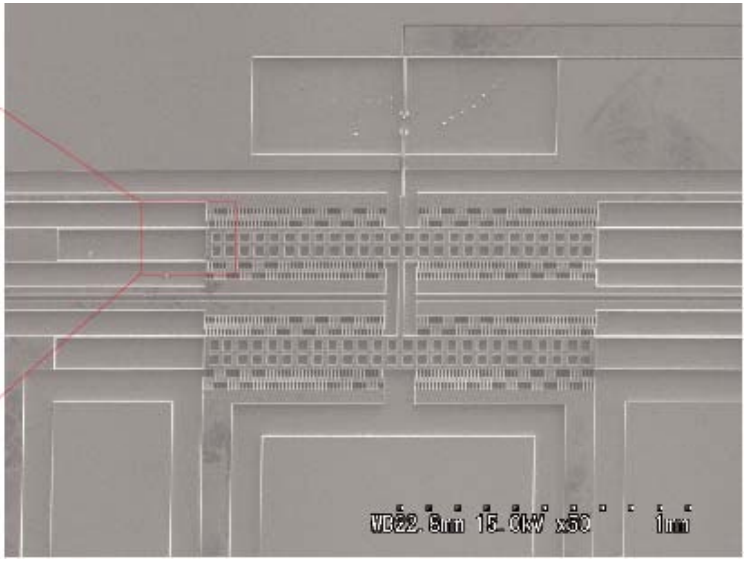
Expansion of Micro-sensor application

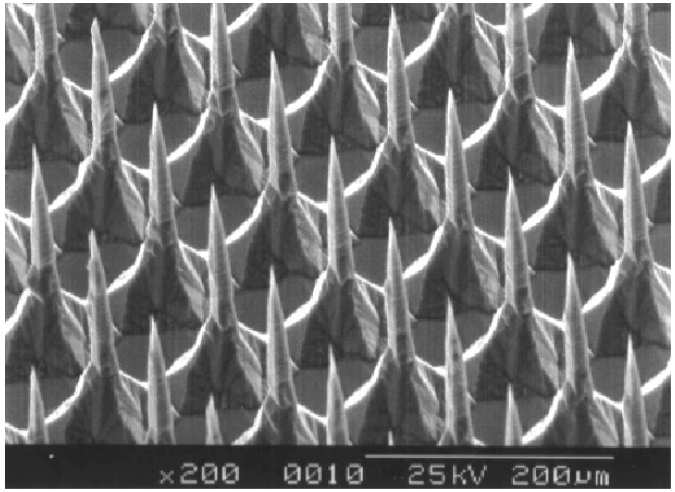
MEMS applications



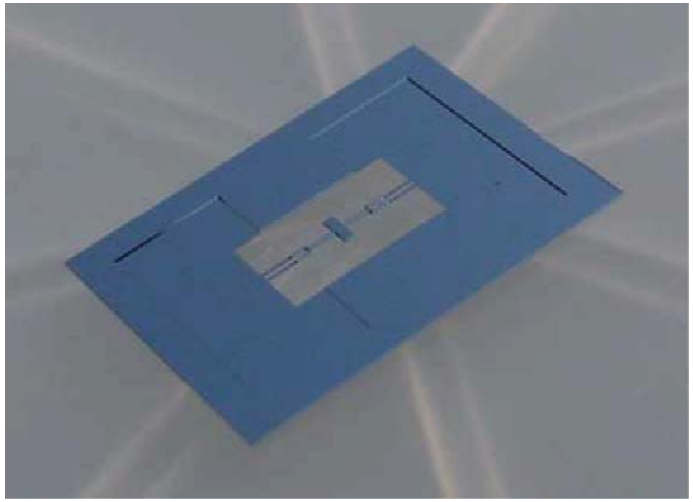


Electrostatic actuator

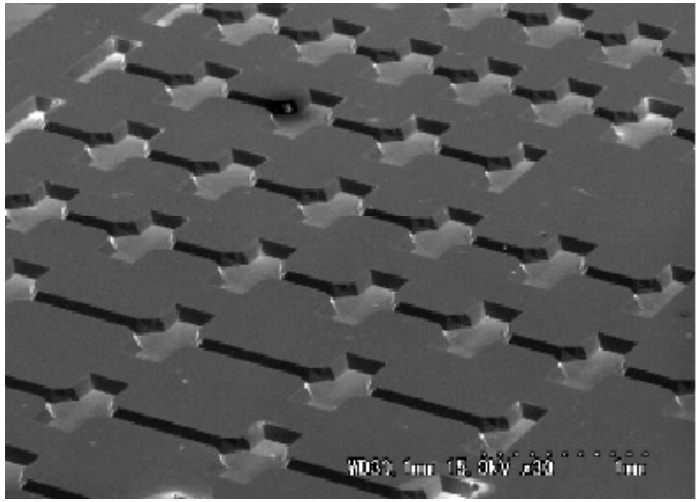




Micro-needle



Optical scanner



V-grooves for optical fibers

Difficulty of MEMS development

- ✓ Large amount of capital investment vs. Market size
- ✓ High-mix low-volume production
- ✓ Complexity of fabrication process
- ✓ Variety of device packaging
- ✓ multidisciplinary research field
- ✓ Scale effects

Micro-sensor in MEMS

Fundamental Tech.

①Fabrication
- Etching
- LIGA
- Deposition

②Packaging
- Bonding
- Packaging
- Interconnection

③Evaluation
- Mechanical properties

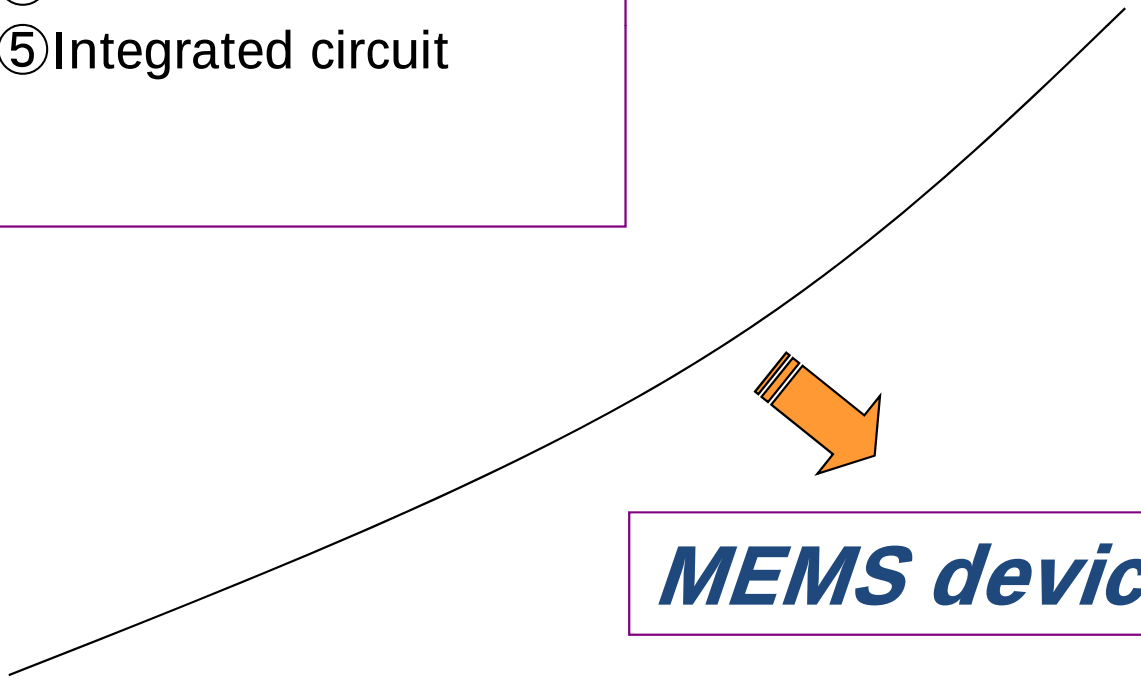
④Design support
- CAE,CAM

Device

①Sensor
②Actuator
③Energy
④RF
⑤Integrated circuit

System Tech.

①Contorol
②Interface



MEMS devices

Micro-sensor application

Micro sensor	Detection principle	分野
Individual identification	Capacitance、Image processing、Heat transfer	Information-communication
Flow sensor	Heat transfer	Production
		Automobile
		Building
	Piezo-resistance	Airplane
Tactile sensor	Capacitance、Piezo-resistance	Information-communication
		Production
Pressure sensor	Capacitance、Piezo-resistance	Medical care
		Automobile (fuel)
		Automobile (tire)
Acceleration sensor	Capacitance、Piezo-resistance	Automobile
		Information-communication
		Amusement
Gyro sensor	Capacitance	Automobile
Probe for sensing	Resonance	Measurement
IR sensor	Diode, Thermoelectric power	Automobile
Chemical sensor	FET、Resonance	Medical care

Fascination points of Micro-sensor

- ✓ Batch process → Reduction of cost
  Improvement of alignment accuracy
- ✓ Miniaturization → Fast response
  （Improvement of time resolution）
  Reduction of footprint
  （Improvement of space resolution）
- ✓ Integration → Reduction of parasitic capacitance
- ✓ Array arrangement → 2D analysis
- ✓ Systemization → Multiple functions
  Reduction of dead space

Example of Micro-sensor

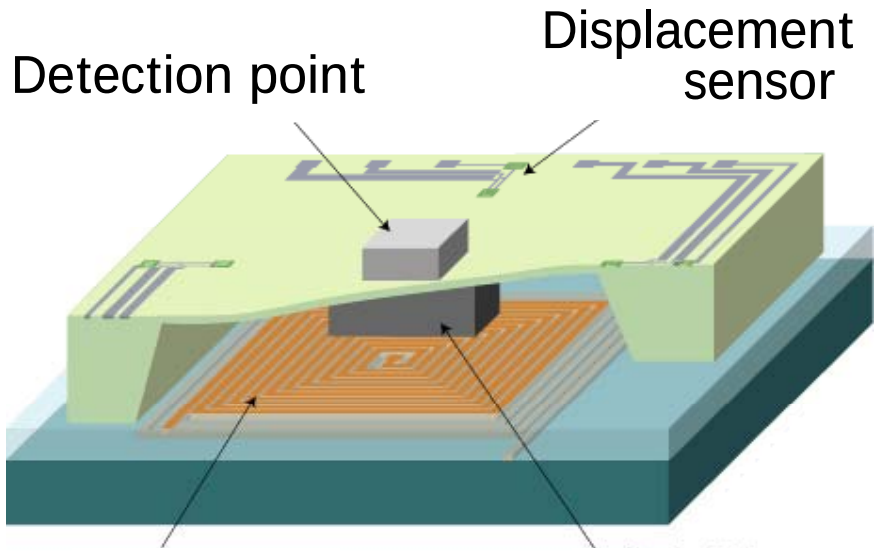
- ✓Tactile sensor
  - Si active tactile sensor
  - Fabric tactile sensor
- ✓Tuning fork probe for AFM
- ✓Flow sensor for medical application

Si active tactile sensor

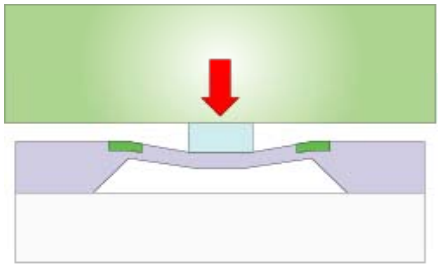
Active tactile sensor:「Passive＋Active elements」

→It can detect both of hardness and force of object

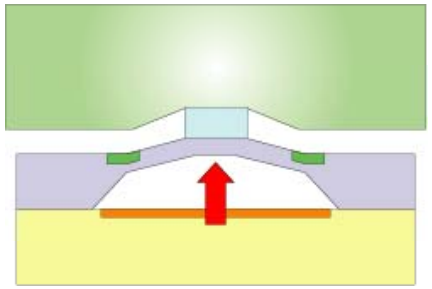
✓Multiple functions



Magnetically driven active tactile sensor



Force detection



Hardness detection

Detection

① Quasi-static mode → Force versus Displacement curve

② Vibration mode → Resonance characteristics

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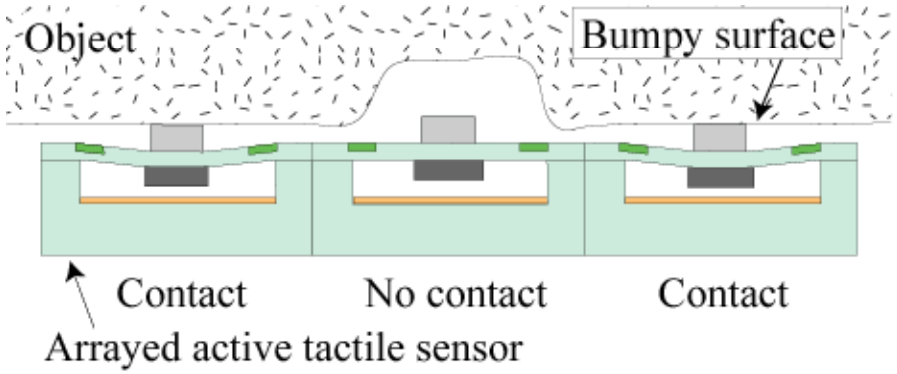
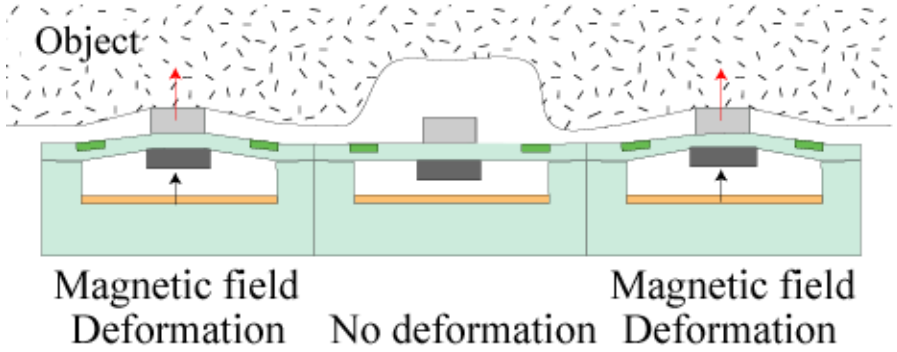
Si active tactile sensor

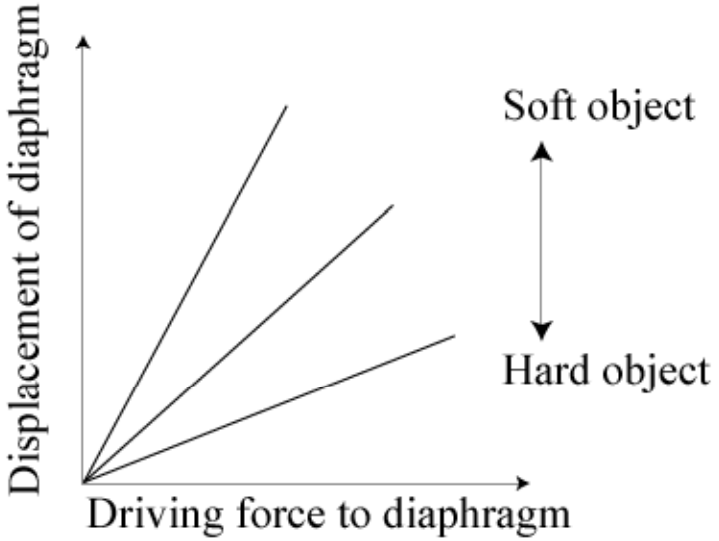
Quasi-static mode



(a) Detecting contact-force distribution and two-dimensional surface texture image



(b) Detecting elastic-coefficient distribution in non-vibrated driving



(c) Relationship between displacement and driving force at diaphragm structure

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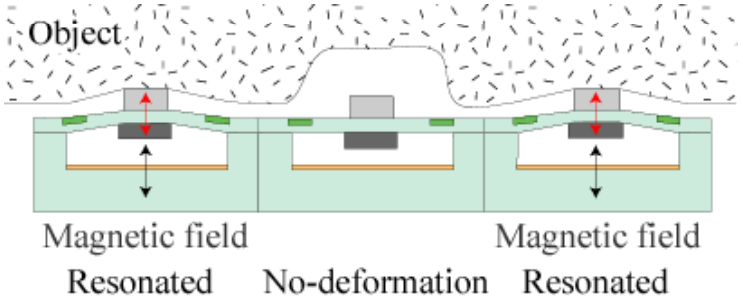
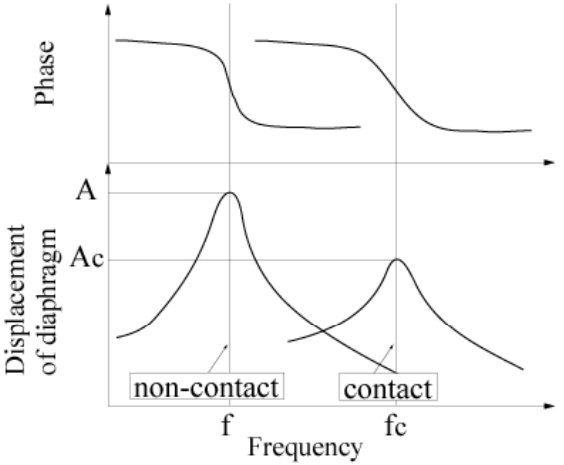
Si active tactile sensor

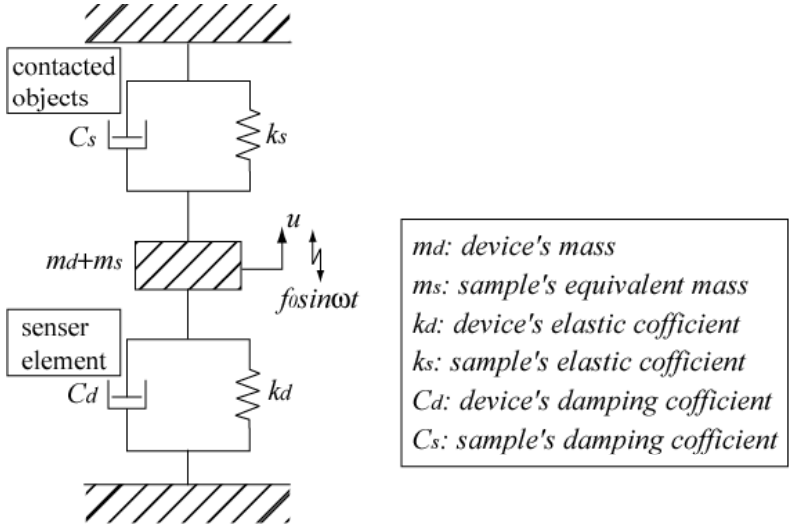
Vibration mode



(a) Detecting elastic- and damping coefficient in vibrated driving



(b) Relationships between displacement and phase shift versus frequency of input signal at diaphragm structure



(c) Lumped parameter circuit of sensor system

$$\omega_n = \sqrt{\frac{K_d + K_s}{m_d + m_s}}$$

$$Q = \frac{\sqrt{(m_d + m_s)(K_d + K_s)}}{C_d + C_s}$$

$$u_n = \frac{f_0}{C_d + C_s}\sqrt{\frac{m_d + m_s}{K_d + K_s}}$$

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Si active tactile sensor

Hybrid assembly

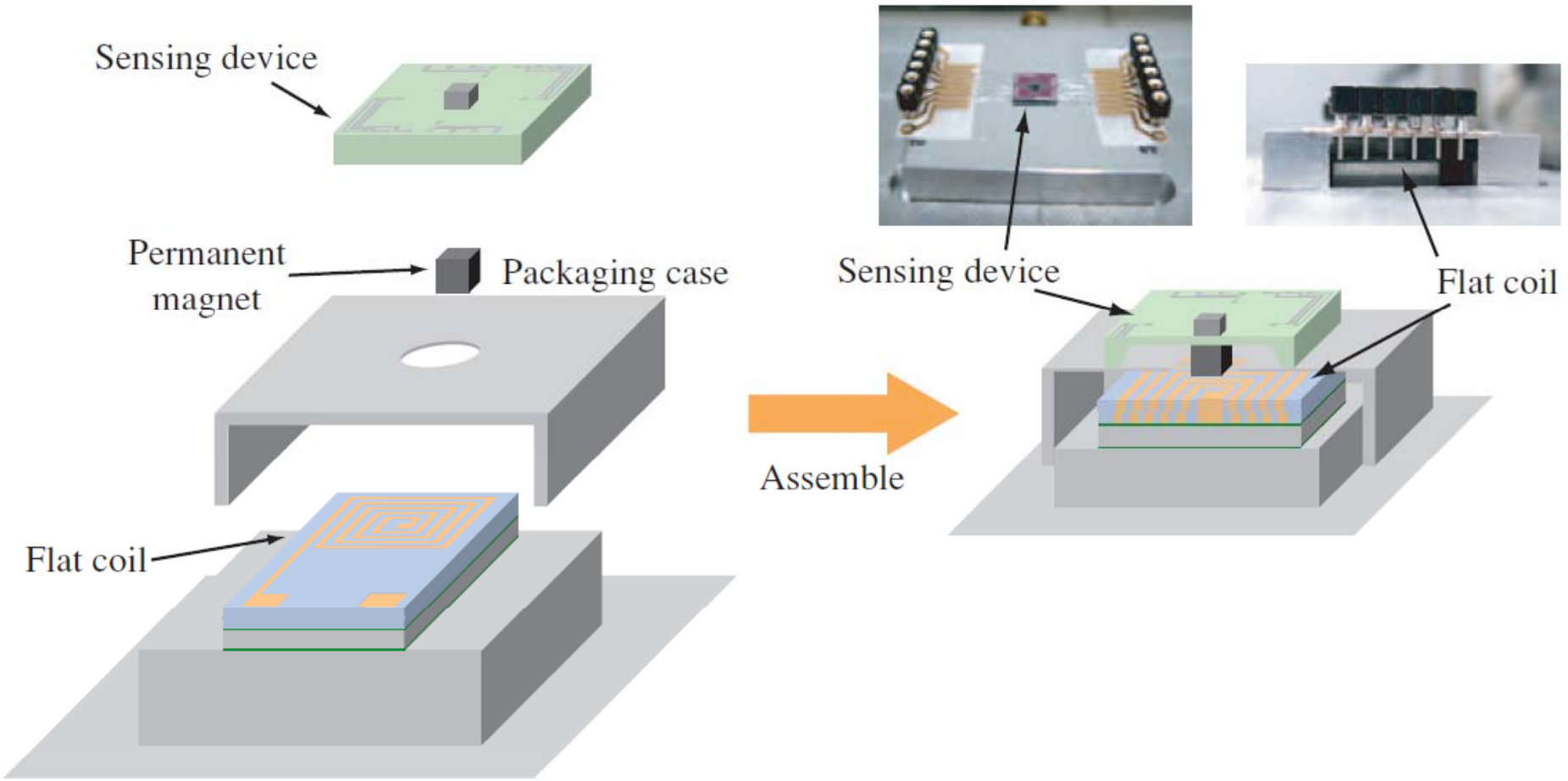

Figure 7. Assembled magnetically driven active tactile sensor.

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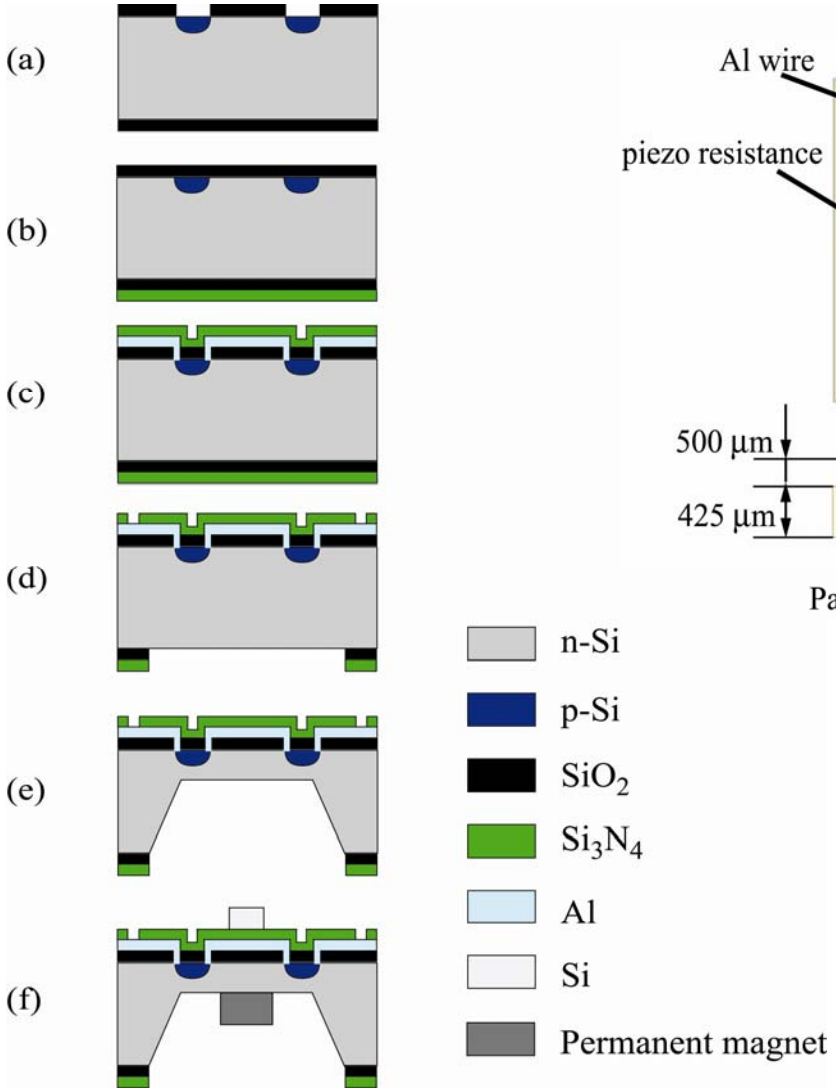
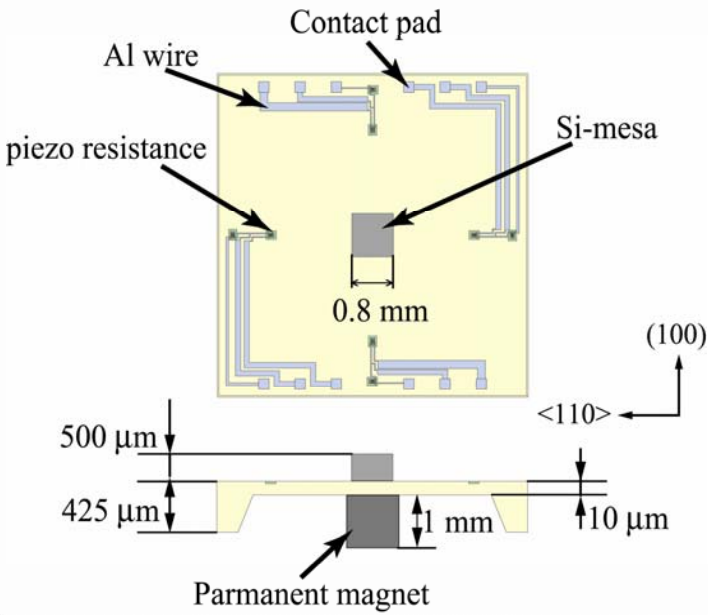
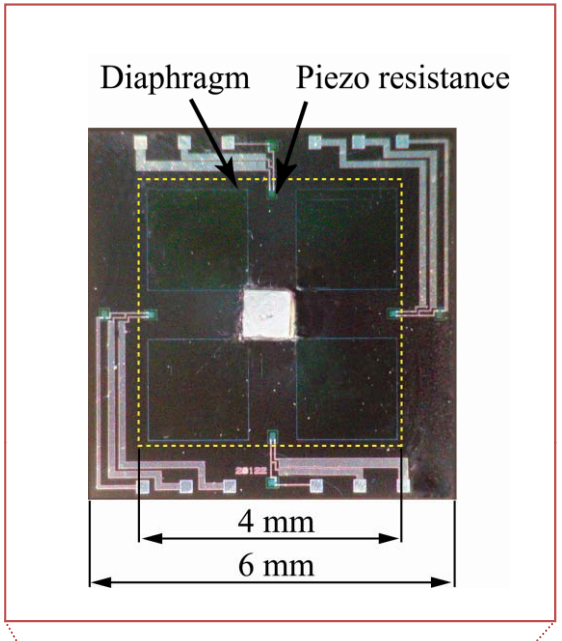
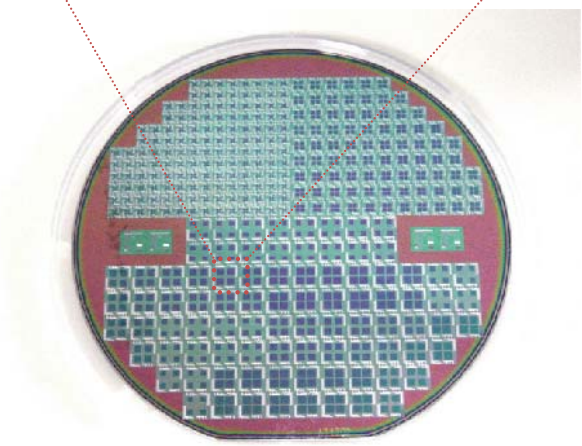
Si active tactile sensor

Fabrication of sensing element





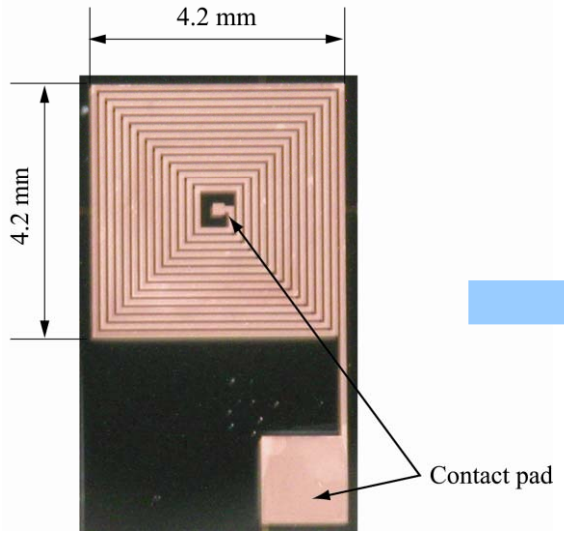




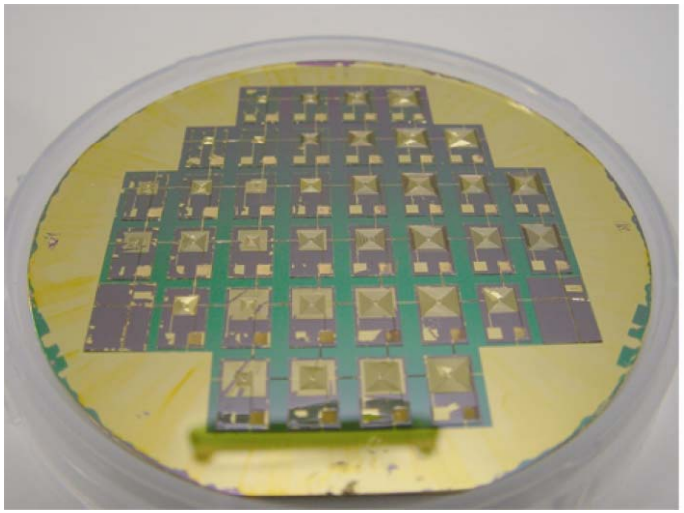
Si active tactile sensor

Fabrication of flat coil for magnetic actuation

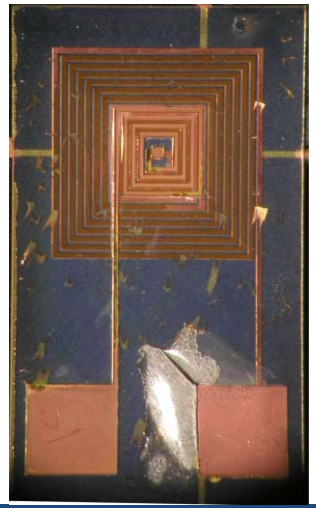
Plated first coil



Coil pattern for second plating

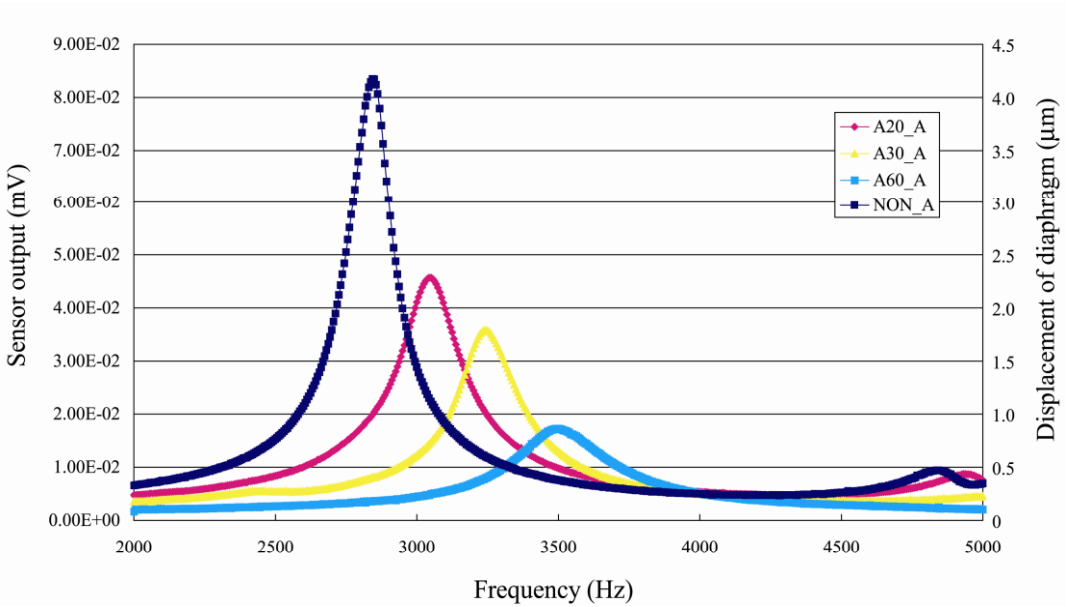


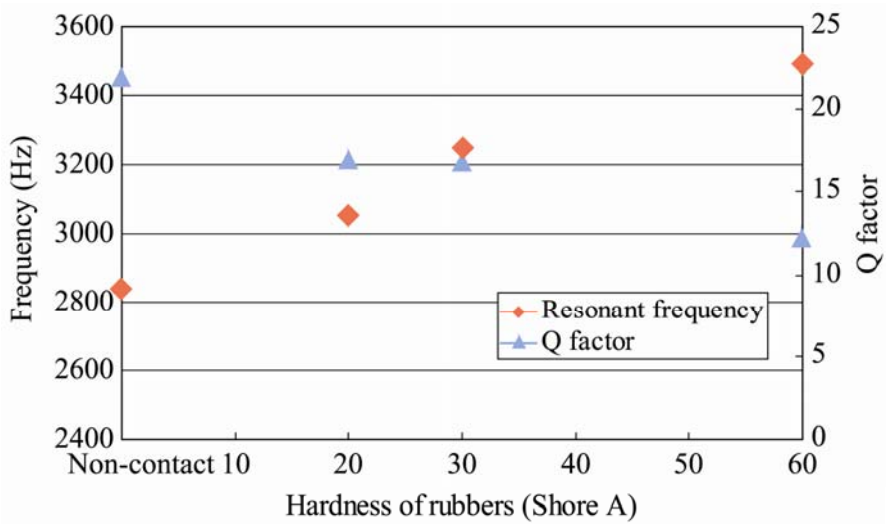
Plated second coil



Si active tactile sensor

Change of resonance with difference of resin materials





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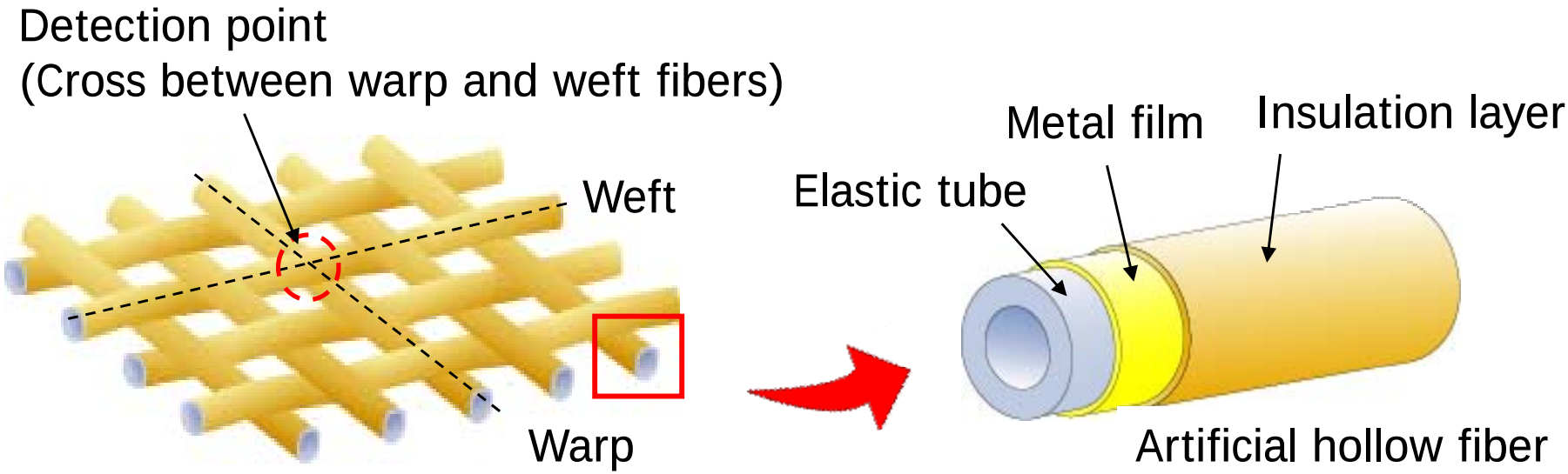
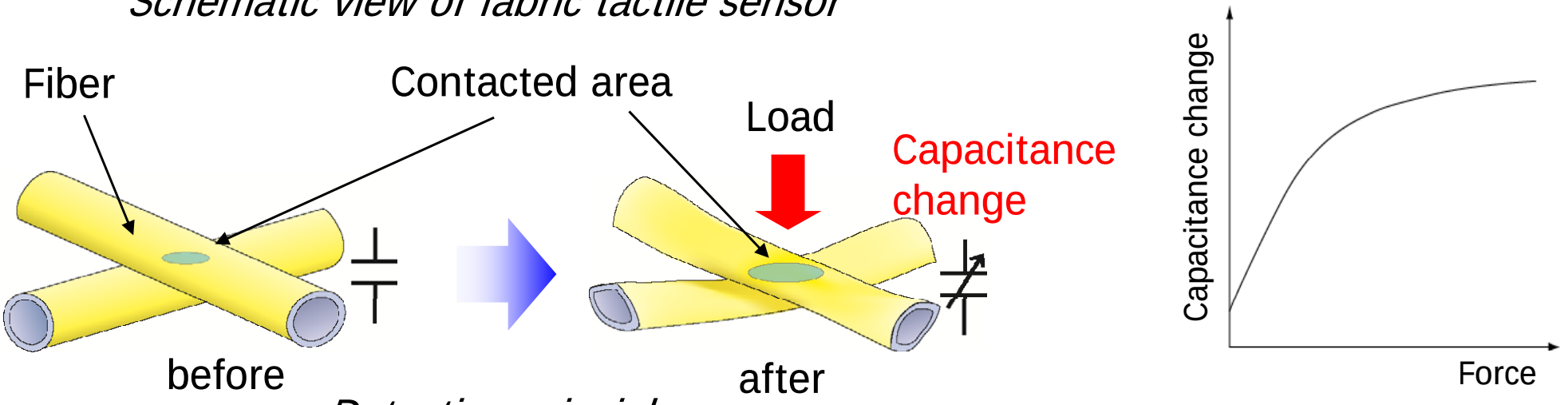
Fabric tactile sensor

Wearable fabric tactile sensor made from hollow fiber



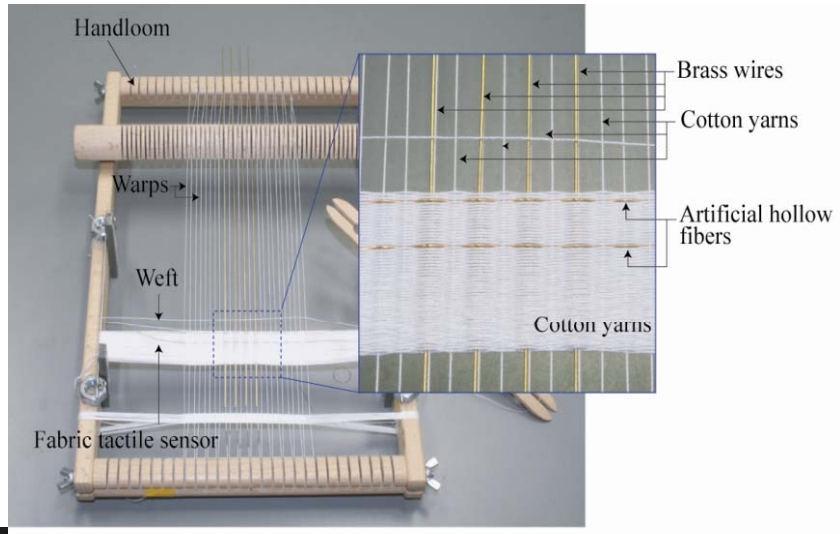
Schematic view of fabric tactile sensor

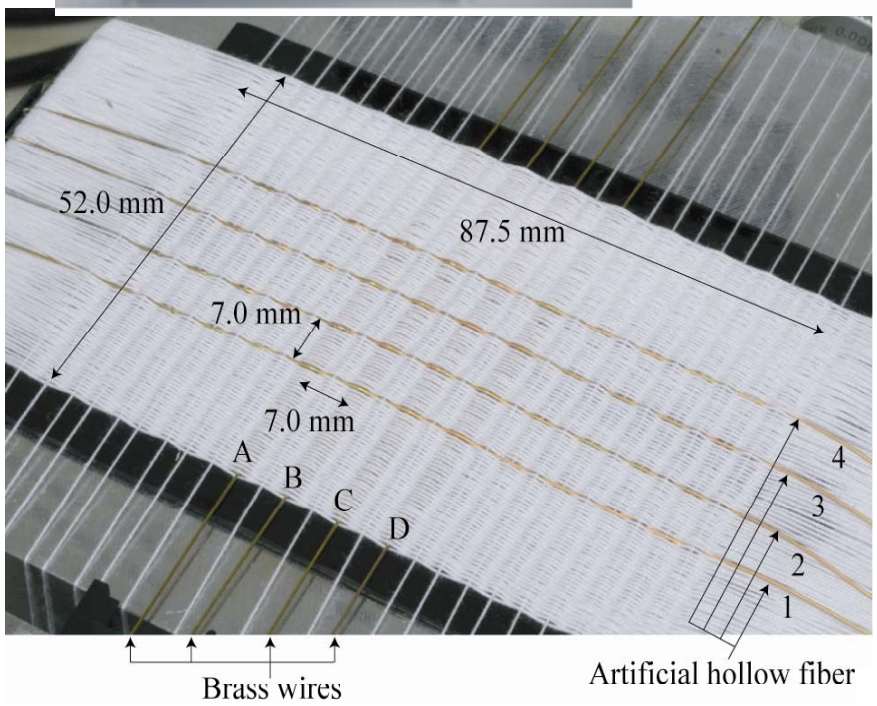


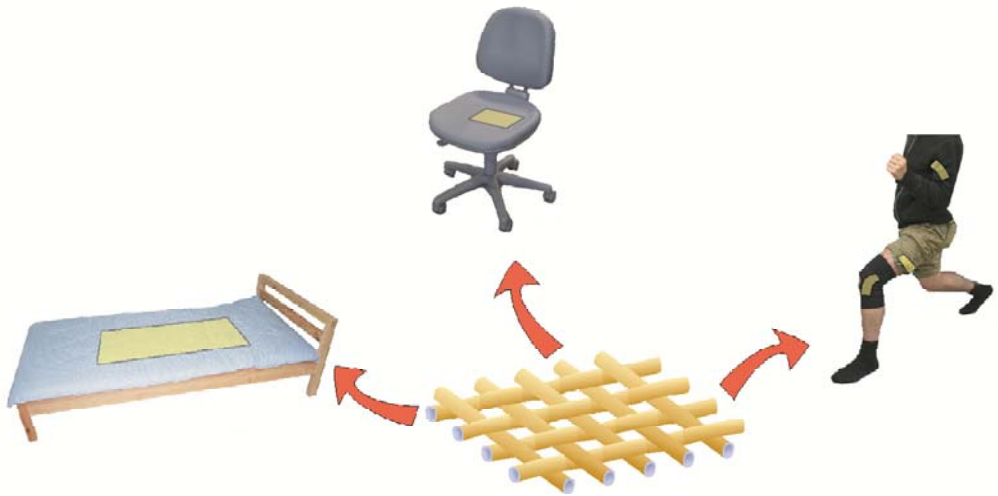
Detection principle

Y. Hasegawa, et al., J. Micromech. Microeng., 18 (2008), 085014(8pp)

Fabric tactile sensor







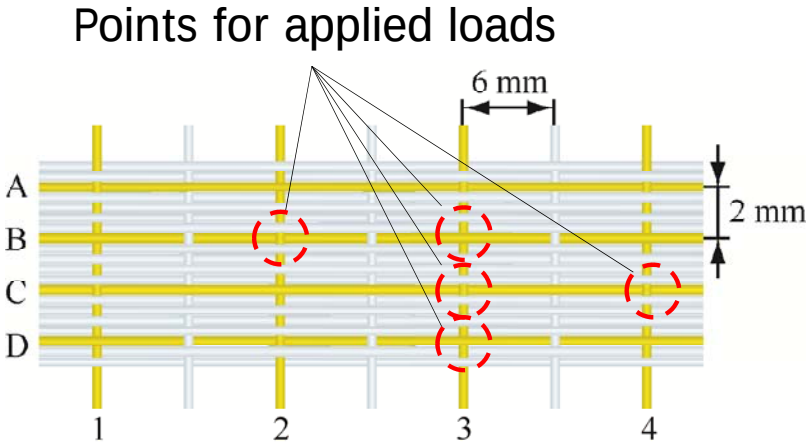
Advantages

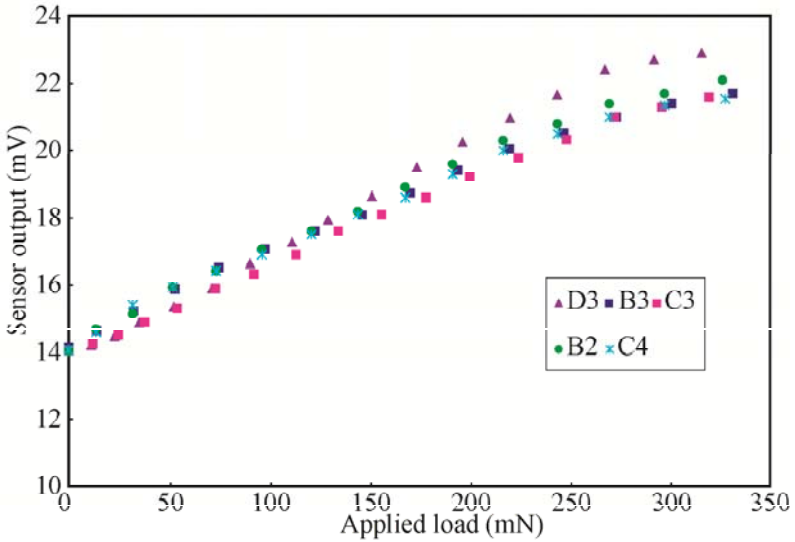
- ✓ Can fit any arbitrary surface
- ✓ Can be easily increased in size
- ✓ Can produce wearable sensor

G. Kita, et al., Micro & Nano Letters, 5 (2010), pp.389-392

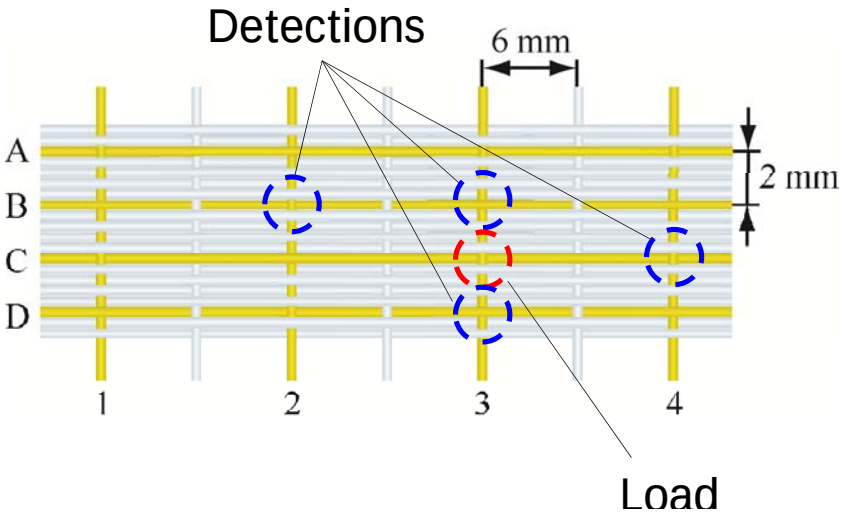
Fabric tactile sensor

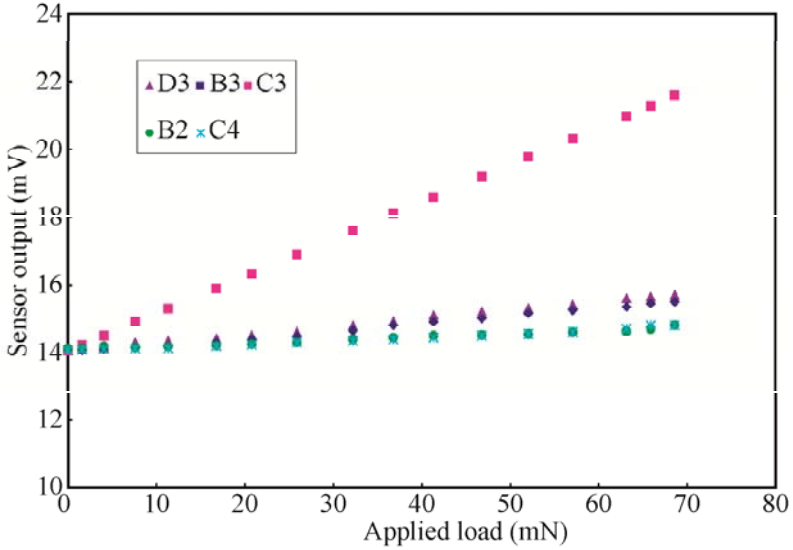
Uniformity





Cross-talk

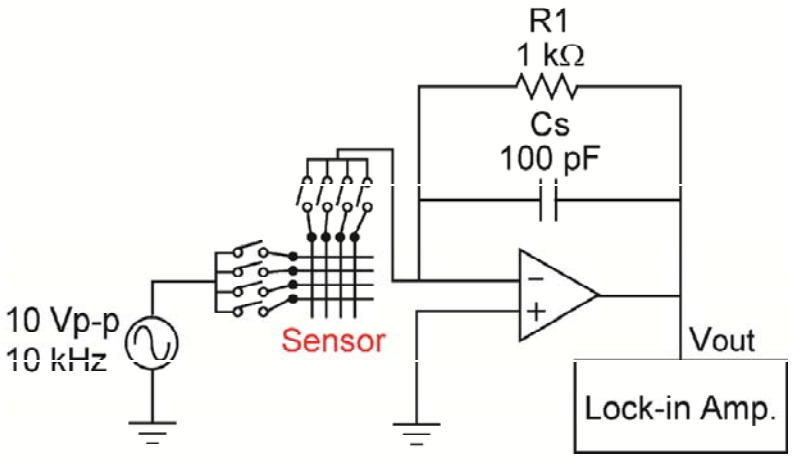




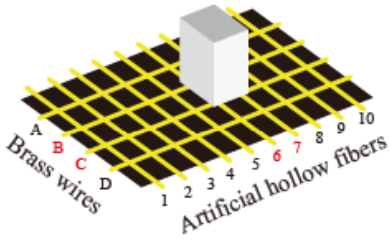
Y. Hasegawa, et al., J. Micromech. Microeng., 18 (2008), 085014(8pp)

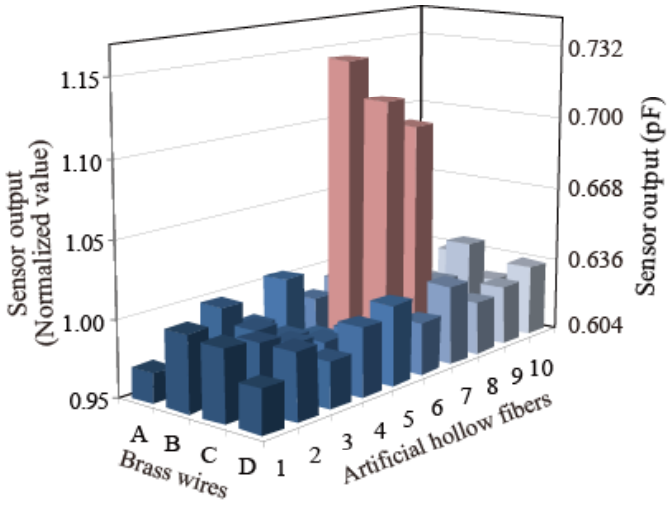
Fabric tactile sensor

Weight detection



CV-circuit





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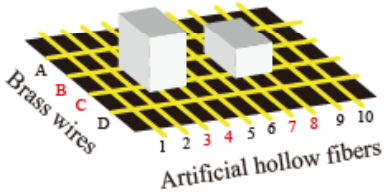
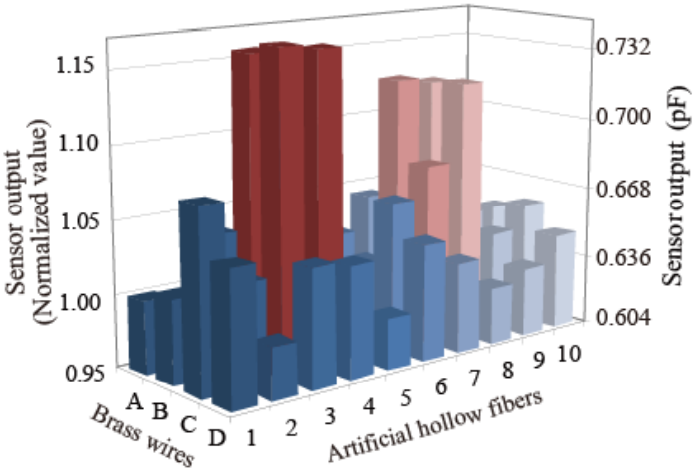




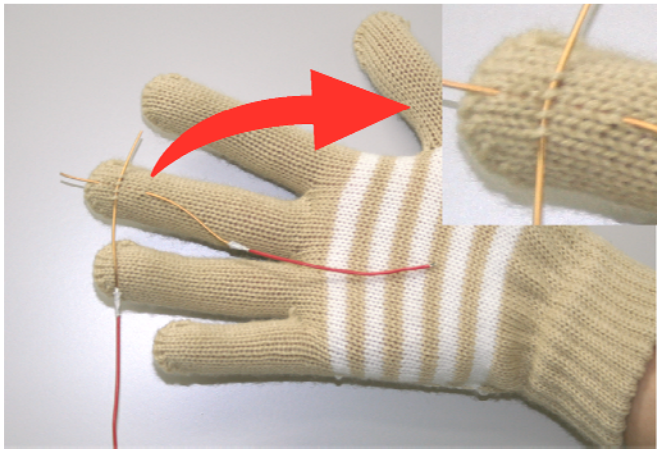
b

G. Kita, et al., Micro & Nano Letters, 5 (2010), pp.389-392

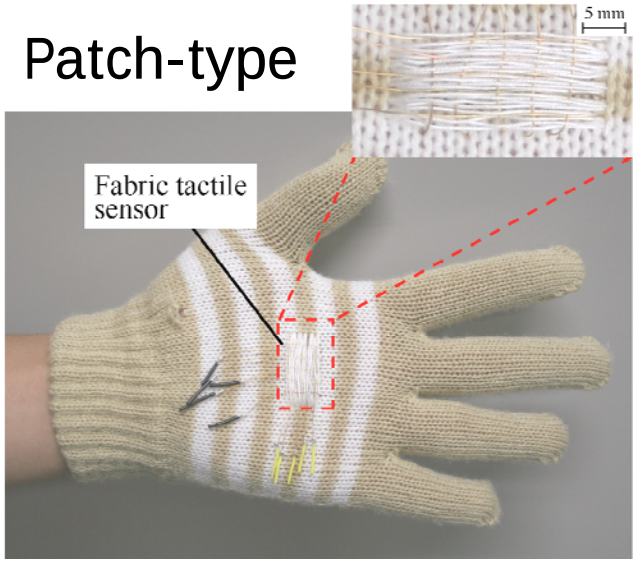
Fabric tactile sensor

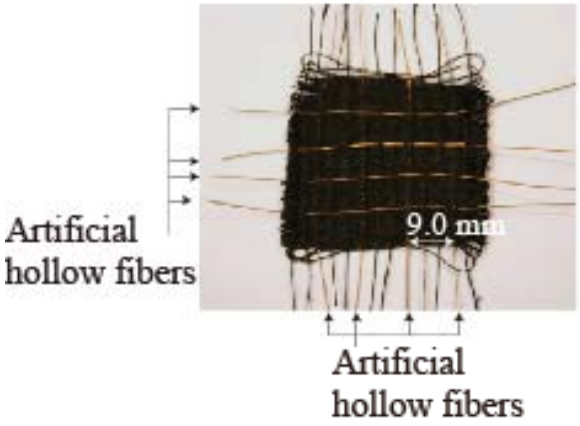
Demonstration

Embedded-type



Patch-type





Fabric sensor patched on knee guard

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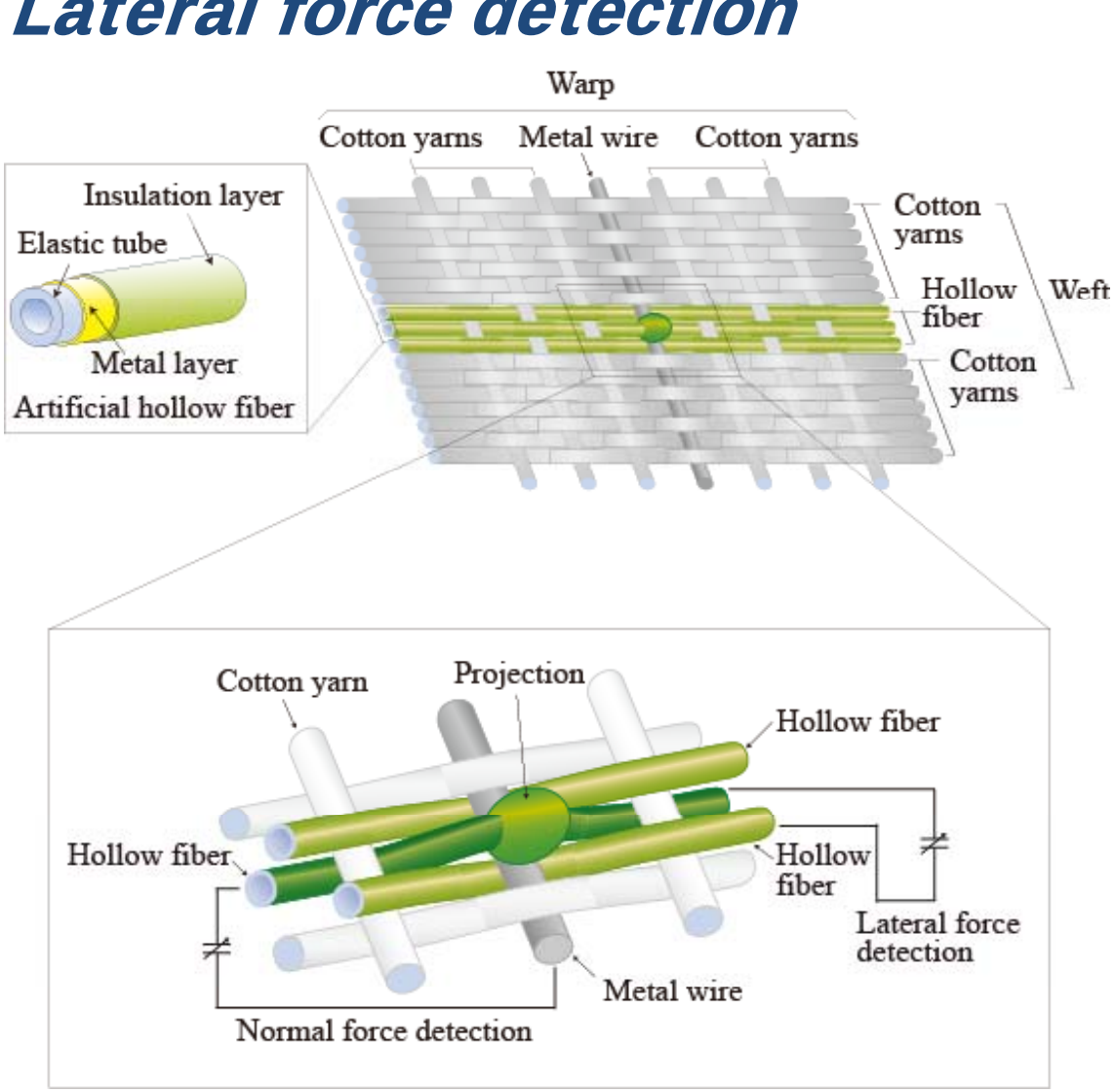
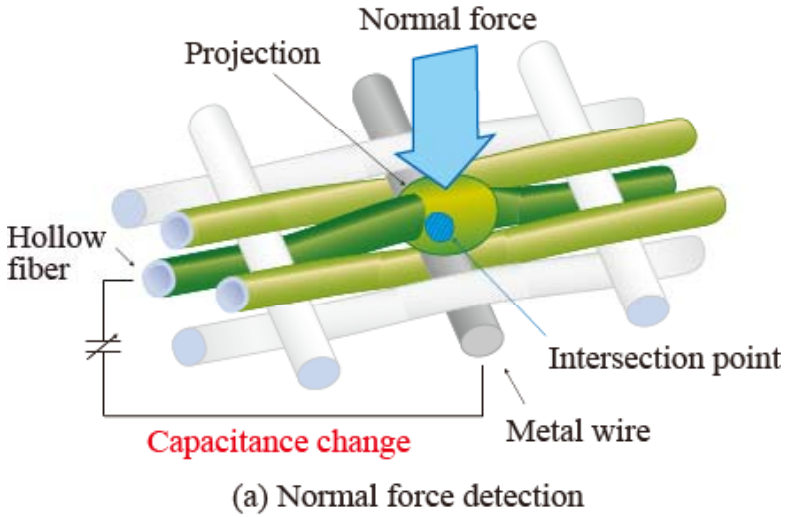
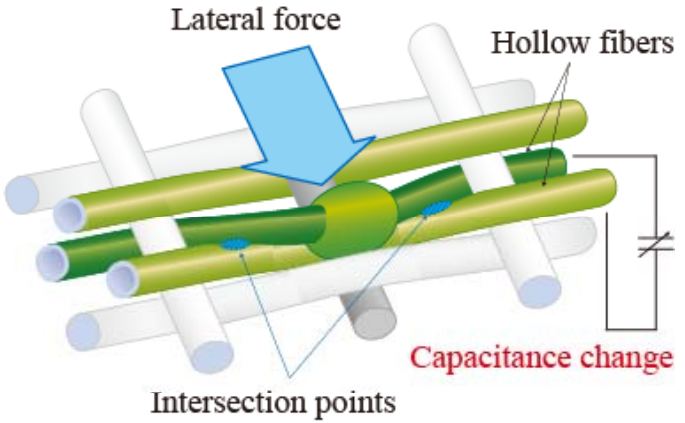
Fabric tactile sensor

Lateral force detection





(a) Normal force detection

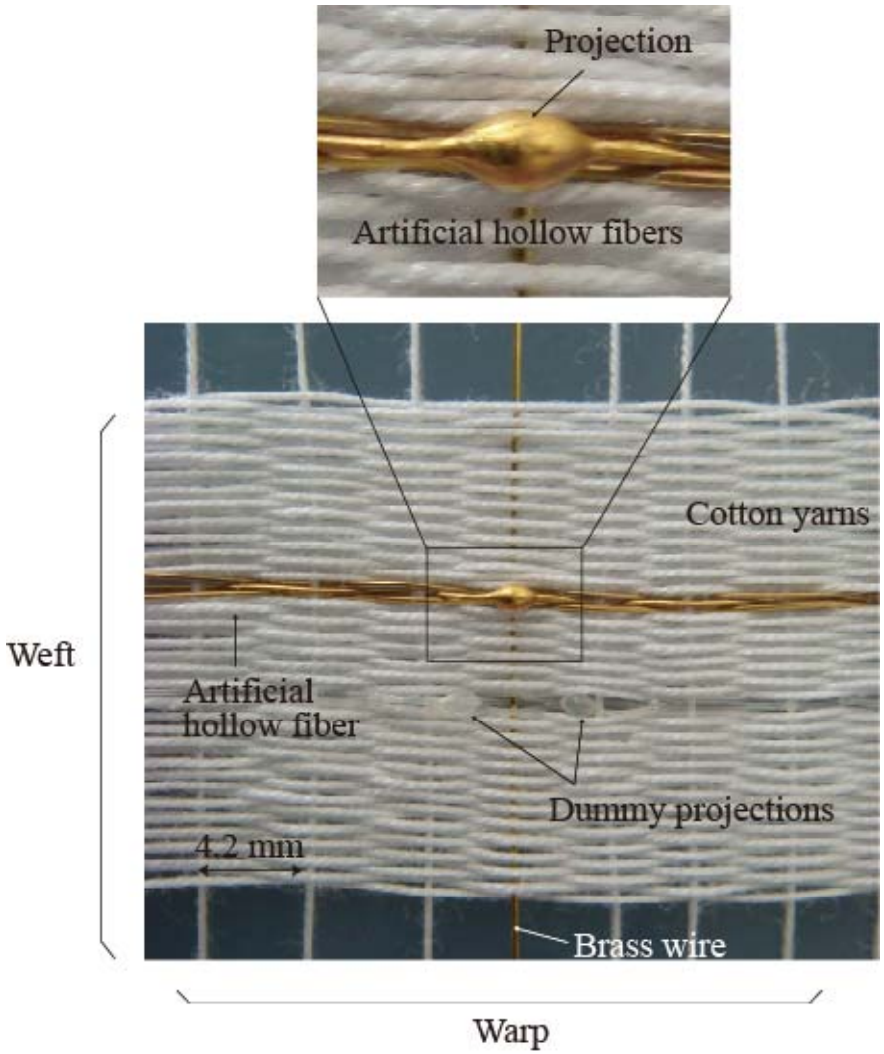


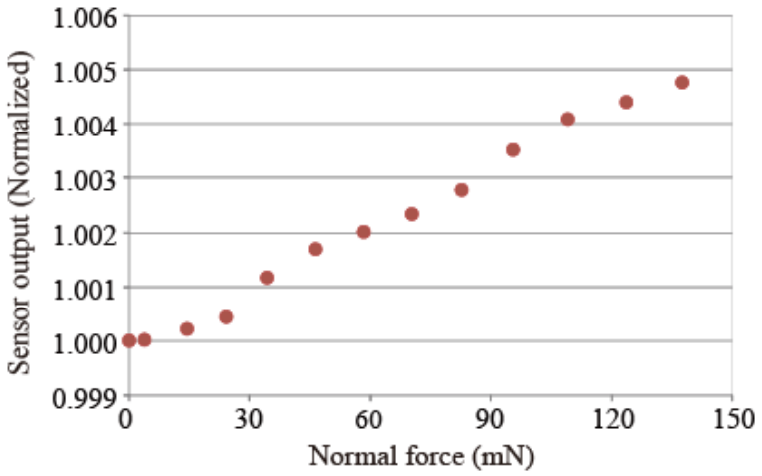
(b) Lateral force detection

G. Kita, et al., Micro & Nano Letters, 5 (2010), pp.211-214

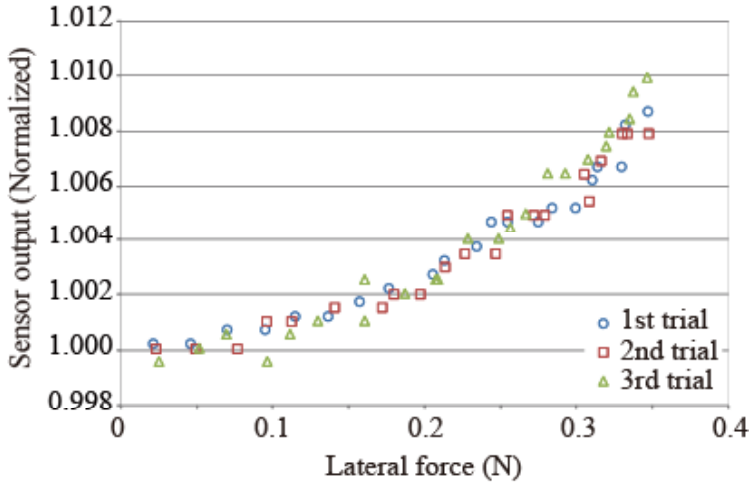
Fabric tactile sensor

Lateral force detection





(a) Normal force vs. sensor output



(b) Lateral force vs. sensor output

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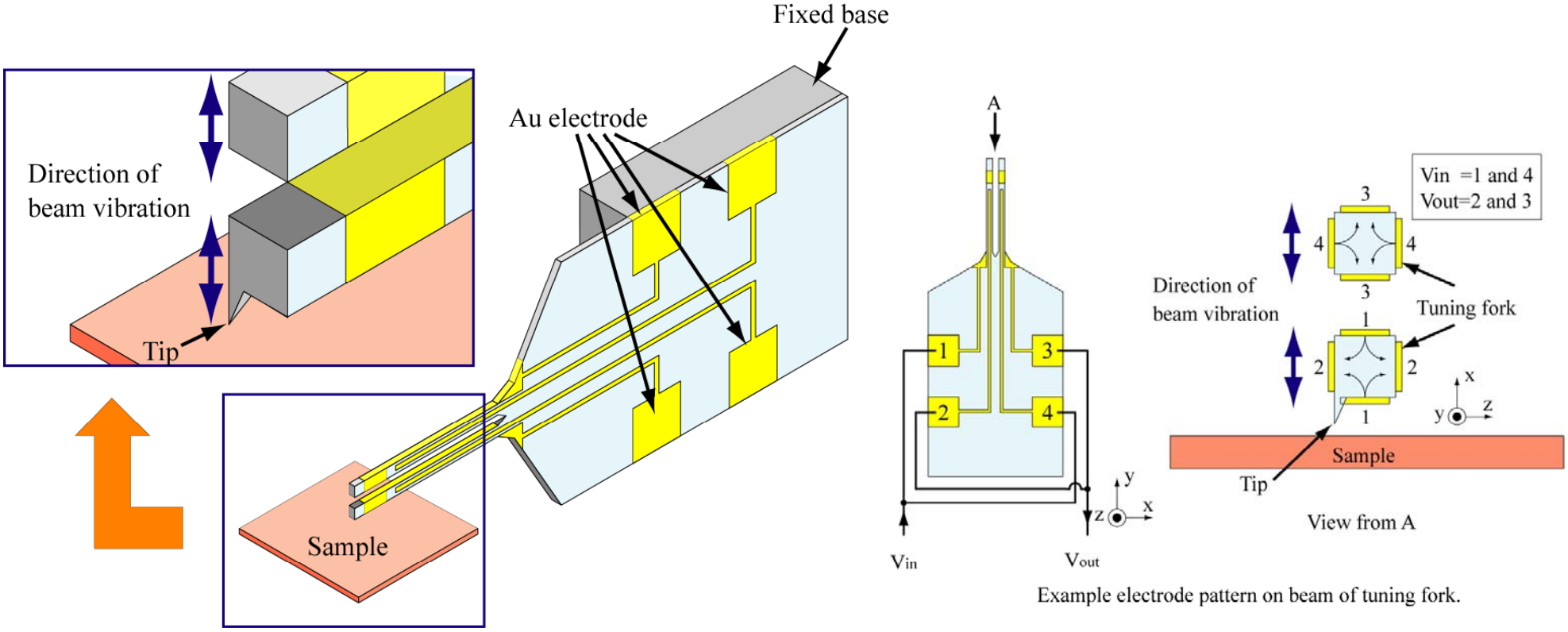
Tuning fork probe for AFM

Self-vibration and -detection AFM Probe by using quartz tuning fork



Example electrode pattern on beam of tuning fork.

Advantages

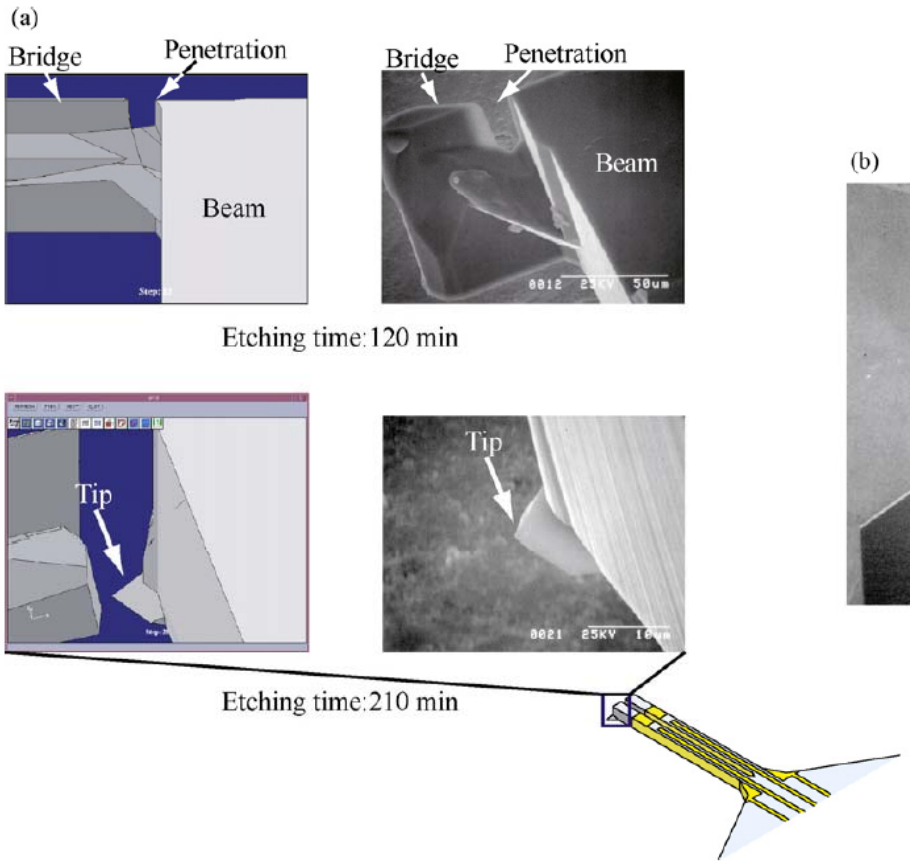
Tuning fork structure→ Increase of detection sensitivity

Quartz material (piezo electric)→ Self-vibration and detection

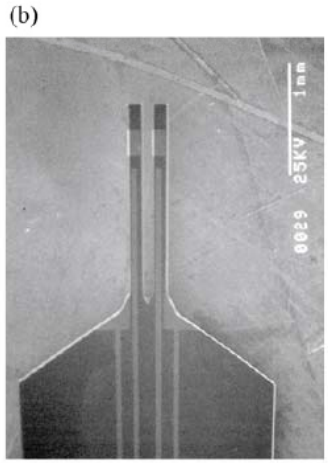
H. Hida, et al., Sensors and Actuators A 148(2008), 311-318

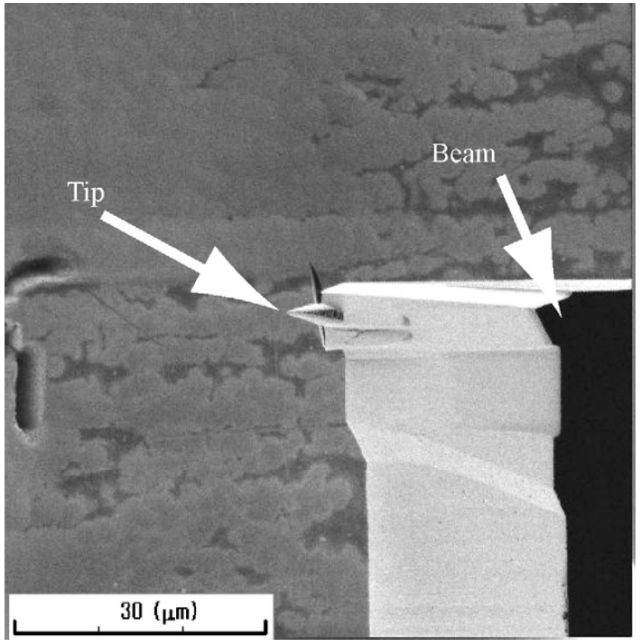
Tuning fork probe for AFM

Fabrication



Anisotropic wet etching





FIB

H. Hida, et al., Sensors and Actuators A 148(2008), 311-318

Tuning fork probe for AFM

Characteristics

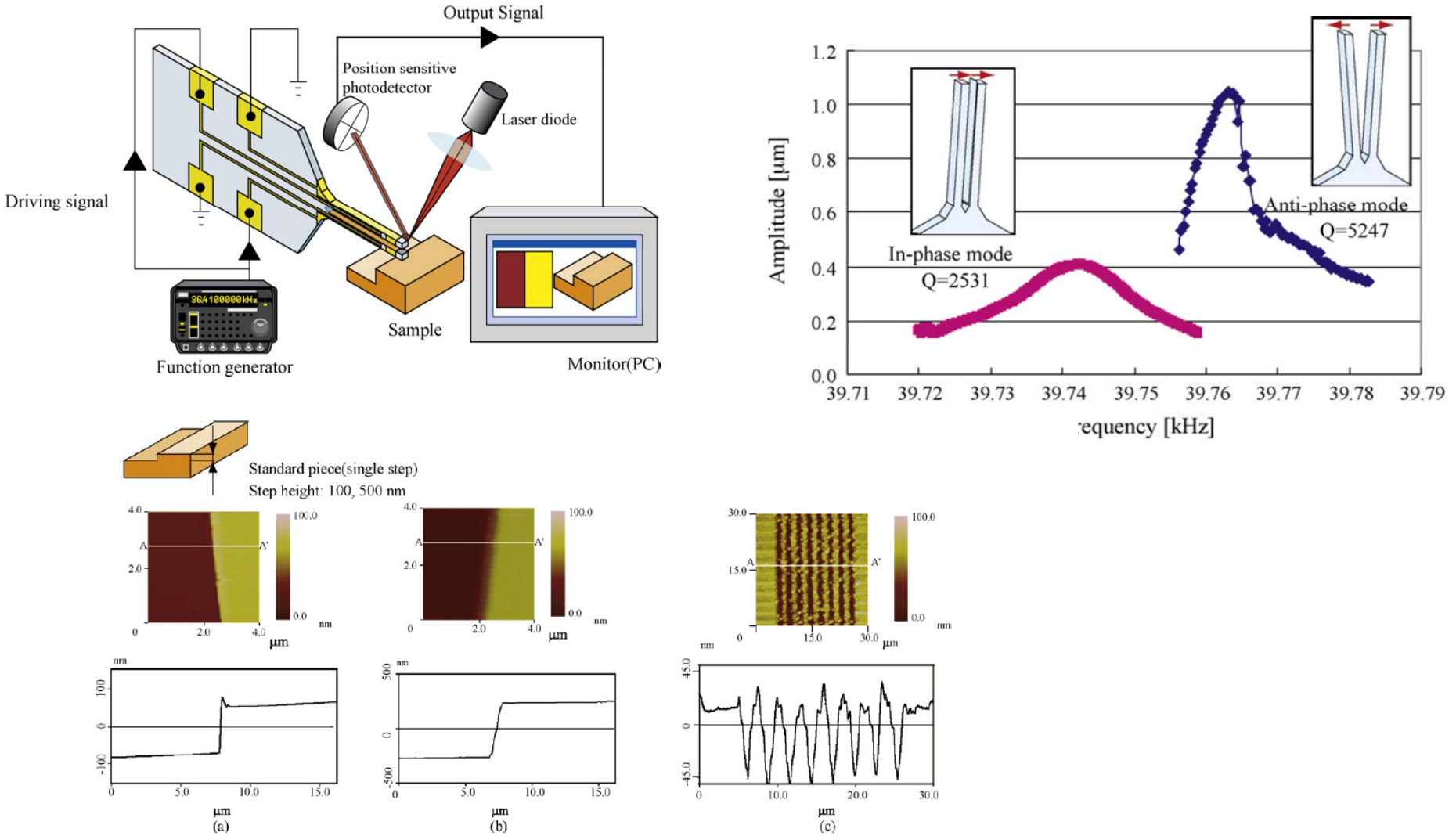
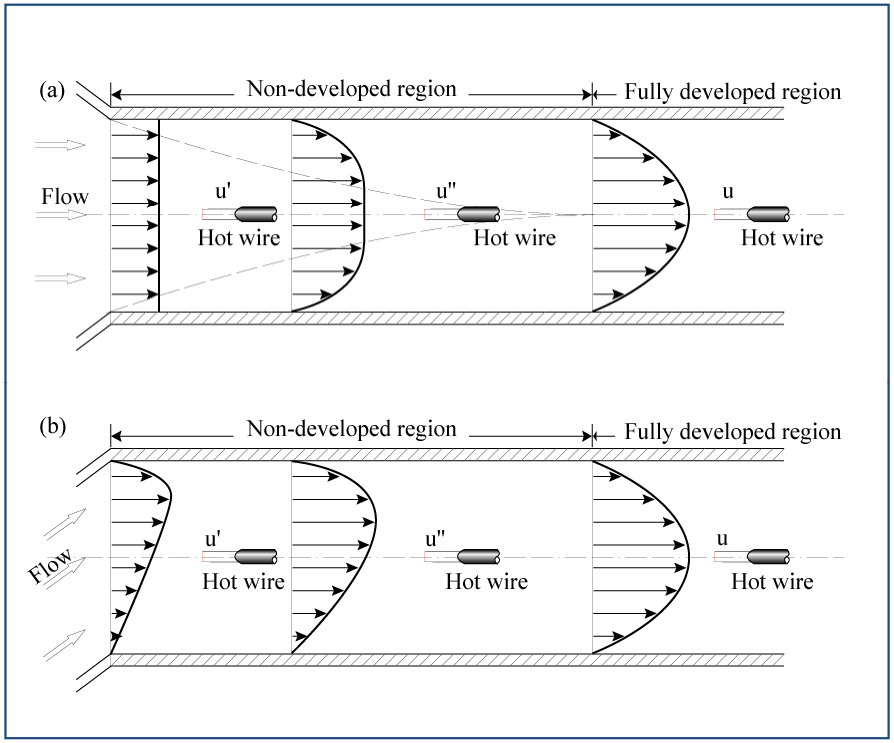


Fig. 14. AFM images obtained using the fabricated tuning-fork and commercial Si cantilevered probe. (a) Single step (height: 100 nm, tuning-fork probe); (b) single step (height: 500 nm, commercial Si probe); and (c) periodic step (cycle: 3 μm, depth: 75 nm).

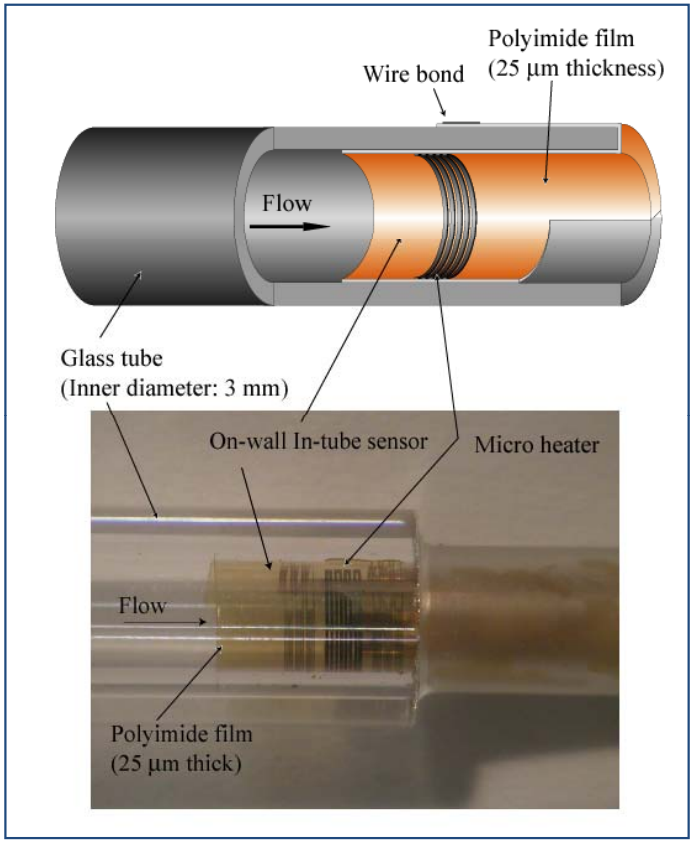
H. Hida, et al., Sensors and Actuators A 148(2008), 311-318

Flow sensor

Conventional flow sensor



On-wall In-tube flow sensor



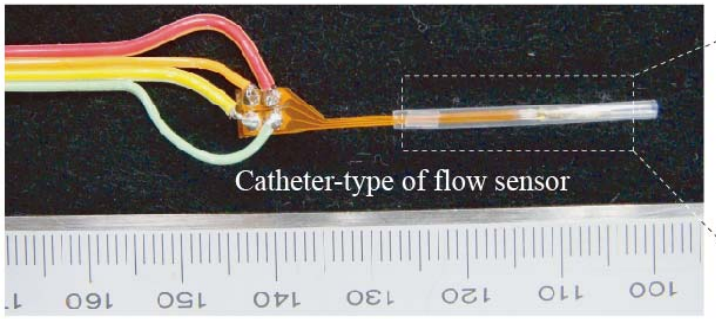
Advantage

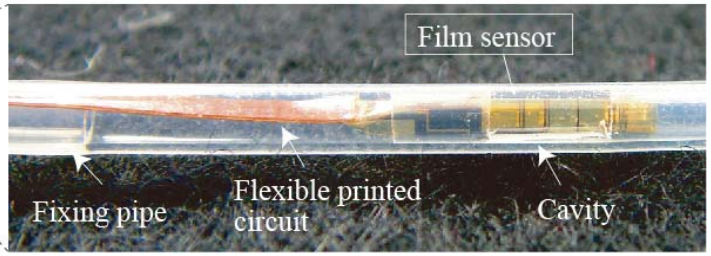
- ✓ Can measure flow rate under non-developed region
- ✓ Can measure flow rate at the end of bent tube

Z. Tan, et al., J. Micromech. Microeng., 17 (2007) 679-686

Flow sensor

Micro-flow sensor for medical applications
Collaboration with Prof. Kawabe

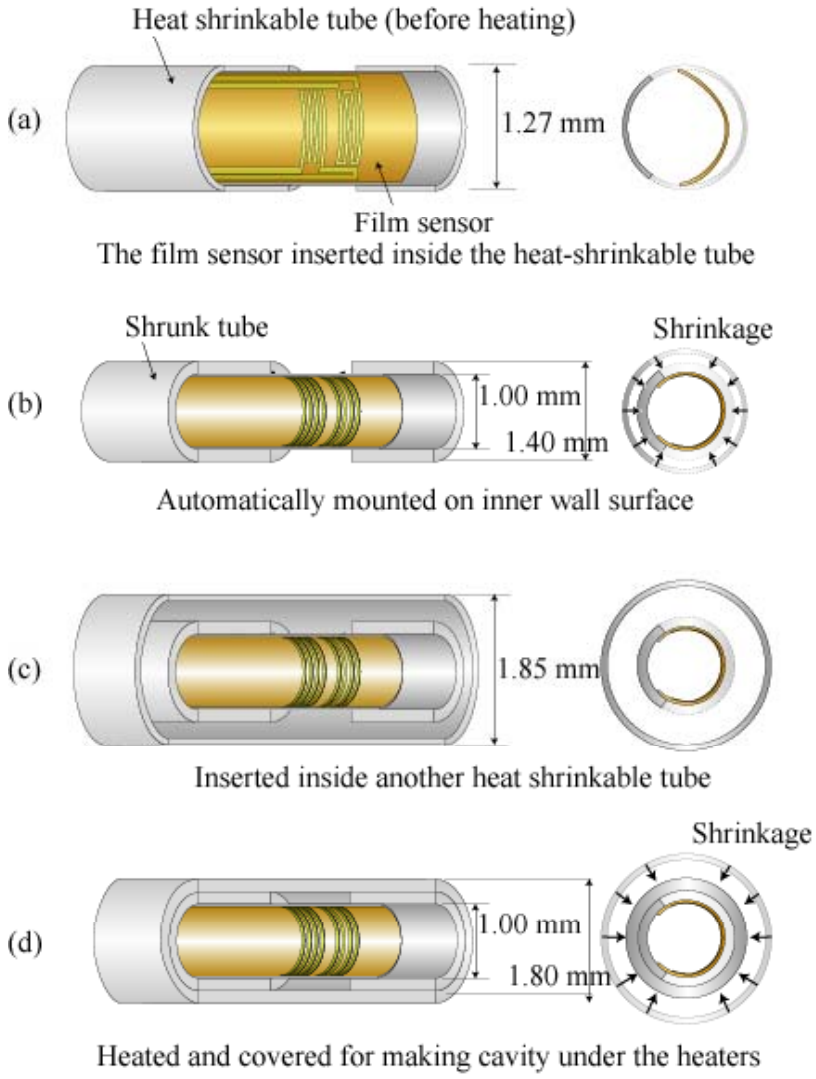


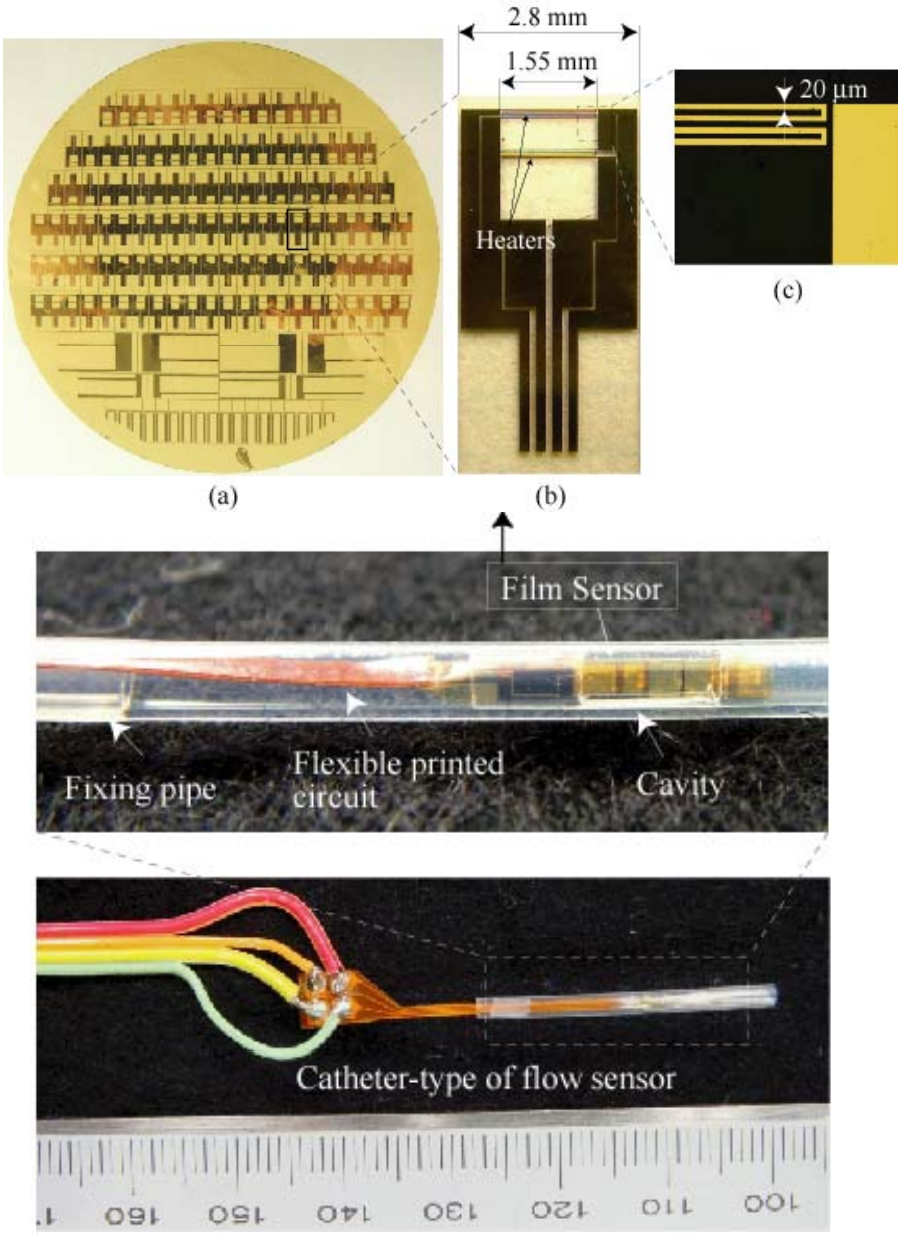


M. Shikida et al., J. Micromech. Microeng., 19 (2009) 105027 (9pp)

Flow sensor

Fabrication process

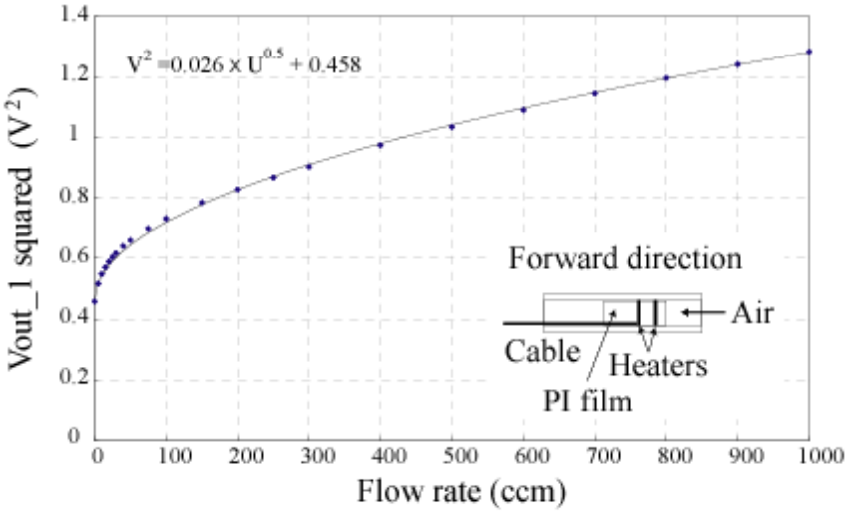


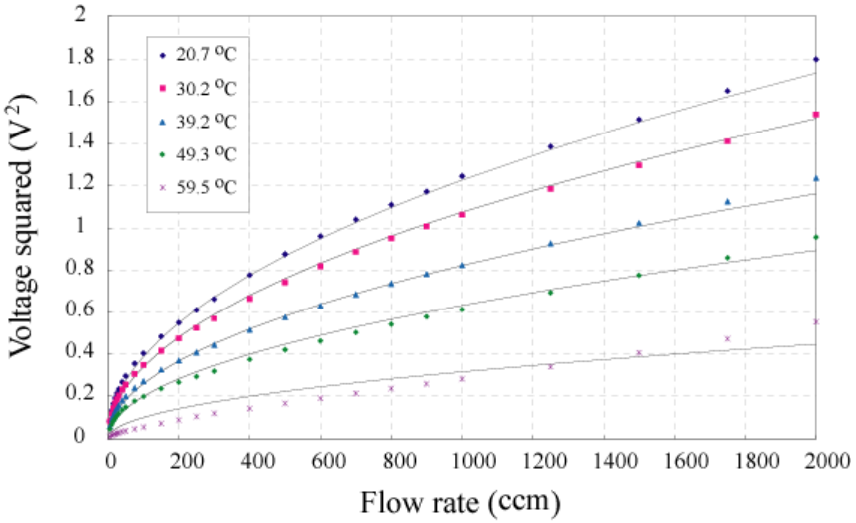


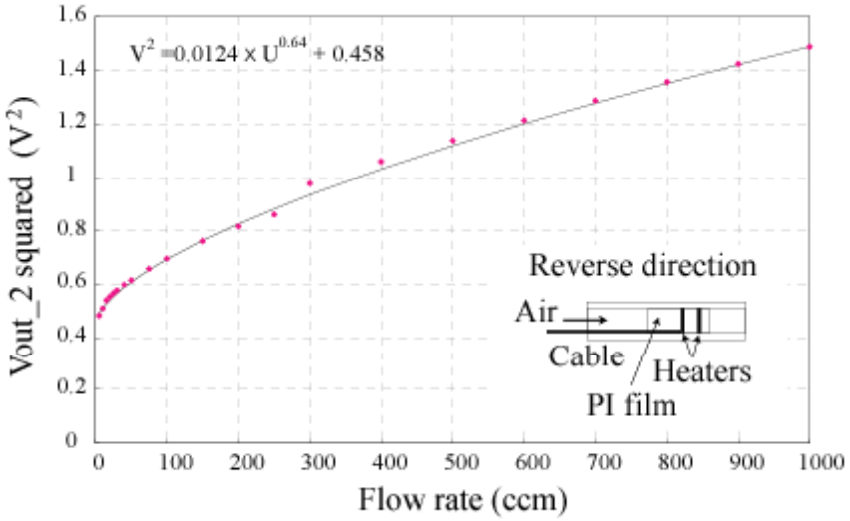
M. Shikida et al., J. Micromech. Microeng., 19 (2009) 105027 (9pp)

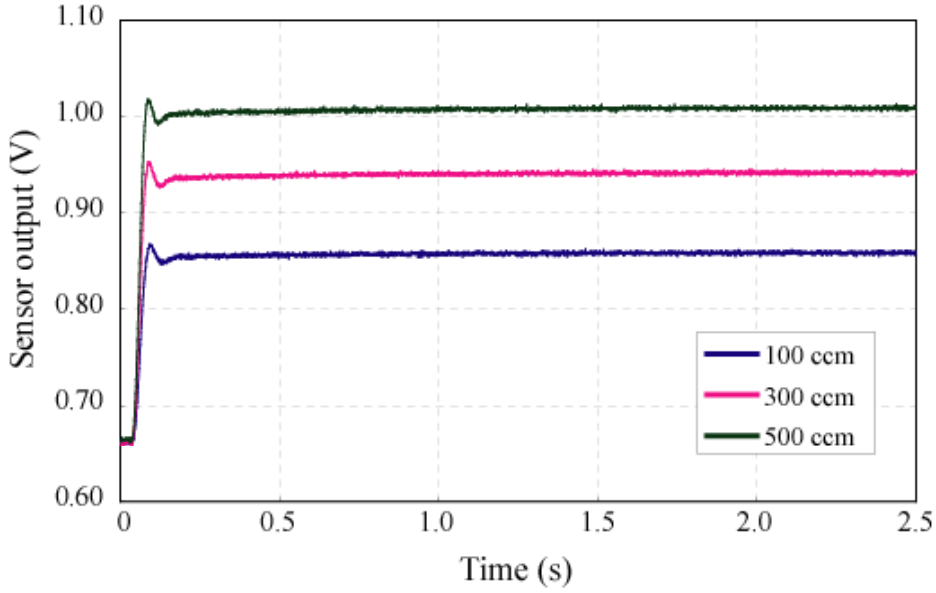
Flow sensor

Characteristics





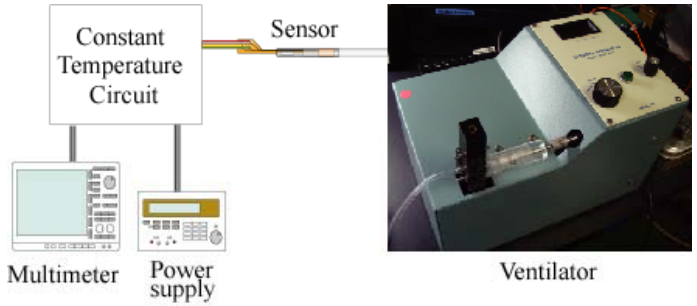




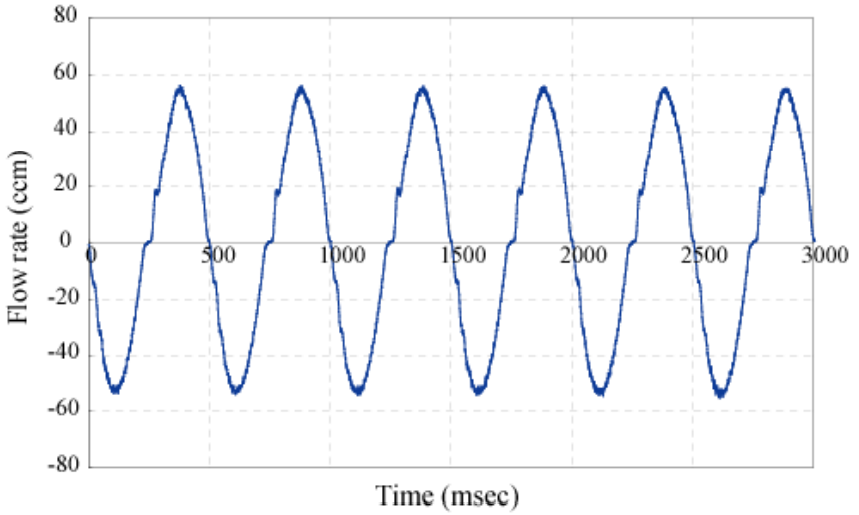
M. Shikida et al., J. Micromech. Microeng., 19 (2009) 105027 (9pp)

Flow sensor

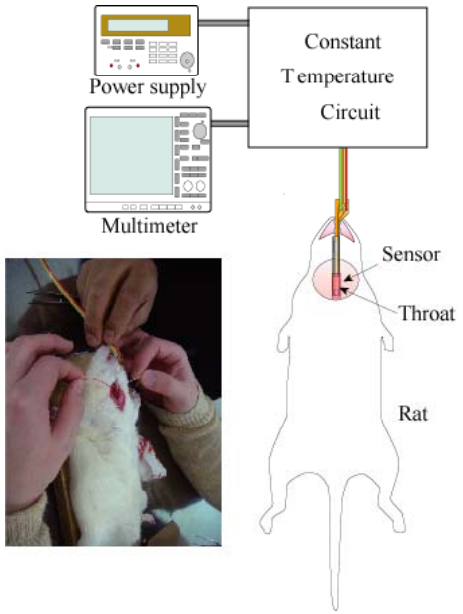
Characteristics

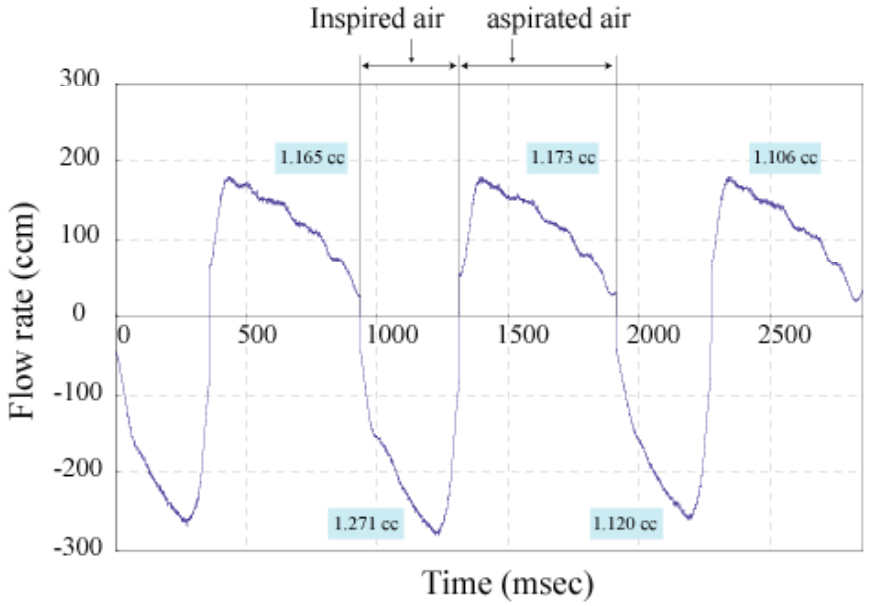


(a) Experimental setup



(b) Sensor output





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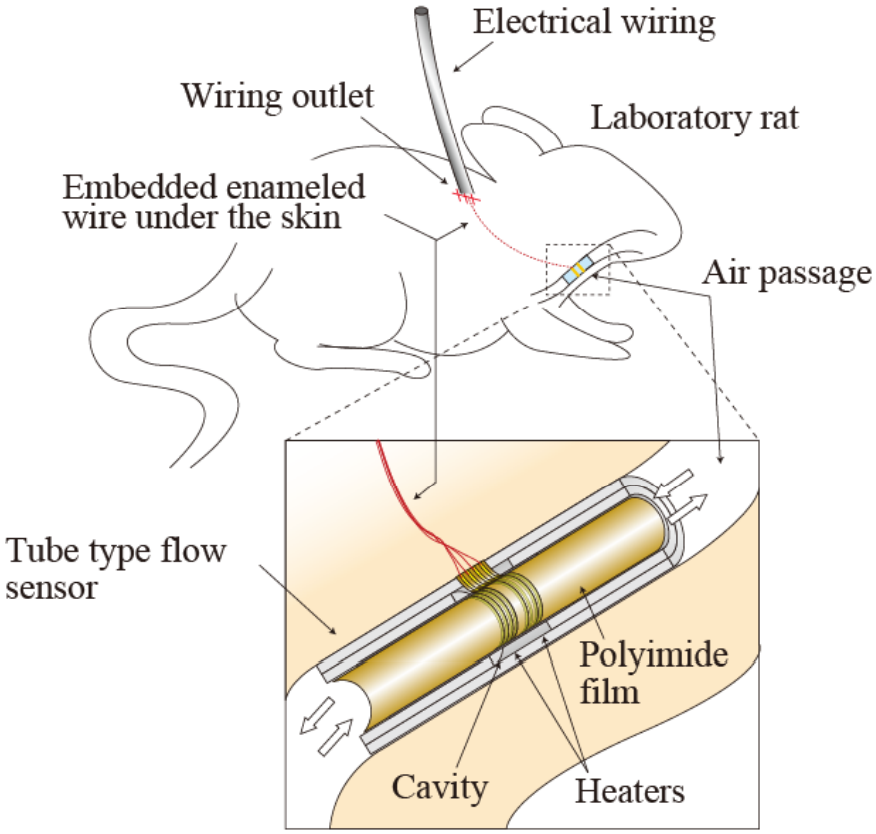
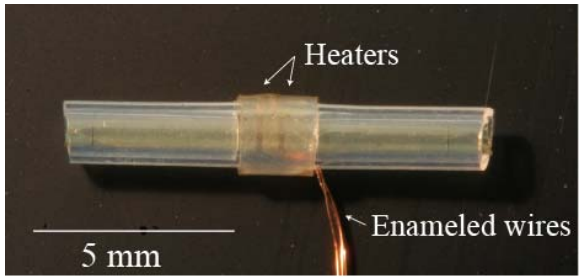
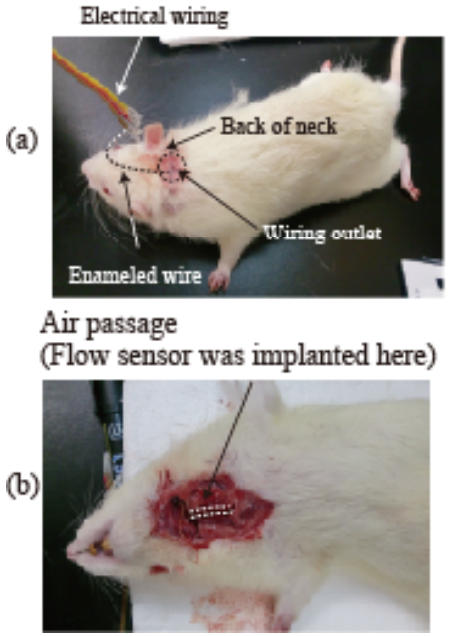
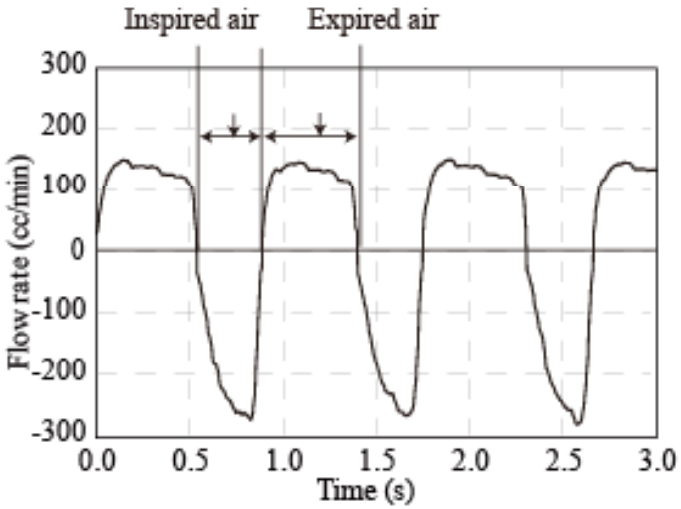
Flow sensor

Implanted measurement







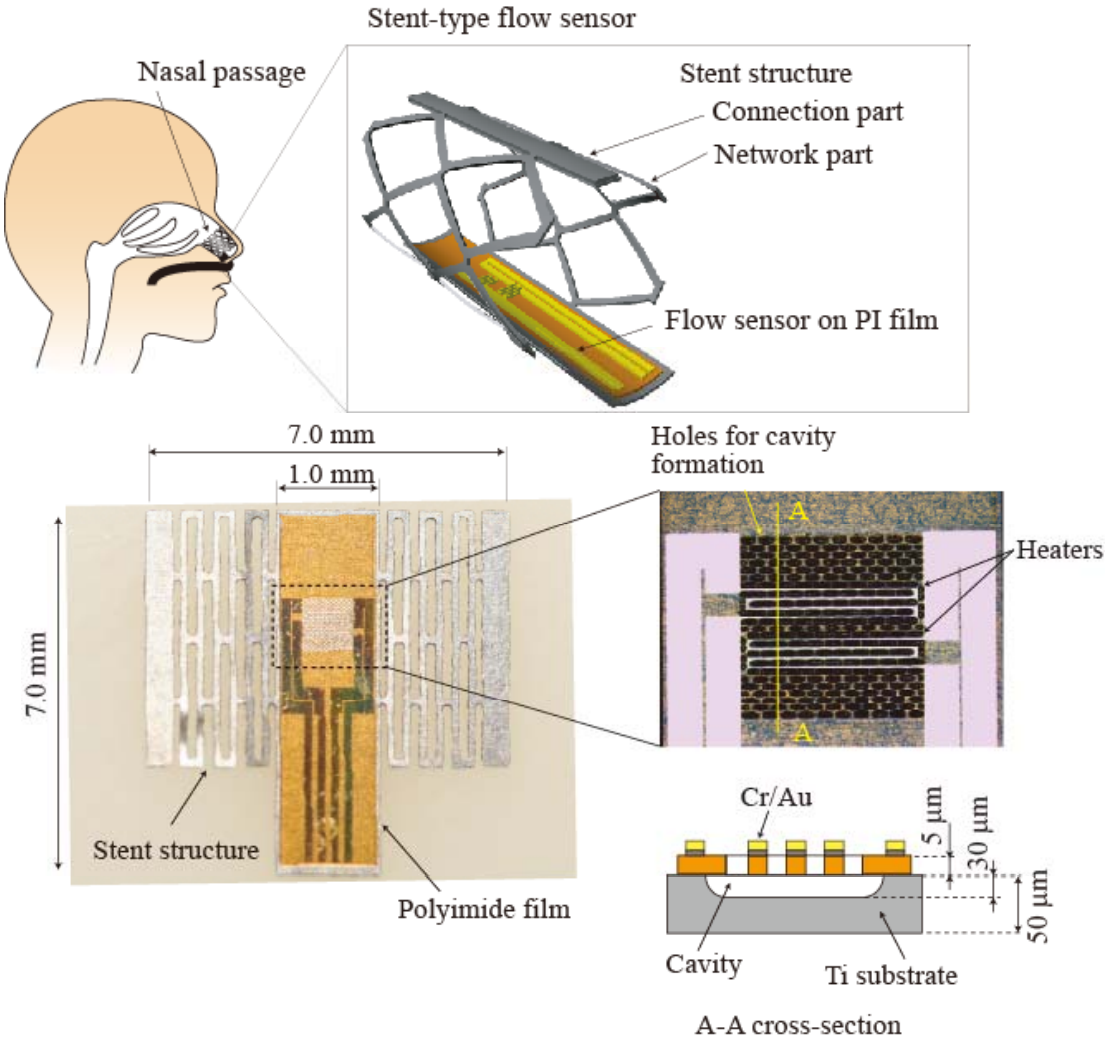


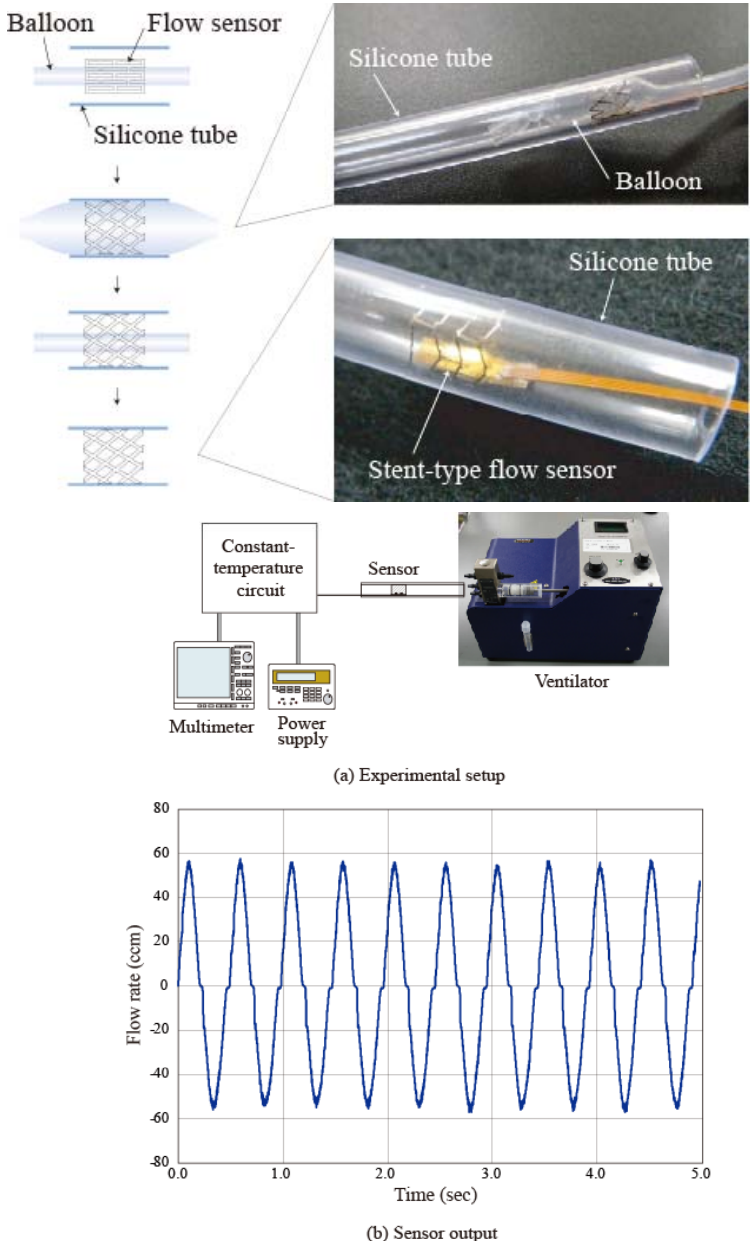
(c) Inspired- and expired-air waveform measured by developed flow sensor

M. Shikida et al., J. Micromech. Microeng., 20 (2010) 125030 (11pp)

Flow sensor

Stent-type





M. Shikida et al., J. Micromech. Microeng., 20 (2010) 055029 (8pp)

Summary

- ✓History
- ✓Micro-sensor in MEMS
- ✓Fascinations of Micro-sensor
- ✓Examples
  - ✓Tactile sensor
  - ✓Tuning fork probe for AFM
  - ✓Flow sensor for medical applications