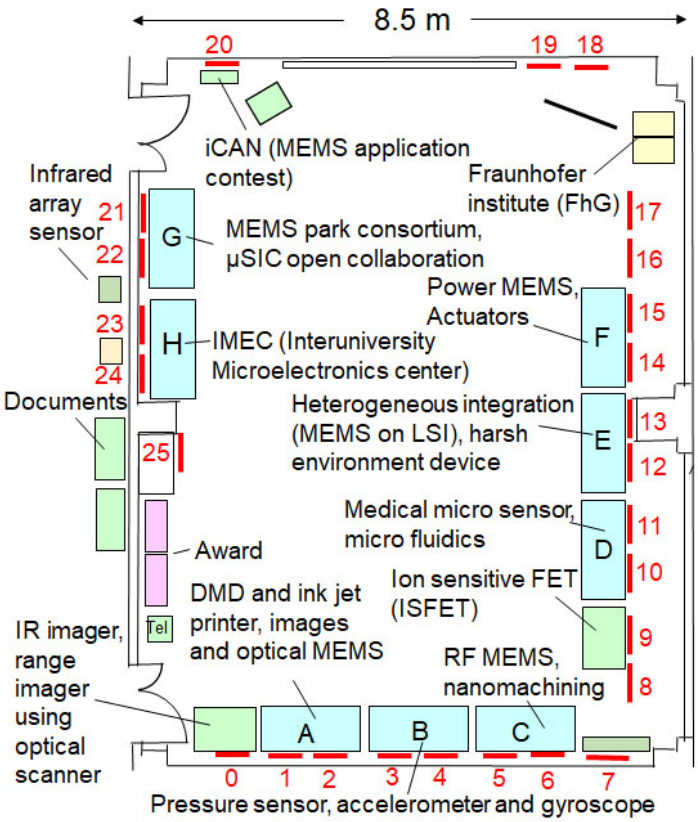
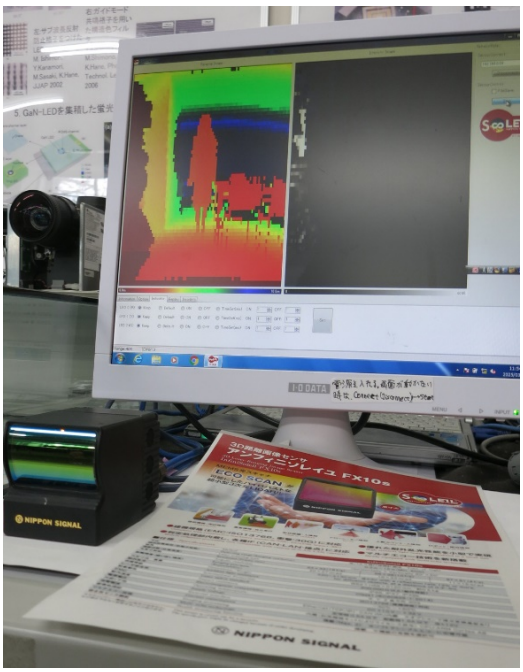
0 Sendai MEMS showroom



Poster

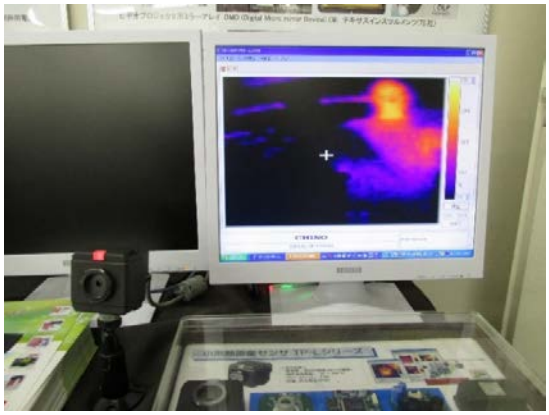
0 Sendai MEMS showroom
1 What is MEMS?
2 Optical MEMS and Micro/Nano-Optics (Hane, Kanamori)
3 RF MEMS
4 Mechanical sensors
5 Micromachining and packaging
6 Nanomachining and ultra-high sensitive sensing
7 PZT thin films for MEMS
8 Sensor network (Kuwano)
9 Micro sensors for medical monitoring
10 Minimally invasive medical devices and health care devices (Y. Haga)
11 Tactile sensor network
12 Heterogeneous integration of MEMS on LSI by transfer
13 Development of massive parallel EB exposure system
14 Power MEMS
15 MEMS for production, testing, environment and safety
16 Examples of MEMS industrialization by Tohoku Univ.-industry collaboration
17 Advantest, High-Frequency, Low power consumption MEMS Relay
18 Fraunhofer institute (Germany)
19 Fraunhofer project center in Tohoku University
20 ICAN (International contest of innovAtioN)
21 MEMS park consortium
22 Open collaboration and µSIC
23 IMEC (Interuniversity Microelectronics Center) (Belgium)
24 Start-up companies related to µSIC
25 Activities of Nishizawa center space users



Range imager (Nippon signal) using 2D optical scanner

Open ceremony (2012/5/26)

Fraunhofer institute (Poster 19 & Case G)



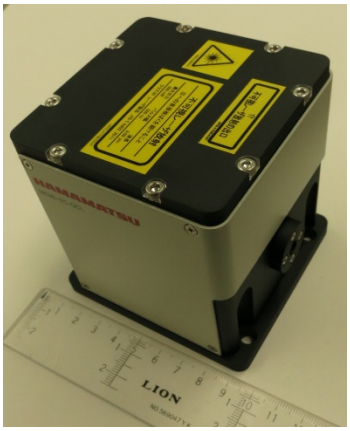
Range imager(Nippon signal), Thermal imager(Chino)

Mirror array (DMD) (TI) (Wafer, projector)

ISFET honored “Denki no ishizue” by IEEJ in 2017

Awards (K.Totsu, M.Moriyama) preent from TSMC etc.

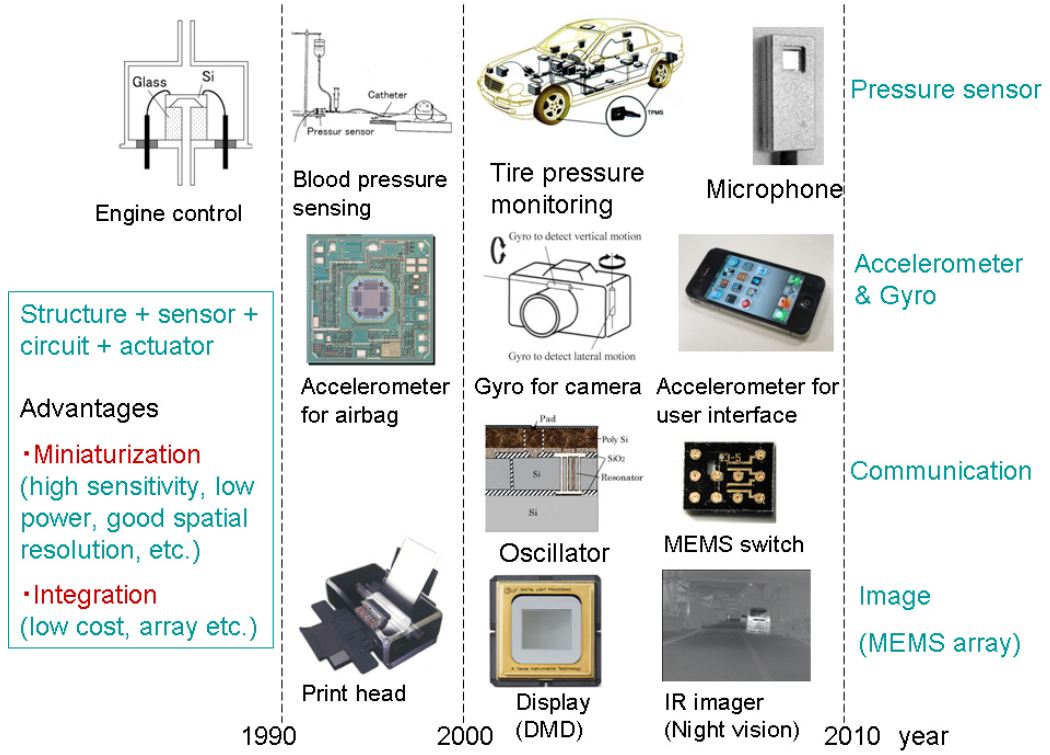
iCAN (International Contest of InnovAtion)



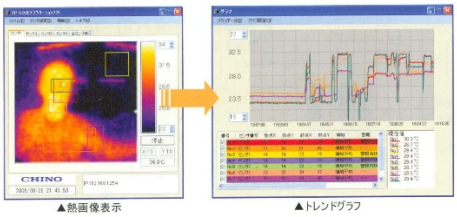
Quantum pulse cascade laser (Hamamatsu photonics)

(commercialization based on Hands-on access fabrication facility)

1 What is MEMS ?

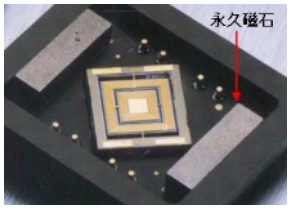


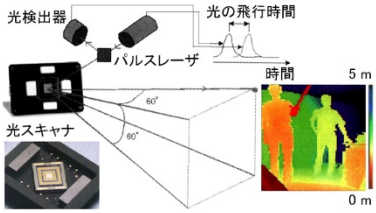
Trend of MEMS (Micro Electro Mechanical Systems) product



Compact thermal image sensor (Infrared imager) (Chino Ltd.)

Infrared imager for smartphone (FLIR (USA))





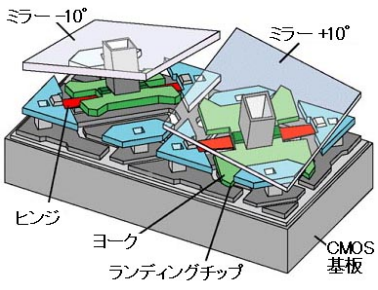
2 axes optical scanner (Nppon signal, Tohoku Univ.)

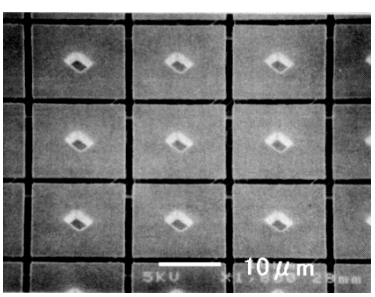
Range imager (Nippon signal)

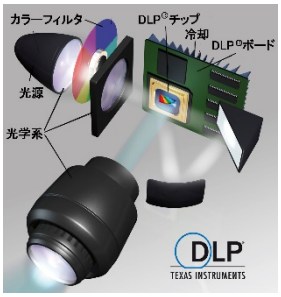
Application to platform door (JR Ebisu station)

Application to LIDAR

(N.Asada et.al., IEEE Trans. on Magnetics, 30 (1994) 4647) (T. Ishida, Technical Report in Japan Signal, 33 (2009) 41)





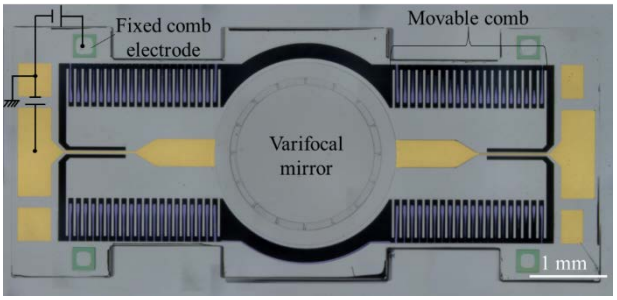


Mirror array for video projector DMD (Digital Micro mirror Device) (Texas Instruments (USA))

2 Optical MEMS and Micro/Nano-Optics (Hane, Kanamori)

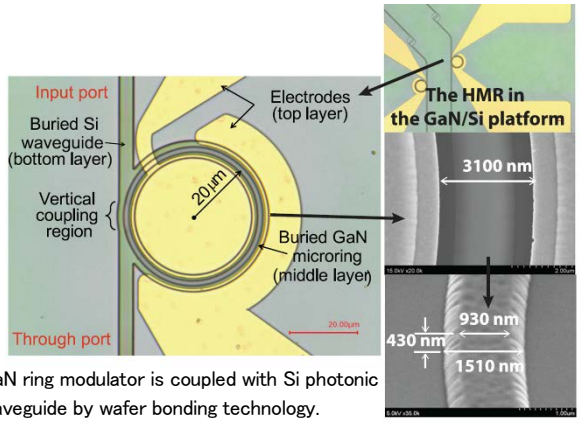
Optical MEMS and Micro/Nano-Optics are studied in this laboratory.
1. Micro-mirrors for display, telecommunication and sensing, 2. Optical micro-sensors for mechatronics and spectroscopy, 3. Silicon nanowire waveguide devices for telecommunication, 4. GaN-MEMS, 5. Nano-structured optics and meta-materials (color filter, antireflection, plasmonics)

Scanner with Varifocul Micro-Mirror



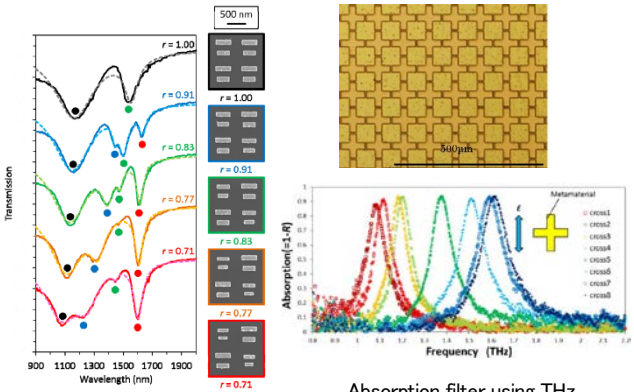
Focus and scan angle are varied. The changes are monitored by Si piezoresistive sensors. K. Nakazawa, J. J. MEMS,26,(2017)440

GaN ring modulator coupled to Si waveguide



GaN ring modulator is coupled with Si photonic waveguide by wafer bonding technology. Lightwave is modulated by the refractive index change of electro-optic effect of GaN. B. Thubthimthong, Appl. Phys. Lett. 122 (2018) 071102

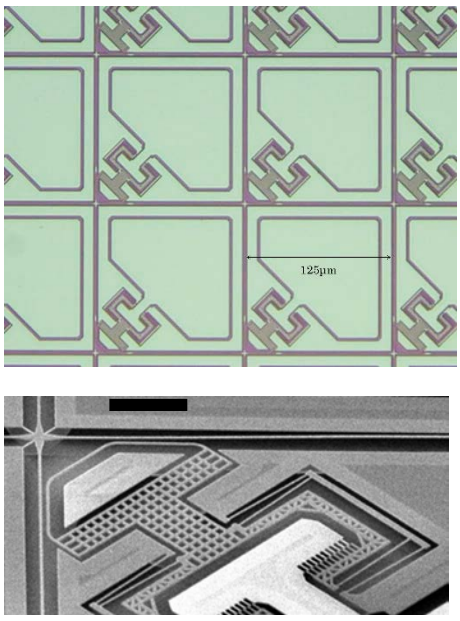
Nano structural optics (Meta-material)



Metamaterial filter using Fano resonance, Y.Moritake, Opt Exp.24(2016)9332

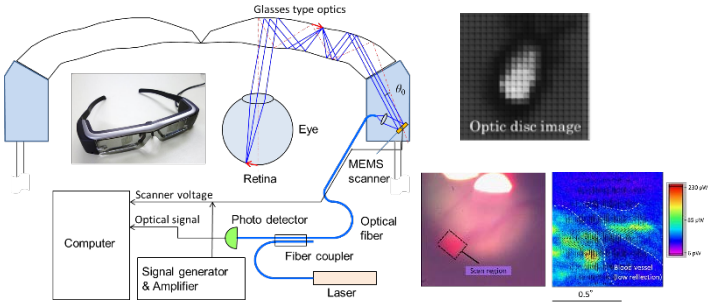
Absorption filter using THz metamaterials Y.Ishi,IEEJ 136-E (2016) 172

Silicon waveguide switch for cross connect



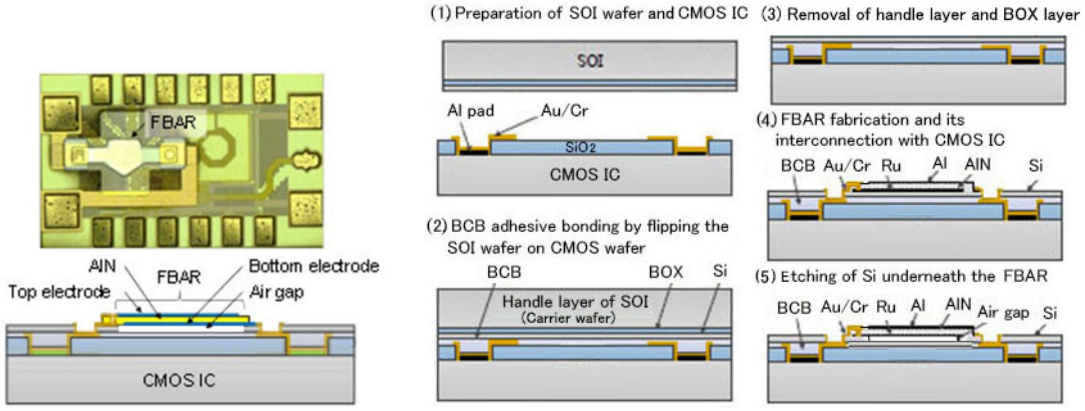
Matrix type switch consists of Si photonic waveguides. Gaps of couplers are varied by comb-drive actuator for switching. The couplers are located near the cross points of Si waveguides. The switch is developed for cross connect in data centers. S.Abe, Photon.Technol. Lett. 26 (2014) 1553

Smart glasses retinal imaging with MEMS scanners

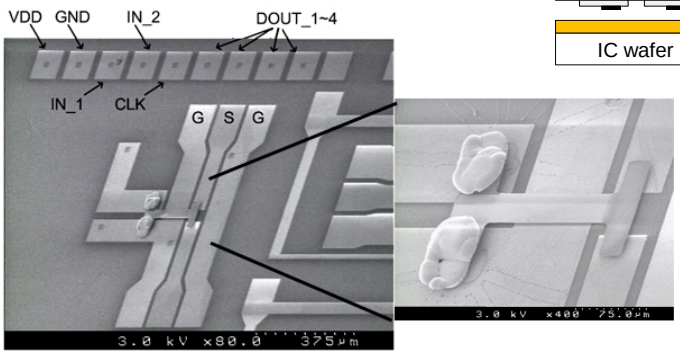


Retinal imaging using smart glasses and MEMS scanners. Retinal images of pig eyes, N.Kaushik,International Display workshops, Dec. 6-8, 2017, Sendai

3 RF MEMS

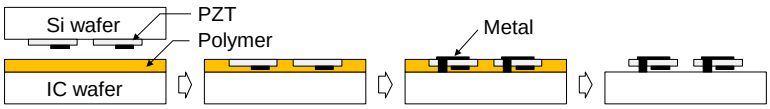


FBAR（film bulk acoustic resonator）on LSI (Kochhar et. al, 2012 IEEE Internl. Ultrasonic Symp. (2012) 1047)

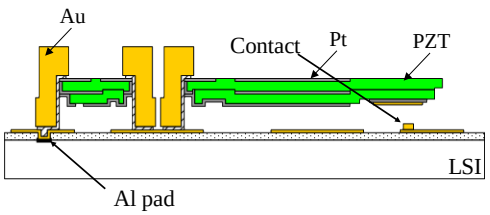


PZT MEMS switch fabricated on 0.35 μm CMOS LSI

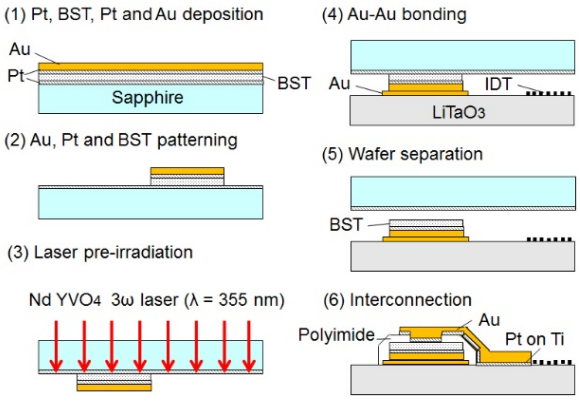
（Matsuo *et al.*, IEEE MEMS 2012, pp. 1153–1156）

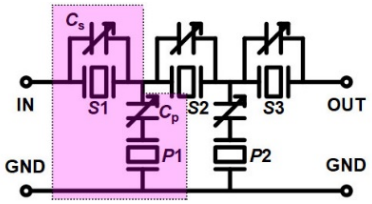


IC 上への PZT MEMS の集積化プロセス



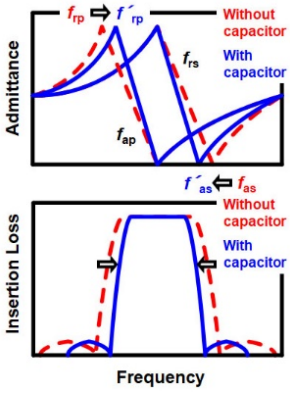
Cross sectional view of PZT MEMS switch

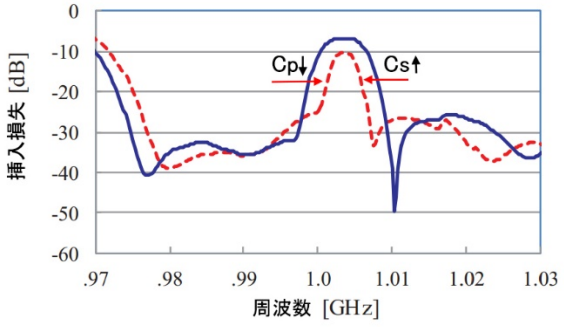


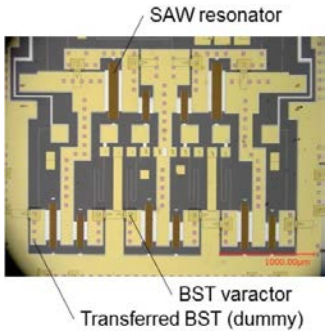


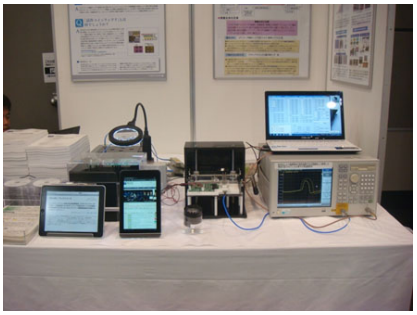
$$f'_{rp} = f_{rp}\sqrt{1+\frac{C_{1p}}{C_{0p}+C_p}}$$

$$f'_{as} = f_{rs}\sqrt{1+\frac{C_{1s}}{C_{0s}+C_s}}$$





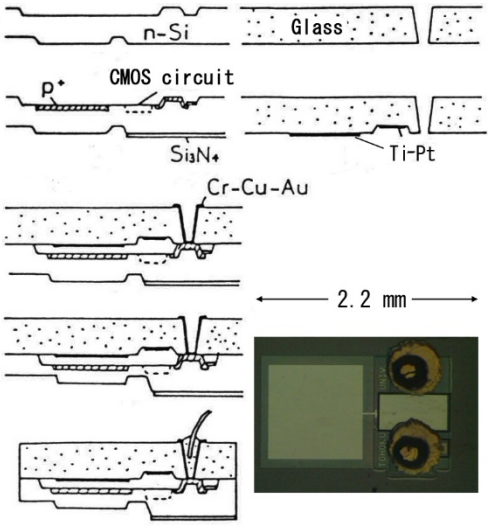


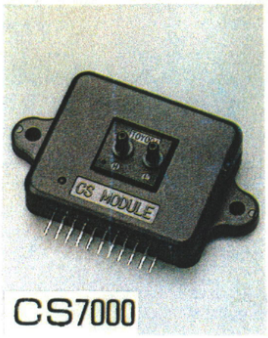


Tunable bandwidth filter fabricated by selective transfer of feroelectric variable capacitor on SAW device

(H.Hirano et.al, J. of Micromech. Microeng., 23, 2 (2013) 025005(9pp))

4 Mechanical sensors





For low pressure measurement

10mmH2O～300mmH2O

Frequency and analog output

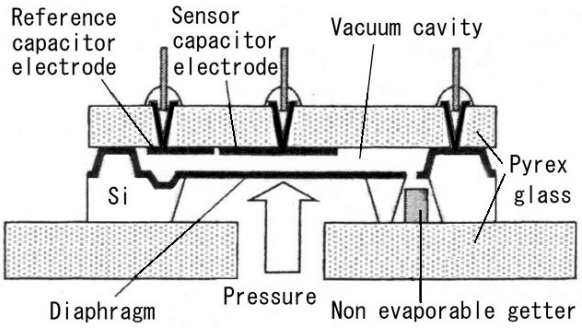
TOYODA

Toyoda Machine Works, LTD.

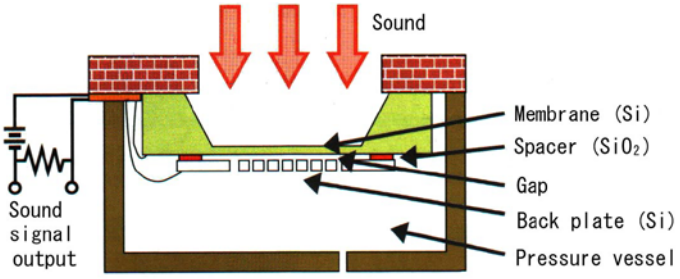
Monolithic capacitive pressure sensor

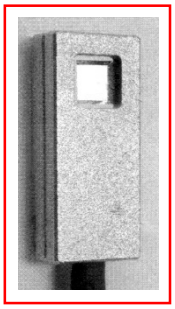
Integrated capacitive pressure sensor

(Y.Matsumoto, S.Shoji and M.Esashi, Ext. Abstracts of the 22nd Conf. on Solid State Devices and Materials (1990) 701)

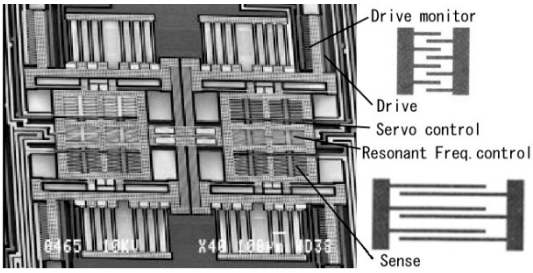


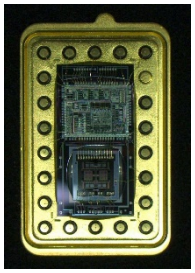
Silicon capacitive vacuum sensor (H.Miyashita et.al., ANELVA technical report, 11 (2005) 37)

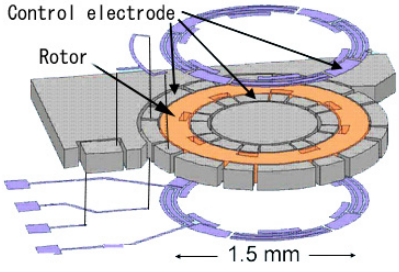


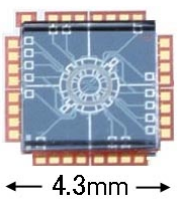


Silicon microphone (NHK) (T.Tajima, N.Saito, M.Esashi et.al., Microelectronic Engineering, 67-68 (2003) 508)





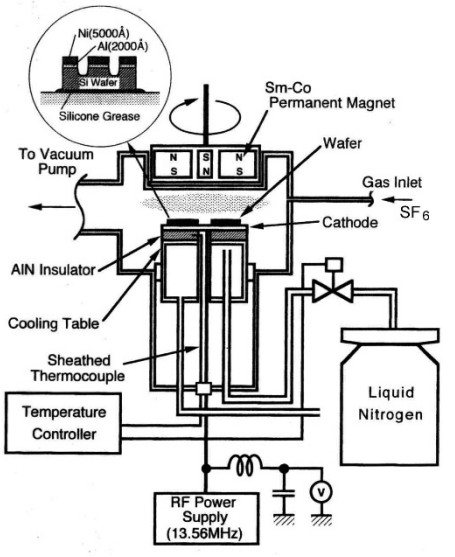


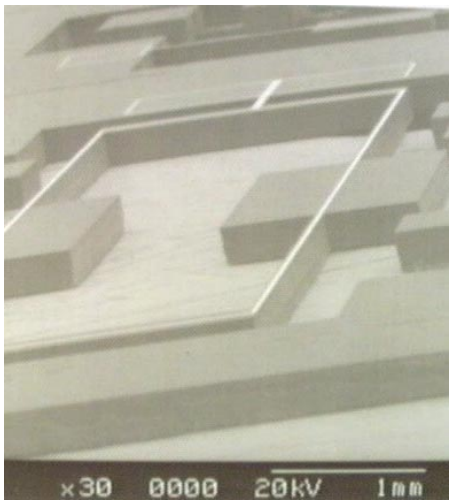


Yaw rate & acceleration sensor (Toyota motor Ltd.)
(M.Nagao, et.al., 2004 SAE World Congress, 01-1113 (2004))

Electrostatically levitating rotational gyro (Tokyo keiki Ltd.)
(T.Murakoshi, et.al., Jpn. J. Appl. Phys., 42 (2003) 2468)

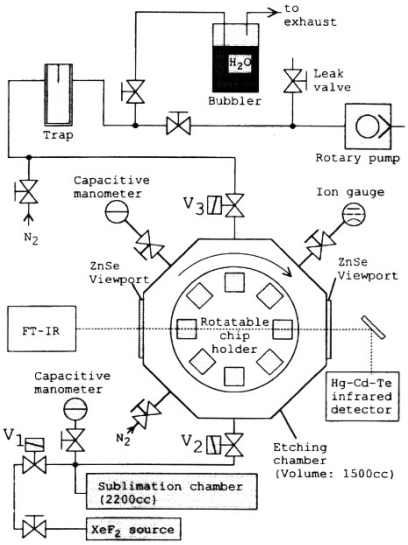
5 Micromachining and packaging





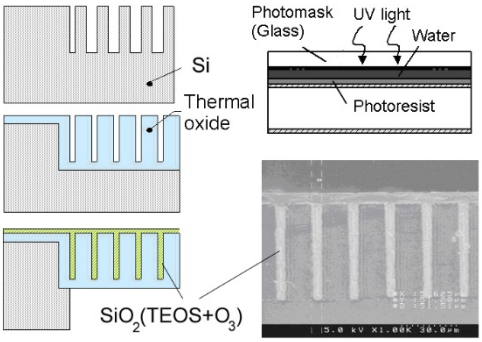
Deep RIE system and resonating gyro fabricated using it

(M.Takinami,Tech.Digest of the 11th Sensor Symp.(1992)15)



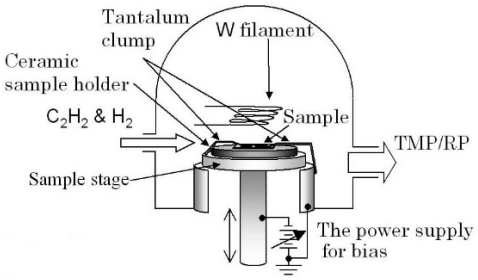
Si etching system using XeF_2

(R.Toda,Sensors & Actuators,A66(1998) 268)



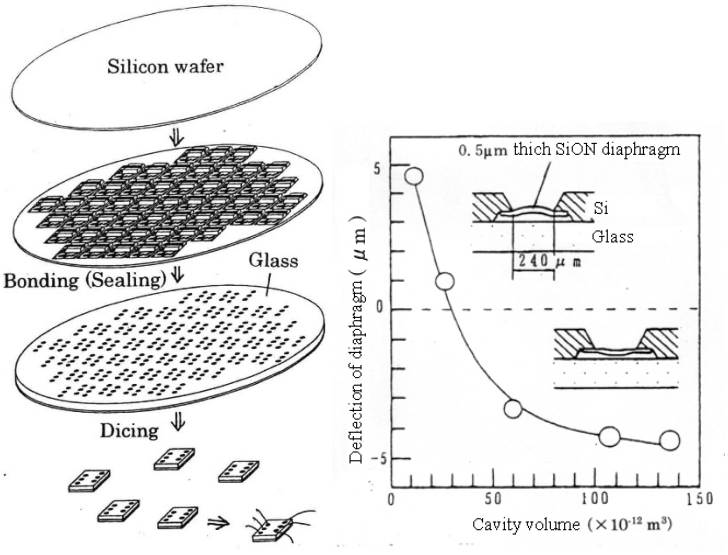
Water immersion contact lithography and trench refill.

(K.S.Chang, et.al, J.of Micromech. Microeng., 15 (2005) S171)



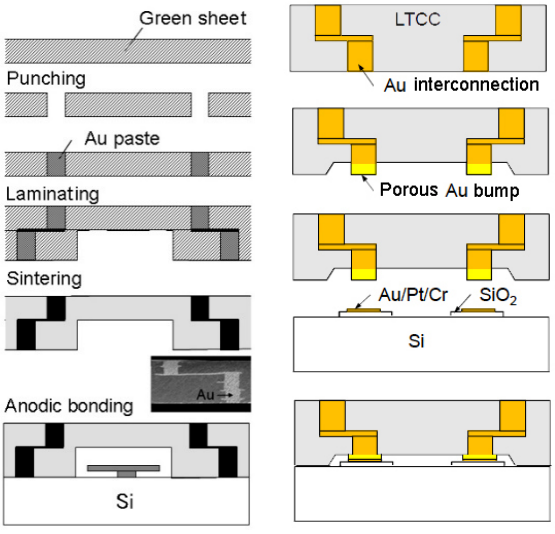
Hot filament CVD used for Carbon nanotube growth (or diamond film deposition).

(T.Ono et.al., Nanotechnology, 13 (2002) 62–64)



Wafer level packaging (WLP). O_2 generation during anodic bonding.

(M.Esashi, J.of Micromech. and Microeng., 18 (2008) 073001)



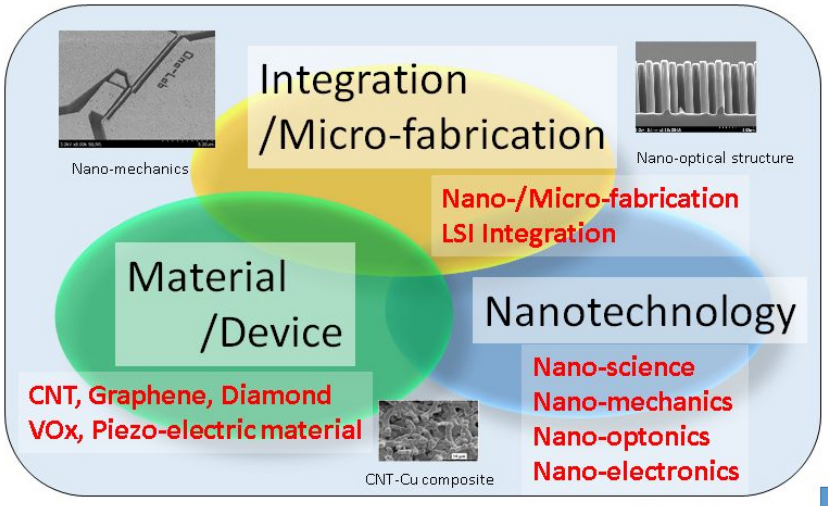
WLP using LTCC with electrical feedthrough.

(S.Tanaka et.al.,Technical Digest IEEE MEMS, (2012) 369)

6 Nanomachining and ultra-high sensitive sensing

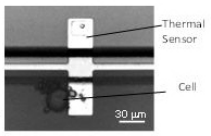
Graduate School of Engineering
Department of Mechanical Systems Engineering
Ono·Toan Lab. / Toda Lab.

We have developed micro/nanomechanics and related technologies based on nanotechnology and microfabrication for information technology, bio-medicals, energy, environments and nanoscience. In addition, ultimate sensor and sensing technologies have been developed and applied to new applications.



Nano-science

- Extreme sensor
- Nano-probe



Thermal sensor for single cell

Bio/Healthcare

- Thermal biosensor
- Photo-acoustic sensing

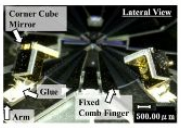
Nano-mechanical computation element

Electronics

- Nano-mechanical computer
- Nano-mechanical resonator
- Optical element

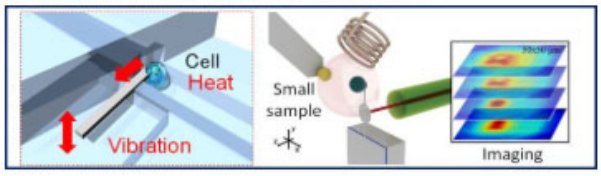
Energy/ Environmental sensing

- Environmental gas sensing
- Thermo-electronic power generator



Miniature IR spectroscopic analyzer

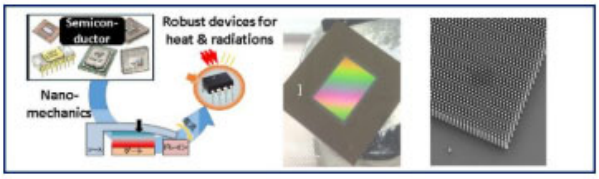
Ultimate Sensing, Spintronics



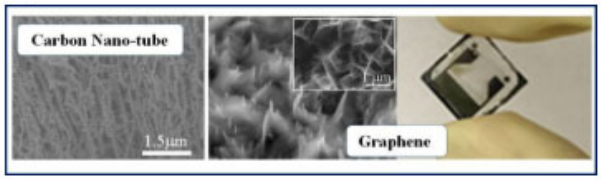
Micro/Nano Energy Systems, Wearable

IoT Sensors, Miniature Systems

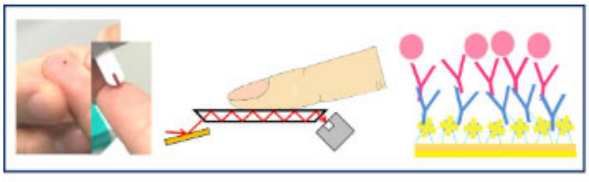
Nanomechanics, Quantum electromechanics



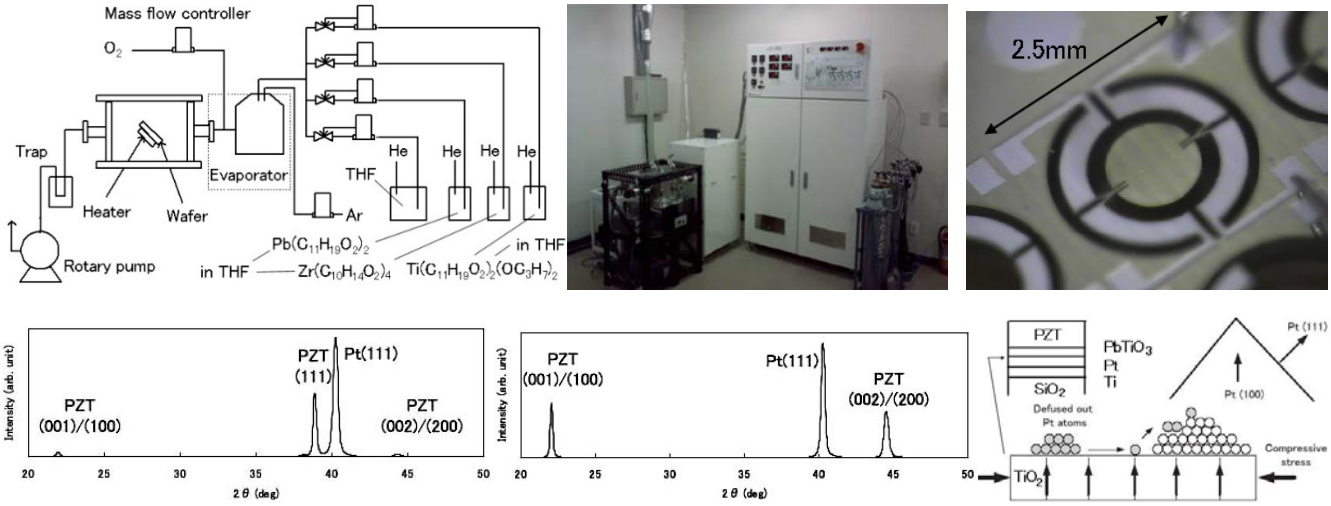
Genious Materials for Micro/Nano Systems



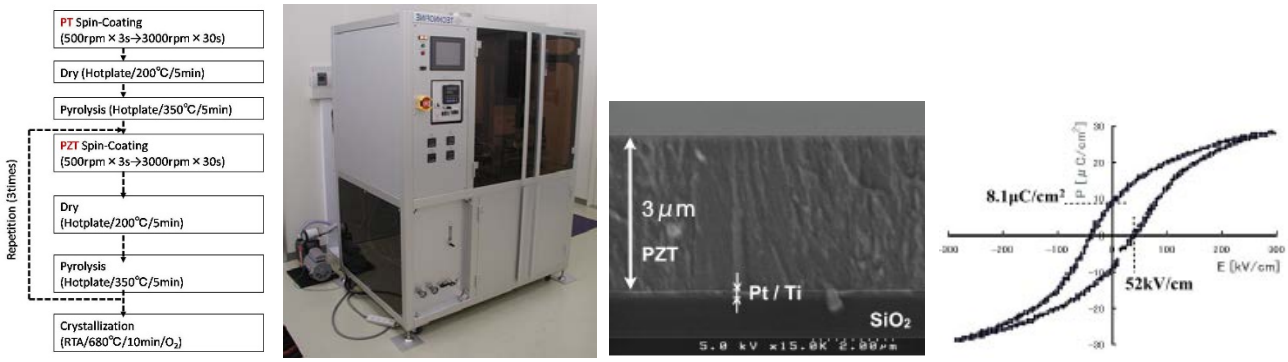
Healthcare, Bio-Applications



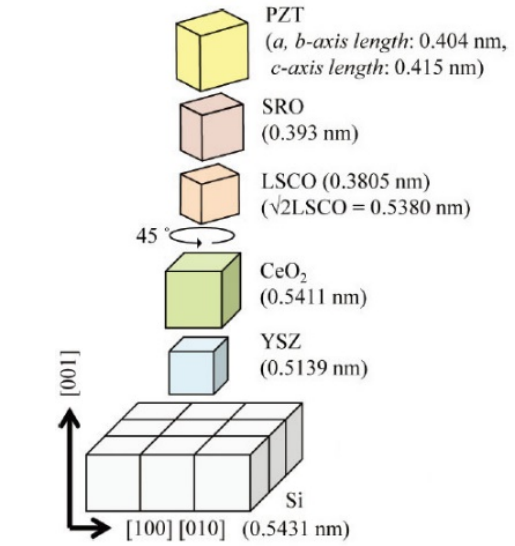
7 PZT thin films for MEMS

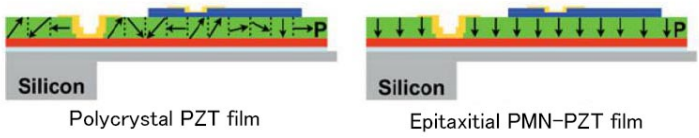


PZT thin film by MOCVD (H.Matsuo, Y.Kawai, S.Tanaka and M.Esashi, Jap. J. Appl. Phys, 49 (2010) 061503)



PZT thin film by sol-gel method (Y.Kawai, N.Moriwaki, M.Esashi and T.Ono, Proc. of the 27th Sensor Symp. (2010) 21)





	Polycrystal PZT (MPB)	Epitaxial PMN-PZT	AlN	Epitaxial PMnN-PZT	40%Sc-AlN
$e_{31,f}$ [C/m²]	-12	-25	-1	-14	-2.5
ε_{33r}	1000	1500	10	270	30
$(e_{31,f})^2/(\varepsilon_0\varepsilon_{33r})$ [GPa]	16	47	11	80	20

Application	Figure of Merit (FOM)
Actuator	Piezoelectric constant d
Active sensor (e.g. Gyroscope)	(Piezoelectric constant)²/(Dielectric constant) d^2/ε
Energy harvester	Electromechanical coupling factor $K^2 \propto d^2/\varepsilon$
Resonator (e.g. Acoustic wave filter)	(Electromechanical coupling factor) × (Q factor) K^2Q
Passive sensor (e.g. Microphone)	(Piezoelectric constant)/(Dielectric constant) $g = d/\varepsilon$

Epitaxial PZT thin film with buffered layer by sputter deposition (S.Yoshida, et.al., IEEE Trans. on Ultrasonics, Ferroelectrics and Frequency Control, 61, 9 (2014) 1552)

8 Sensor network （Kuwano）

TOHOKU UNIVERSITY

Activity on Prof. Kuwano's Working Group

1. Introduction — Sensor Communication Society

New applications, New data services, and New infrastructures

Data Center

Medical | Structural diagnostic | Security | Traffic/Logistic | Environment | Sensor Cloud

- ○**Big data as an informative infrastructure**
  ⇒Security app., disaster alert, etc..
- ○**Big data for open source**⇒New business creation
- ○**Wide-dispersed system of wireless sensor nodes**

<Key technologies>
- -Sensors for wireless systems
- -Micro energy sources
- -New fabrication technologies

2. Sensors for wireless systems

SAW multi-sensors module

Angular velocity ω | Gyro- sensor | Strain S | Strain Sensor | Gas absorption Δm | Gas Sensor | Switching device | Mixer | Counter chip. | L.O.

SAW Strain Sensor

Frequency shift(f/f0)×10⁻² | oscillator | resonator | strain[μ]

<Front side> | <Back side> | CMOS inverter | SAW resonator | 10 mm

Resonator chip

Amplification circuit | SMA connector | SAW chip | 2 mm

Oscillator chip

Detected strain [μstrain] | Wirelessly detected strain | Strain gauge | Loaded stress [N/m²]

Power manager | Antenna | SAW sensor (measurement) | Communication chip | Signal processors | SAW sensor (reference)

Wireless module

SAW Gyroscope

SAW H_2S Sensor

Differential value for initial resonant frequency [kHz] | Base Pressure | Time [min.]

Output Frequency [MHz] | 500 [deg/s] | 1000 [deg/s] | 1500 [deg/s] | Time [min.]

3. Micro Energy Sources

Piezoelectric type harvester

Material breakthrough

Normalized power density (W/g⁻²m³) | Micromachined MgZrO co-doped AlN/Si (Our work) | Micromachined KNN/Si (Our work) | Micromachined AlN/Si | Micromachined PZT/Si | Macro AlN/SUS | Macro PZT/Si | High performance | Frequency (Hz)

Beam (piezoelectric harvester) | Proof mass | 500 μm | Contact window

- Pb free $(K,Na)NbO_3$
- Pb free Zn,Mg co-doped AlN

Wide band power generation

Si quatrefoil-shaped proof mass | Double clamped type harvester | Top Elec. 2 | Top Elec. 1 | 1mm

KNN | Top Elec. | Si | 50μm | Top Elec. 2 | Si beam | Top Elec. 1 | 200μm

Load Resistance | 1 kΩ | 9.9 kΩ | 32.7 kΩ | 100 kΩ | Power [nW] | Frequency [Hz]

8639 nW | 253 Hz | Power [nW] | Bandwidth [Hz] | Acceleration [m/s²]

DC operation

Ball impact type harvester | Top electrode | KNN /Si cantilever | Bottom electrode | Cylindrical housing | Metalball | Recess

Device A | Device B | Average power [nW] | Frequency [Hz]

Electret stype harvester

Ferroelectric Dipole Electrets (FDE)

(a) Poling with DC voltage | (b) Flux was trapped between the electrodes | Ultrathin Capacitor (~1 nm in thickness) | (c) Peel out the electrodes | (d) Flux from the dipole was released | Electric Field

Upper Electrode | Ferroelectric | Bottom Electrode | Power supplier | Load R

Vibration test | Sample F | CPE | D | B | Time (sec)

Output power for the load resistance | Sample F | E | CPE | D | C | B | A | R (Ω)

Output power for electric field int. | Sample F | CPE | AB | C | D | E | E_z (V/m)

4. New fabrication technologies

Nanoparticle synthesis

Trench (blue colored) | Reservoir (red colored) | Micro pump | Atomizer | Micro pump | 10 mm | Print board

Atomization of D. I. water

Atomization of Acetone

Micro FIB system

Extractor and lens array | 500 μm

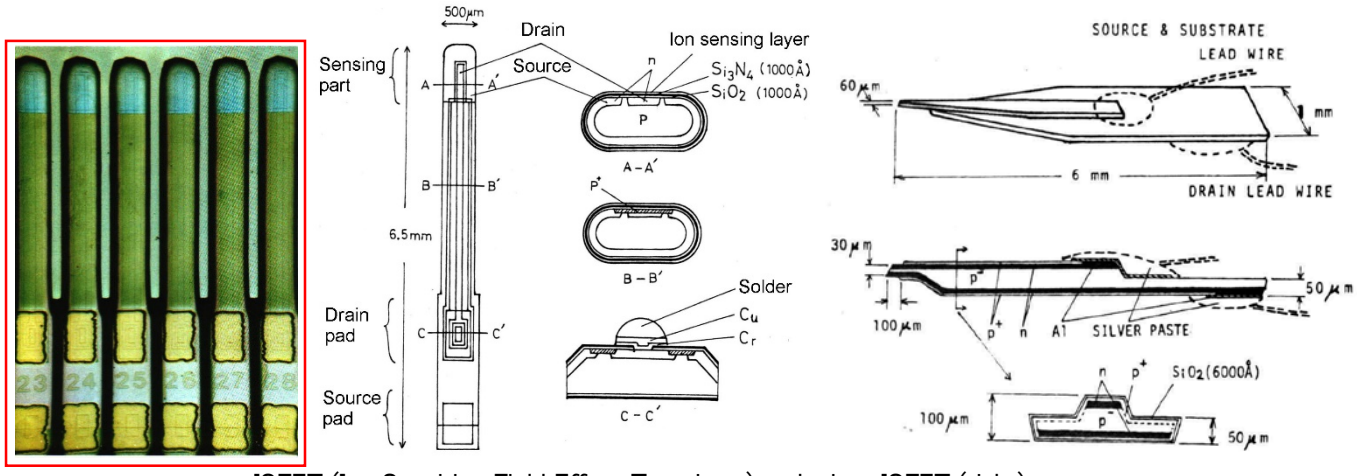
Emitter array | 1 mm | 100 μm

Distance of ions-target D (μm) | Radii of etched marks r (μm) | 2.5 kV | 11° | 7.9°

2 mm | 70 μm | 40 μm | 10 μm | Etching mark of silicon sub.

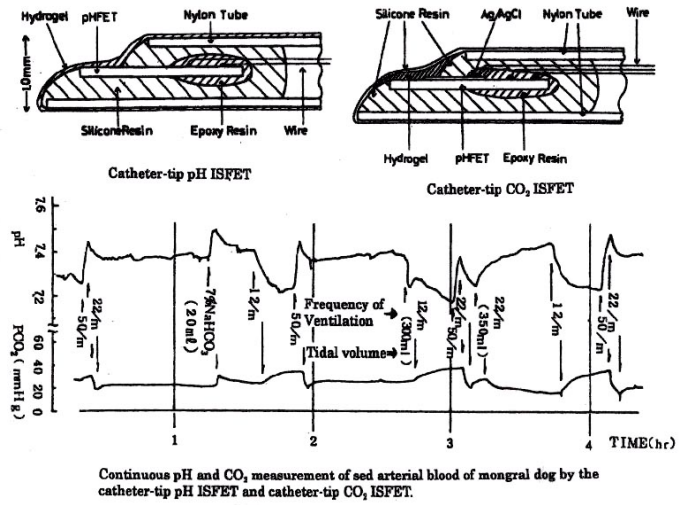
Ion current (nA) | Time (sec) | V_{ex}=2.0 kV | V_{ex}=1.8 kV | V_{ex}=1.7 kV

9 Micro sensors for medical monitoring

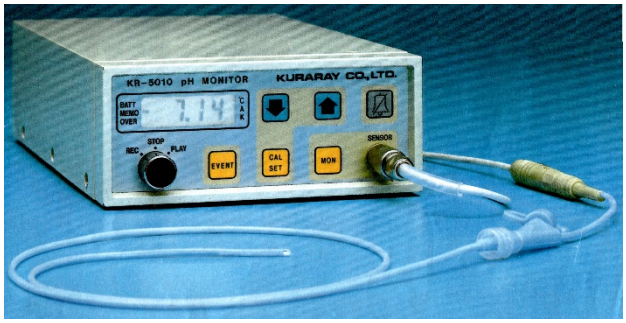


ISFET (Ion Sensitive Field Effect Transistor) and micro ISFET (right)

(M.Esashi and T.Matsuo, J.of the Japan Soc. of Applied Physics, 44, Supplement (1975) 339)



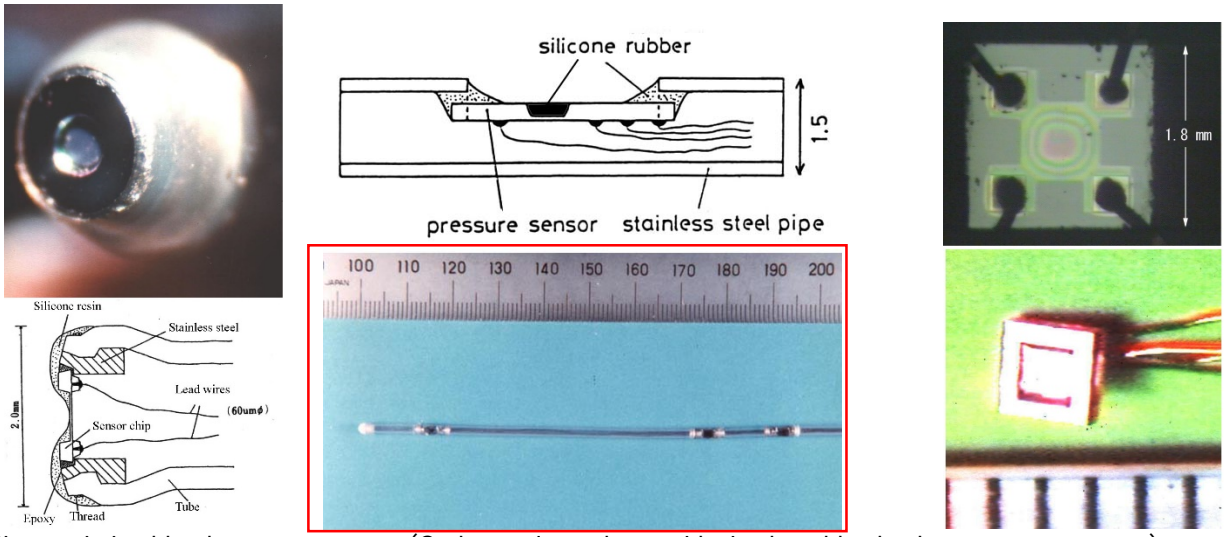
Continuous pH and CO_2 measurement of sed arterial blood of mongral dog by the catheter-tip pH ISFET and catheter-tip CO_2 ISFET.



ISFET and reference electrode in 2.4mm diameter catheter

Commercialized pH, CO_2 monitor catheter (1980 Kurare Co.Ltd., Nihon koden Corp.)

(K. Shimada, M. Yano, K. Shibatani, Y. Komoto, M. Esashi and T. Matsuo, Med. & Biol. Eng. & Comput., 18 (1980) 741)

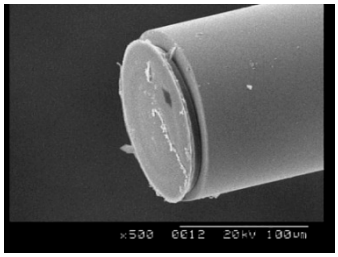


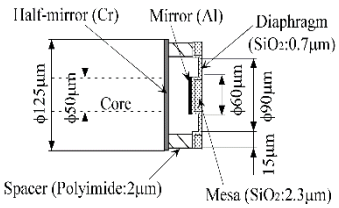
Piezoresistive blood pressure sensor (Catheter tip, catheter side, implantable absolute pressure sensor)

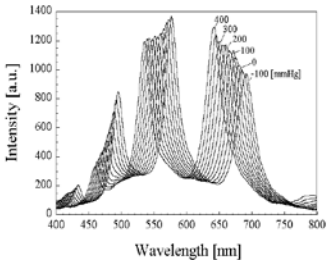
(M.Esashi H.Komatsu, T.Matsuo, M.Takahashi, T.Takishima, K.Imabayashi and H.Ozawa, IEEE Trans. on Electron Devices,ED-29 (1982) 57)

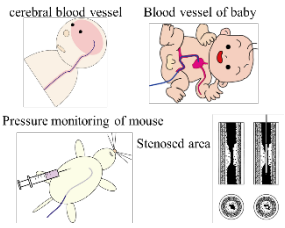
(M.Esashi, Y.Matsumoto and S.Shoji, Sensors and Actuators, A21-A23 (1990) 1048)

10 Minimally invasive medical devices and health care devices (Y. Haga)

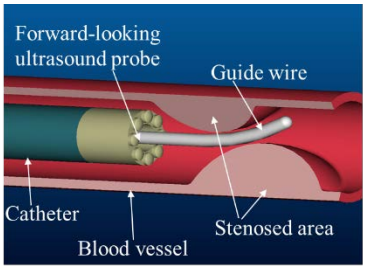


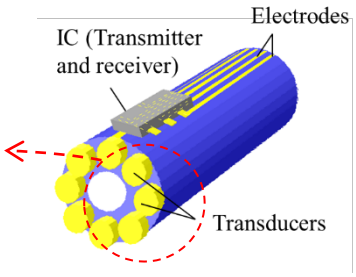


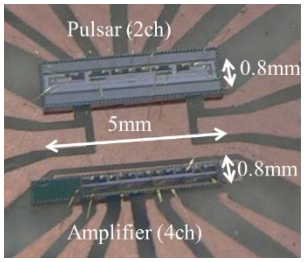




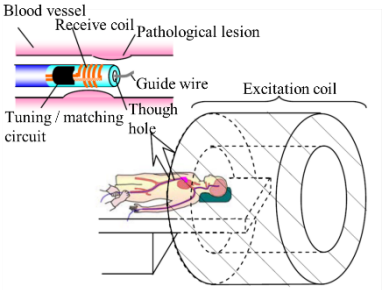
Ultra miniature fiber optic pressure sensor Structure Reflection spectrum for different pressures Applications
(K. Totsu *et.al.*, J.of Micromech. Microeng., 15 (2005) 71–75)

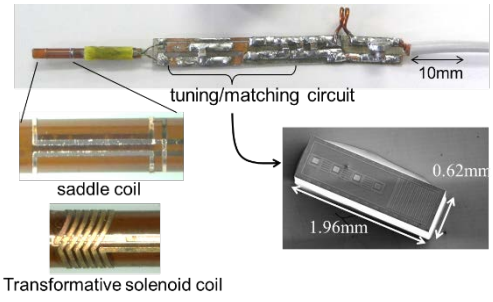


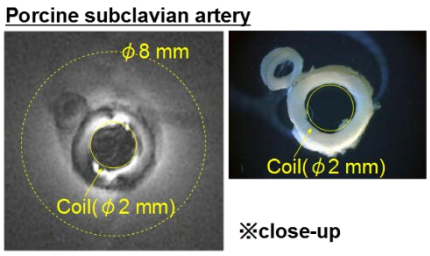




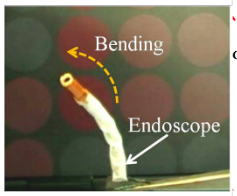
Forward-looking intravascular ultrasound imager and fabricated transducers, pulsar and amplifier (μSIC)
(J. J. Chen *et. al.*, Proc. of MEMS (2004))

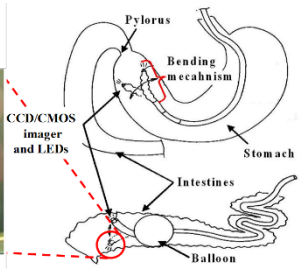


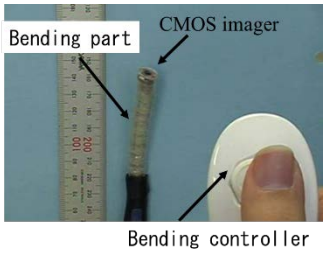


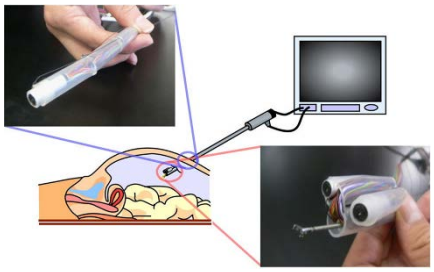


Intraluminal MRI probe Fabricated MRI probe and variable capacitor (μSIC) Imaging results
(S.Goto *et. al.*, Proc. of MEMS (2007)) (S. Ichimura *et. al.*, Proc. ISMRM (2010))

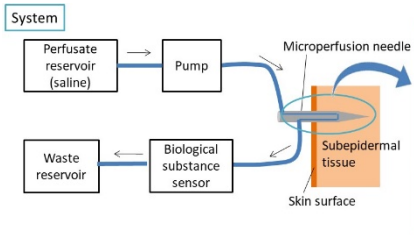


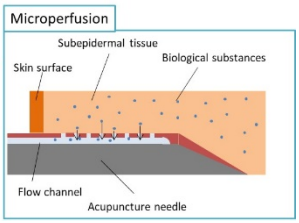


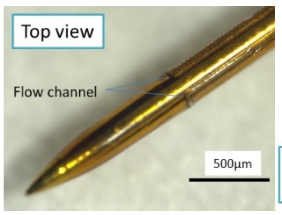


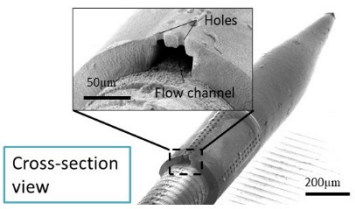


Disposable endoscope using shape memory alloy Thin endoscope(Φ3.9mm) Colonoscope(Φ9mm)
(Y. Haga *et. al.*, IEEJ Trans. SM, 131 (2011) 102–110) (S. Suda, *et. al.*, J.JSCAS, 17 (2015), 83–90)



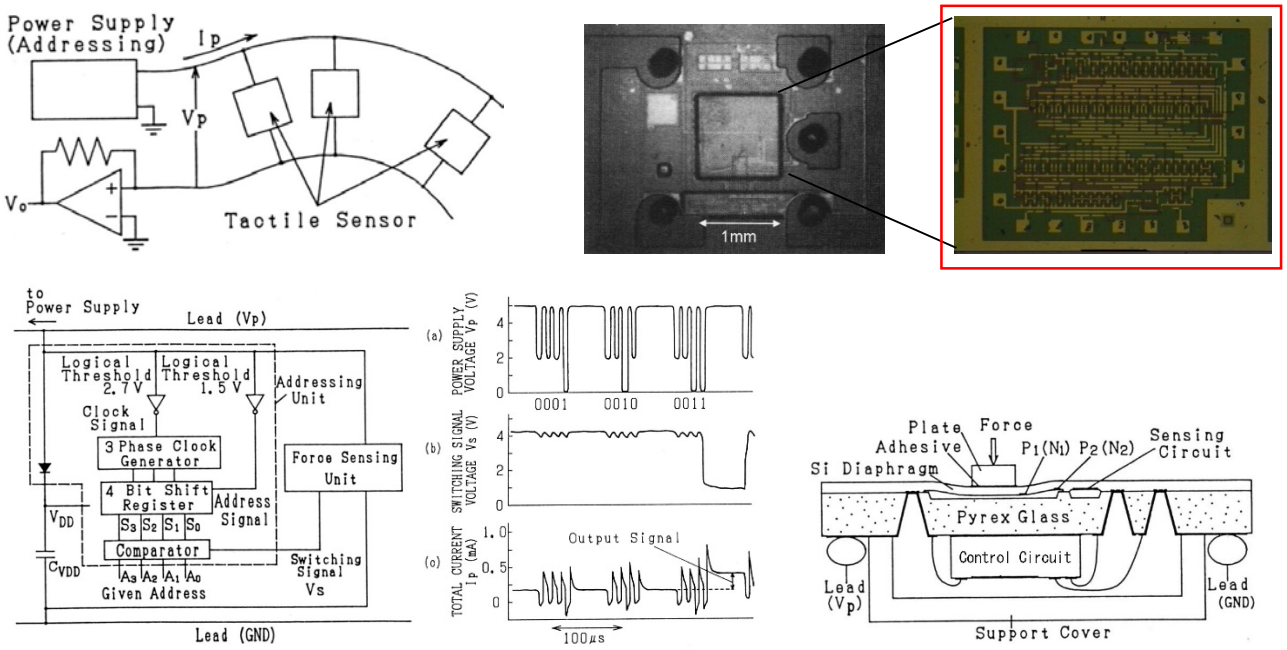






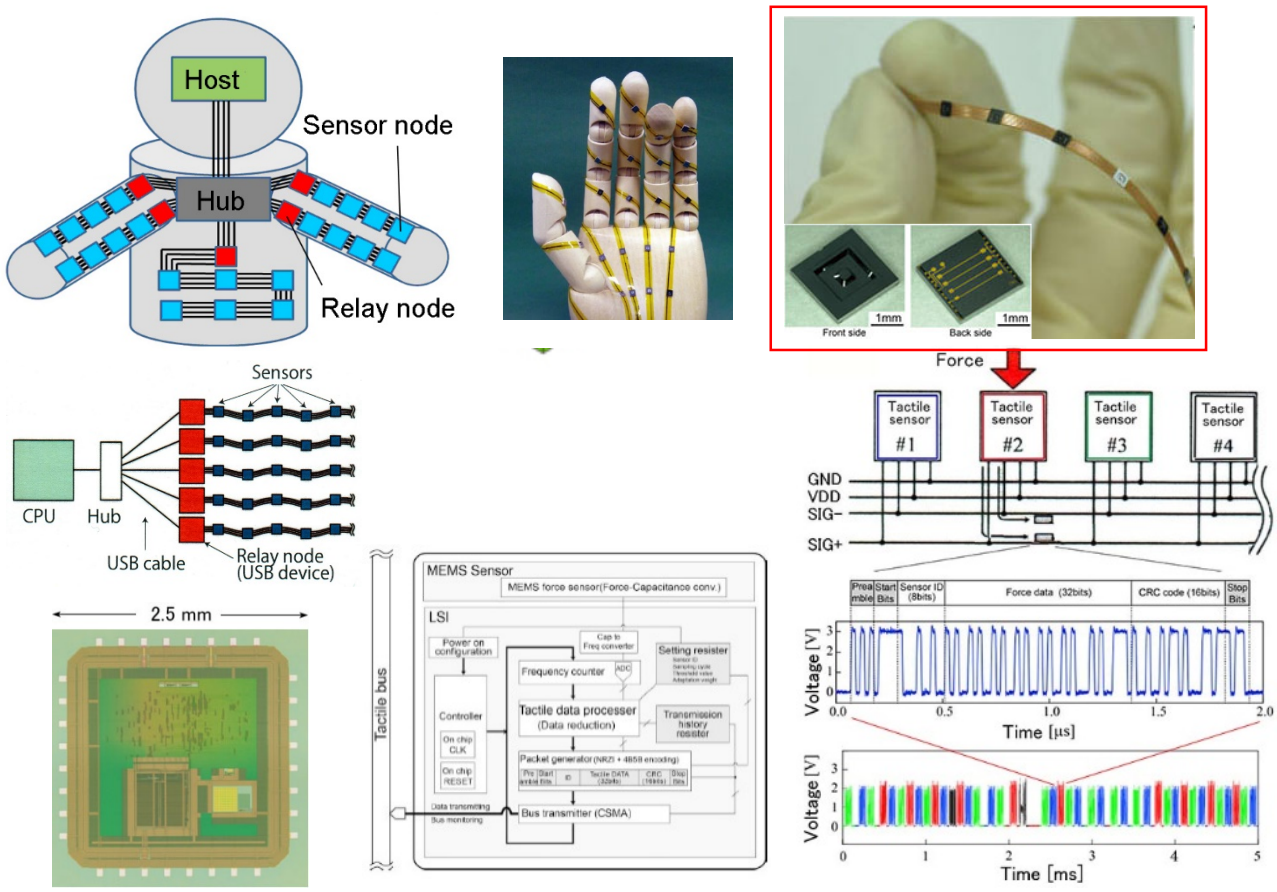
Minimally invasive continuous monitoring system for biological substances, and fabricated microanalysis needles with flow channel (N. Tsuruoka *et. al.*, Biomed. Microdevices (2016) 18:19)

11 Tactile sensor network



Common two-lead tactile sensor array (poling type)　Number of transistors max 100 /chip in our laboratory
(In company, 1 milion /chip at that time, 10 billion /chip at present)

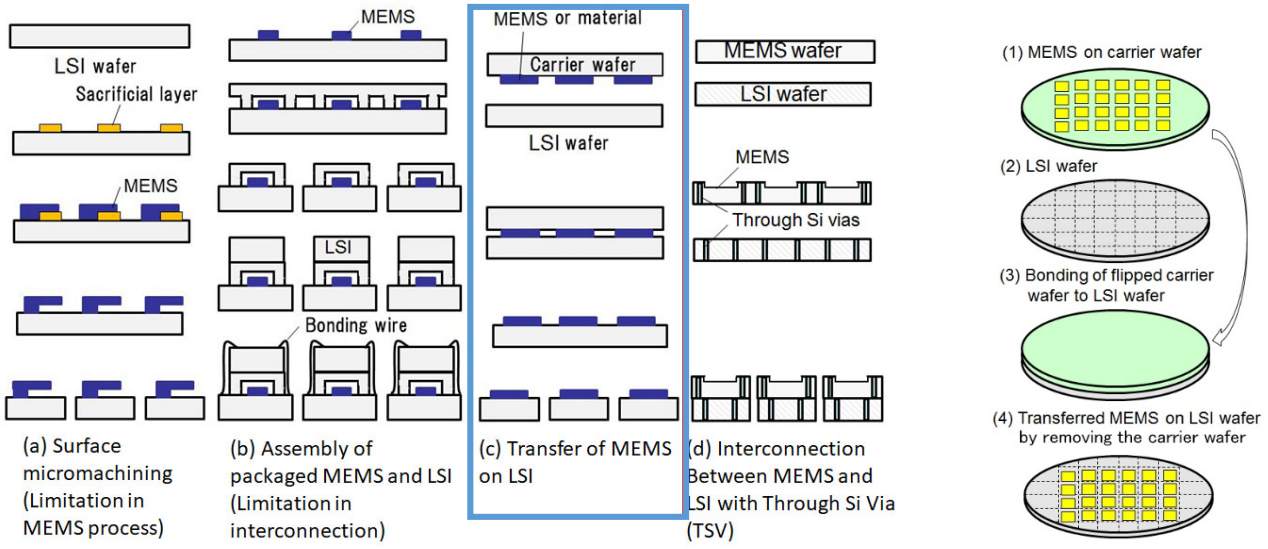
(S.Kobayashi, T.Mitsui, S.Shoji and M.Esashi : Two-Lead Tactile Sensor Array Integrated CMOS Interface Circuits, Using Piezoresistive Effect of MOS Transistor, Technical Digest of the 9th Sensor Symposium,(1990) 137-140)



Tactile sensor network (event driven tipe) (Tohoku Univ. Toyota, Toyota central research laboratory)

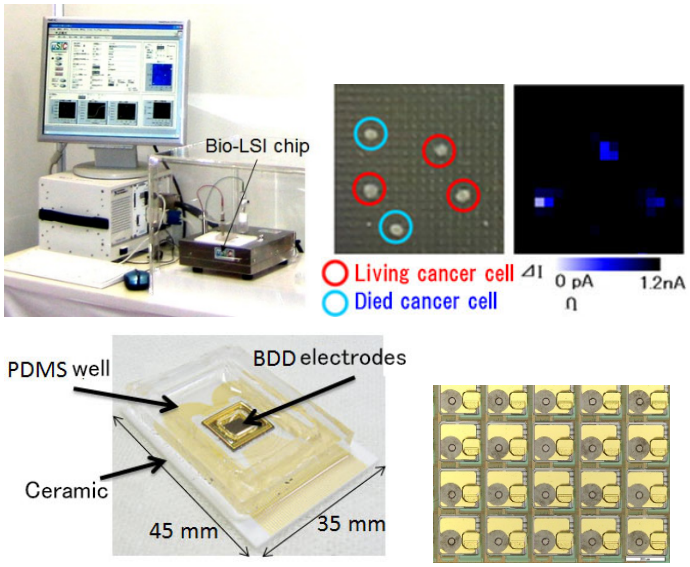
(M.Makihata, S.Tanaka, M.Muroyama, S.Matsuzaki, H.Yamada, T.Nakayama, U.Yamaguchi, K.Mima, Y.Nonomura, M.Fujiyoshi and M.Esashi : Integration and Packaging Technology of MEMS-on-CMOS Capacitive Tactile Sensor for Robot Application Using Thick BCB Isolation Layer and Backside-grooved Electrical Connection, Sensors and Actuators A, 188 (2012) 103-110)

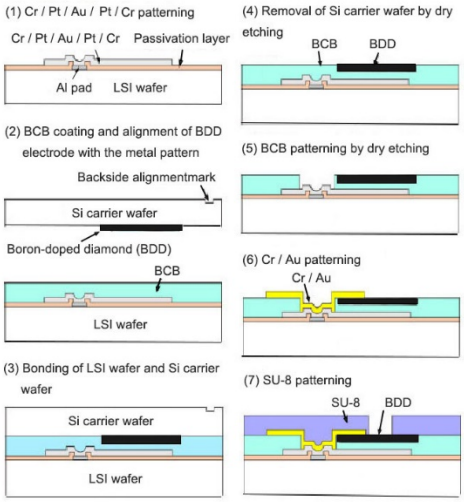
12 Heterogeneous integration of MEMS on LSI by transfer



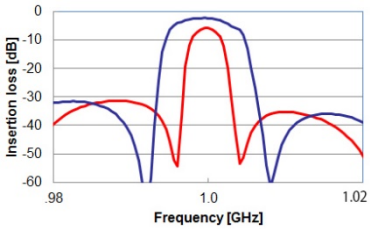
Heterogeneous integration

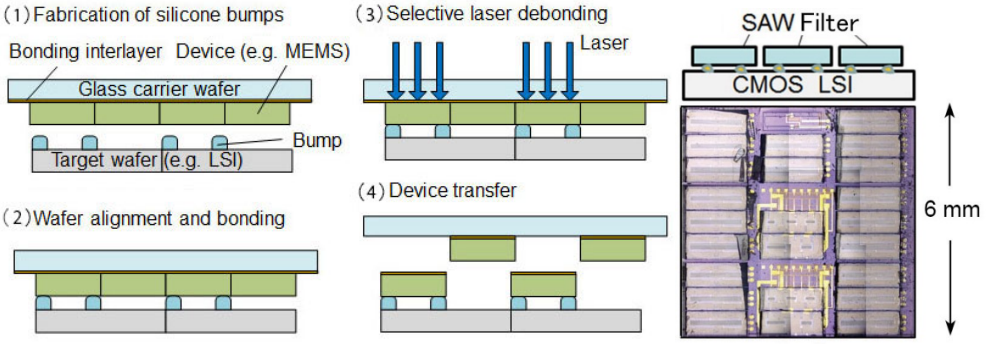
Transfer of MEMS or materials onLSI

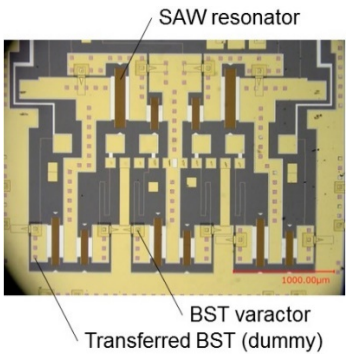




BioLSI made by the transfer of boro doped diamond (BDD) film on LSI (Matsue)



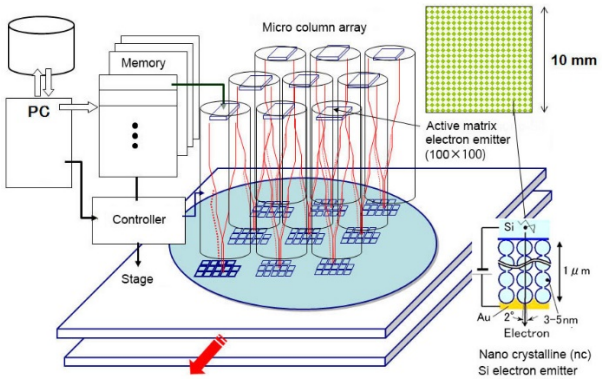




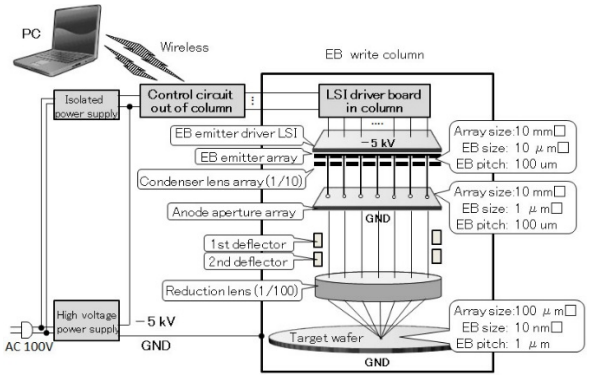
Selective transfer process and multi SAW filter on LSI bade by the process

Tunable SAW filter by selective transfer

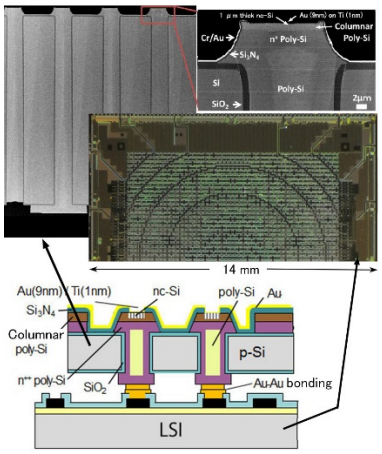
13 Development of massive parallel EB exposure system

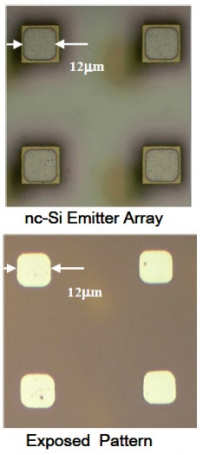


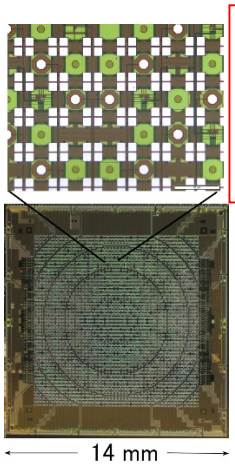
EB exposure system using active matrix electron source array



Structure of a single column (prototype is lateral)

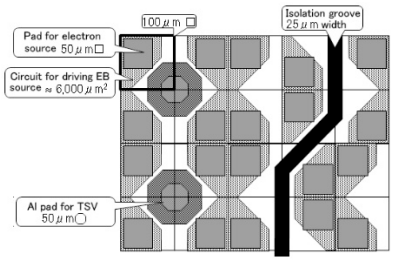




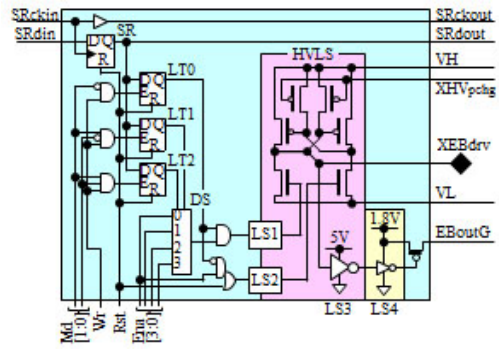


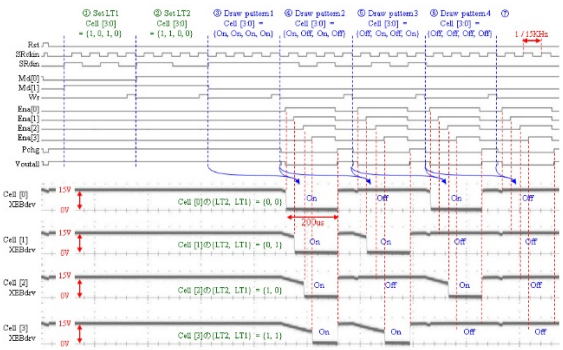
Active matrix electron source chip, the EB exposure system and published book "Development of massive parallel Electron Beam Write System" are displayed in the next room (Historical museum of technology).

Nanocrystaline (nc) Si electron source connected to LSI with TSV

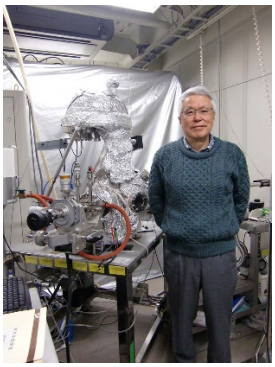


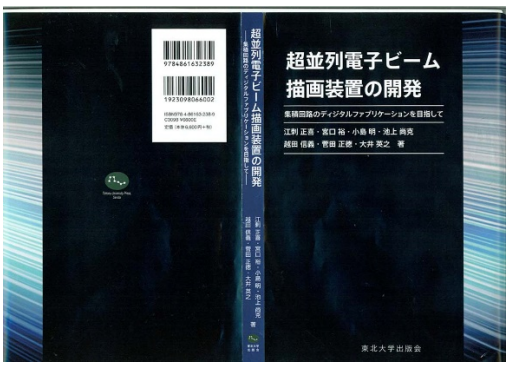
Driving LSI (100×100 cells)





M.Esashi, A.Kojima, N.Ikegami, H.Miyaguchi and N.Koshida : Development of Massively Parallel Electron Beam Direct Write Lithography Using Active-matrix Nanocrystalline-silicon Electron Emitter Arrays, Microsystems & Nanoengineering (2015) 1, 15029(1-8)



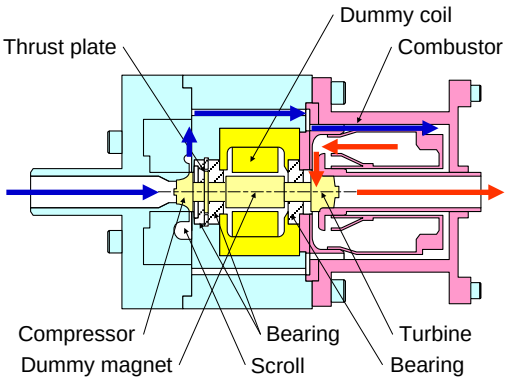


(H.Miyaguchi, M.Esashi, A.Kojima, N.Ikegami, H.Ohi, M.Sugata) (N.Koshida) (Tohoku University Press 2018)

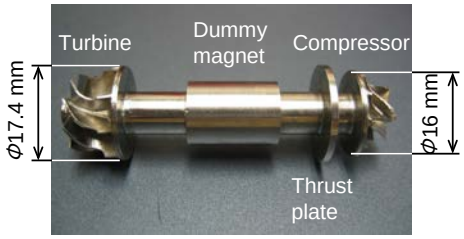
(The EB exposure system is displayed in the Historical museum of technology)

14 Power MEMS

Ultra-small Gas Turbine Generator



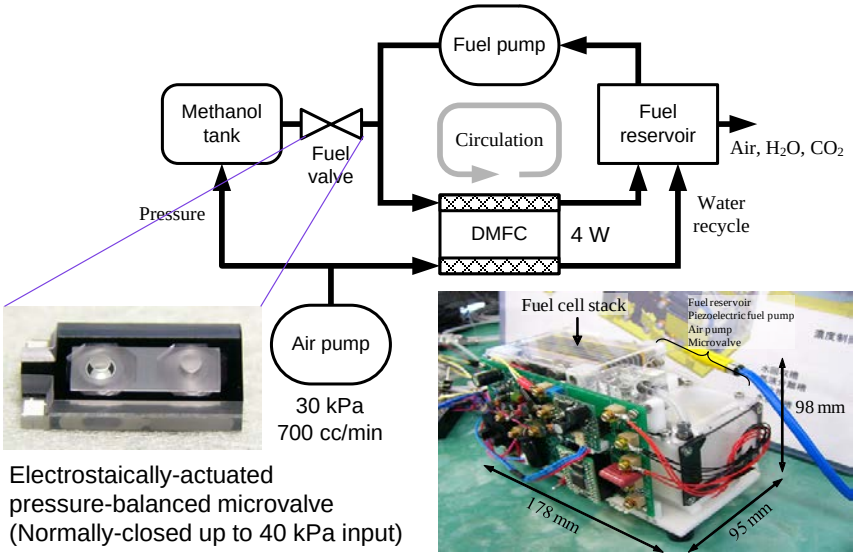
World's smallest gas turbine (2007)
(Collaboration with IHI, Tohoku Gakuin Univ. etc.)
(Tanaka *et al.*, PowerMEMS 2007, pp. 359-362)



Laboratory-made rotor for the gas
(Inconel one-piece structure)

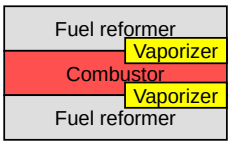
Portable gas turbine generator
prototyped by IHI (2012)
(Based on achievement in 2007)

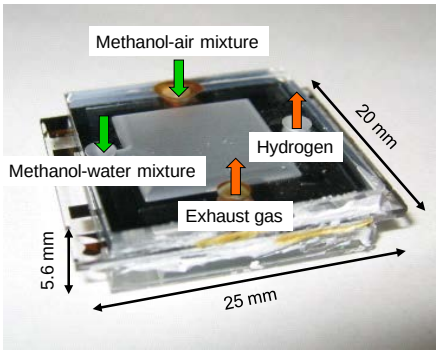
Portable Fuel Cell



Electrostaically-actuated
pressure-balanced microvalve
(Normally-closed up to 40 kPa input)

Reactor configuration

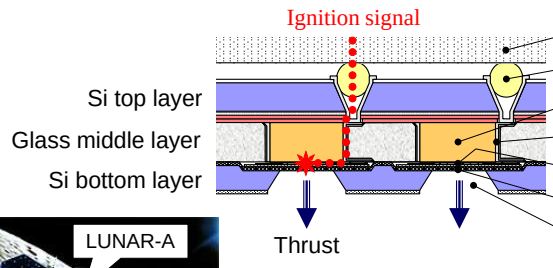


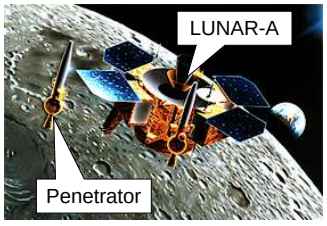


Electrostatic MEMS valve and direct methanol fuel cell system using the valve
(Collaboration with Panasonic Electric Works)
(K. Yoshida *et al.*, Sensors and Actuators A, 157 (2010)
p pp. 290-298, p. 299-306)

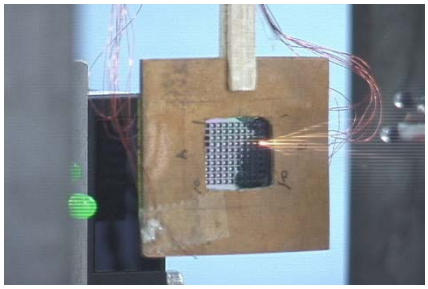
Integrated micro fuel reformer
(Collaboration with Panasonic Electric Works)
(K. Yoshida *et al.*, J. Micromech. Microeng.,
16 (2006) pp. S191-S197)

Micro Rocket Array Thruster





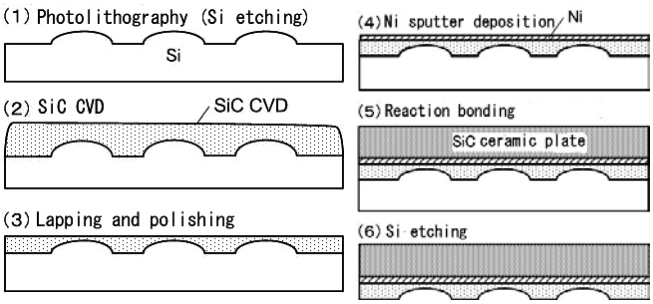
Structure of micro rocket array thruster
(Collaboration with ISAS/JAXA and Nichiyu Giken Kogyo)
(S. Tanaka *et al.*, Trans. Jpn. Soc. Aeronautical Space Sci., 46, 151 (2003) pp. 47-51)

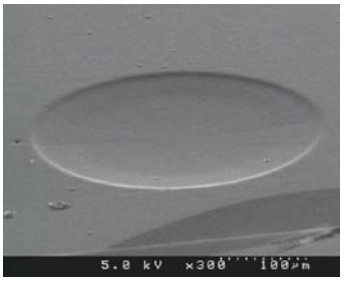


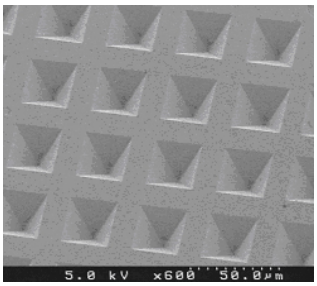
Micro rocket array thruster under test

The micro-thruster was developed for Penetrator injected to lunar surface.

15 MEMS for production, testing, environment and safety

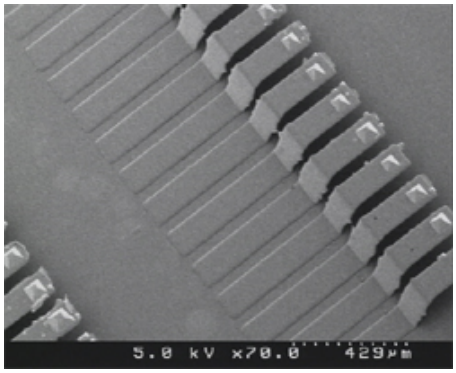


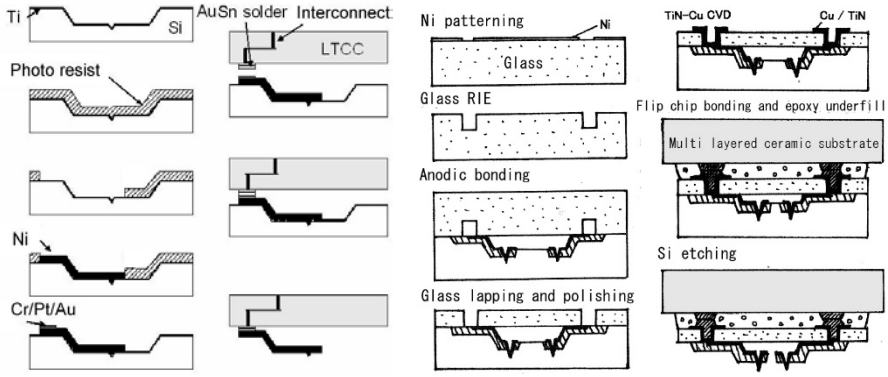




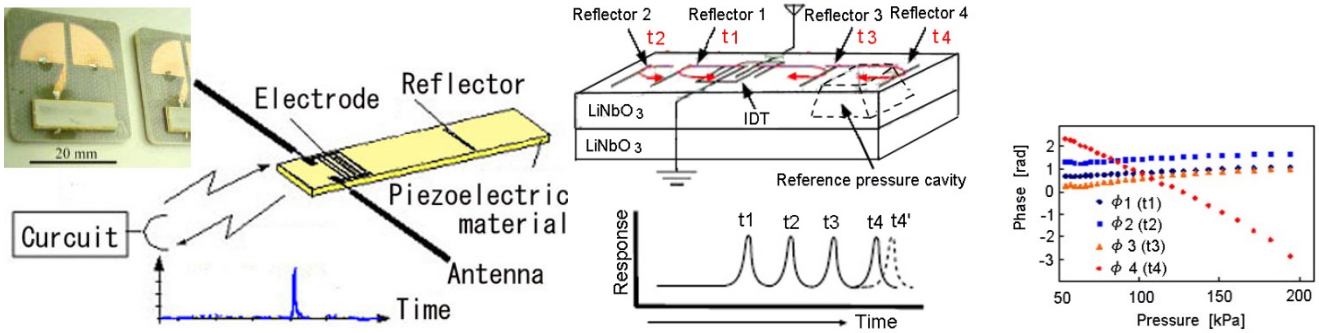
SiC mold　　Glass formed by press with SiC mold

SiC mold for glass press molding (T.Itoh, J.of Microelectromechanical Systems, 15 (2006) 859)



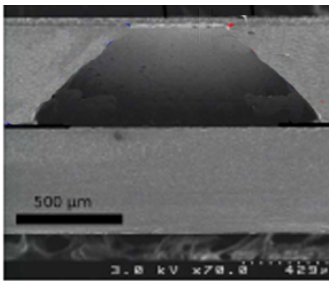


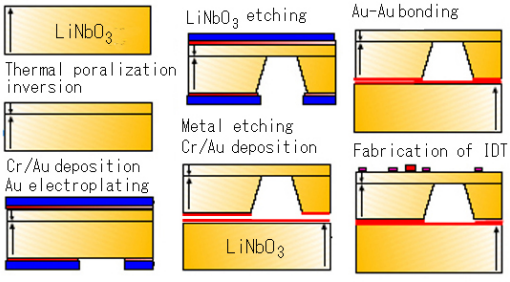
Probe card for testing LSI wafer (S.-H.Choe et.al., IEEE Internl. Test Conf. 2007 (2007))

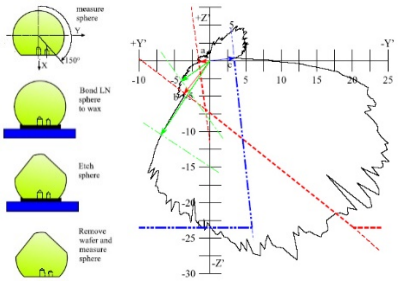


Surface Acoustic Wave (SAW) wireless passive sensor. Tire pressure monitoring system and its $LiNbO_3$ diaphragm

(S.Hashimotoet.al(Nissan motor), Transaction of IEEJ, 128-E (2008) 231)







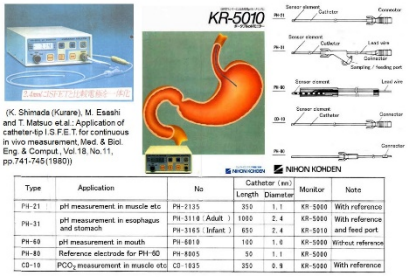
$LiNbO_3$ diaphragm and its fabrication process using thermal polarization. inversion and anisotropic etching

(A.B.Randles et.al, Jap. J. of Applied Physics, 46,45 (2007) L1099-1101)

Anisotropic etching of $LiNbO_3$ depending on crystal orientation.

(A.B.Randles et.al, IEEE Trans. on Ultrasonics, Ferroelectrrics, and Frequency Control, 57, 11 (2010) 2372-2380)

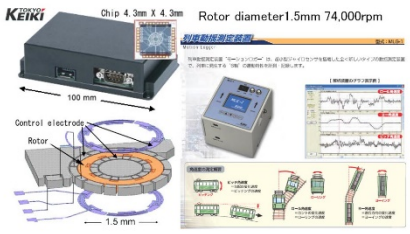
Examples of MEMS Industrialization by Tohoku Univ. – industry Collaboration



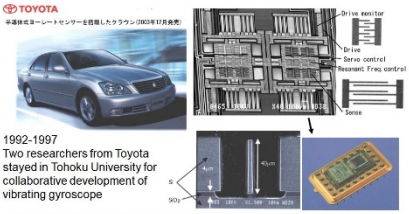
Catheter pH, PCO_2 monitor
(Kurare, Nihon Kohden)

Portable pH sensor
(Shindengen)

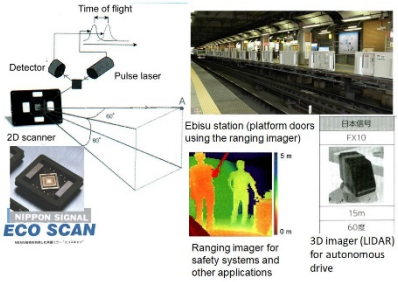
Instrument to detect H. pylori
(Nihon Kohden)



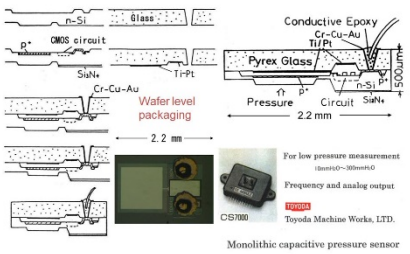
Electrostatically levitated rotational
(Tokyo Keiki)



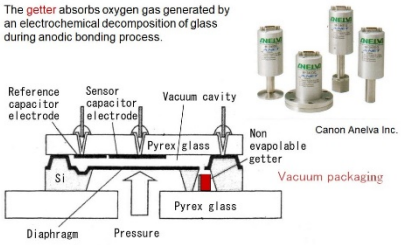
Yaw rate-Accelerometer
(Toyota)



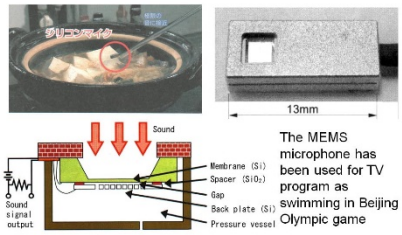
2-axes optical scanner
(Nippon signal)



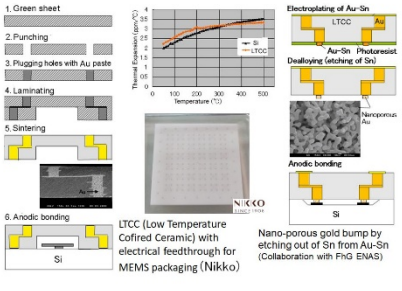
Integrated capacitive pressure sensor
(JTEKT)



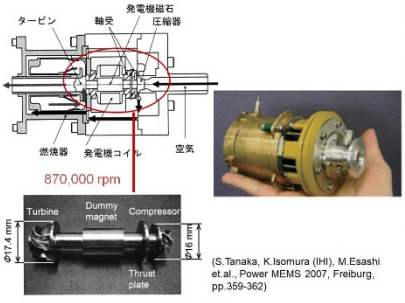
Diaphragm vacuum gauge
(Canon ANELVA)



Silicon microphone
(NHK, Panasonic)



LTCC with electrical feedthrough
for MEMS packaging (Nikko)



(S.Tanaka, K.Isomura (IHI), M.Esashi et.al., Power MEMS 2007, Freiburg, pp.359-362)

Palm-top silent gas turbine engine
power generator for robot (IHI)

MEMS switch for LSI tester
(Advantest)

ADVANTEST

ADVANTEST CORPORATION

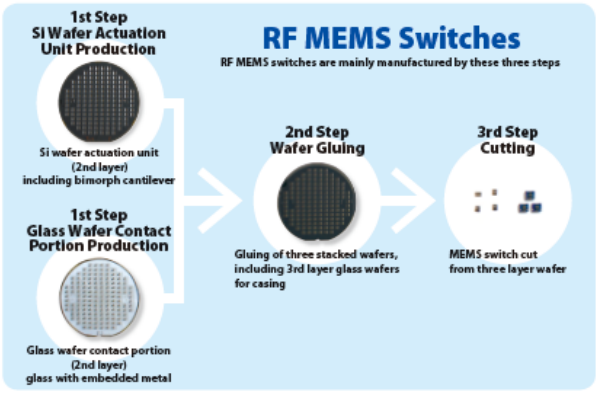
High-Frequency, Low Power Consumption MEMS Relay

Advantest's high-frequency MEMS relay utilizes piezoelectric actuation to achieve low power consumption and high reliability. Via Advantest's proprietary deposition technology, the relay features a piezoelectric film only 1 micron thick, making low actuation voltage possible. The relay also has high reliability, using contact-point control technology honed in Advantest's semiconductor testing equipment, and it can handle up to 20 GHz high-frequency transmission, using Advantest's high-frequency measurement technology.

MEMS Relay Applications

Semiconductor Testing Equipment, High-Speed Communications Devices, High-Frequency Measurement Equipment

MEMS Relay Production Process



MEMS R&D & Production

R&D Centers :	Advantest Gunma R&D Center Advantest Laboratories (Sendai) Brought to Practicality Under the Guidance of Prof. Masayoshi Esashi of Tohoku University
Production Center :	Advantest Component (Sendai) In-House Production of MEMS-Related Products, Compound Semiconductors, and SiPs for High-Frequency Modules

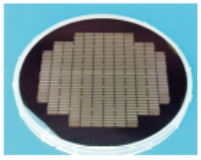
Main MEMS Relay Features (for reference)

Frequency Range :	DC- 20 GHz
Actuation Voltage :	12 V
Contact Form :	SPDT
Size (2 types) :	5.4 x 4.2 x 0.9 mm 2.9 x 3.4 x 0.9 mm
Isolation :	> 20 dB (to 20 GHz)
Insertion Loss :	< 1 dB (to 20 GHz)
Characteristic Impedance :	50 Ω

MEMS Probe Pin

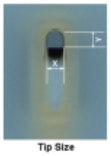
Probe pins for probe cards used in wafer test are manufactured using MEMS technology.

Probe Pitch: P	60um / 50um	
Probe Length : L	978.5um	
Probe Width : W	50um / 40um	
Tip Size	X: 15um	Y: 10um
Tip Total Thickness	39.0um	
SEM Image		



6 inch Wafer

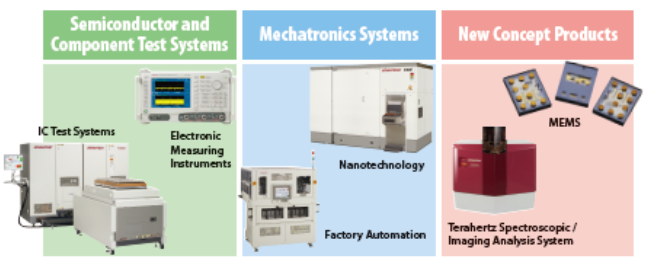
Probe Size



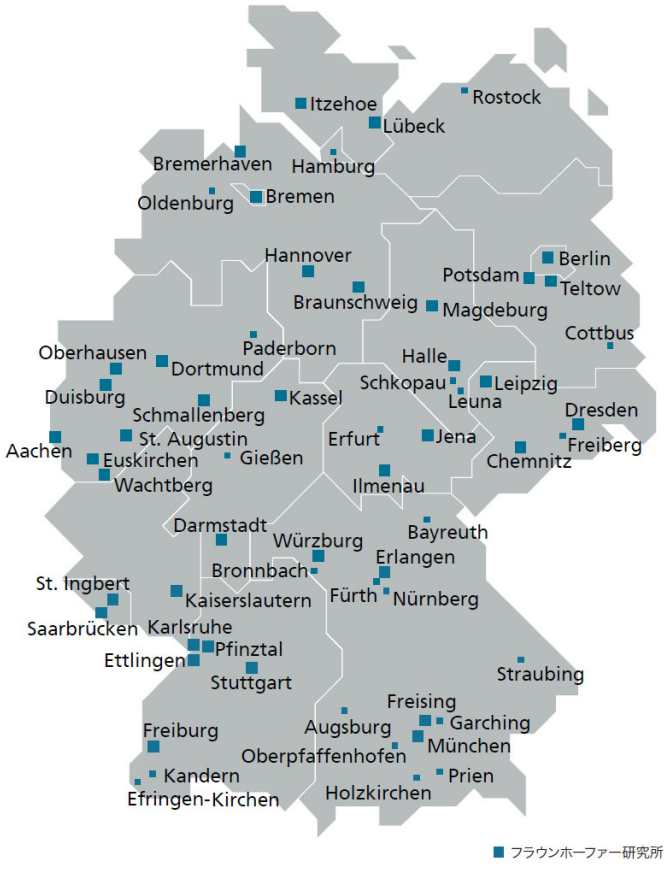
Tip Size

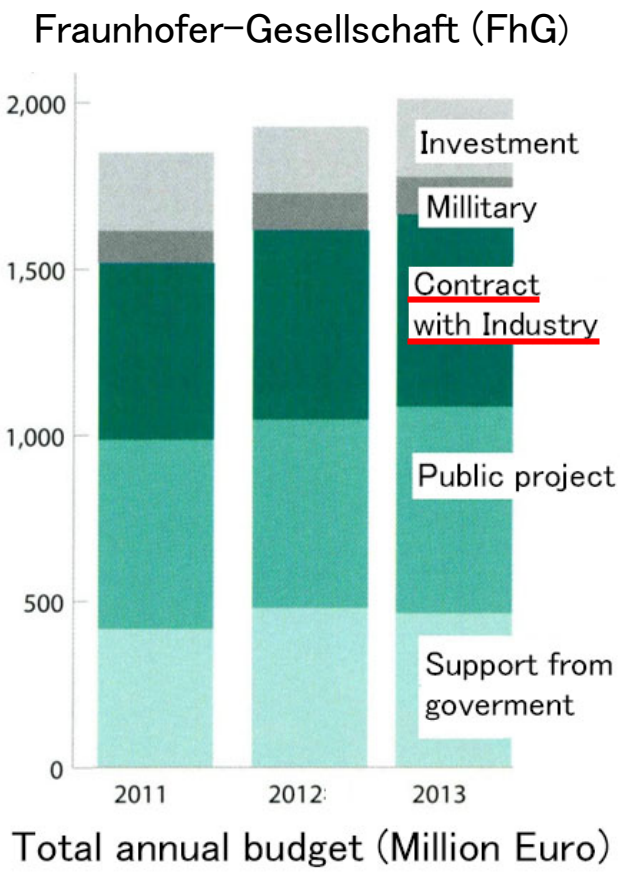
About Advantest

A leading company in measurement and testing, Advantest is involved in industries that require leading-edge testing technology, such as electronics, telecommunications, and semiconductor production. In the semiconductor and component test system business, Advantest offers test systems that support reliability in every semiconductor device category, and holds global market share of roughly 50 %.

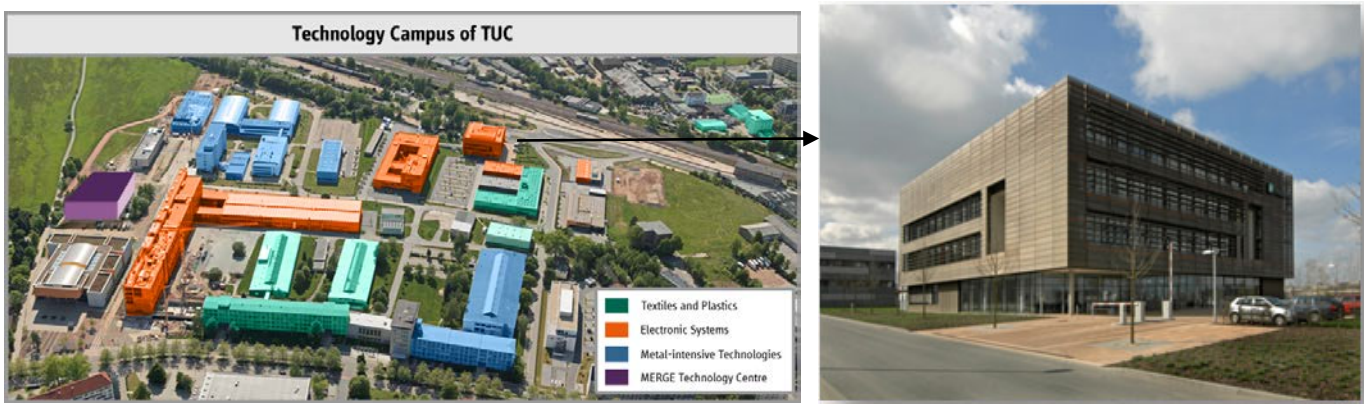


18 Fraunhofer institute (Germany)





67 research institutes and units are distributed
and collaborating with universities



Fraunhofer ENAS (Electronic NAno System) located in the campus of Cemnitz institute of Technology

Fraunhofer Representative Office Japan

Representative : Dr. Hideya Miki

German Cultural Center 1F, Akasaka 7-5-56, Minato-ku, Tokyo 107-0052, Japan

Phone +81-3-3586-7306, E-mail : info@fraunhofer.jp www.fraunhofer.jp

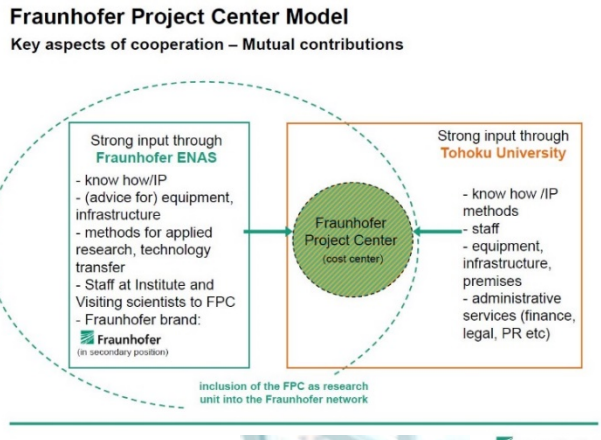
Functions : BridgesJapanese companies and Franunhofer institutes, Support project, Introduces Fraunhofer technologies

19 Fraunhofer project center in Tohoku University

FhG Germany – Sendai city partnership signing ceremony in Munich (July15,2005)

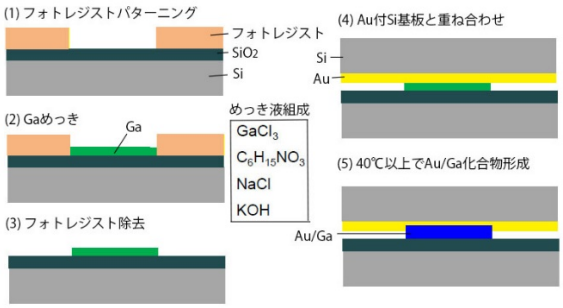
1st Fraunhofer Symposium in Sendai (Oct.19, 2005)

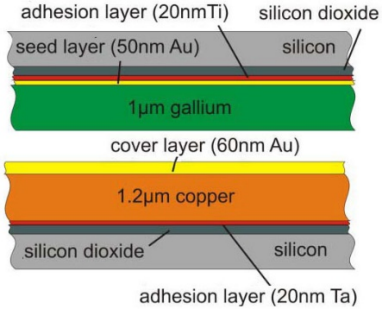
FhG Germany – WPI-AIMR Tohoku Univ. partnership signing ceremony in Sendai (Nov. 8, 2011)

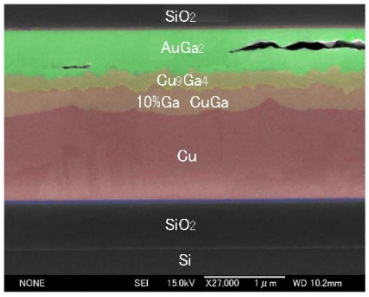


FhG Project center in WPI-AIMR, Tohoku Univ. (April 1, 2012)

Assoc. Prof. Joerg .FrÖmel







Low temperature SLID (Solid-Liquid Inter-Diffusion) bonding with Cu- Ga

(J.Froemel et.al. (ENAS, Fh.G), J. of Microelectromechanical Systems, 24 (2015) 1973)

Old method to fill an eroded tooth (amalgam method) (UV curable resin at present)
Cu powder + Hg → Solidify (Metallic compound)

20 iCAN (International Contest of innovAtioN) (Totsu et.al)

International Contest of innovAtioN (iCAN)) http://www.ican-contest.org

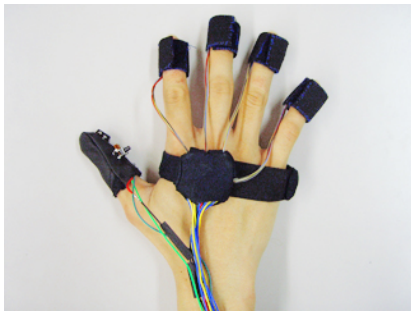
(1st (iCAN' 09) – 7th (iCAN' 16) had been **International Contest of Application in Nano / micro technologies**)

【Domestic Sponsor】 MEMS Park Consortium, Micro System Integration Center, Tohoku University

【Intention】 iCAN is a contest for students that propose idea of applications and realize the application by using MEMS devices. Teams of students from high school, college, university can participate iCAN. Preliminary contests are held in each county, followed by the final international contest.

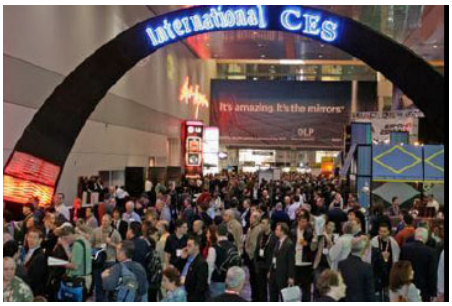
【Contact person】 Kentaro Totsu, Micro System Integration Center, Tohoku University

Phone : +81-22-229-4113, E-mail: totsu@mems.mech.tohoku.ac.jp



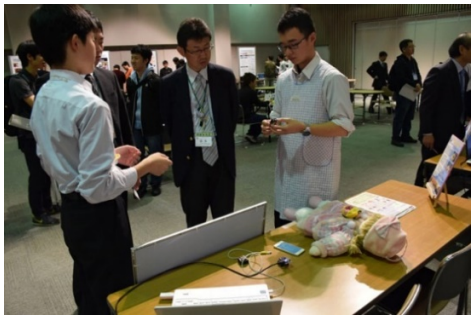
Talking Equipment from Manual Sign (Kyoto Univ.) (Winner iCAN' 11)

Anywhere Sadou (Tohoku Univ., Osaka Univ., Natural science) (Winner iCAN' 15)



Demonstration ib CES (Consumer Electronics Show) (Lasvegas)

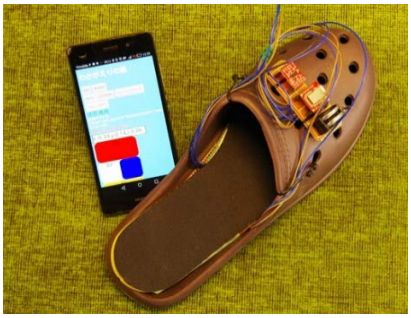
Home seculity robot (Kohriyama North Technology High school) Prime minister Award, (Winner iCAN' 14)



Baby Informer (Kohriyama North Technology High school) (3rd prize iCAN' 16)

Demonstration by students in iCAN' 17 (Beijing)

Self neck corrector (Tohoku Univ., Natural science) (Winner iCAN' 17)



Anti-aging shoes (Tohoku Gakuin Univ., Tohoku Univ., Natural science)

Super Kendama Brothers (Tohoku Univ.)

21 MEMS Park Consortium

Who we are

MEMS Park Consortium is the voluntary association aimed at supporting R&D and industrialization of MEMS technology through networking among domestic and foreign R&D supporting organization by industry-government-academia alliance.

MEMS Intensive Course in Kyoto (2011)

Our Organization

- Representative: Prof. Masayoshi Esashi (Tohoku Univ.)
- Originator: Tohoku Univ. City of Sendai, Miyagi Prefectural Government, Tohoku Bureau of Economy, Trade and Industry
- Membership: Financial member (66 companies), Partner member (10 groups)

Our Activities

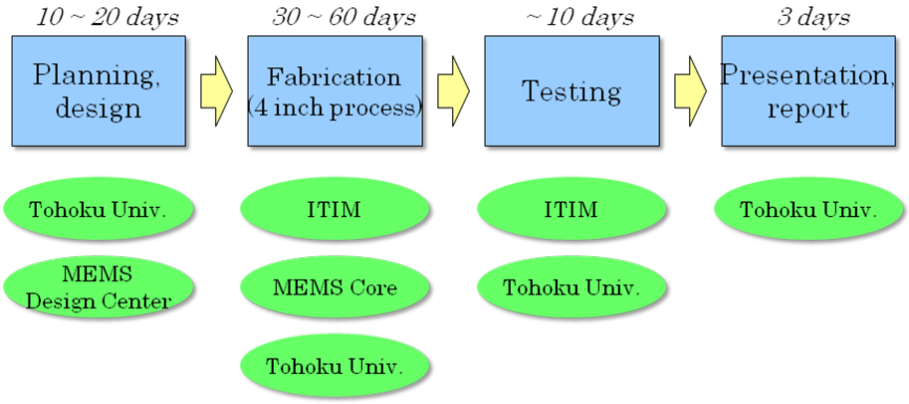
◆Information Dissemination

Disseminate information about micro technology by organizing MEMS Intensive Course, Open Seminars, MEMS Engineer Forum, by utilizing website, mailing list, twitter and participating in Exhibitions.

Three axis capacitive accelerations sensor achieved by a trainee

◆Human Resource Development

1. MEMS Training Program for Researchers and Developers (as needed)



Domestic contest for iCAN2012

Comprehensive MEMS training program for three months containing planning, design, fabrication, testing, report. Trainees propose a targeting MEMS device and carry on the process fabrication by themselves, under full-support service by Tohoku University, Industrial Technology Institute, Miyagi Prefecture and MEMS Core.

- Trainees

RICOH, MEMS CORE, PENTAX, ADVANTEST, ALPS ELECTRIC, NIPPON DENPA, SYSTEC INOUE, YAMAHA, TOPPAN, KONICA MINOLTA, SEKISUI, MURATA, FUJI MACHINE, DENSO, AHIKO FINETECH, YAMAMOTO ELECTRIC WORKS, JAXA

- Targeting devices

Optical scanner, Gyro, Micro probe, RF switch, Acceleration sensor, RF relay, Pressure sensor, Micro 2D stage, Variable inductor, Variable capacitor

2. Human Resource Development for young people

Organize domestic contest for *International Contest of Application in Nano/Micro Technology (iCAN).*

◆Technical Support (Network for Experimental Production Support)

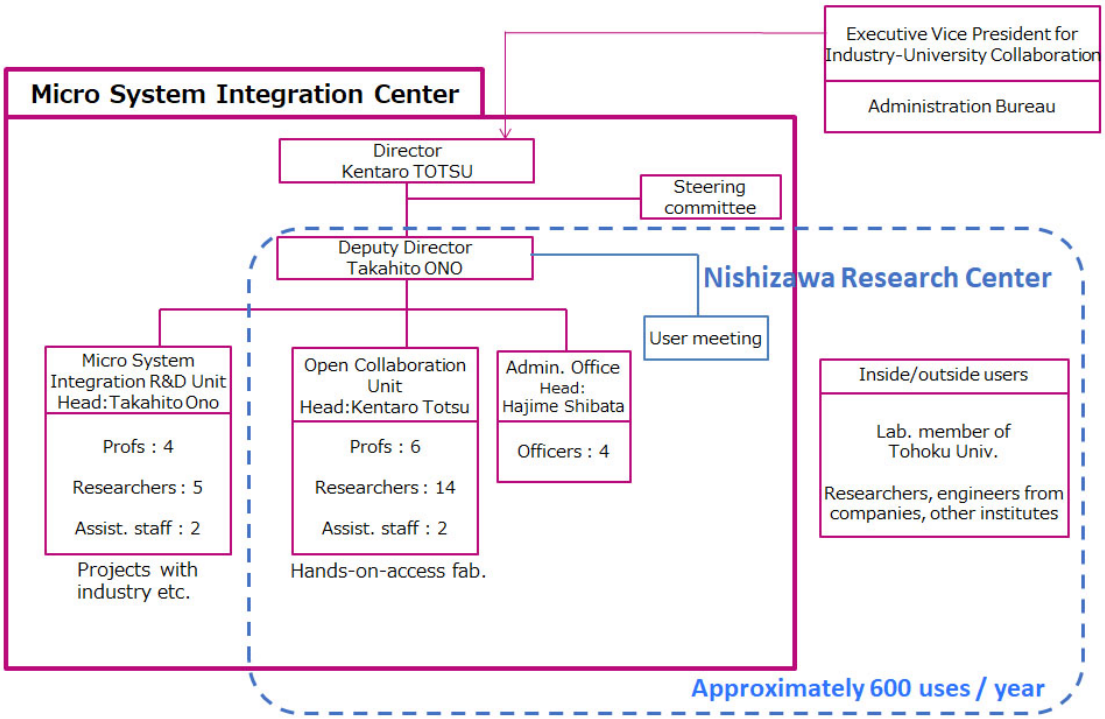
Support member companies by serving as an intermediary between a member company who has obstacles to R&D or industrialization in MEMS technology and universities or public R&D institutes.

◆Networking

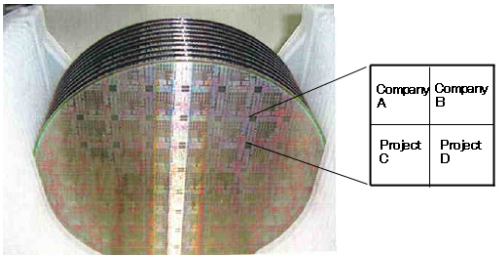
Offer a place to information exchange among member companies.

22 Open collaboration and μSIC

As of April 2025



MEMS prototyping (20mm□wafer)



Shared wafer (16 companies)

Partnership between FhG and Sendai

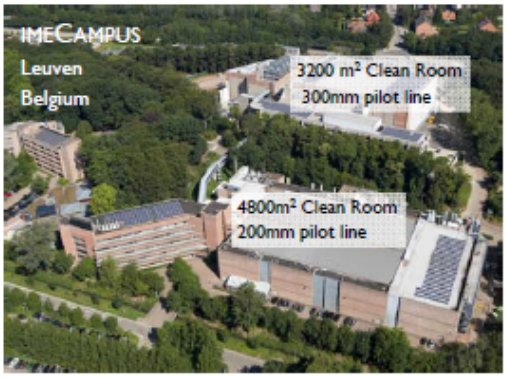
MicroNanomachining Research & Education Center (MNC)

Micro System Integration Center (μSIC)

AIST Research Center for Ubiquitous MEMS and Micro Eng. (UMEMSME)

MEMS Core Co. Ltd.

23 IMEC (Interuniversity Microelectronics Centre) (Belgium)



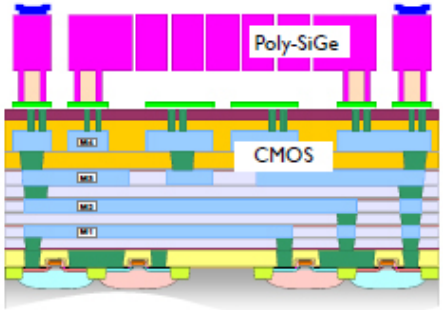
IMEC: HOME OF SIGE MEMS

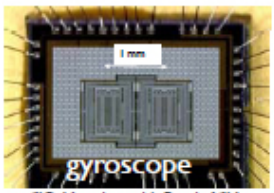
Background

In imec's 200mm fab a dedicated **poly-SiGe above-IC MEMS** (Micro Electro-Mechanical Systems) platform has been set up to integrate MEMS and its readout and driving electronics on one chip. This monolithic approach results in more compact systems with a reduced assembly and packaging cost and a higher performance than current hybrid systems.

Platform

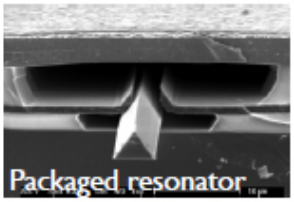
The **SiGe MEMS platform** consists of a number of standard modules: CMOS protection layer, MEMS via and poly-SiGe electrode, anchor and poly-SiGe structural layer and an optional thin-film poly-SiGe packaging module. Extra modules, such as a piezoresistive layer (see exhibit #1) can be added depending on the functionality that is needed.



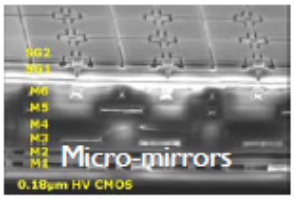


SiGeM project with Bosch, ASM, Philips (now NXP), IMSE-CNM

Project with Intel and Nanochip



Project with Panasonic



Project with ASML, NXP, Bruco, Philips Applied Technologies

Demonstrators

With this platform and together with our partners, several **successful demonstrators** have been built already. Examples are an integrated gyroscope for automotive applications (exhibit #2), a reliable 11 megapixel micro-mirror array for high-end industrial applications (exhibit #3), a cantilever array for probe-based data storage, SiGe thin film packaged SOI resonators with quality factors >200 000, ...

(Co-)development

Concept Design	Process development Packaging Testing Reliability	Product Qualification

CMORE

Prototyping

Prototyping Low-volume prototyping @ imec	Transfer

Production

High-volume manufacturing @ foundry partner

CMORE service

This SiGe platform is one of the technologies that imec offers to industrial customers through our **CMORE service**. Within CMORE innovative concepts are turned into products. Academic customers can make use of the SiGe **MPW service** within **Europractice** (exhibit #4)

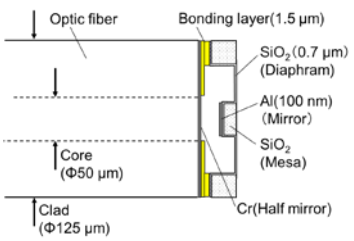
imec

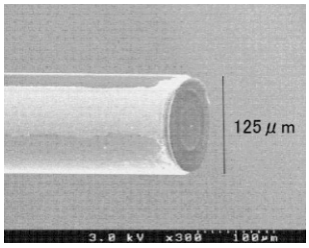
24 Start-up companies related to μSIC

MEMSAS Co., Ltd. (K. Kato, Y. Haga, T. Matsunaga, et al.)

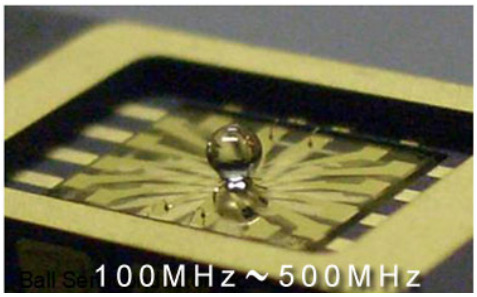
The venture company MEMSAS, aimed at applying MEMS sensor to medical devices such as minimally invasive medical catheters, was established in September 2004.

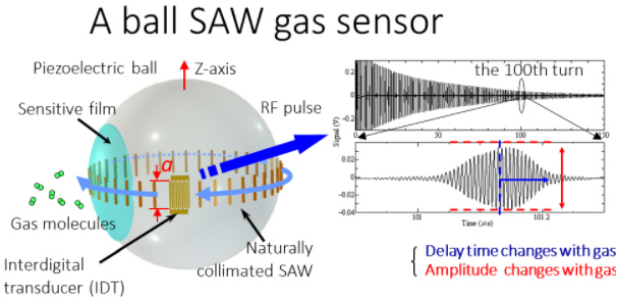
We are trying to commercialize ultra-miniature fiber-optic pressure sensor for blood pressure monitoring.





Ball Wave Inc. (Shingo Akao, Kazushi Yamanaka,Nobuo Takeda, Yusuke Tsukahara)
http://www.ballwave.jp/english/index.html

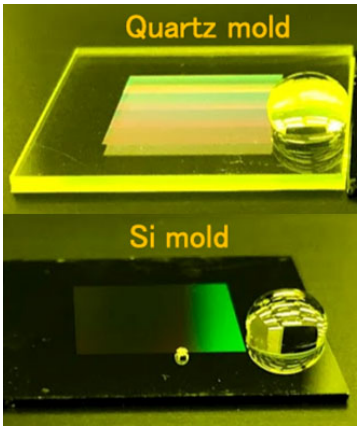




Diffraction-free surface acoustic waves (SAWs) can be generated on a solid sphere and be propagated around the sphere in many turns without spreading if the source width is a geometrical mean of the diameter of the sphere and the wave length of SAWs. A tiny change in the surface elastic properties causes a large variation in the SAW propagation because of the long propagation distance around the sphere in many turns. Depositing a thin sensitive film on the sphere realizes a small ball SAW sensor with a rapid response and a high sensitivity.

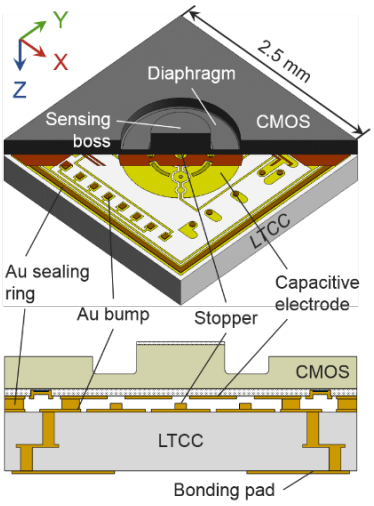
Der Nächste Co., Ltd. (Masashi Nakao) http://www.dernaechste.com/

It is a senior company that was started after retirement. Using μSIC-equipment and foundry manufacturers, we mainly support the study of various manufacturing processes in the research and development stage and cooperate with prototyping. In particular, we are carrying out comprehensive production of imprint technology, which allows nano-pattern transfer with high throughput and low cost, which we have been involved in for many years. In the imprint transfer process, it was usual to create a quartz mold or Si mold (as shown in the photo, there are water droplets to check the releasability) using EB lithography and dry etching, and then transfer the pattern from the mold to the resist. Aiming to simplify the process and improve the transfer accuracy, we are also developing a new etching-free pattern transfer technology using UV-curable PDMS.



REISense, Inc. (Shuji Tanaka, Masanori Muroyama, Hideki Hirano)
https://resense.co.jp/

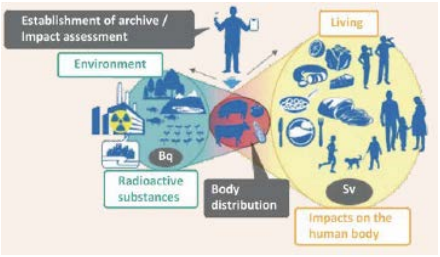
We provide MEMS-CMOS integrated tactile sensors and their network systems for next-generation robots with tactile sensing capabilities. We have developed a custom-designed sensor platform LSI using the TSMC 0.13 μm CMOS process, and further processed it with wafer-level MEMS technology to fabricate 2.7 mm-square capacitive tactile sensor devices that can detect 3-axis forces. The manufacturing yield exceeds 90%. By utilizing the event-driven response and serial bus communication functions embedded in the integrated LSI, we have successfully connected 100 devices using only six wires and achieved high-speed data acquisition from all 100 devices. Moreover, by using the sensor platform LSI, we can effectively network not only tactile sensors but also a wide variety of other sensors.



25 Activities of Nishizawa center space users

Masatoshi Suzuki (International Research Institute of Disaster Science, IRIDeS)

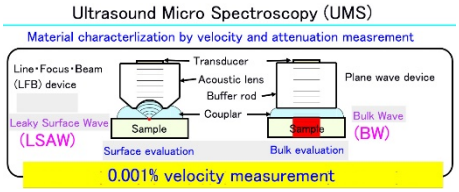
We are conducting an environmental radiation assessment to evaluate radiation doses and biological responses of wild Japanese macaques, which are the closest species to humans among wild animals in the affected areas of the Fukushima Daiichi Nuclear Power Plant accident. Nuclear disasters raise concerns about radiation exposure, but there is a lack of scientific knowledge due to the infrequency of such disasters. We have been continued our research to develop lessons learned from disaster-affected animals and to update the information on the concerns of residents and decommissioning workers.



Junichi Kushibiki

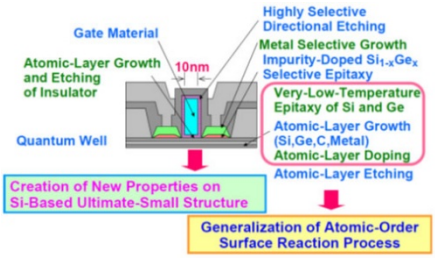
Characterization and quality control of bulk/film materials and device production processes concerned with bonded piezo substrate for SAW devices

1. Standarization of bonded piezo substrate by ultrasonic velocity
2. 3D homogenization of LT/LN film Thickness design for device structure.



Junichi Murota

For the fabrication of high-performance Si-based devices, the Atomically Controlled Processing for group IV semiconductor based on atomic-order surface reaction by Chemical Vapor Deposition (CVD) is investigated. The atomic-layer level mechanism of impurity-doped Si, $Si_{1-x}Ge_x$, and Ge epitaxial growth is described using a newly proposed modified Langmuir-type model, and the adsorption site density for reactive gases on the group IV semiconductor surface is under investigation.

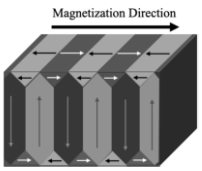


Shigeru Suzuki

In collaboration with research organizations inside and outside the university, we mote R & D to solve important issues and aims to return the achievements to the society.

1. In the electronics field, we are conducting R & D on evaluation and control of metal sngle crystals, which are promising substrates for next-generation power semiconductor thin films.
2. In the energy field, we are promoting R & D from a microscopic viewpoint on magnetic materials for designing functional devices such as high-performance actuators and sensors.
3., We are also engaged in the application of knowledge obtained through multiscale analysis for the utilization of various elements on the earth in the field of environment and resources.

Substrate crystal for thin power semiconductors



Micromagnetism for Function Characterization

Yasubumi Furuya:

1. Materials Processing and Energy Materials Engineering
2 Intelligent Materials Engineering and Smart Material Development
3 Development of Various Sensor and Actuator Materials & Devices
4 Non-Destructive Testing and Material Evaluation using Electromagnetism
5 Development of Magnetostrictive Alloys for Energy Harvesting, IoT-Compatible Sensor Devices
6 Green Energy Surplus Utilization Systems and Smart Agriculture Field Demonstrations
7 Research and Social Implementation of IoT-based Safe and Sustainable Technologies For Personal Infrastructure Spaces

Overview of the Demonstration Experiment Utilizing the Natural Energy Storage GEMCOS-IoT Control System at the Ayu Aquaculture Facility in the Akaishi River Basin, Shirakami Foothills, Ajigasawa Town, Aomori Prefecture