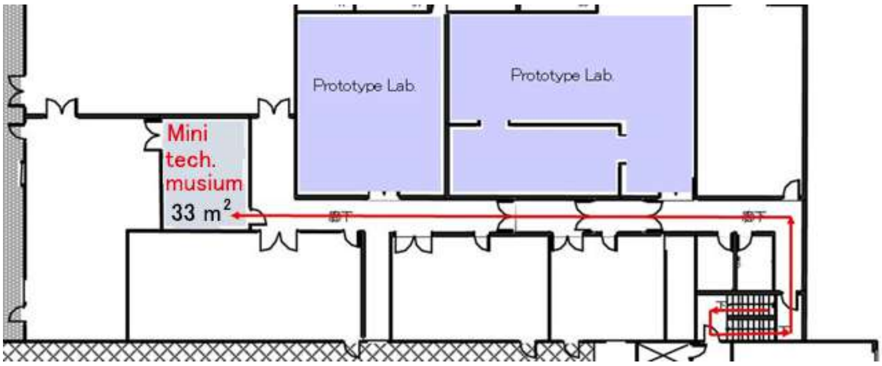
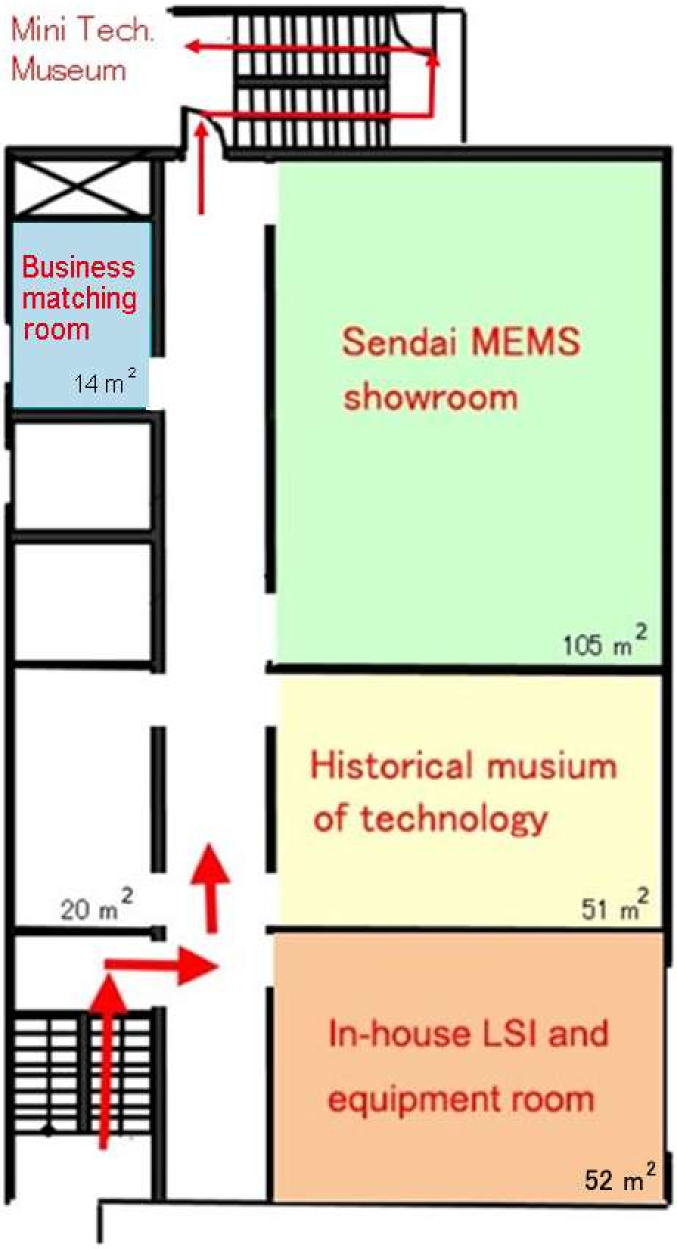
Exhibition rooms in Jun-ichi Nishizawa Memorial Research Center



Sendai MEMS showroom



2nd floor

Historical museum of technology

In-house LSI and equipment room

Business matching room

Mini tech. museum

1　展示室（Exhibition room）

日本語

1 西澤潤一記念研究センター内の展示室紹介(表紙)

英語（English）

21 Exhibition rooms in Jun-ichi Nishizawa Memorial Research Center (cover)

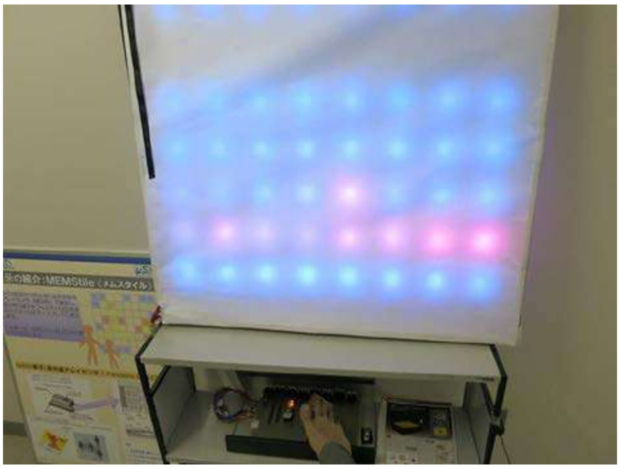
日本語		English	
2 仙台 MEMS ショールーム　ポスター 0-25	7 カード A1-A14	22 Sendai MEMS showroom　Poster 0-25	27 Card A1-A14
	8 カード B1-B14		28 Card B1-B14
	9 カード C1-C14		29 Card C1-C14
	10 カード D1-D14		30 Card D1-D14
	11 カード E1-E14		31 Card E1-E14
	12 カード F1-F14		32 Card F1-F14
	13 カード G1-G4		33 Card G1-G4
	14 カード H1-H7		34 Card H1-H7
	15 カード I1-I2		35 Card I1-I12
3 近代技術史博物館　ポスター 0-25	16 カード J1-J17	23 Historical Museum of Technology Poster 0-25	36 Card J1-J17
4 自作集積回路・装置室　ポスター 0-18	17 カード K1	24 In-house IC and equipment room Poster 0-18	37 Card K1
5 ビジネスマッチング室　ポスター 0-7	18 カード L1	25 Business matching room　Poster 0-7	38 Card L1
6 ミニテックミュジアム　ポスター 0-14	19 カード M1	26 Mini tech Museum　Poster 0-14	39 Card M1
廊下	20 カード N1-N4	Corridor	40 Card N1-N4

廊下展示写真（Photo of exhibition in corridor）

以前の計測器と試作品（Old equipment and prototype）

半導体研究振興会や西澤先生の書籍および MEMS 学会資料
（Books by Semiconducror Research Institute and Prof. Nishizawa, and proceedings on MEMS）

MEMS 学会資料（Proceedings on MEMS）



電子レンジ用赤外線センサアレイ（Infrared sensor array for microwave oven）

List of cards (samples are shown in red frame)

A1 Infrared sensor, imager
A2 Infrared sensor
A3 2 axis galvano optical scanner
A4 DMD (Digital Micromirror Device)
A5 Digital cinema DMD
A6 Optical encoder
A7 Piezoelectric, thermal inkjet printer head
A8 Electrostatic inkjet printer head
A9 MEMS resonator
A10 MEMS resonator (disk, Lamb etc.)
A11 FBAR (Film Bulk Acoustic Resonator)
A12 SAW device on LSI
A13 Tunable SAW filter using variable capacitor
A14 SAW passive wireless sensor

B1 Piezoresistive pressure sensor
B2 Integrated capacitive pressure sensor
B3 Resonant pressure sensor
B4 Capacitive vacuum sensor
B5 Capacitive vacuum sensor products
B6 MEMS microphone
B7 MEMS microphone wafer
B8 MEMS microphone for humid environment
B9 Capacitive accelerometer for automobile
B10 Wafer of accelerometer by surface micromachining
B11 Various accelerometers
B12 Integrated capacitive accelerometer
B13 3-axis accelerometer
B14 Electrostatically levitated rotational gyroscope

C1 Electromagnetically driven resonating gyroscope
C2 Silicon ring gyroscope
C3 Piezoelectric gyroscope
C4 Electrostatically driven capacitive sensing gyroscope
C5 Yaw rate, acceleration sensor
C6 Accelerometer and gyroscope for automobile and smartphone
C7 Patterning
C8 Etching (Deep RIE, XeF_2 Etching, etc)
C9 Deposition
C10 Probe for scanning probe microscope (SPM)
C11 Near-field optical probe and bow-tie antenna
C12 Highly sensitive sensors using thin resonator
C13 Multi-probe data storage
C14 Electron source

D1 Electrode for biopotential recording
D2 Semiconductor ion sensor (ISFET)
D3 Catheter pH, CO_2 sensor
D4 Intermittent sampling continuous blood gas monitor
D5 Application of ISFET to dentistry, oceanography and fish cultivation
D6 Micro ISFET and integrated micro probe
D7 Gas sensors
D8 Disposable chemical analysis chip
D9 Bio LSI and tactile sensor network
D10 Catheter blood pressure sensor
D11 Active catheter
D12 Multi-link motion mechanism using shape memory alloy
D13 Imaging for minimal invasive medicine
D14 Implantable stimulator

E1 LIGA process
E2 Laser processes and stealth dicing
E3 Anodic bonding
E4 Anodically bondable LTCC with electrical feedthrough
E5 Bonding materials
E6 Shared CMOS LSI wafer
E7 Laser-erased wafer process
E8 Massive parallel electron beam write
E9 Micro pump, micro valve and chemical analysis system for liquid
E10 Micro mixer and particle analysis
E11 Flow sensor and mass-flow controller for gas
E12 Bakable micro valve and anticorrosive mass-flow controller
E13 Sensing in harsh environment
E14 Silicon carbide (SiC) mold for glass press-molding

F1 Small size gas turbine engine dynamo

F2 Si micro–turbine and thermoelectric generator

F3 SiC and PZT by lost–mold process, Si_3N_4 by reaction sintering

F4 Micro fuel cell

F5 Micro fuel reformer

F6 Digital micro thruster (solid rocket engine array)

F7 Electrostatic micro motor, actuator

F8 Distributed electrostatic micro actuator

F9 Piezoelectric micro stage

F10 Lateral motion piezoelectric microactuator

F11 Tactile display and tactile imager

F12 Micro refrigeration system

F13 Thermal MEMS switch

F14 Electrostatic and piezoelectric MEMS switch

G1 Wavelength swept pulsed quantum cascade laser

G2 Optical melt pressure & temperature sensor

G3 Capacitive high sensitive differential pressure sensor "MANOSTAR"

G4 10th anniversary of SEMI MEMS seminar

H1 Tohoku Univ. and Belgium IME

H2 Poly–SiGe for MEMS sensor applications

H3 MEMS gyroscope on CMOSIC using poly–SiGe

H4 SiGe micro–mirror array on CMOS IC

H5 CMORE SiGeMEMS mluti project wafer

H6 Holographic displays

H7 MEMS for energy harvester & electronic noise

I1 Piezoelectric and electrostatic optical scanners

I2 Immunological analyzer of Helicobacter pylori's urease

J1 Telegraph using electric wire in bottom of ocean

J2 CPU board for super computer

J3 Microwave radar using anode split magnetron

J4 Shimada laboratory in which high power anode split magnetron was developed before the end of war (Z project)

J5 Crystal detector and point contact transistor

J6 Transitions of power devices used in Shinkansen

J7 Massive parallel electron beam write

J8 Electromagnetically levitated lamp

J9 Model railway of magnetically levitated linear liner

J10 Linear Chuo Shinkansen using superconductivity and its model railway

J11 Linear subway (Linear metro) travelling on wheels

J12 Micro car

J13 Disassembly of FOMA (3G) smartphone

J14 Continuous arterial pressure waveform with Tonometry

J15 Topics related to collected books

J16 Micro flying robot (μ FR)

J17 Planimeter (area meter) and proportional compass

K1 Books, photograph and 0ther materials about Prof. Jun–ichi Nishizawa

L1 Hermetic seal bonding at low temperature with sub–micron Au particles

M1 Five-storied pagoda made of glass

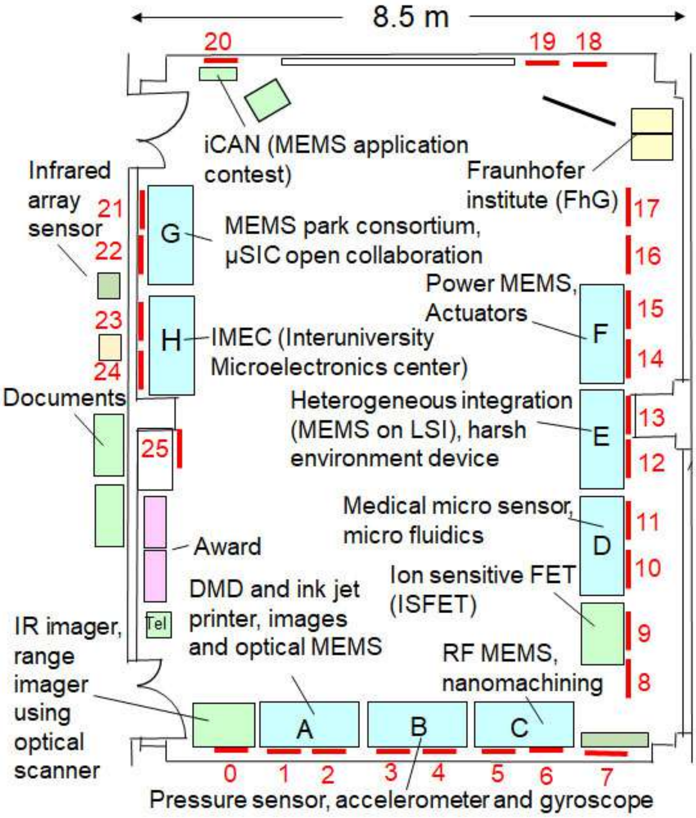
N1 Infrared array sensor (Panasonic Corp.)

N2 3D LSI (Honda research Institute Japan, Co Ltd)

N3 Remote control switch using energy harvester (EnOcean GmpH)

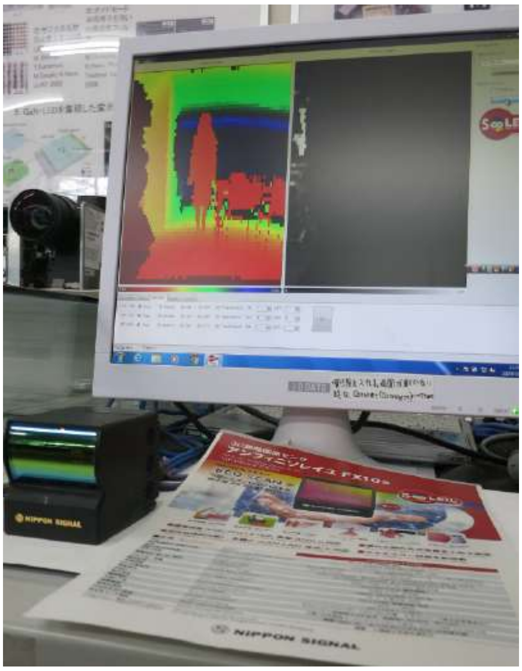
N4 Membrane switch array for electrophoresis display and oscillometric blood pressure monitor (E–paper, Tokyo Sanyo Electric Co. Ltd, Kazuo Senda)

0 Sendai MEMS showroom



Poster

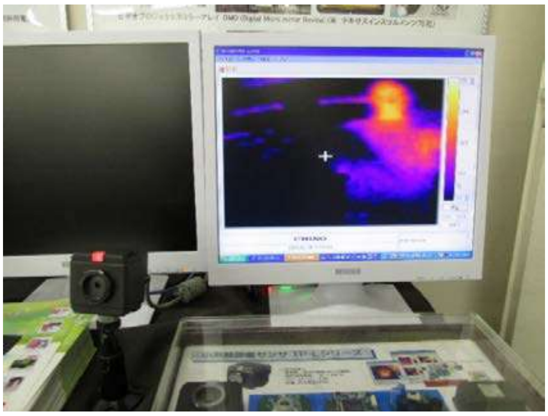
0 Sendai MEMS showroom
1 What is MEMS?
2 Optical MEMS and Micro/Nano-Optics (Hane, Kanamori)
3 RF MEMS
4 Mechanical sensors
5 Micromachining and packaging
6 Nanomachining and ultra-high sensitive sensing
7 PZT thin films for MEMS
8 Sensor network (Kuwano)
9 Micro sensors for medical monitoring
10 Minimally 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)



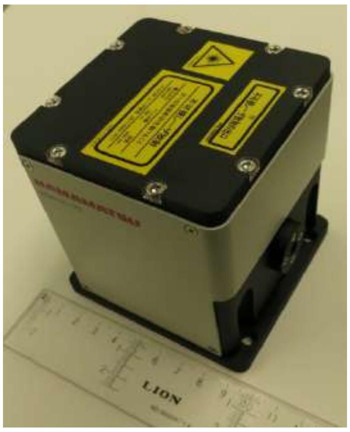
Range imager(Nippon signal), Thermal imager(Chino)

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

ISFET honored “Denki no ishizue” by IEEJ in 2017

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

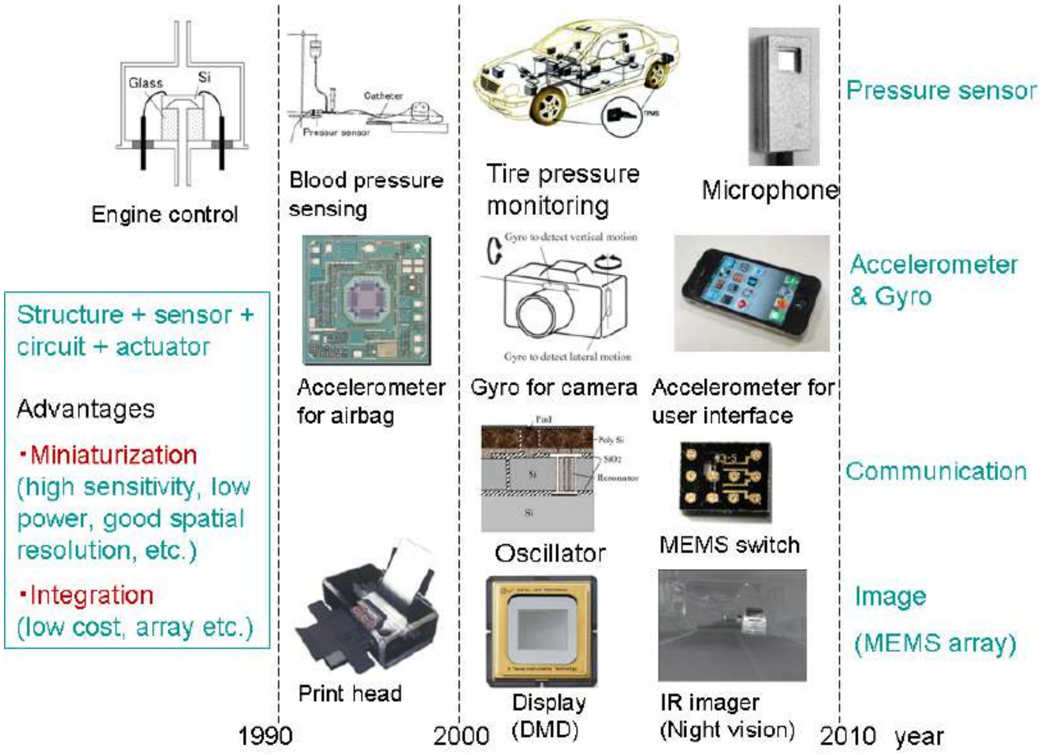
iCAN (International Contest of InnovAtion)



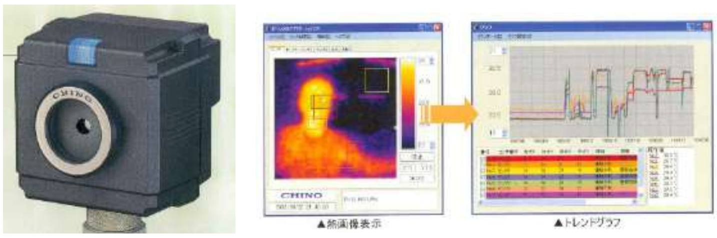
Quantum pulse cascade laser (Hamamatsu photonics)

(commercialization based on Hands-on access fabrication facility)

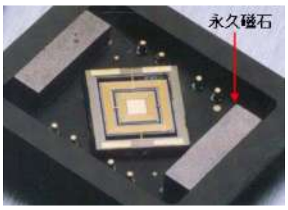
1 What is MEMS ?

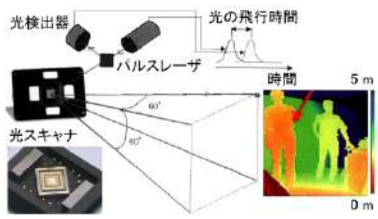


Trend of MEMS（Micro Electro Mechanical Systems) product



Compact thermal image sensor (Infrared imager)（Chino Ltd.）　Infrared imager for smartphone (FLIR (USA))

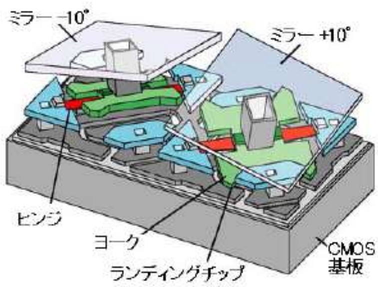


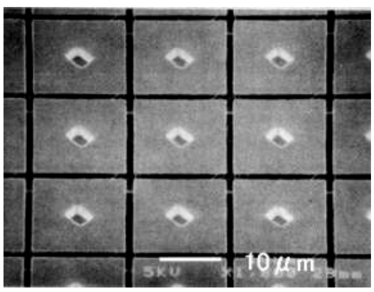


2 axes optical scanner　Range imager (Nippon signal)　Application to platform door　Application to LIDAR

(Nppon signal, Tohoku Univ.)　(JR Ebisu station)

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



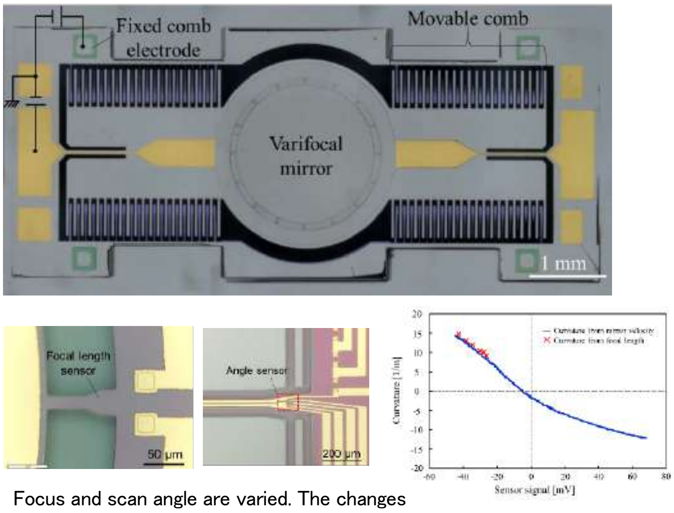


Mirror array for video projector DMD (Digital Micro mirror Device) (Texas Instruments (USA))

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

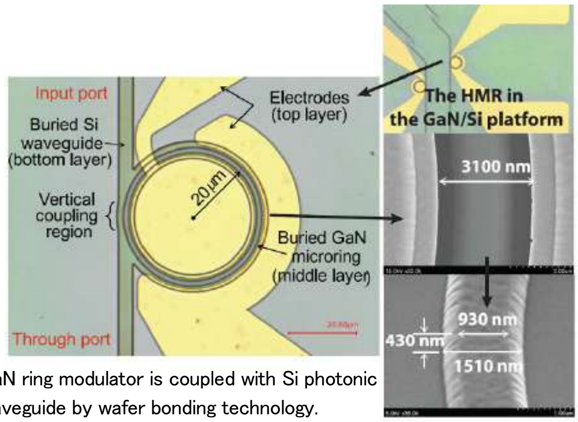
Optical MEMS and Micro/Nano-Optics are studied in this laboratory.
1. Micro-mirrors for display, telecommunication and sensing, 2. Optical micro-sensors for mechatronics and spectroscopy, 3. Silicon nanowire waveguide devices for telecommunication, 4. GaN-MEMS, 5. Nano-structured optics and meta-materials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

Scanner with Varifocul Micro-Mirror



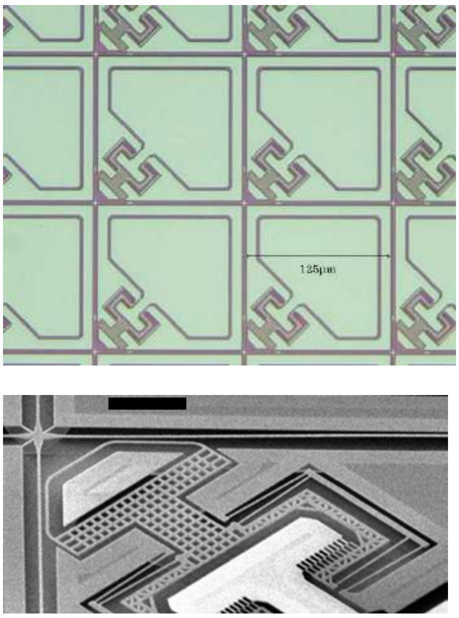
Focus and scan angle are varied. The changes are monitored by Si piezoresistive sensors. K. Nakazawa, J. J. MEMS,26,(2017)440

GaN ring modulator coupled to Si waveguide



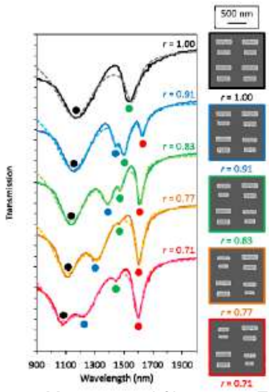
GaN ring modulator is coupled with Si photonic waveguide by wafer bonding technology. Lightwave is modulated by the refractive index change of electro-optic effect of GaN. B. Thubthimthong, Appl. Phys. Lett. 122 (2018) 071102

Silicon waveguide switch for cross connect

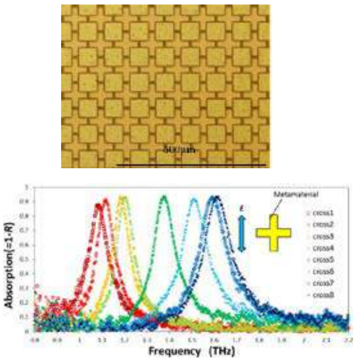


Matrix type switch consists of Si photonic waveguides. Gaps of couplers are varied by comb-drive actuator for switching. The couplers are located near the cross points of Si waveguides. The switch is developed for cross connect in data centers. S.Abe, Photon.Technol. Lett. 26 (2014) 1553

Nano structural optics (Meta-material)

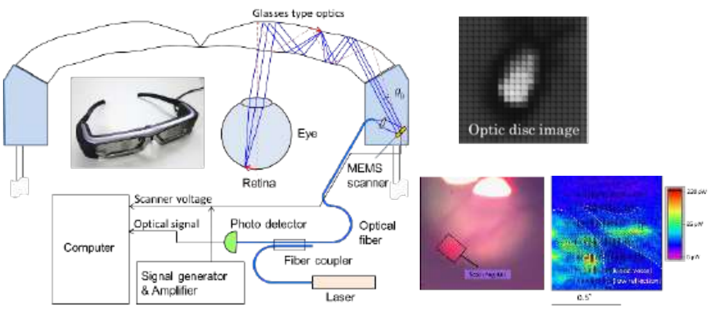


Metamaterial filter using Fano resonance, Y.Moritake, Opt Exp.24(2016)9332



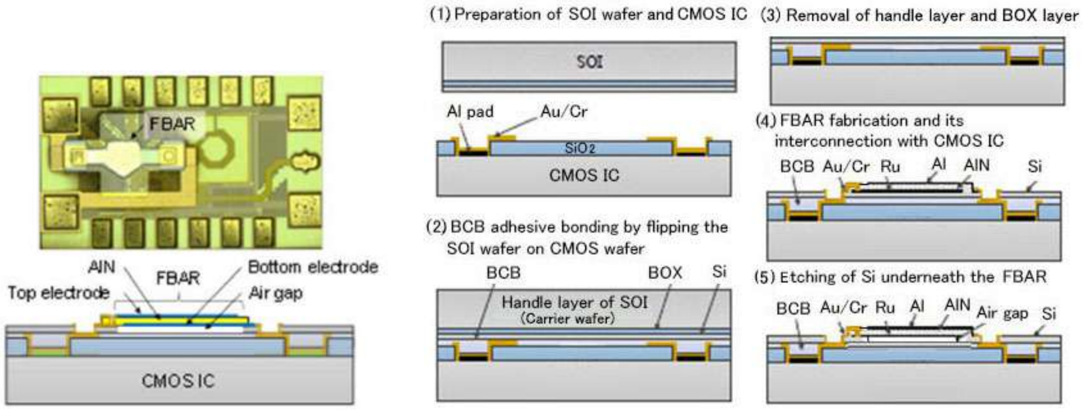
Absorption filter using THz metamaterials
Y.Ishi,IEEJ 136-E (2016) 172

Smart glasses retinal imaging with MEMS scanners

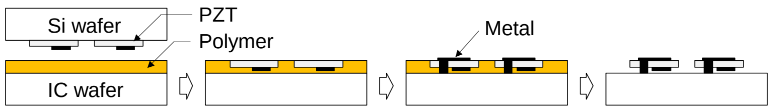


Retinal imaging using smart glasses and MEMS scanners. Retinal images of pig eyes, N.Kaushik,International Display workshops, Dec. 6-8, 2017, Sendai

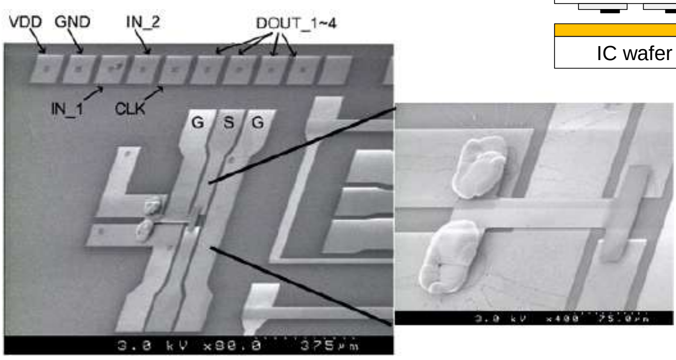
3　RF MEMS

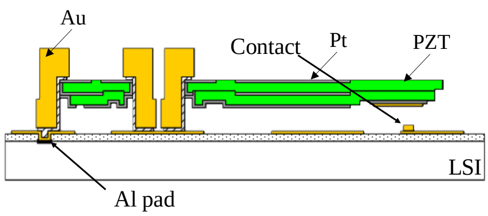


FBAR（film bulk acoustic resonator）on LSI (Kochhar et. al, 2012 IEEE Internl. Ultrasonic Symp. (2012) 1047)



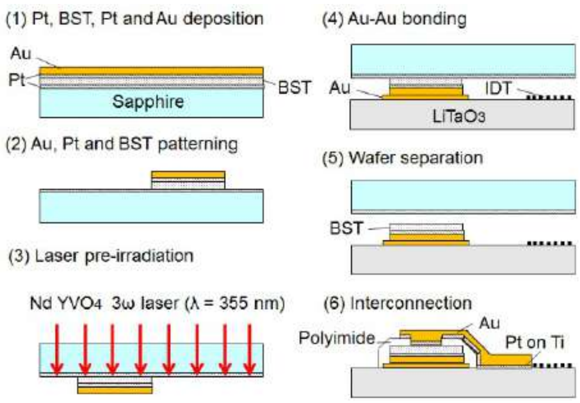
IC 上への PZT MEMS の集積化プロセス

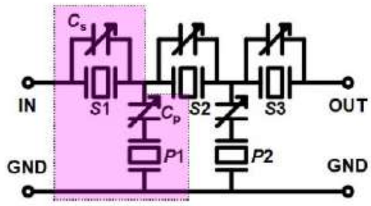




PZT MEMS switch fabricated on 0.35 μm CMOS LSI　　　　Cross sectional view of PZT MEMS switch

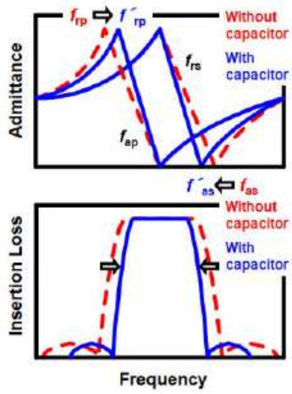
（Matsuo *et al.*, IEEE MEMS 2012, pp. 1153–1156）

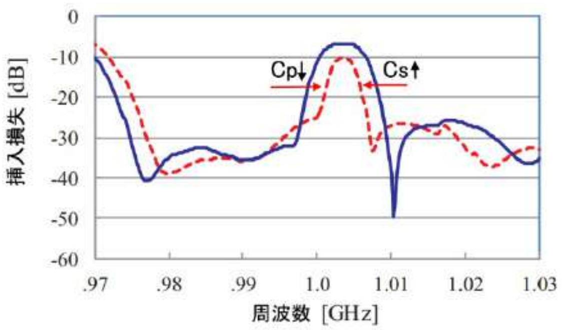


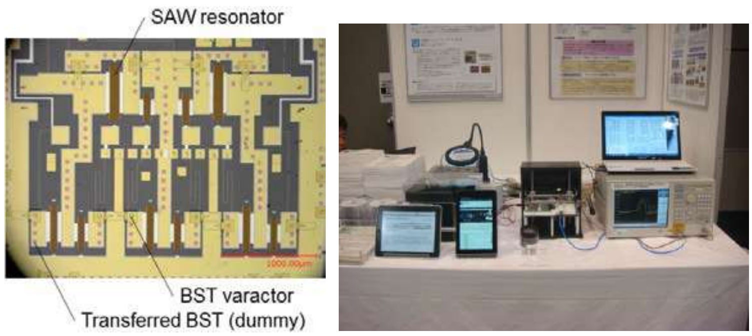


$$f'_{\mathrm{rp}} = f_{\mathrm{rp}}\sqrt{1+\frac{C_{1\mathrm{p}}}{C_{0\mathrm{p}}+C_{\mathrm{p}}}}$$

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



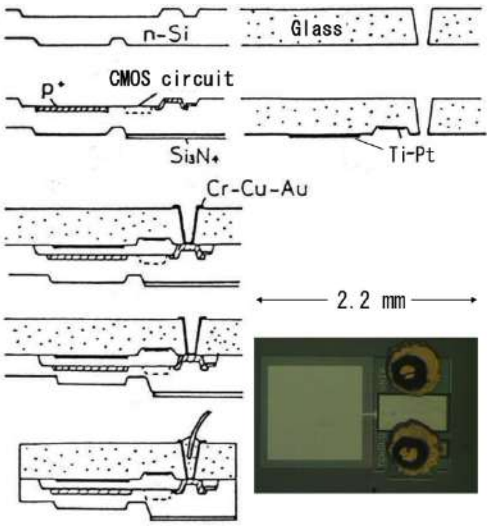


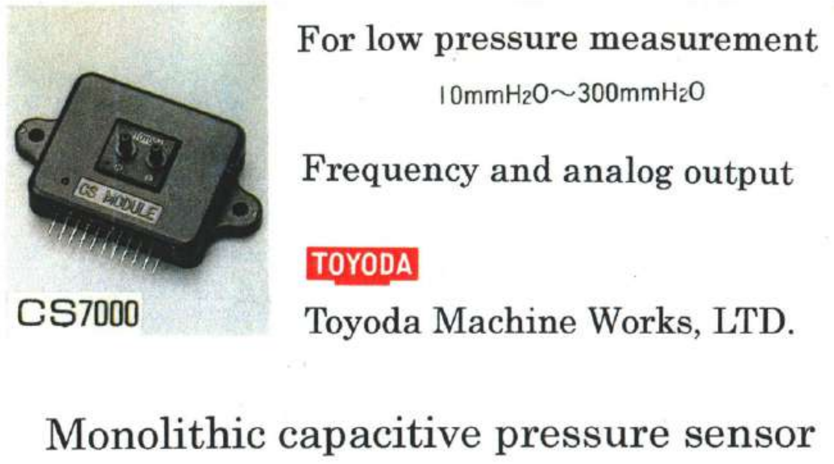


Tunable bandwidth filter fabricated by selective transfer of feroelectric variable capacitor on SAW device

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

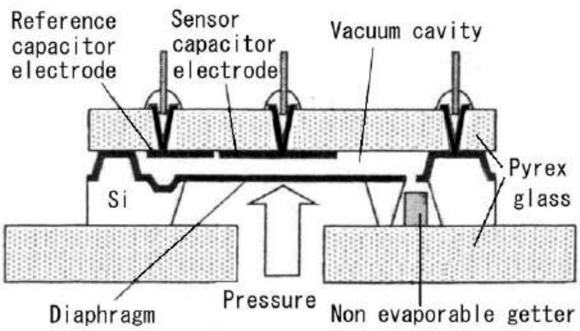
4 Mechanical sensors



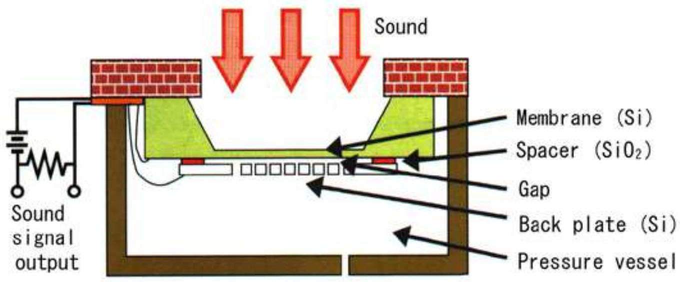


Integrated capacitive pressure sensor

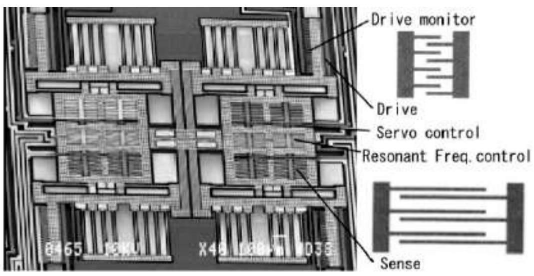
(Y.Matsumoto, S.Shoji and M.Esashi, Ext. Abstracts of the 22nd Conf. on Solid State Devices and Materials (1990) 701)

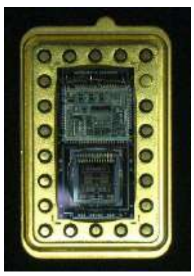


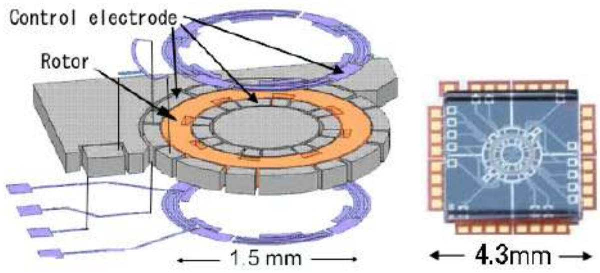
Silicon capacitive vacuum sensor (H.Miyashita et.al., ANELVA technical report, 11 (2005) 37)



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



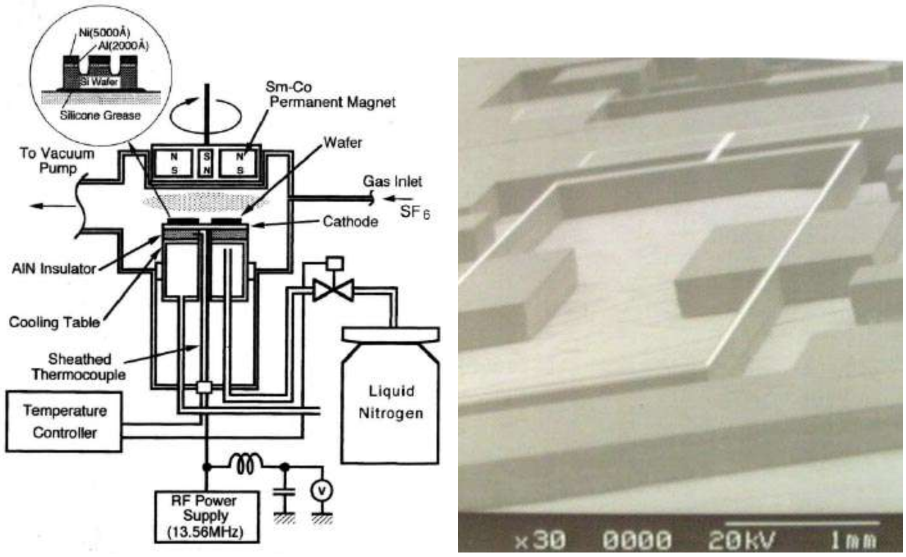


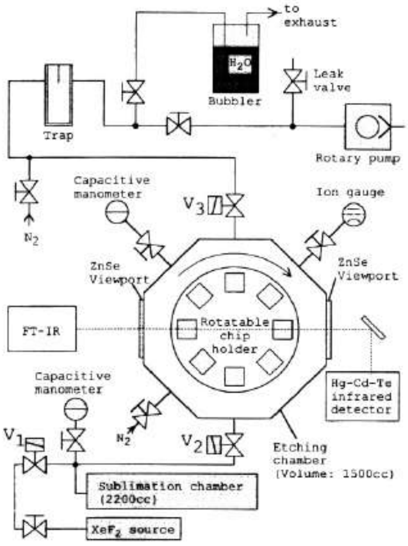


Yaw rate & acceleration sensor (Toyota motor Ltd.) Electrostatically levitating rotational gyro (Tokyo keiki Ltd.)

(M.Nagao, et.al., 2004 SAE World Congress, 01-1113 (2004)) (T.Murakoshi, et.al., Jpn. J. Appl. Phys., 42 (2003) 2468)

5 Micromachining and packaging



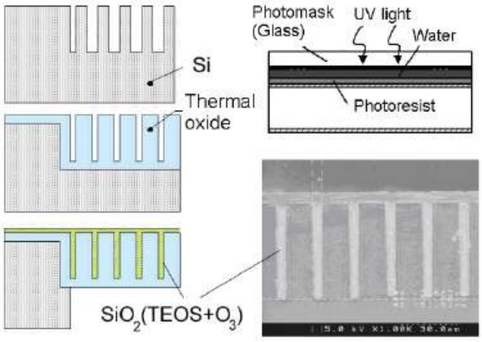


Deep RIE system and resonating gyro fabricated using it

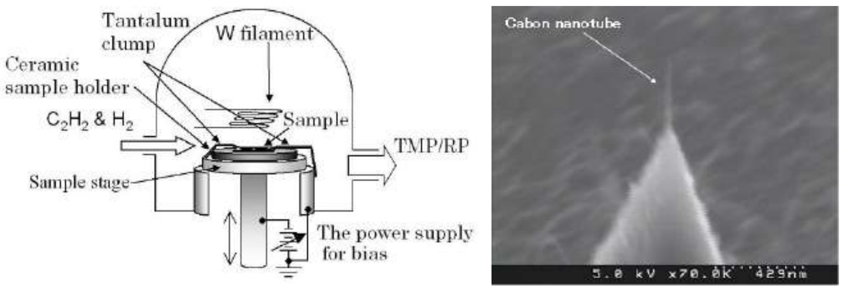
(M.Takinami,Tech.Digest of the 11th Sensor Symp.(1992)15)

Si etching system using XeF_2

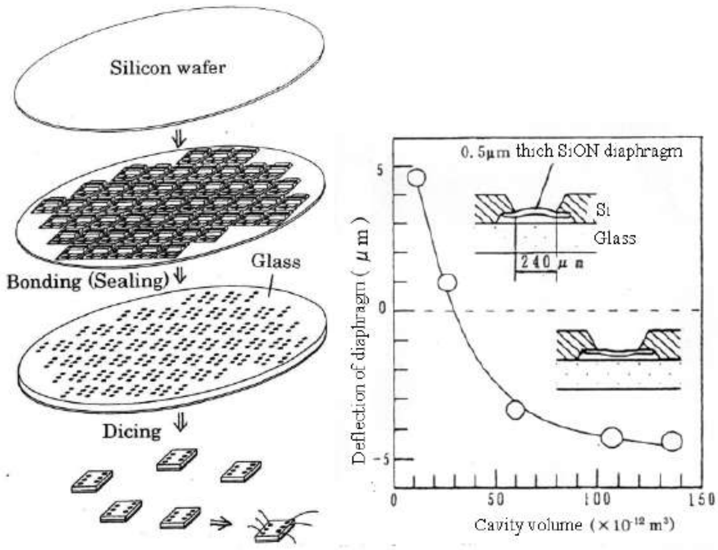
(R.Toda,Sensors & Actuators,A66(1998) 268)



Water immersion contact lithography and
trench refill.
(K.S.Chang, et.al, J.of Micromech. Microeng., 15 (2005) S171)

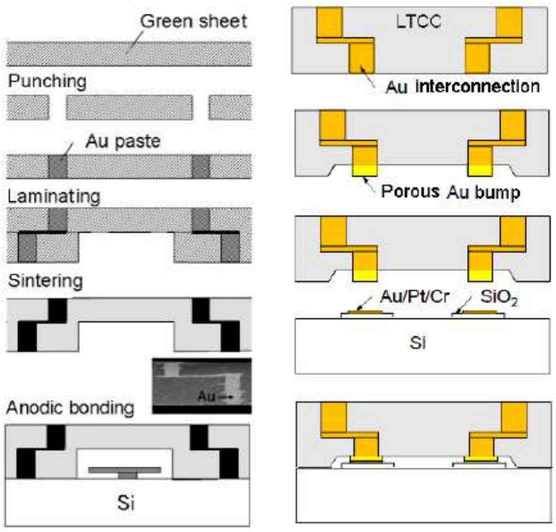


Hot filament CVD used for Carbon nanotube growth
(or diamond film deposition).
(T.Ono et.al., Nanotechnology, 13 (2002) 62–64)



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.

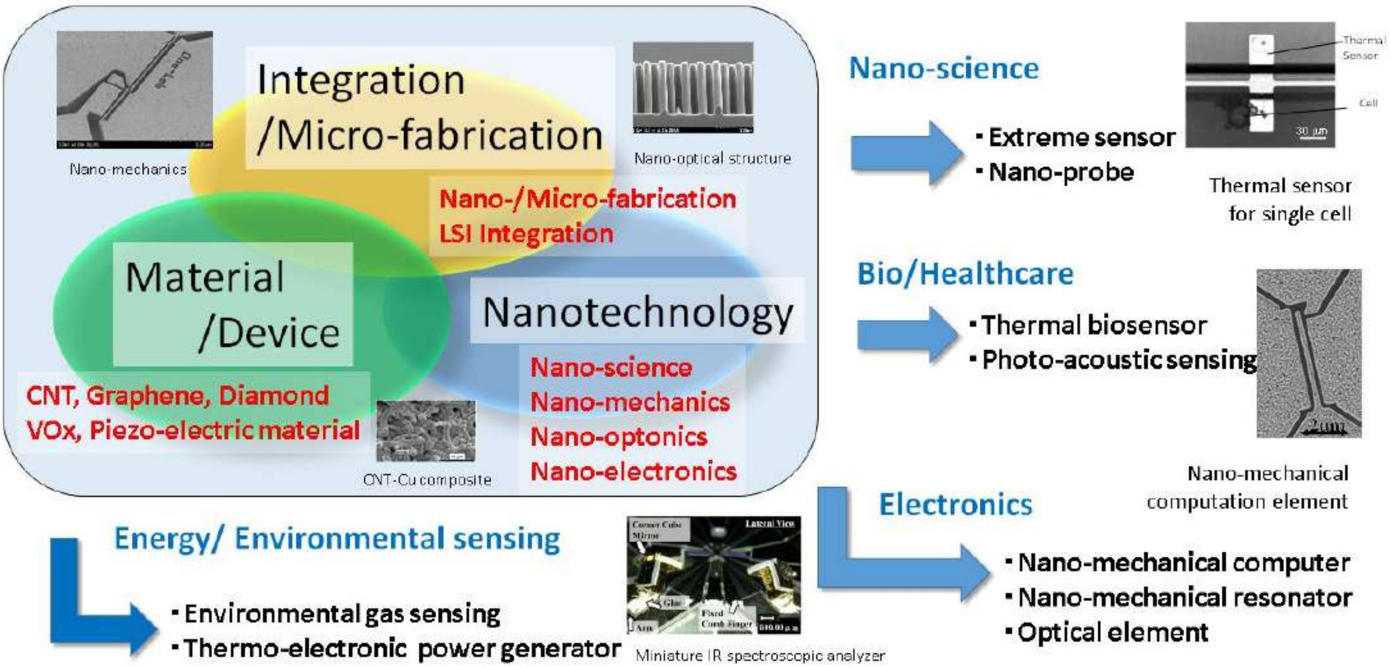
(S.Tanaka et.al.,Technical Digest IEEE MEMS, (2012) 369)

6 Nanomachining and ultra-high sensitive sensing

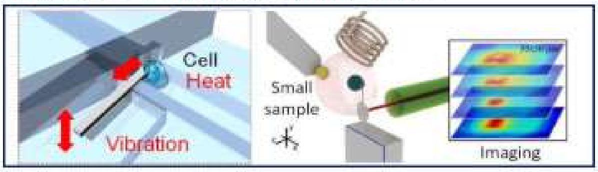
Graduate School of Engineering
Department of Mechanical Systems Engineering

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.

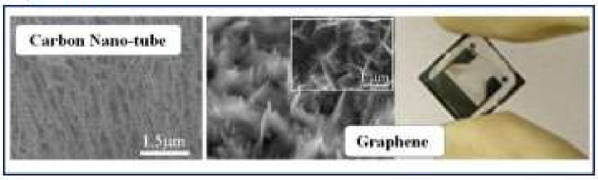


Ultimate Sensing, Spintronics



Micro/Nano Energy Systems, Wearable

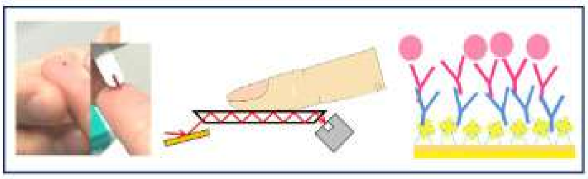
Genious Materials for Micro/Nano Systems



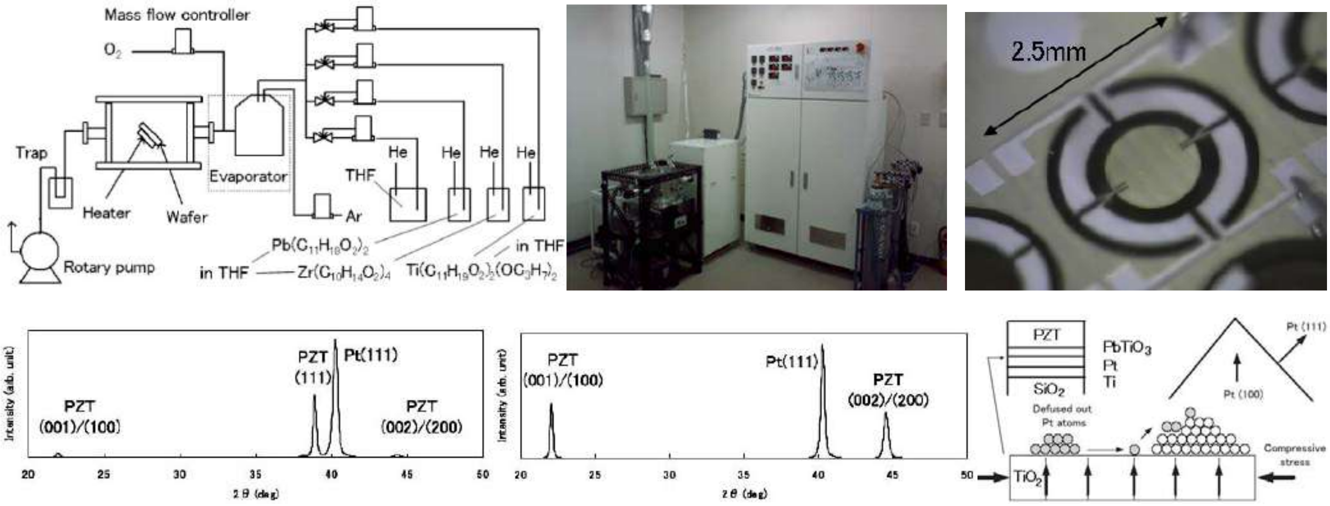
IoT Sensors, Miniature Systems

Nanomechanics, Quantum electromechanics

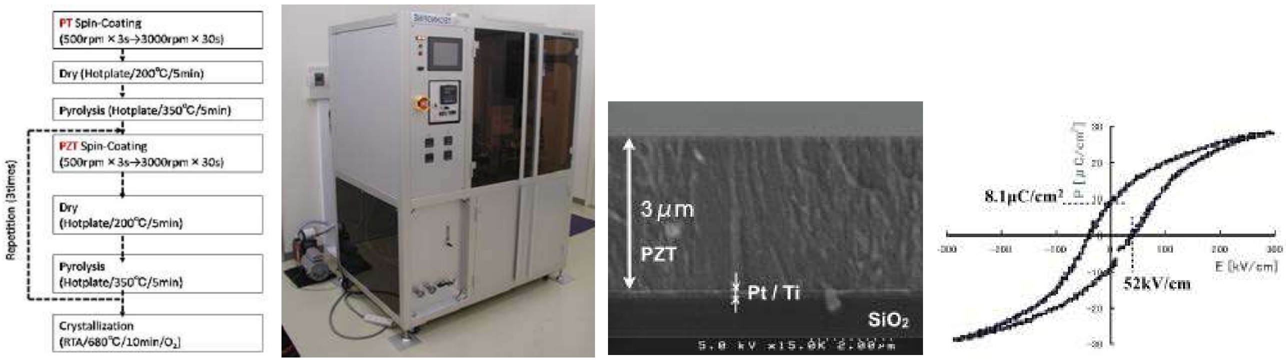
Healthcare, Bio-Applications



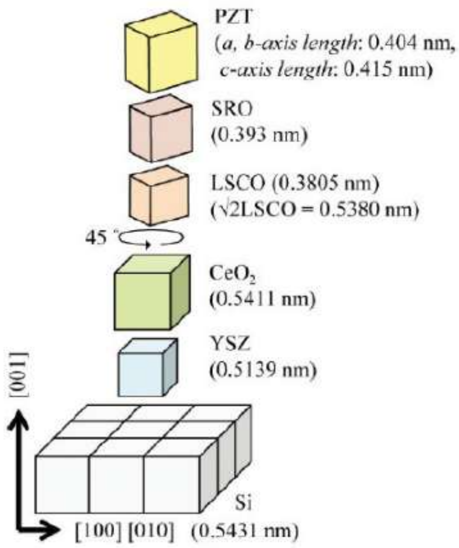
7 PZT thin films for MEMS

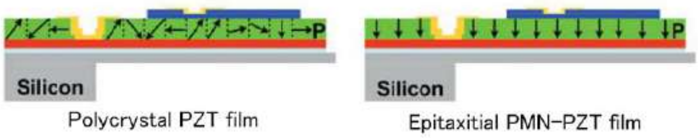


PZT thin film by MOCVD (H.Matsuo, Y.Kawai, S.Tanaka and M.Esashi, Jap. J. Appl. Phys, 49 (2010) 061503)



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



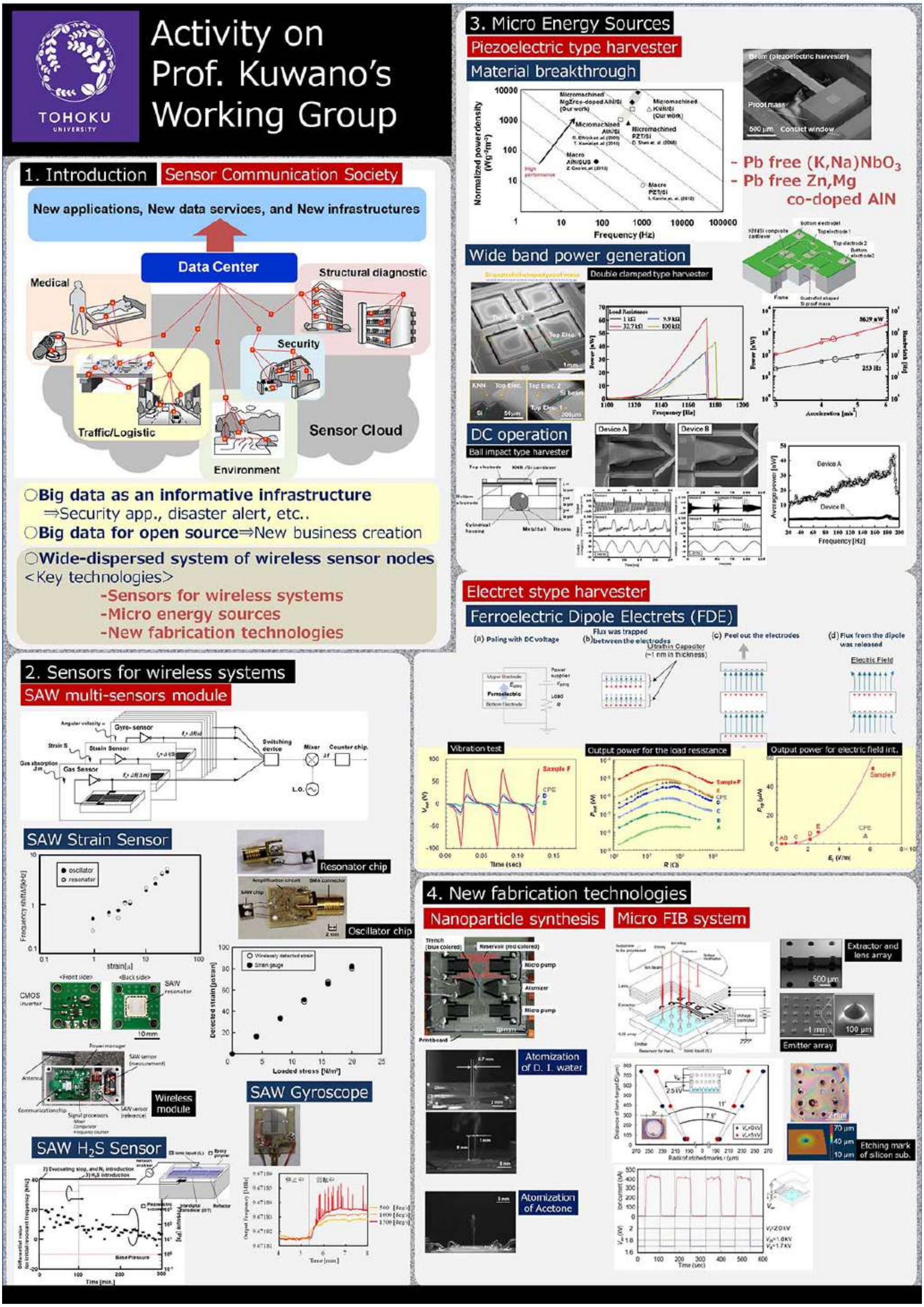


	Polycrystal PZT (MPB)	Epitaxial PMN-PZT	AlN	Epitaxial PMnN-PZT	40%Sc-AlN
$e_{31,f}$ [C/m²]	-12	-25	-1	-14	-2.5
ε_{33r}	1000	1500	10	270	30
$(e_{31,f})^2/(\varepsilon_0\varepsilon_{33r})$ [GPa]	16	47	11	80	20

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) $g = d/\varepsilon$

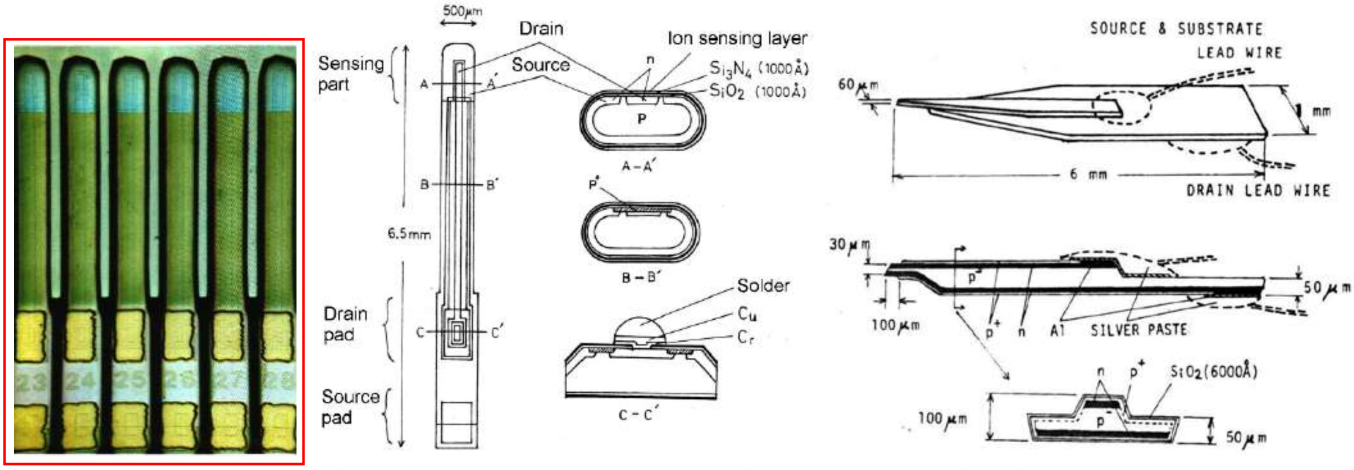
Epitaxial PZT thin film with buffered layer by sputter deposition (S.Yoshida, et.al., IEEE Trans. on Ultrasonics, Ferroelectrics and Frequency Control, 61, 9 (2014) 1552)

8 **Sensor network** (Kuwano)



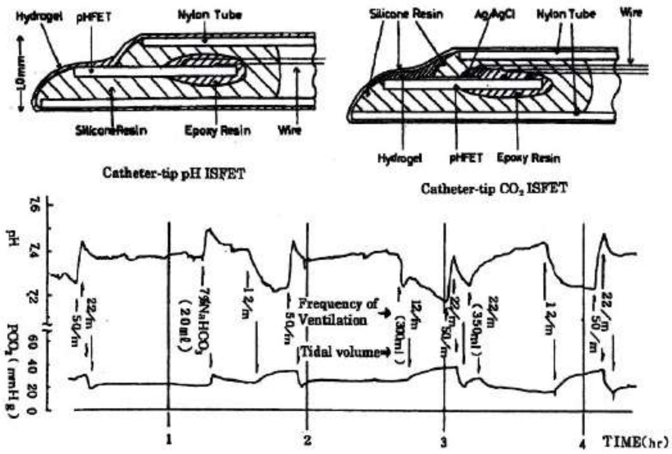
9

Micro sensors for medical monitoring

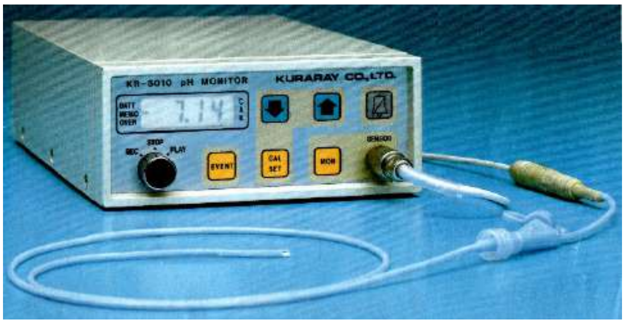


ISFET (Ion Sensitive Field Effect Transistor) and micro ISFET (right)

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



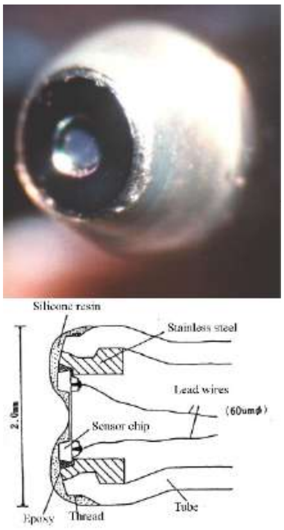
Continuous pH and CO_2 measurement of sed arterial blood of mongral dog by the catheter-tip pH ISFET and catheter-tip CO_2 ISFET.

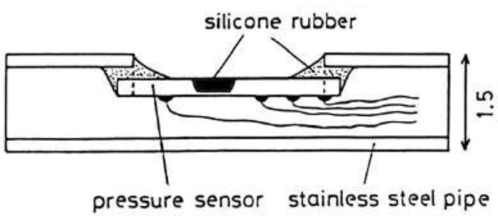


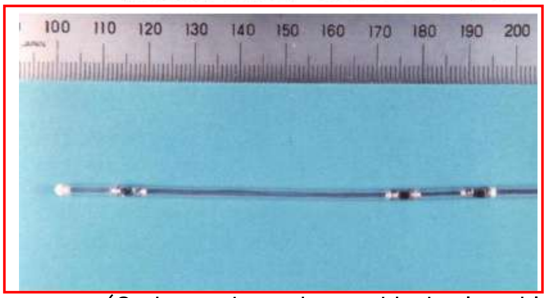
ISFET and reference electrode in 2.4mm diameter catheter

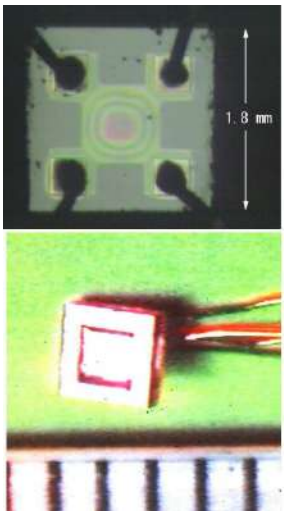
Commercialized pH, CO_2 monitor catheter (1980 Kurare Co.Ltd., Nihon koden Corp.)

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







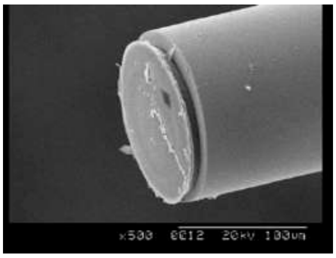
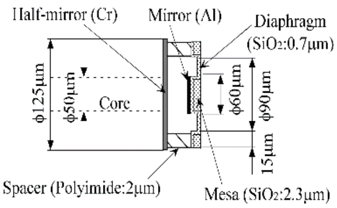


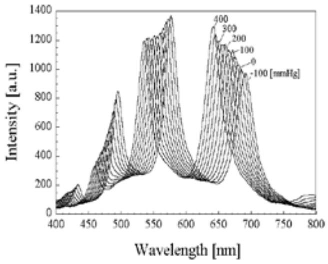
Piezoresistive blood pressure sensor (Catheter tip, catheter side, implantable absolute pressure sensor)

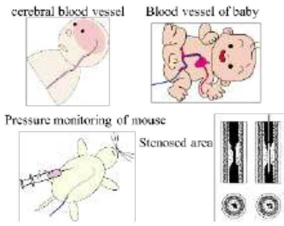
(M.Esashi H.Komatsu, T.Matsuo, M.Takahashi, T.Takishima, K.Imabayashi and H.Ozawa, IEEE Trans. on Electron Devices,ED-29 (1982) 57)

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

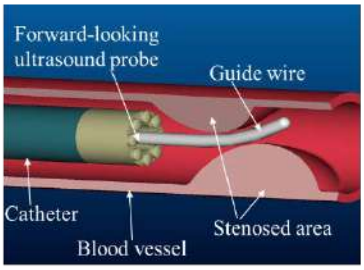
10 Minimally invasive medical devices and health care devices (Y. Haga)

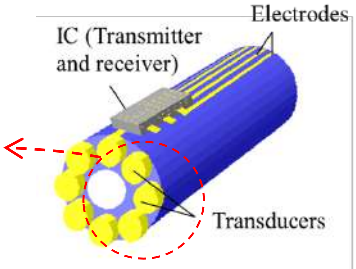



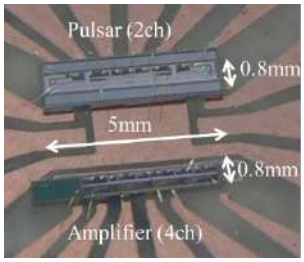




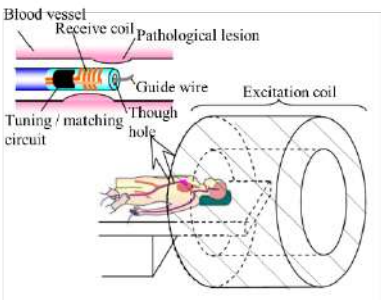
Ultra miniature fiber optic pressure sensor   Structure   Reflection spectrum for different pressures   Applications
(K. Totsu *et.al.*, J.of Micromech. Microeng., 15 (2005) 71–75)

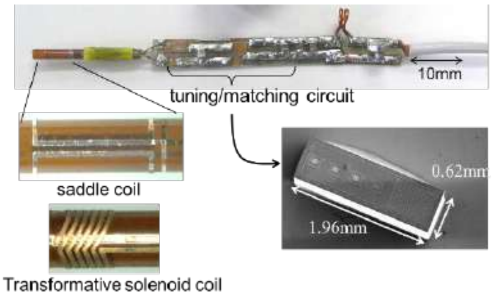


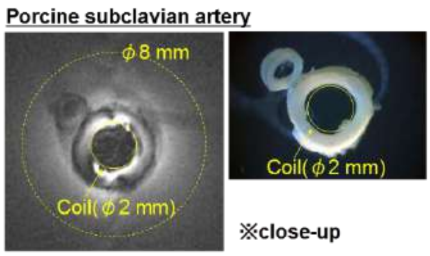





Forward-looking intravascular ultrasound imager and fabricated transducers, pulsar and amplifier (μSIC)
(J. J. Chen *et. al.*, Proc. of MEMS (2004))

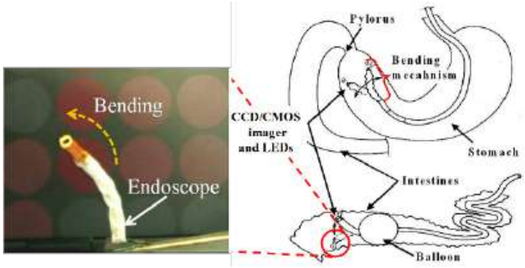


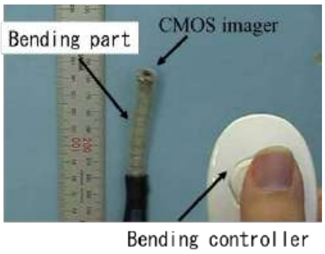


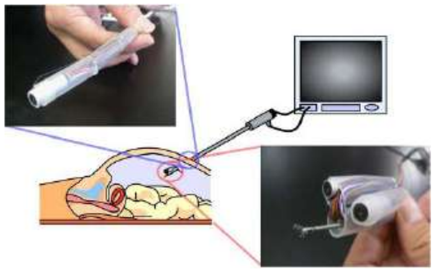


Intraluminal MRI probe   Fabricated MRI probe and variable capacitor (μSIC)   Imaging results

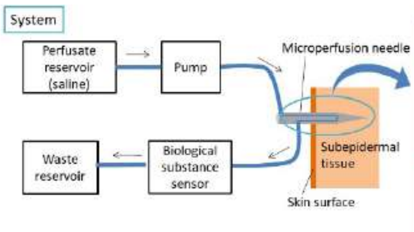
(S.Goto *et. al.*, Proc. of MEMS (2007))   (S. Ichimura *et. al.*, Proc. ISMRM (2010))

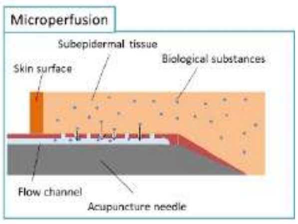


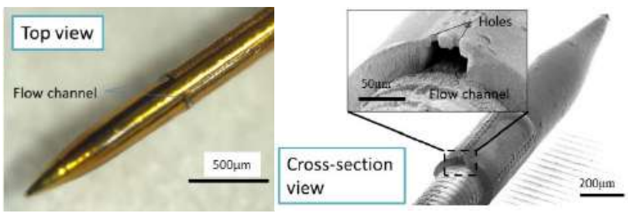




Disposable endoscope using shape memory alloy   Thin endoscope(Φ3.9mm)   Colonoscope(Φ9mm)
(Y. Haga *et. al.*, IEEJ Trans. SM, 131 (2011) 102–110)   (S. Suda, *et. al.*, J.JSCAS, 17 (2015), 83–90)

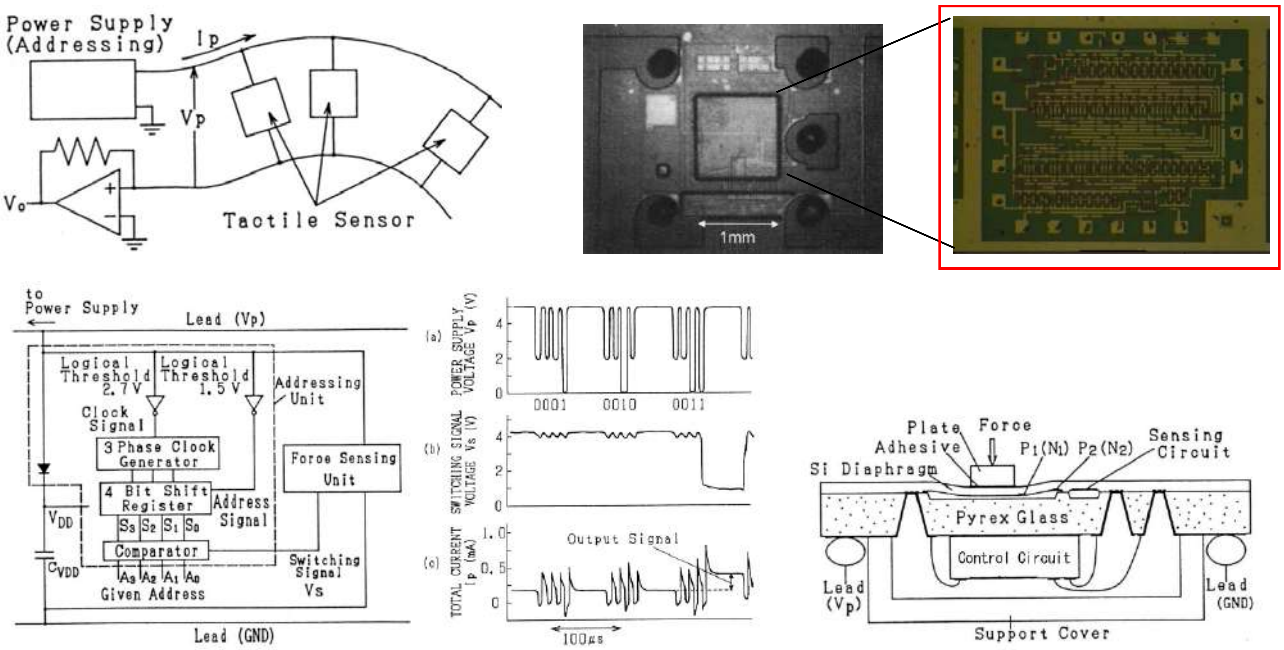






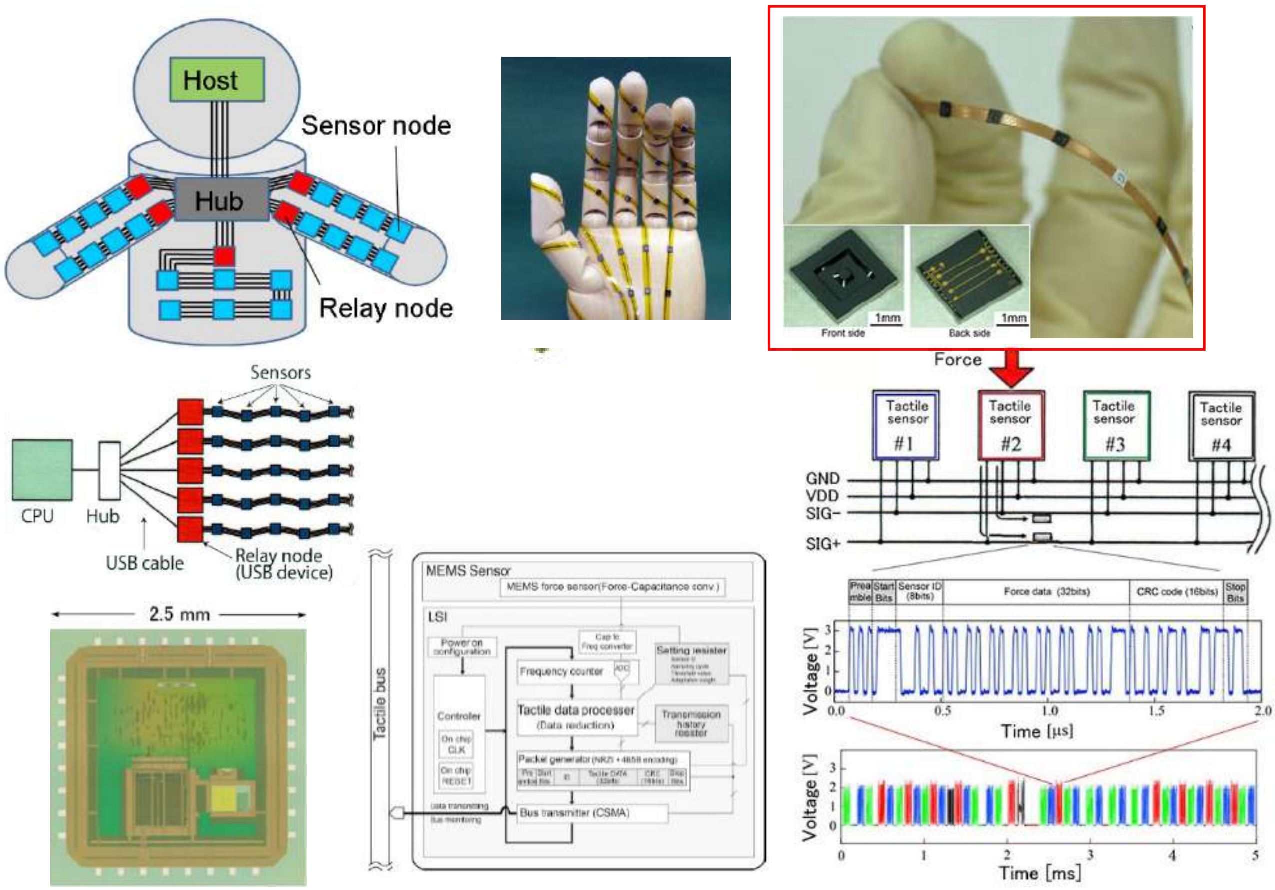
Minimally invasive continuous monitoring system for biological substances, and fabricated microanalysis needles with flow channel   (N. Tsuruoka *et. al.*, Biomed. Microdevices (2016) 18:19)

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)

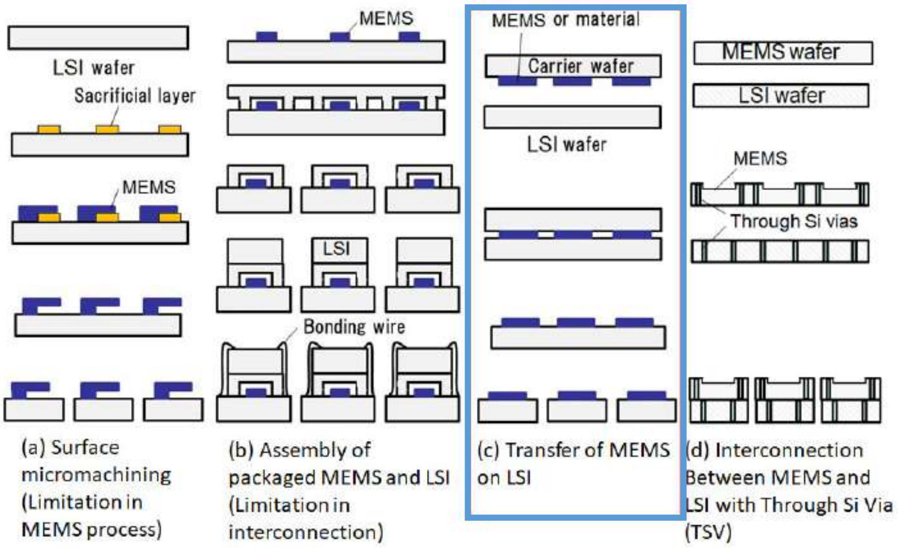
(S.Kobayashi, T.Mitsui, S.Shoji and M.Esashi : Two-Lead Tactile Sensor Array Integrated CMOS Interface Circuits, Using Piezoresistive Effect of MOS Transistor, Technical Digest of the 9th Sensor Symposium,(1990) 137-140)



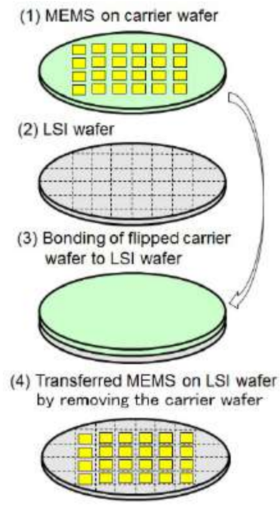
Tactile sensor network (event driven tipe) (Tohoku Univ. Toyota, Toyota central research laboratory)

(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)

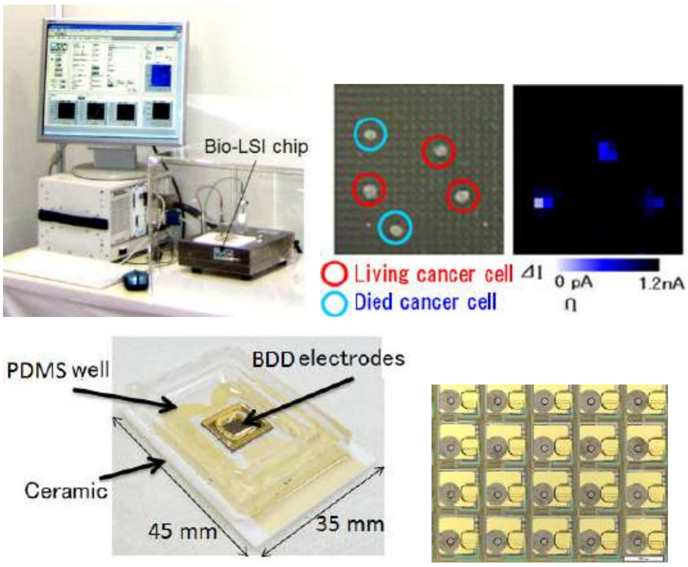
12 Heterogeneous integration of MEMS on LSI by transfer

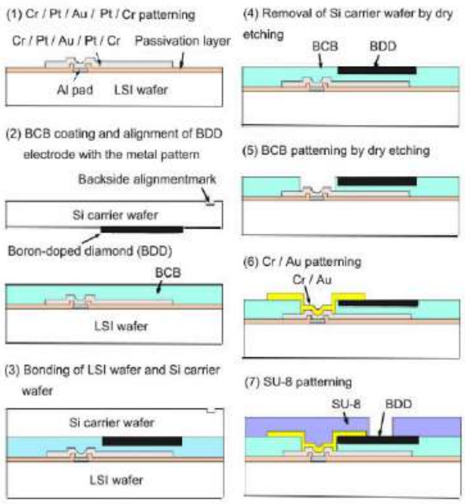


Heterogeneous integration

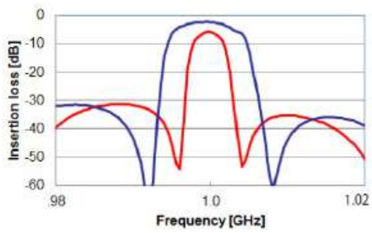


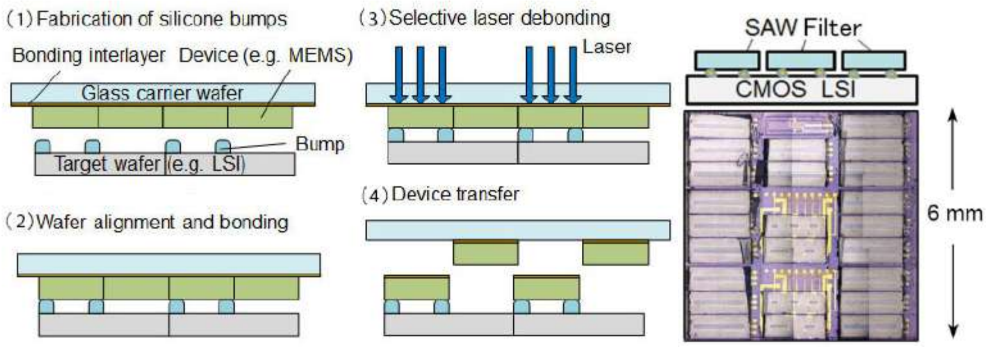
Transfer of MEMS or materials onLSI



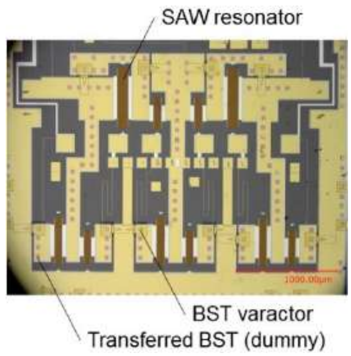


BioLSI made by the transfer of boro doped diamond (BDD) film on LSI (Matsue)



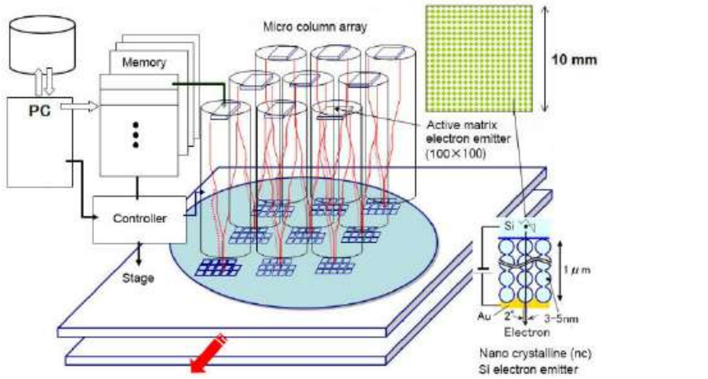


Selective transfer process and multi SAW filter on LSI bade by the process

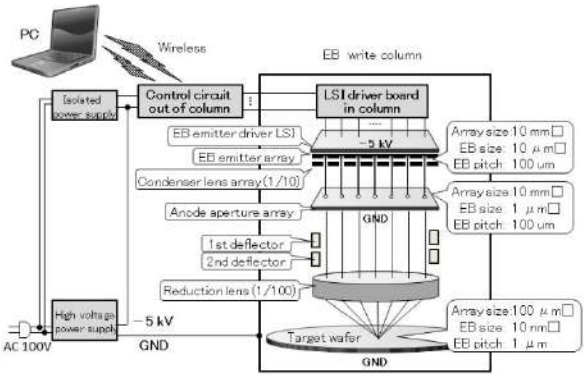


Tunable SAW filter by selective transfer

13 Development of massive parallel EB exposure system

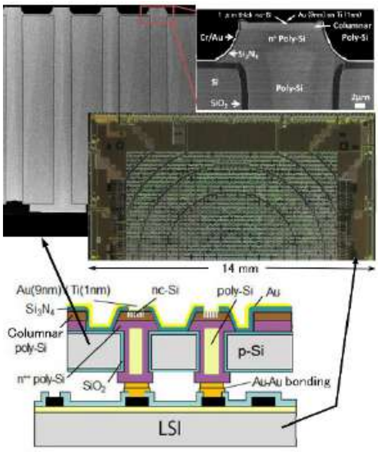


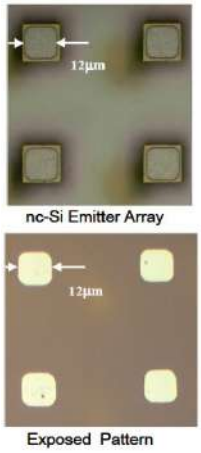
EB exposure system using active matrix electron source array

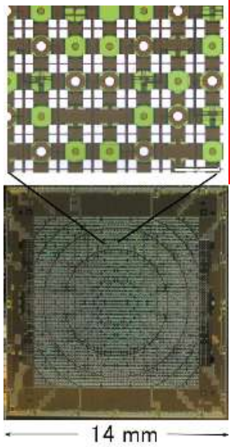


Structure of a single column (prototype is lateral)

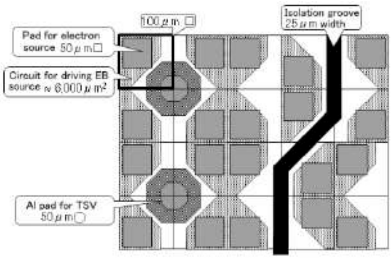
Active matrix electron source chip, the EB exposure system and published book “Development of massive parallel Electron Beam Write System” are displayed in the next room (Historical museum of technology).



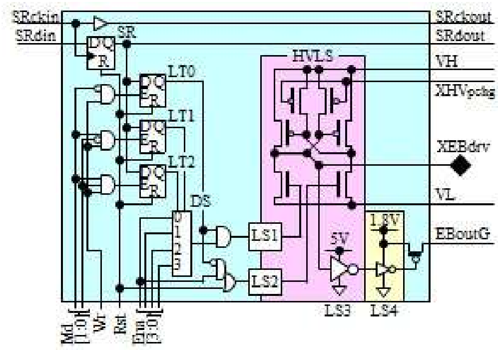


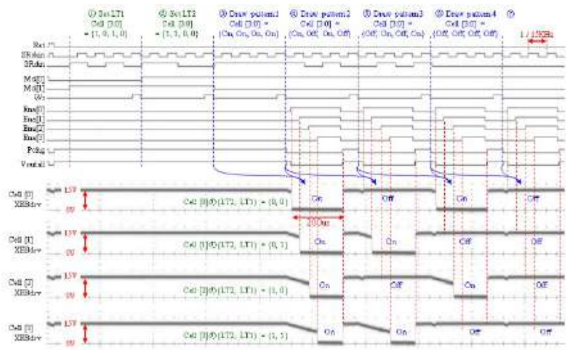


Nanocrystaline (nc) Si electron source connected to LSI with TSV

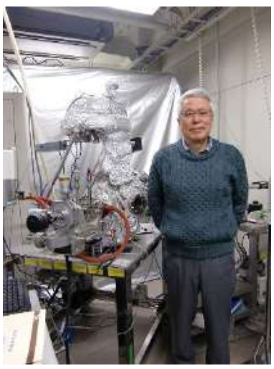


Driving LSI (100×100 cells)





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)



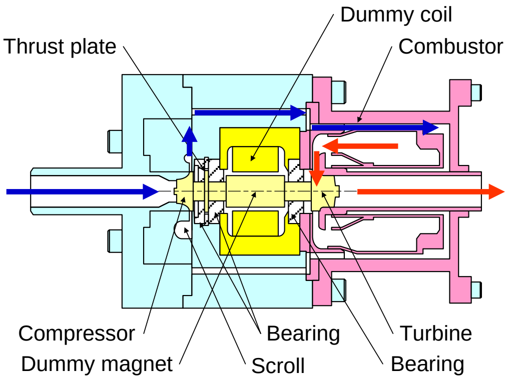
(H.Miyaguchi, M.Esashi, A.Kojima, N.Ikegami, H.Ohi, M.Sugata) (N.Koshida)

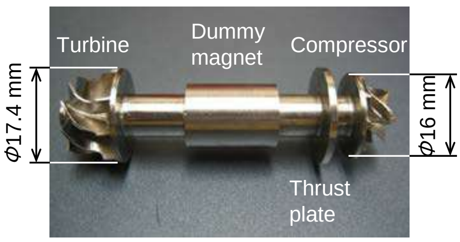
(Tohoku University Press 2018)

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

14 Power MEMS

Ultra-small Gas Turbine Generator



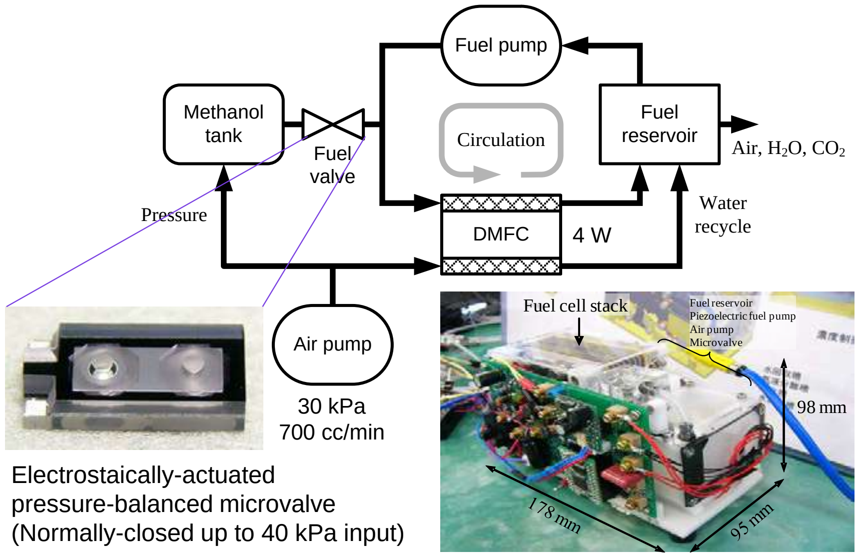


World's smallest gas turbine (2007)
(Collaboration with IHI, Tohoku Gakuin Univ. etc.)
(Tanaka *et al.*, PowerMEMS 2007, pp. 359–362)

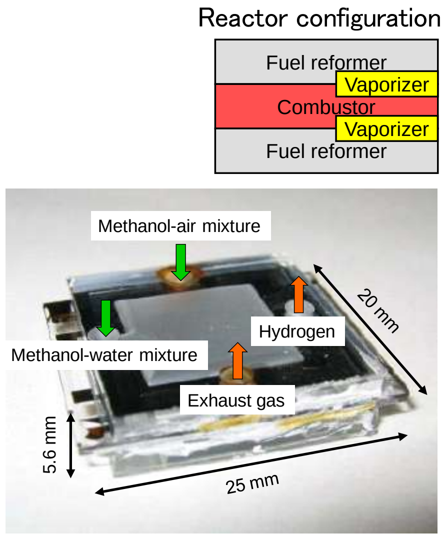
Laboratory-made rotor for the gas
(Inconel one-piece structure)

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

Portable Fuel Cell



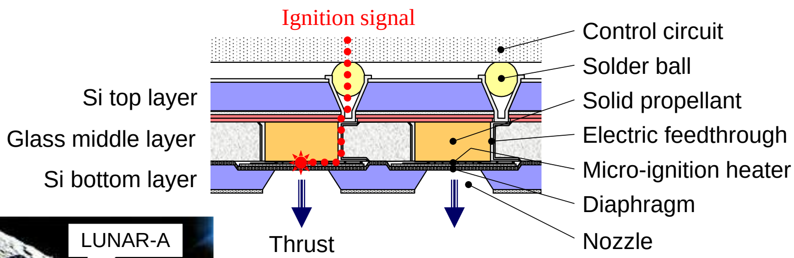
Electrostaicaly-actuated
pressure-balanced microvalve
(Normally-closed up to 40 kPa input)

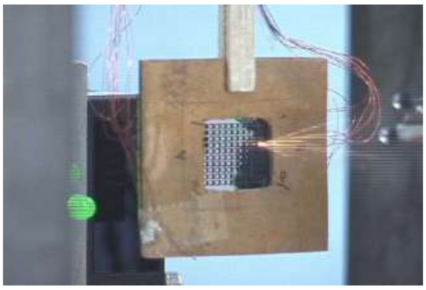


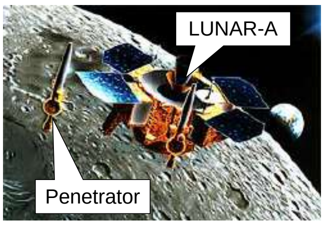
Electrostatic MEMS valve and direct methanol fuel cell system using the valve
(Collaboration with Panasonic Electric Works)
(K. Yoshida *et al.*, Sensors and Actuators A, 157 (2010)
p pp. 290–298, p. 299–306)

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







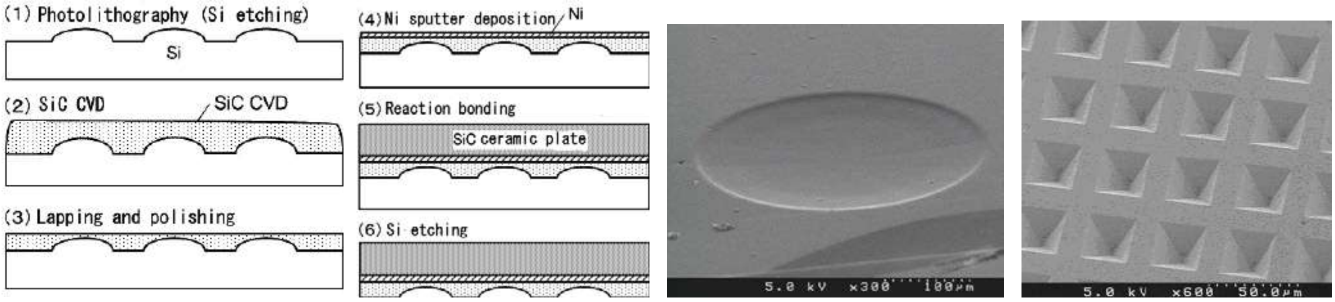
Structure of micro rocket array thruster

Micro rocket array thruster under test

(Collaboration with ISAS/JAXA and Nichiyu Giken Kogyo)
(S. Tanaka *et al.*, Trans. Jpn. Soc. Aeronautical Space Sci., 46, 151 (2003) pp. 47–51)

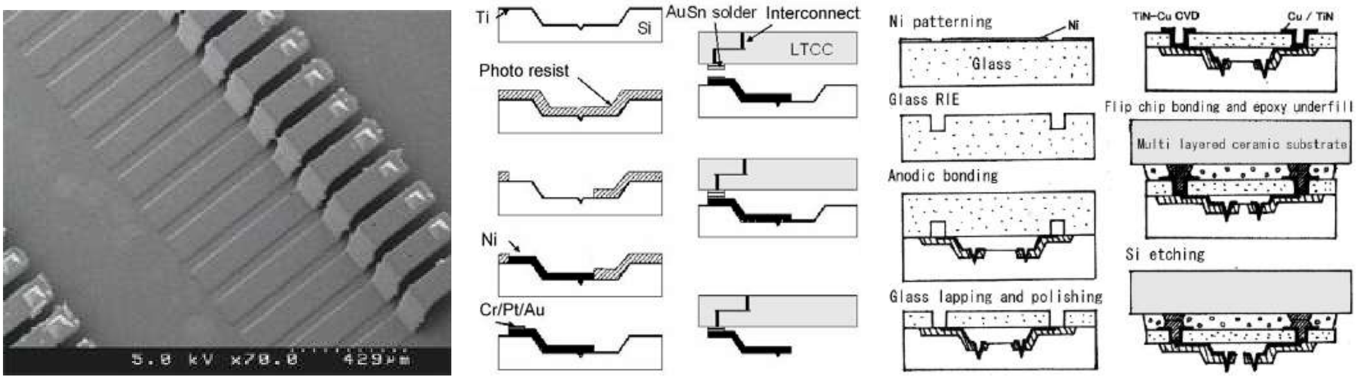
The micro-thruster was developed for Penetrator injected to lunar surface.

15 MEMS for production, testing, environment and safety

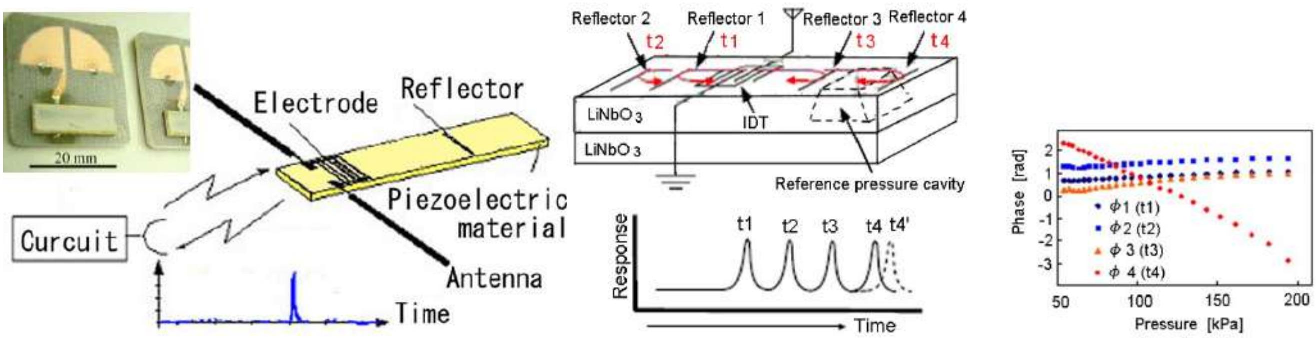


SiC mold   Glass formed by press with SiC mold

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

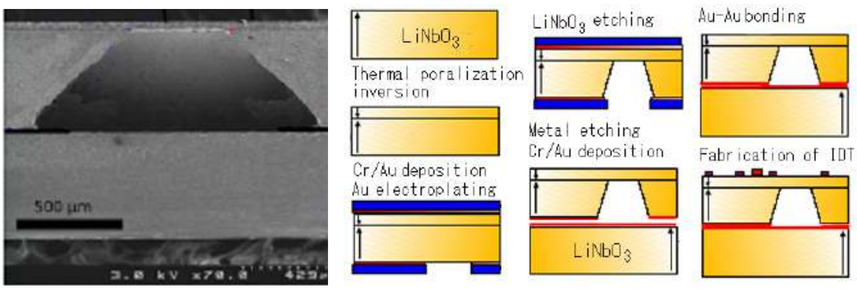


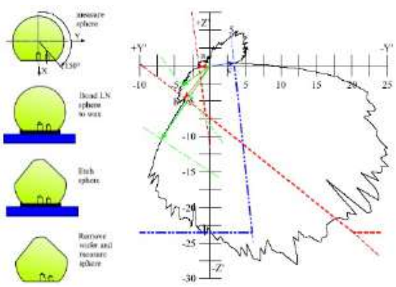
Probe card for testing LSI wafer (S.-H.Choe et.al., IEEE Internl. Test Conf. 2007 (2007))



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

Anisotropic etching of $LiNbO_3$ depending on crystal orientation.

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

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

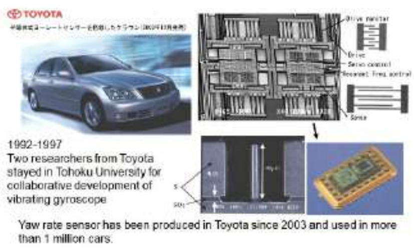
Examples of MEMS Industrialization by Tohoku Univ. – industry Collaboration

Catheter pH, PCO_2 monitor
(Kurare, Nihon Kohden)

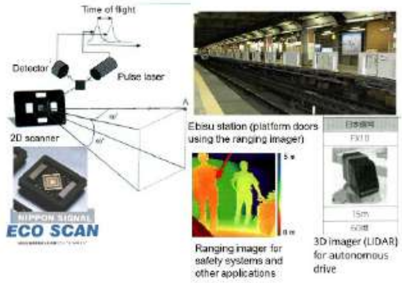
Portable pH sensor
(Shindengen)

Instrument to detect H. pylori
(Nihon Kohden)

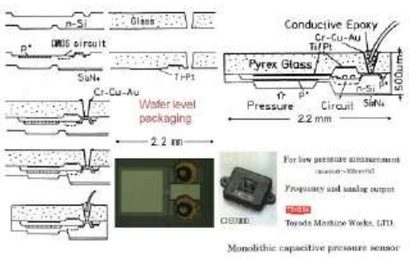
Electrostatically levitated rotational
(Tokyo Keiki)



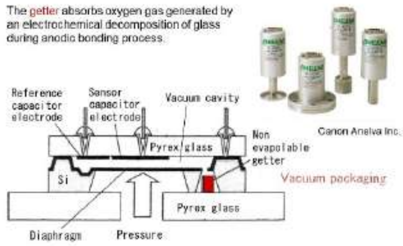
Yaw rate-Accelerometer
(Toyota)



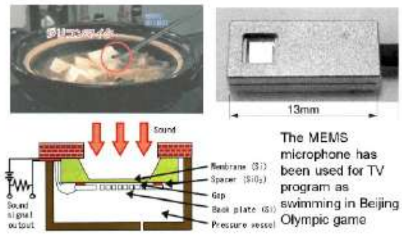
2-axes optical scanner
(Nippon signal)



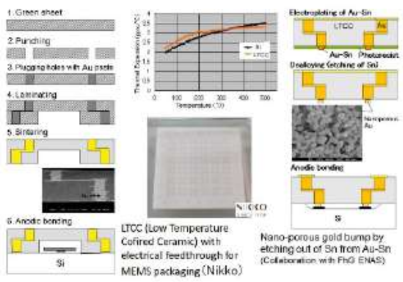
Integrated capacitive pressure sensor
(JTEKT)



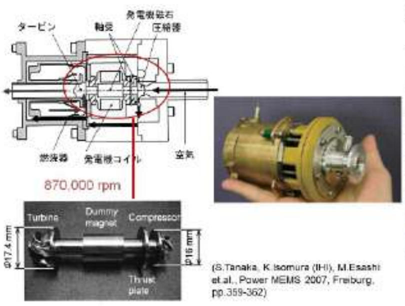
Diaphragm vacuum gauge
(Canon ANELVA)



Silicon microphone
(NHK, Panasonic)



LTCC with electrical feedthrough
for MEMS packaging (Nikko)



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

MEMS switch for LSI tester
(Advantest)

ADVANTEST

ADVANTEST CORPORATION

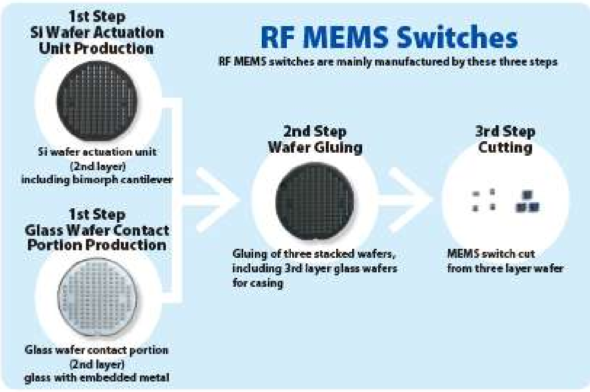
High-Frequency, Low Power Consumption MEMS Relay

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

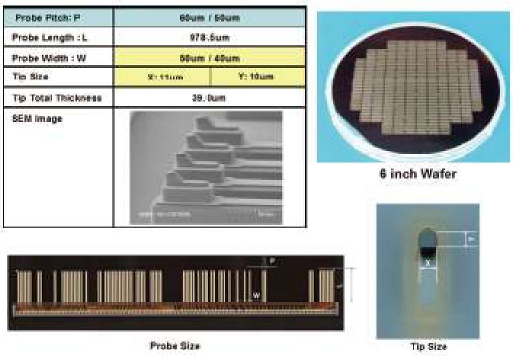
R&D Centers :	Advantest Gunma R&D Center Advantest Laboratories (Sendai) Brought to Practicality Under the Guidance of Prof. Masayoshi Esashi of Tohoku University
Production Center :	Advantest Component (Sendai) In-House Production of MEMS-Related Products, Compound Semiconductors, and SiPs for High-Frequency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

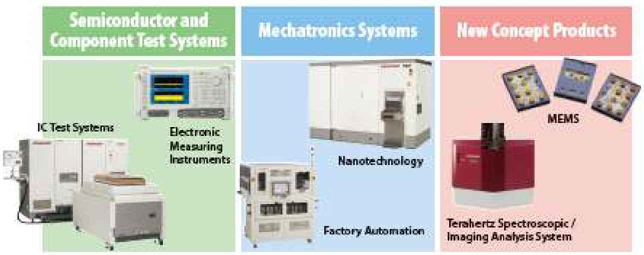
MEMS Probe Pin

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

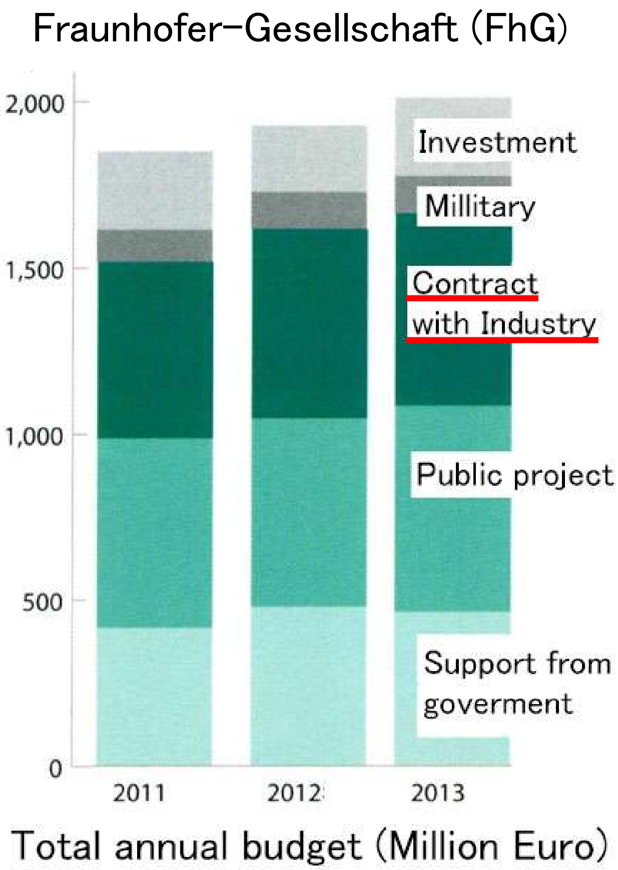


About Advantest

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

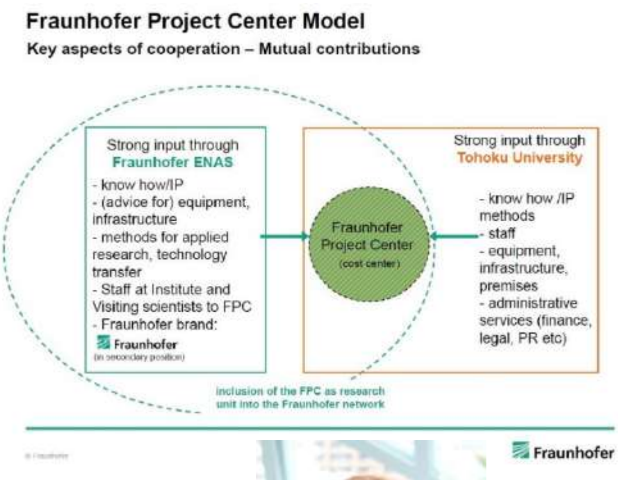
Phone +81-3-3586-7306, E-mail : info@fraunhofer.jp www.fraunhofer.jp

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)

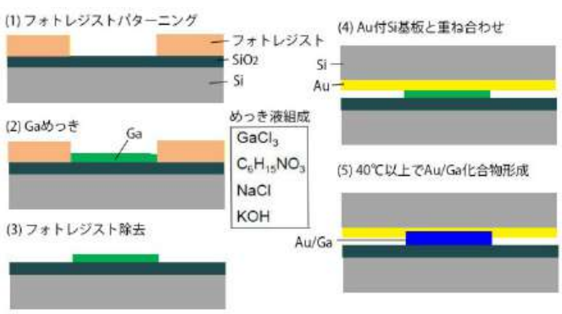
1st Fraunhofer Symposium in Sendai (Oct.19, 2005)

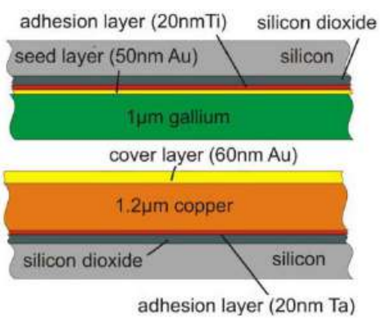


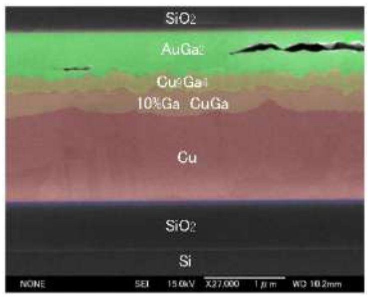
FhG Germany – WPI-AIMR Tohoku Univ. partnership signing ceremony in Sendai (Nov. 8, 2011)

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

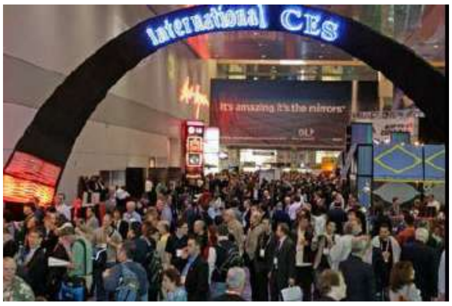
【Intention】 iCAN is a contest for students that propose idea of applications and realize the application by using MEMS devices. Teams of students from high school, college, university can participate iCAN. Preliminary contests are held in each county, followed by the final international contest.

【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

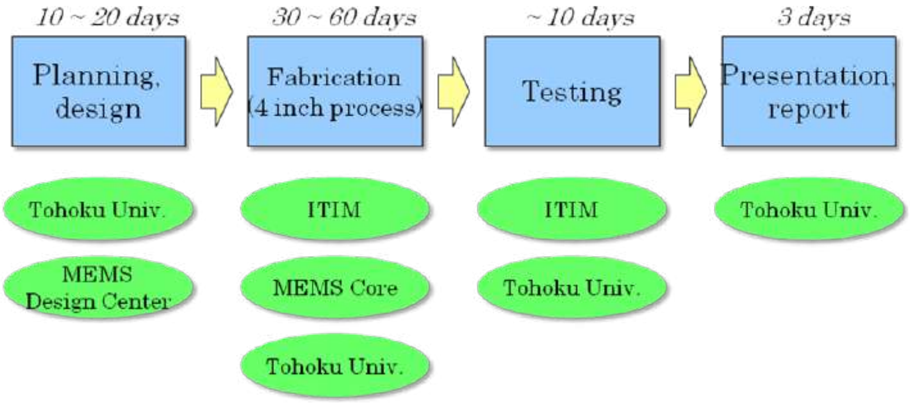
◆Information Dissemination

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).*

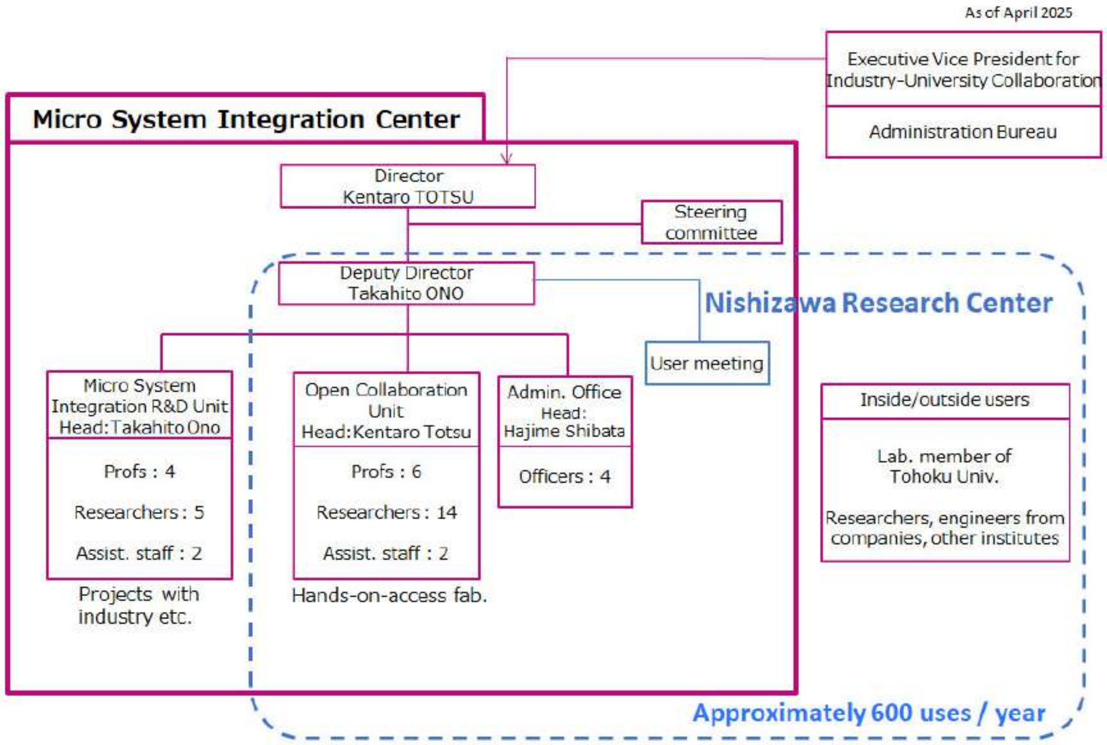
◆Technical Support (Network for Experimental Production Support)

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.

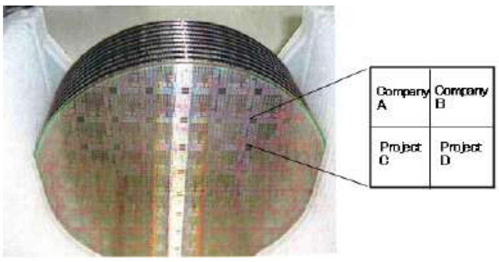
◆Networking

Offer a place to information exchange among member companies.

Open collaboration and μSIC



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)

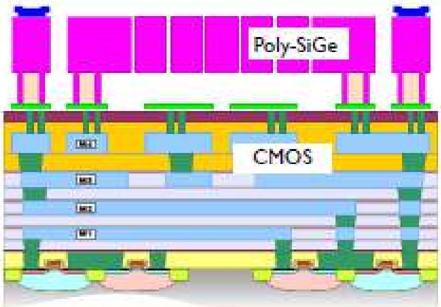
IMEC: HOME OF SIGE MEMS

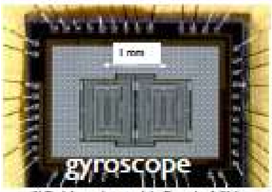
Background

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.

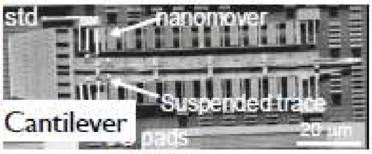
Platform

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 1I 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, ...

CMORE

(Co-)development			Prototyping		Production
Concept Design	Process development Packaging Testing Reliability	Product Qualification	Prototyping Low-volume prototyping @ imec	Transfer	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)

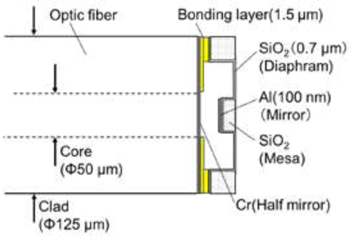
imec

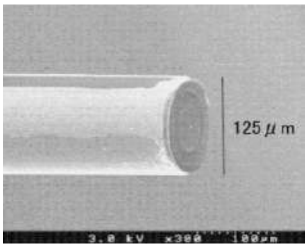
24 Start-up companies related to μSIC

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

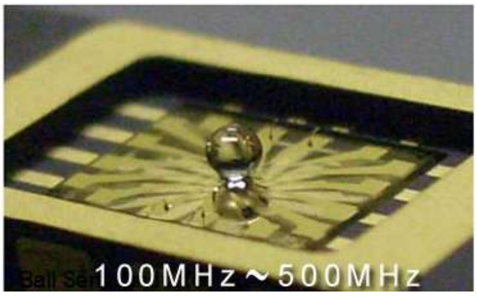
The venture company MEMSAS, aimed at applying MEMS sensor to medical devices such as minimally invasive medical catheters, was established in September 2004.

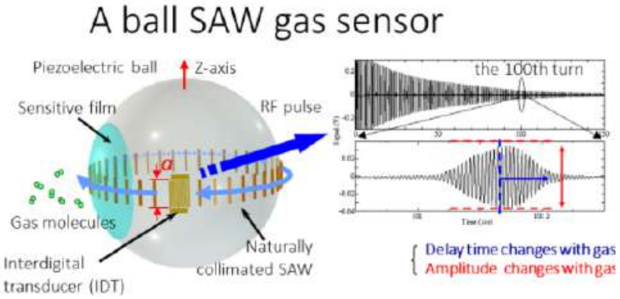
We are trying to commercialize ultra-miniature fiber-optic pressure sensor for blood pressure monitoring.





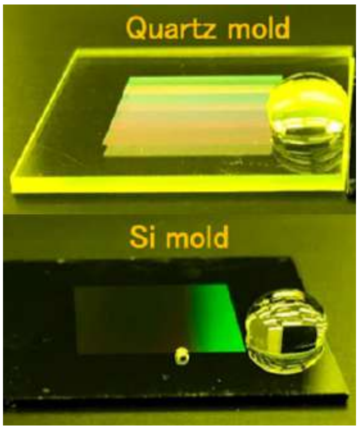
Ball Wave Inc. (Shingo Akao, Kazushi Yamanaka, Nobuo Takeda, Yusuke Tsukahara)
http://www.ballwave.jp/english/index.html





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.

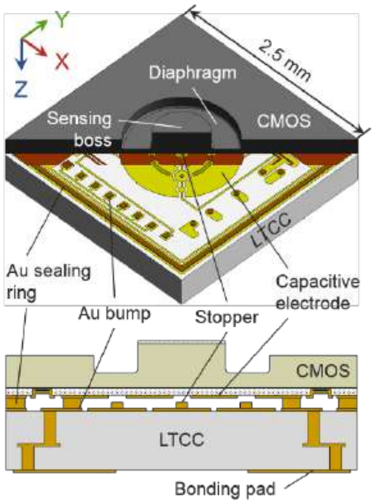
Der Nächste Co., Ltd. (Masashi Nakao) http://www.dernaechste.com/



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/

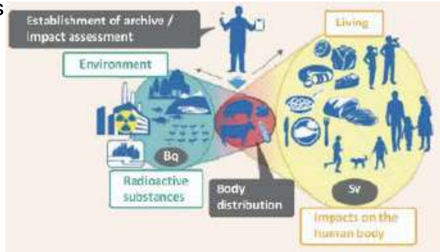
We provide MEMS-CMOS integrated tactile sensors and their network systems for next-generation robots with tactile sensing capabilities. We have developed a custom-designed sensor platform LSI using the TSMC 0.13 μm CMOS process, and further processed it with wafer-level MEMS technology to fabricate 2.7 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)

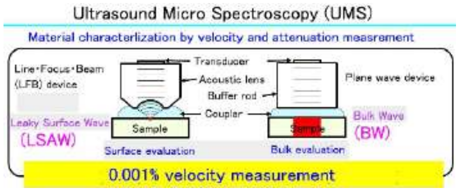
We are conducting an environmental radiation assessment to evaluate radiation doses and biological responses of wild Japanese macaques, which are the closest species to humans among wild animals in the affected areas of the Fukushima Daiichi Nuclear Power Plant accident. Nuclear disasters raise concerns 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

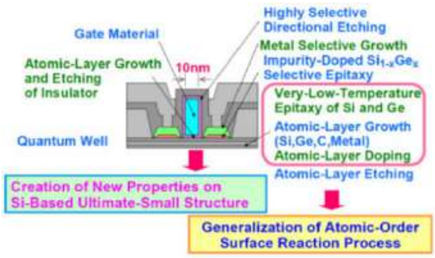
Characterization and quality control of bulk/film materials and device production processes concerned with bonded piezo substrate for SAW devices

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



Junichi Murota

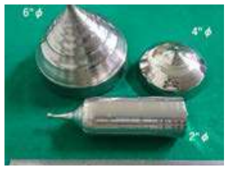
For the fabrication of high-performance Si-based devices, the Atomically Controlled Processing for group IV semiconductor based on atomic-order surface reaction by Chemical Vapor Deposition (CVD) is investigated. The atomic-layer level mechanism of impurity-doped Si, $Si_{1-x}Ge_x$, and Ge epitaxial 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.



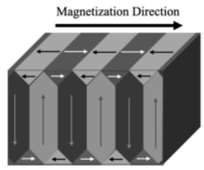
Shigeru Suzuki

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



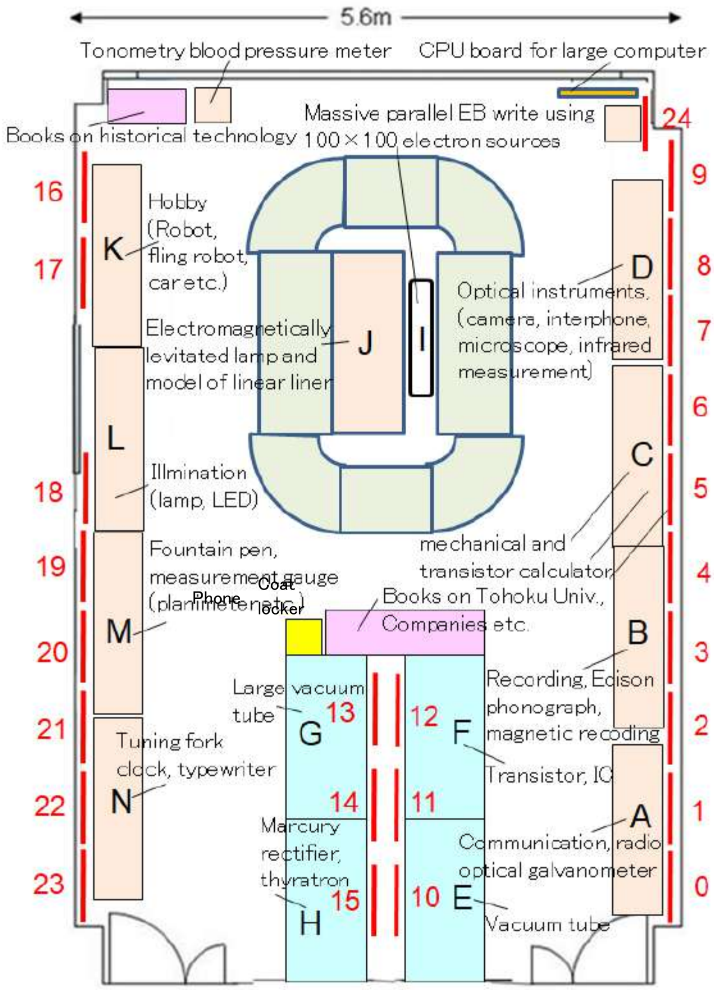
Micromagnetism for Function Characterization

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

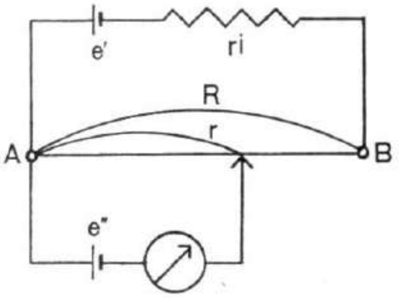
0 Historical Museum of Technology



Poster

0 Historical museum of technology
1 Electrical measurement
2 Wired communication
3 Wireless communication
4 Recording
5 Calculator (1) (Analog)
6 Calculator (2) (Digital)
7 Optical instruments (1) (Camera)
8 Optical instruments (2) (Microscope)
9 Optical instruments (3) (Infrared measurement)
10 Vacuum tube
11 Transistor and integrated circuit
12 Haggerty' s forecast (1964)
13 Large size vacuum tube for transmitter
14 Cannonball of anti-aircraft gun using vacuum tube (VT (Variable-Time) fuse)
15 From mercury rectifier and thyratron to power semiconductor
16 Hobby (1) (Robot)
17 Hobby (2) (Car, helicopter)
18 Automobile
19 Illumination and lighter
20 Fountain pen
21 Measure gause.
22 Clock
23 Typewriter
24 Kiyota Manufacturing Co. – Contact probes –

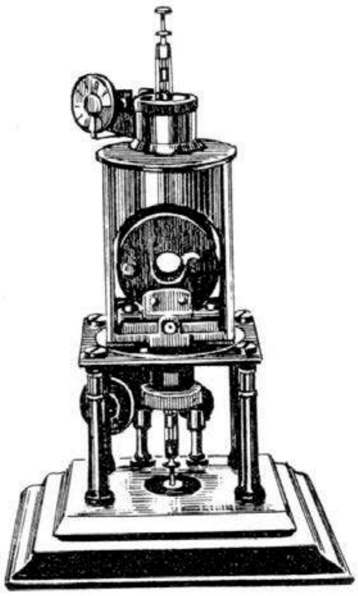
1 Electrical measurement



$$\mathrm{R},\ \mathrm{r_i} \cdots \text{constant} \quad e'' = \frac{\mathrm{r}\,e'}{\mathrm{R} + \mathrm{r_i}}$$

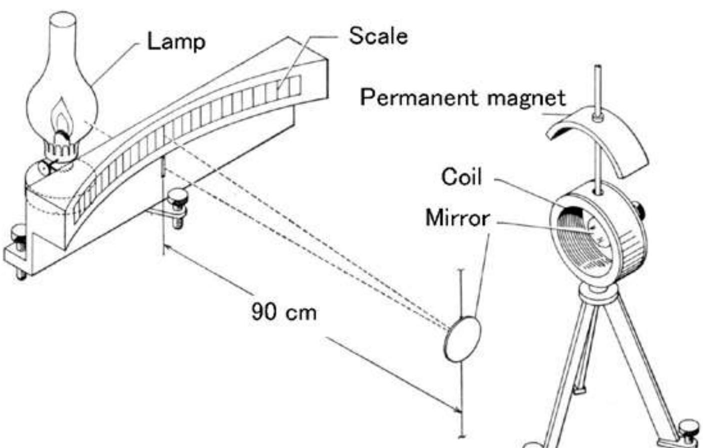
Prof. William Thomson (1824–1907, Sir Kelvin) Glasgow University

Potentiometer (measurement of electromotive force with zero current)



First galvanometer by Sir Kelvin

Optical galvanometer (1)



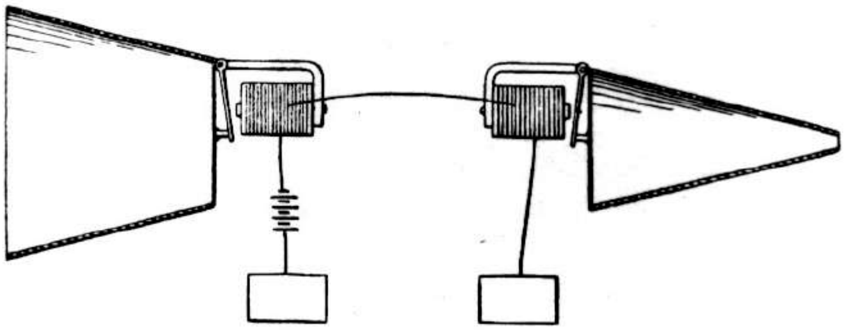
Principle of optical galvanometer by Sir Kelvin

Optical galvanometer (2) (sensitivity 0.02 μA)

(J.Takagi, "History of electricity", Ohm Ltd. (1967))

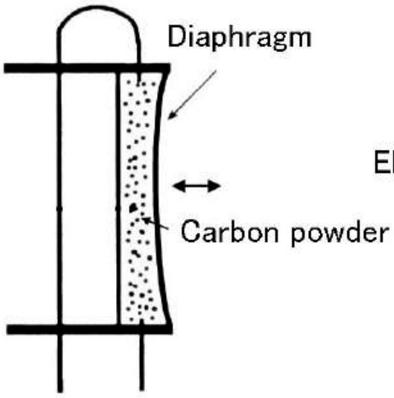
2 Wired communication

Microphone of telephone invented by A.Bell.
"Mr. Watson. Come here. I want you"
was the first voise.

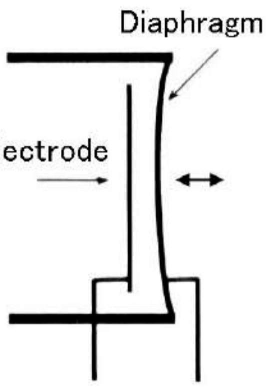


Telephone by A.Bell (1876) Electromagnetic microphone and receiver
(I.Sagara : History of electronics in 20th century, Nikkei electronics (1996))

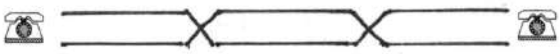
Electromagnetic receiver and carbon microphone



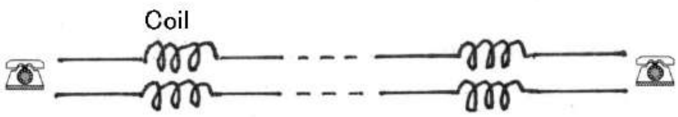
Carbon microphone
Edison (1877)



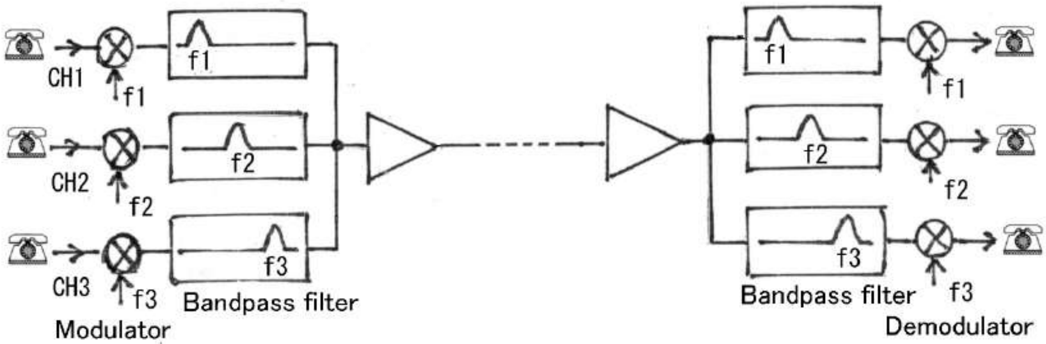
Condenser microphone



(a) Balansed twisted cable



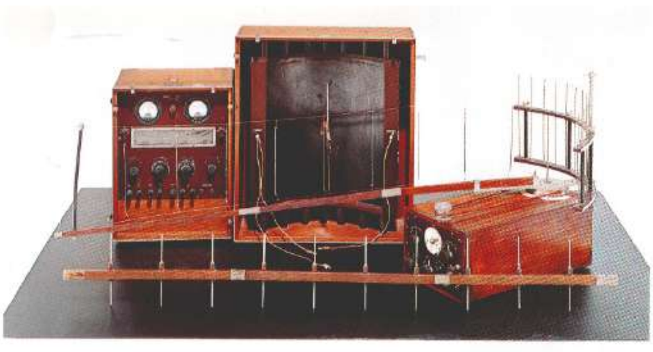
(b) Loaded cable (M.I.Pupin (1899))



(c) Multipled communication using unloaded cable (S.Matsumae (1932))

Donation by Emeritus Prof. Yakichi Higo of Tokyo Institute of Technology

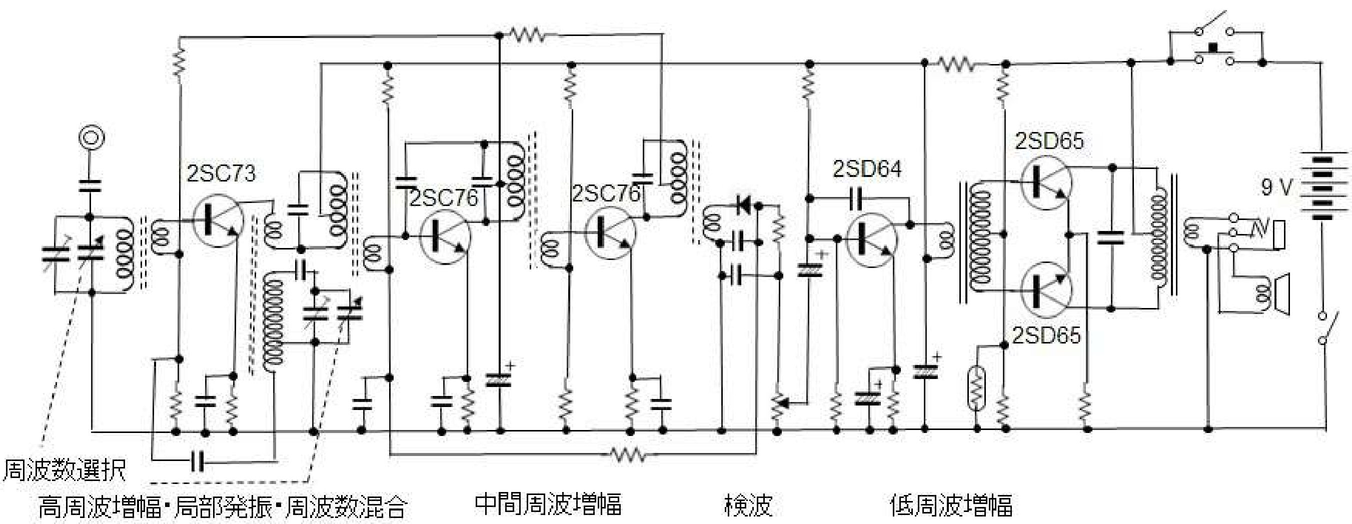
3 Wireless communication




Yagi antenna (1928) (“Tohoku University” 2007/8/1)


Vacuum tube radio [1]

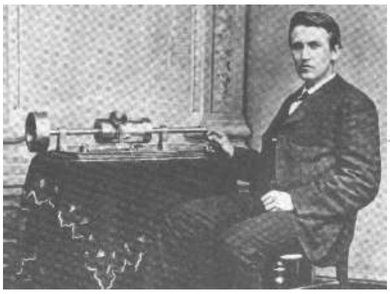

Transistor radio (Sony TRW-621)(1960)
(Clock can be used as timer) [2]

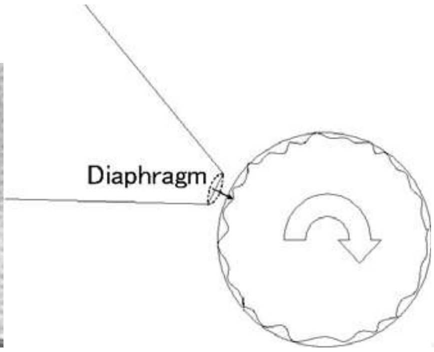


Transistor radio circuit (Sony TRW-621) (1955)[2]
https://www.radiomuseum.org/r/sony_TRW_621

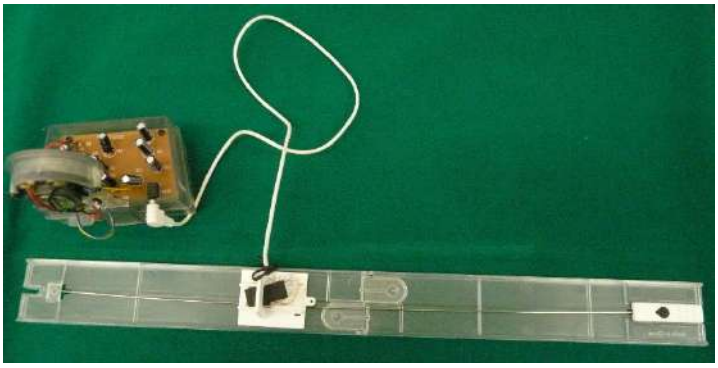
[1] Donation by Mr. Masami Tawara (Optoelectronics)
[2] Donation by Emeritus Prof. Yakichi Higo of Tokyo Institute of Technology

4 Recording

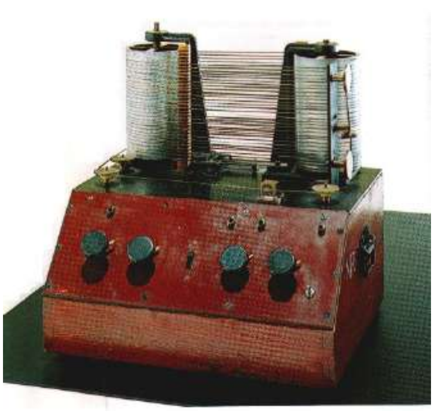


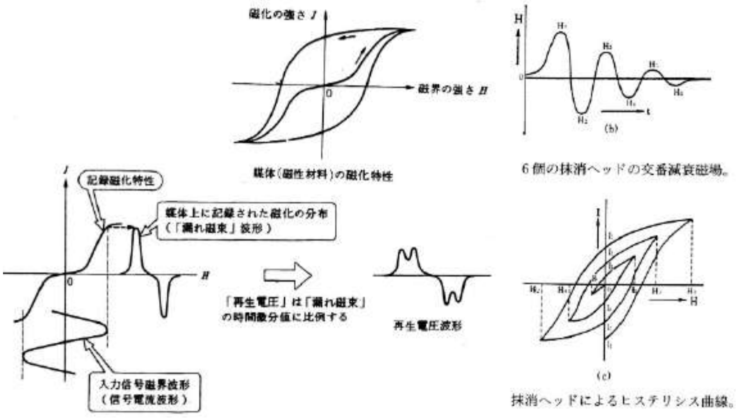


Edison and phonograph (1877) [1]

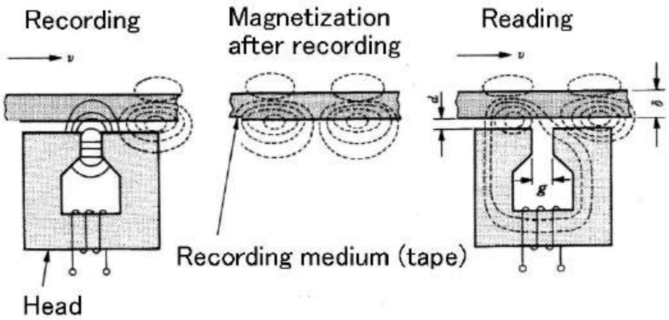


Magnetic wire recording by V.Poulsen (1898), Magnetic wire recording (Gakken)





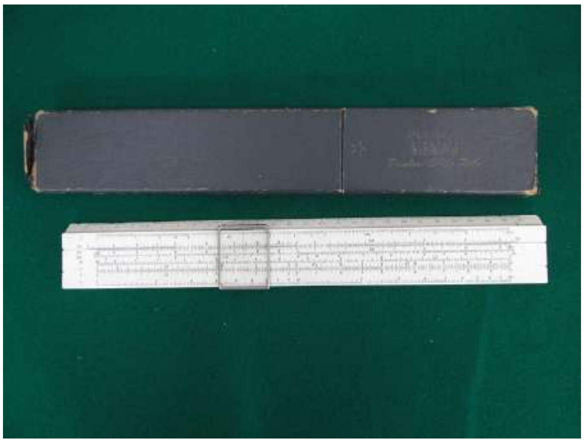
AC bias recording (K.Nagai (Tohoku University)



Vacuum tube tape recorder (Sony)

[1] Donation by Mr. Masami Tawara (Optoelectronics)

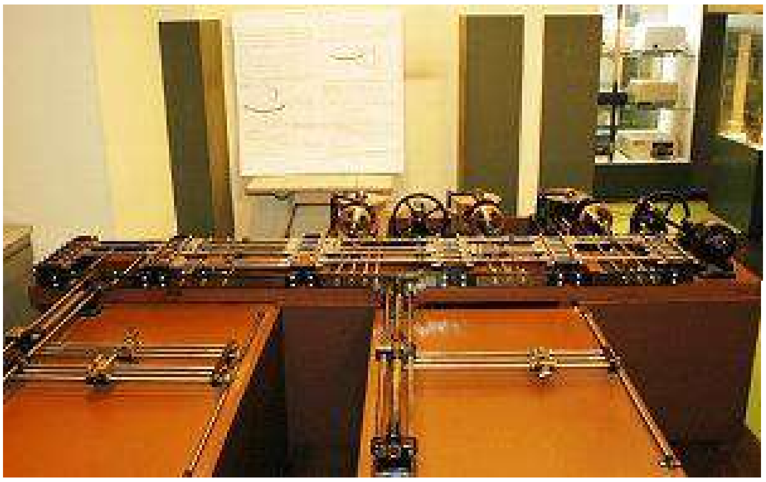
5 Calculator (1) (Analog)



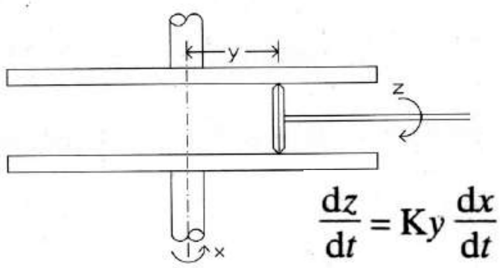
Time and Size can be transformed to equivalent ones which we can imagine using the logarithmic scale.

Time Size Equivalence Scale [1]

Banboo Slide Rule[1] (logAB = LogA+LogB)　　　[1] Donation by Emeritus Prof. Yakichi Higo



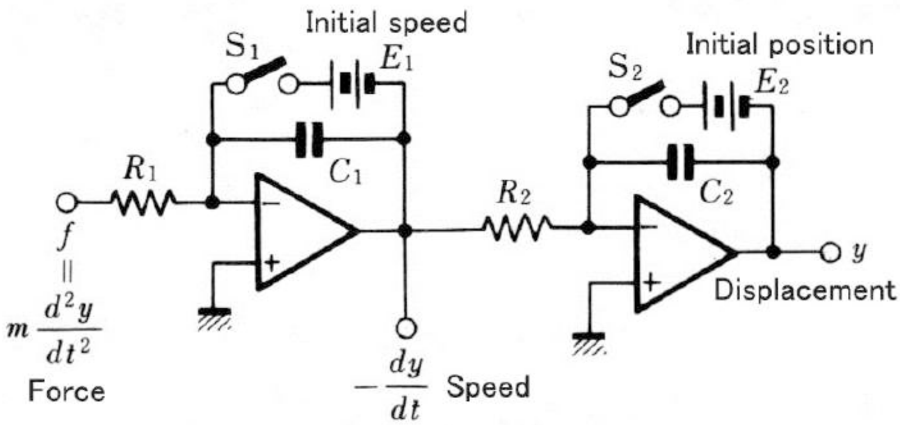
Differential Analyzer　(https://www.tus.ac.jp/info/setubi/museu



Example of element of mechanical computer (Hermann integrator)　(A.Ben Clymer, The mechanical analog computers of Haannibal Ford and William Newell, IEEE Annals of the History of Computing, 15, 2 (1993)

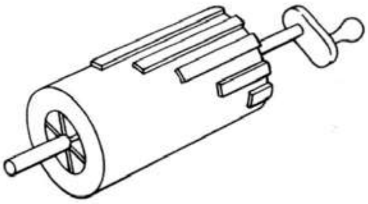
Differential Analyzer is a mechanical analog computer to solve differential equations. It was invented by Prof. V.Bush in MIT in 1931. The machine in the photograph in Tokyo University of Science was used in Shimizu laboratory in the department of mathematics. The principle is an integrator by drawing some area.

Analog computer using operational amplifiers is an electronic computer to solve differential equations.　Motion equation is $f = m\, d^2y/dt^2$ (f : force, m : mass and y : displacement). By combining integrator as shown in the figure and gravity force (f) is applied at the input, speed (dy/dx) is obtained as a negative value of the output of the 1st stage. Further displacement (y) is obtained at the output of the 2nd integrator. The mass (m) is given by the C_1R_1. When S_1 and S_2 are closed the initial speed is set as E_1 on C_1, and initial position E_2 on C_2 respectively. S_1 and S_2 are opened at t=0 and then the time dependent speed and displacement are given.



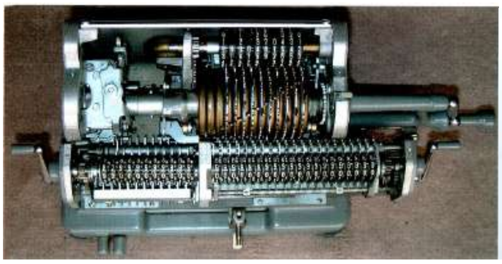
Analog computer

6 Calculator (2) (Digital)

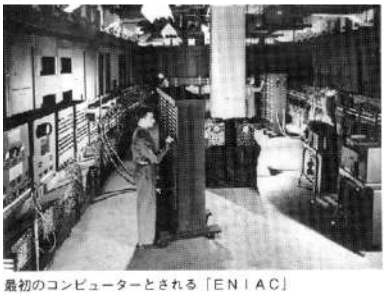




Calculator using gears with steps by Leibniz (around 1700)

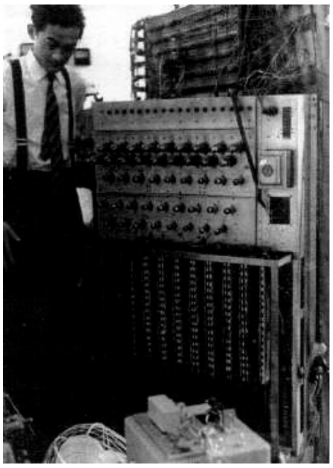
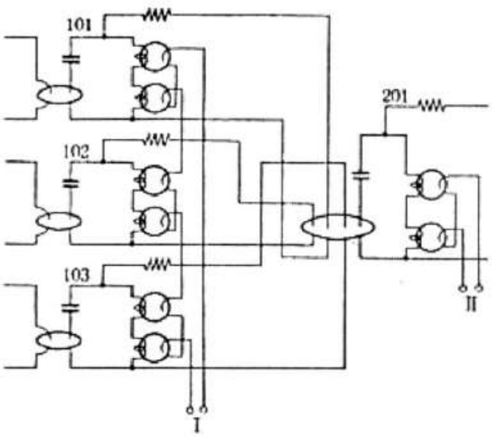
(S.Ohkoma, A history of computer development, Kyoritsu Pub. (2005))



Mechanical digital calculator (around 1960) Model to show the principle




ENIAC (1946) Transistor calculator (1963) Hayakawa electric (now Sharp) Ten key transistor calculator (1964) Canon "Canola 130"

101	102 Phase	103	Drive to 201	Oscillation phase of 201	
−1	−1	−1	−3k	−1	
−1	+1	−1	−1k	−1	AND
+1	−1	−1	−1k	−1	
+1	+1	−1	+1k	+1	
−1	−1	+1	−1k	−1	
−1	+1	+1	+1k	+1	OR
+1	−1	+1	+1k	+1	
+1	+1	+1	+3k	+1	

E.Goto Parametron computer (1971)

[1] Donation by Emeritus Prof. Yakichi Higo of Tokyo Institute of Technology

7 Optical instruments (1) (Camera)

Ricoh 35 lens shutter 35mm film camera (1950's) [1]

Twin-lens reflex camera [2]

Mechanical self-timer for camera[1]

First autofocus camera

Analog recording camera

8mm movie camera and its projector

Digital video camera

[1] Donation by Emeritus Prof. Yakichi Higo of Tokyo Institute of Technology

[2] Donation by Emeritus Prof. Hiromasa Ito of Tohoku Univ.

8 Optical instruments (2) (Microscope)

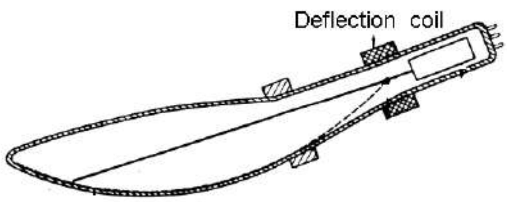
Old biological microscope

First microscope (replica)
(Olympus)

Portable microscope [1]

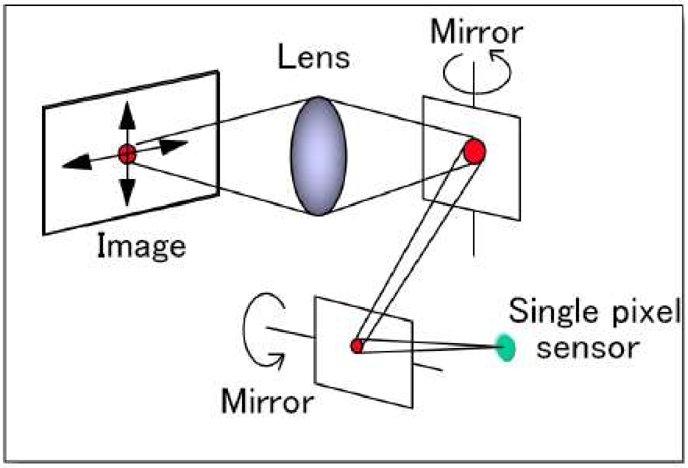
Telescope (1930s) [1]
(donated by Emeritus Prof. Yakichi Higo of Tokyo Institute of Technology)

Corner cube



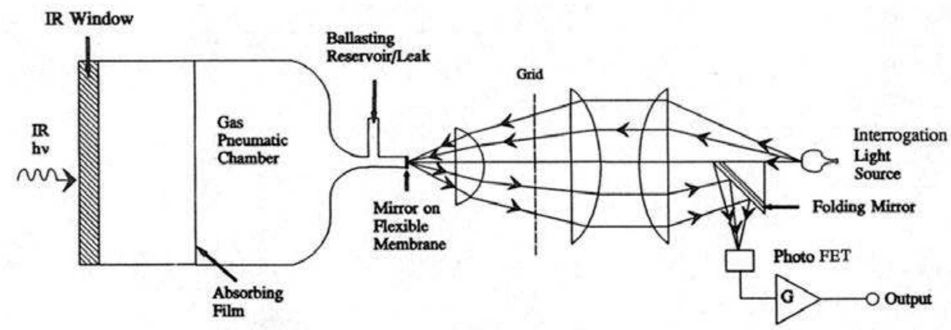
Interphone using flat cathode ray tube (bottom)
(donated by Hiroshi Tanigawa (NEC, Ritsumeikan Univ.)

9 Optical instruments (3) (Infrared measurement)

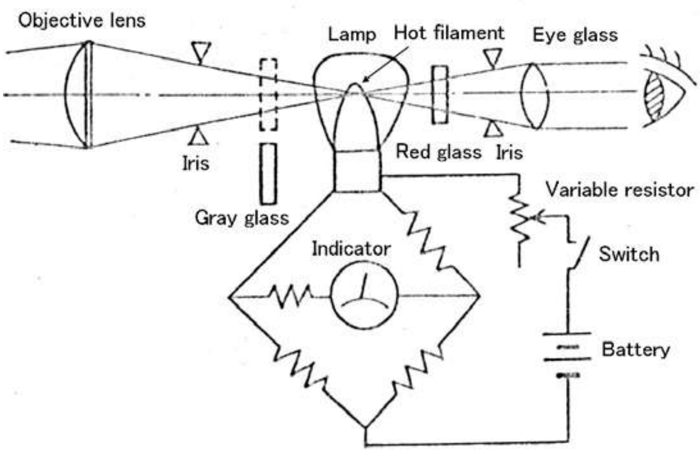


Infrared image is captured by two scanning mirrors and a single pixel sensor

Mechanical scanning infrared imager made in Barnes Company (USA) (donated by Prof. Kimata in Ritsumeikan Univ. ← Prof. Eto in Kinki Univ.)

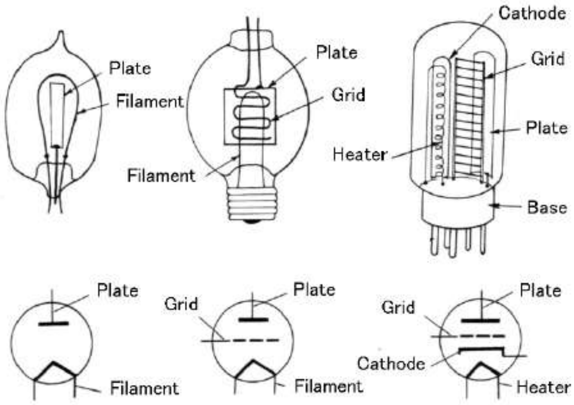


Golay cell (infrared light detector using an expansion of gas)



Radiation temperature meter using diminishing image of hot wire (corridor)

10 Vacuum tube

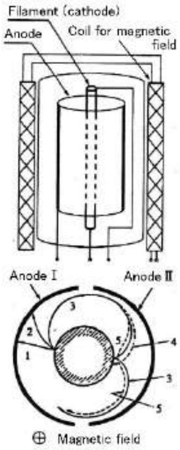


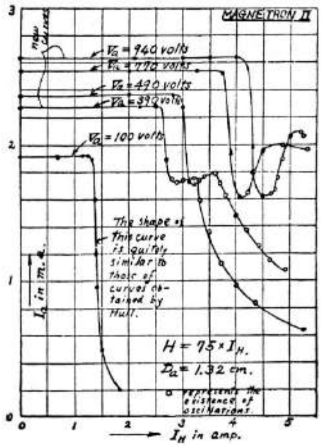
Diode Triode Triode MT tube, GT tube, ST tube, Metal tube, Nuvistor

Fleming (1904) de Forest(1906) (Indirect heating)

K.Okabe (Tohoku Univ.)

Prototype of split-anode magnetron

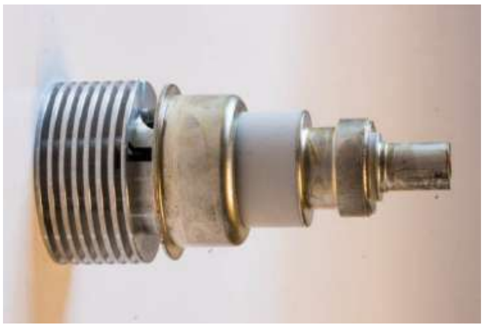




Split-anode magnetron (1932) (History of electronics development (1998))

Magnetron for microwave oven

Klystron



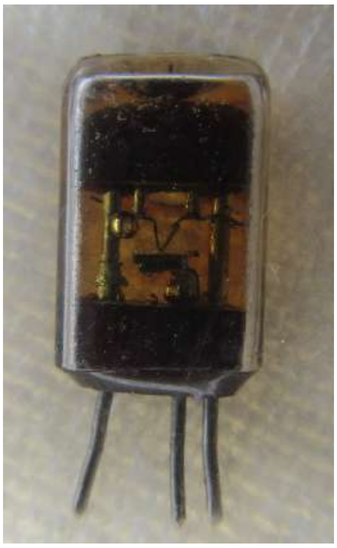
Light house tube

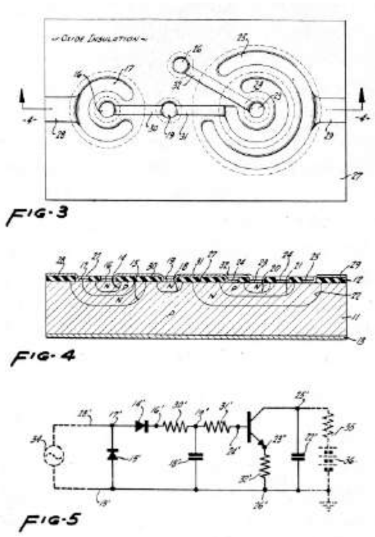
IR image converter tube

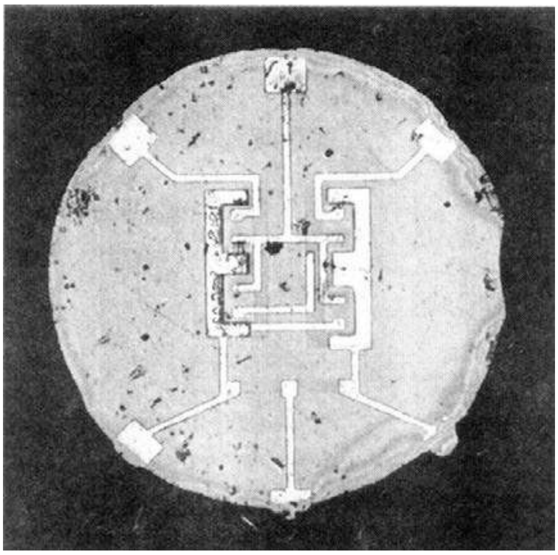
Chalnicon and AP imager (Hamamatsu Photonics)

CRT for oscilloscope

11 Transistor and integrated circuit

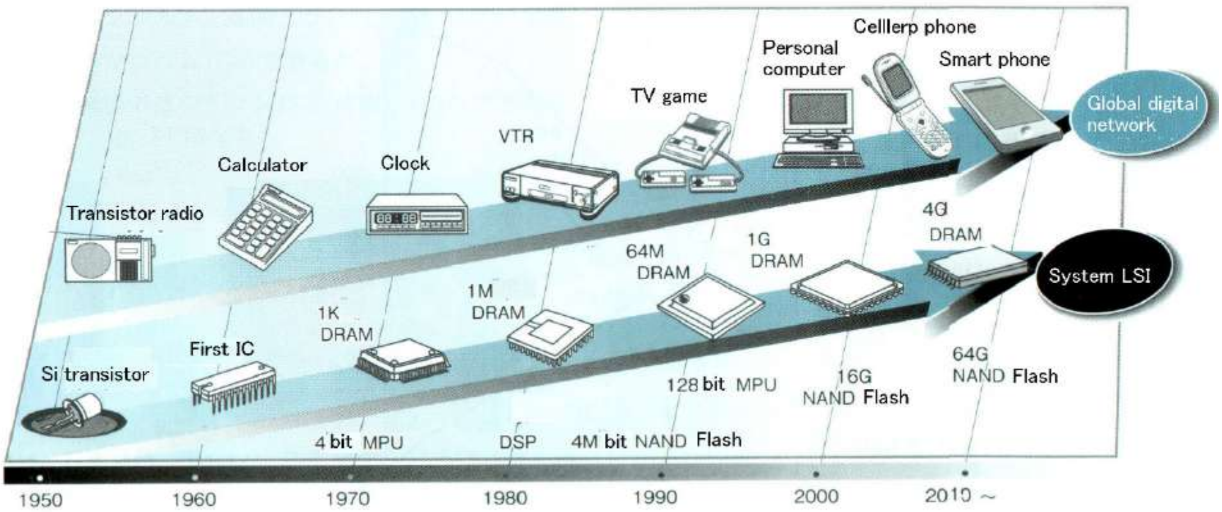




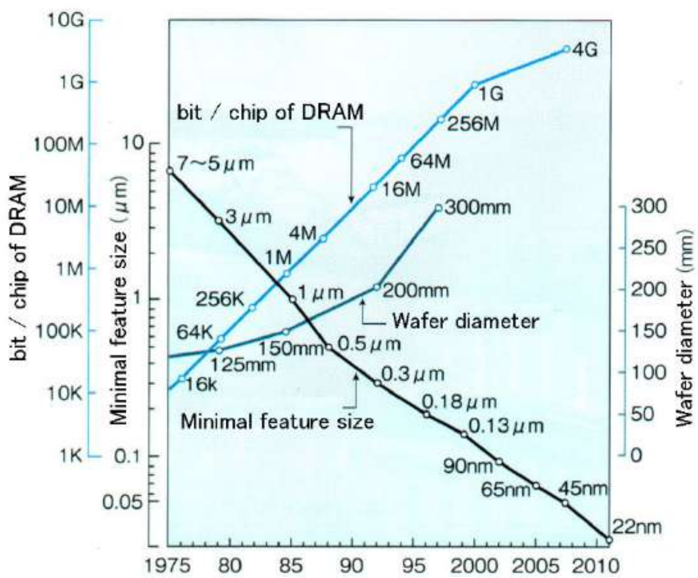


Point contact transistor (1947 Bell Lab.) (Made in Western Electric)

Planer integrated circuit (1959 Fairchild)



Trend of integrated circuit and home electronics



Development of integrated circuit

(Semiconductor IC Guide Book 2, JEIDA (ed), Industry times (2012))

12 Patrick Haggerty's forecast (1964)


Patrick E. Haggerty (President of TI)

The following paragraphs are reproduced from the book by Patrick E. Haggerty, *Management Philosophies and Practices of Texas Instruments* (Dallas: Texas Instruments, 1965).

BARRIERS TO OVERCOME IN ACHIEVING PERVASIVENESS

Yet, in spite of the pertinence of the knowledge and tools, there have been very fundamental limitations to our applying this knowledge and these tools as broadly as they justify and realizing the inherent power and full pervasiveness of electronics. Some of the most harassing have been:

1. The limitation of reliability
2. The limitation of cost
3. The limitation of complexity
4. The limitation imposed by the specialized character of and relative sophistication of the science, engineering and art of electronics.

BASIC REQUIREMENTS FOR FUTURE SUCCESS

The basic requirements to ensure that electronics enters this terminal phase of pervasiveness, I believe, are threefold:

1. A relatively concentrated, highly automated industrial complex which supplies integrated circuitry and closely related compatible discrete componentry to the rest of the electronics industry and to industry in general must exist. Only a few organizations (perhaps five) will supply 90 percent or more of total industry needs, for this will be a heavily capitalized industry with elaborate computer-controlled processing plants necessary to provide the great flexibility essential to produce the wide variety of integrated circuits needed to fulfill 50 percent or more of all electronic function requirements. In essence, this will be a basic materials segment of the electronics industry with the integrated circuits it produces as the basic materials used by the much larger total electronics industry to satisfy the needs of its customers. In a very real sense (although one must not pursue the analog too far), the integrated circuit producers will be to the rest of the industry as the producers of steel are to the automotive industry, the producers of copper are to the electrical industry, or the producers of aluminum to the myriad of organizations which use that material as a basis for their products.

2. This integrated circuits industry must have established a common language for the input and output parameters which specify its products. It will have created a wide variety of computer programs, which will have replaced conventional engineering handbooks as we know them today and truly allow the user of these basic electronic materials, integrated circuits and compatible discrete components, to design the required electronic functions by the input and output parameters available and specified.

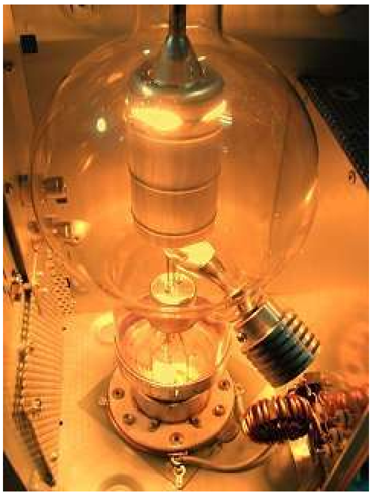
3. A very large number of organizations, probably many more than today, will utilize these basic electronic materials to solve their own and their customers' problems. These organizations will exist in all sectors of our society and will be able to utilize the highly specialized and highly concentrated integrated circuits industry as a substitute for the kind of sophisticated electronics skill described above as the fourth limitation. This will have been made possible by the myriad of computer programs which will allow design by computer through the specification via common language of input and output parameters. A much larger proportion than today of our highly talented electronics engineers will be able to devote their time to the application of electronics to meet the needs of our society rather than to looking inward at electronics itself.

(Seitz & Einspruch, Electronic genie – The tangled history of silicon (1998) Univ.of Illinoiis Press)

13 Large size vacuum tube for transmitter

Triode for transmitter (7T40)

Water cooled triode for transmitter (8T72A))



Triode for transmitter (5T31)

Power triode

Pontoode for transmitter (4P60)

Pulse modulation tube (3F21P) for radar and sonar

14 Cannonball of anti-aircraft gun using vacuum tube (VT (Variable-Time) fuse)

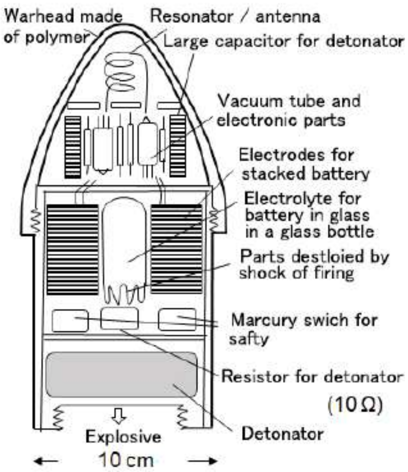
Cannonball of anti-aircraft gun using vacuum tube (VT (Variable-Time) fuse) was developed during the Pacific war in Johns Hopkins University in United State[1]. When radio waves from the cannon ball are reflected by a target airplane, the reflected radio waves containing frequency difference between transmitted and received waves by Doppler effect are detected. This was detected if the distance between the cannon ball and the target airplane is less than 20m. Interval timer is not necessary and hit rate was improved 20 times.

Cannonball of anti-aircraft gun

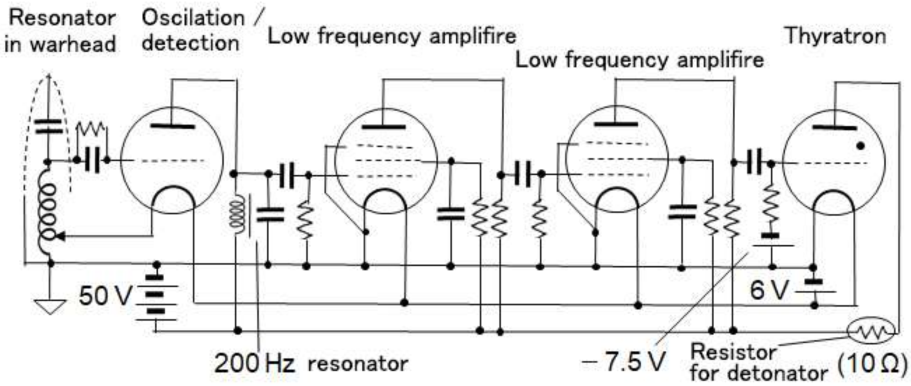
Electronics of VT fuse

Experiment of shot down of aircraft

The structure and circuit of the VT fuse is shown in the following figure[2) 3)]. The transmitter is used as detector as the reflected radio wave and signal of 200 Hz is amplified and trigger a detonator using Thyratron. This has to stand large acceleration (about 10,000 G) and rotation caused by the cannon firing. Subminiature vacuum tube shown in the upper figure and its longitudinal direction is that of travel. Electrolyte for battery is in a glass bottle which is broken by the cannon firing, which is needed for prevent battery discharge and for safety during storage. Since the Battle of the Marianas in June 1944, the VT fuse were equipped in all ships and 2,2 million VT fuse were produced during the second world war[1)]. These were used only in the sea to prevent technology leak by unexploded ordnance, .



Structure

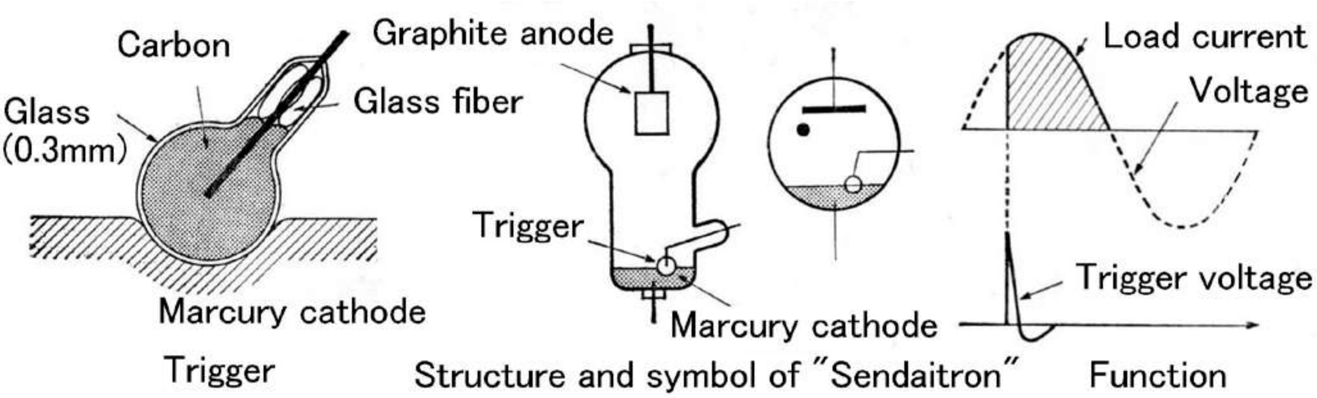


Circuit

1 NHK 取材班編 ："太平洋戦争 日本の敗因 電子兵器 カミカゼを制す", 角川文庫 (1995).
2 貞重孝一 ： 真空管時代のリーディングエッジ電子機器, 映像情報メディア学会誌, **55**, 1 (2001) 70-75.
3 Circuit of VT fuse, http://home.catv.ne.jp/ss/taihoh/vacuumtubes/radar/vtcirct.htm.

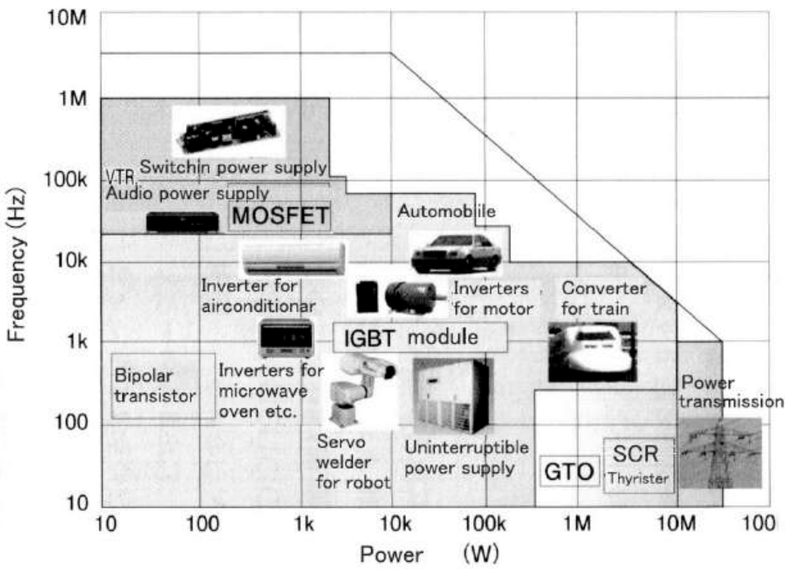
15 From mercury rectifier and thyratron to power semiconductor

Mercury rectifier 5H69 872A 4H72 2H66 Thyratron(power control) (5G69)



"Sendaitron" (Watanabe, Hatta, Kawai (1949))

GTO : Gate Turn-Off transistor, IGBT : Insulated Gate Bipolar Transistor



Model 0 系 (1964~)
ダイオード + 変圧器
端子切り替え

Model 300 (1992~)
and Model 500
GTO + PWM
control
electric power
regeneration brake

Model 700 (1998~)
IGBT Inverter

Application of power semiconductor categorized by
power and frequency (Power semiconductor influencing the worlds (in Japanese)、J. of IEEJ (2008))

16 Hobby (1) (Robot)

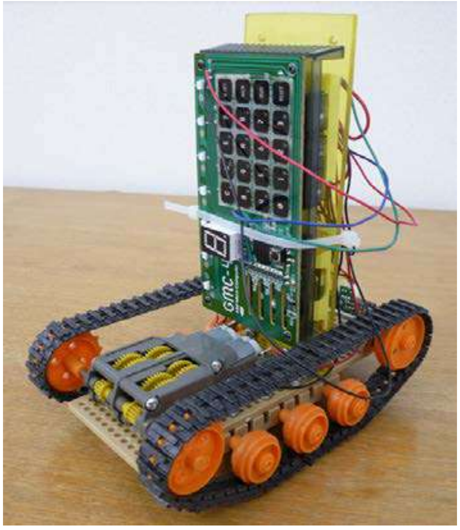
AIBO (Sony)

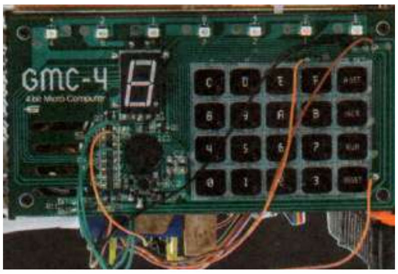
Mechanical doll (Karakuri ningyo) (Gakken)

Small robot

MANOI (Kyosho)

17 Hobby (2) (Car, helicopter)





4bit microcomputer (Gakken) and its application to caterpillar model car

Radio controlled car (Kyence)

Micro fling robot (Seiko Epson)

IR controlled helicopter (CCP)

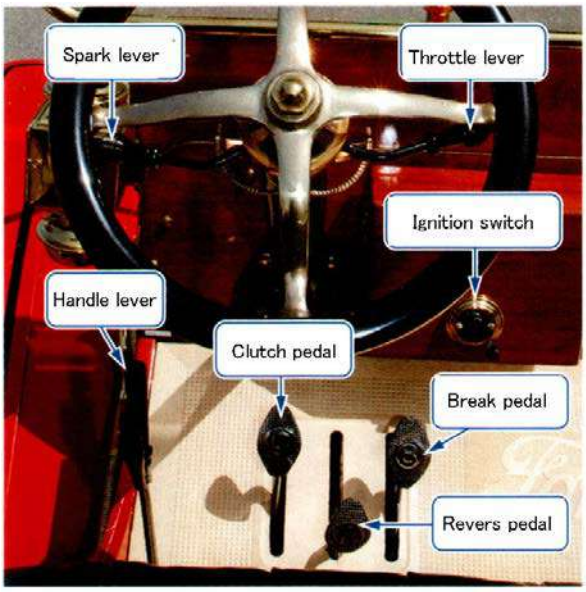
Radio controlled multicopter and helicopter (Keyence)

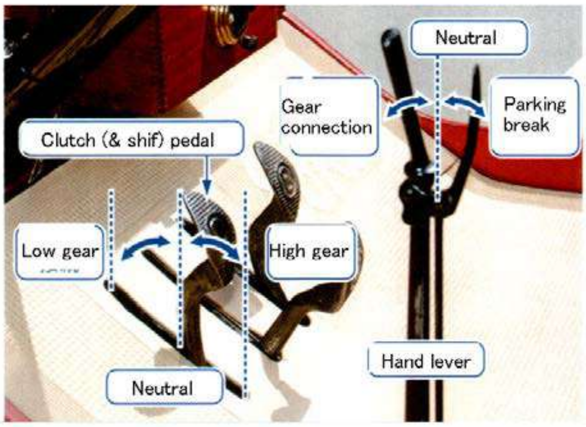
18 Automobile

(Engineering School campus east end)

Model T Ford (1908–1927 15 million cars)

Model A Ford (1927–1931 4 million cars)





Peripheral of handle and pedals of Model T Ford

(Donated by Mr. Masami Tawara (Optoelectronics), Dec. 14, 2005)

19 Illumination and lighter

40W incandescent lamp

40W equivalent fluorescent lamp(8W)

40W equivalent LED(4W)

Current measurement

Air defense incandescent lamp during 2^{nd} world war [1]

At the end stage of the world 2^{nd} war Japan was bombed by US airplane. Dark lamp which illuminate only under the lamp was used for eating and study in order to prevent the light leakage during night. The lamp was made in Matsuda (Toshiba at present). It is 5W for 6–$10m^2$.

Ignition of lighter and fuel [1]

Lighter initiates from a flint and moxa. The moxa was used as an inflammable. The flint and a cord, the flint and petroleum, platinum black and ethyl alcohol (dangerous), flint and gas. spark by a battery and gas and recently piezoelectric device and gas have been used historically.

The left lighter in the photo was made by Tanita in 1970s. This used the battery and the gas in an expensive Ti case.

The right one in the photo is the flint and the cord. Case and chain are made of silver and this was produced before 1965.

[1] Donation by Emeritus Prof. Yakichi Higo of Tokyo Institute of Technology

20 Fountain pen

① Mitsukoshi brand (around 1925) syringe and outer lever
② Atena (Maruzen) (around 1925) syringe and outer lever
③ Sheaffer (made in USA) (around 1930) syringe and outer lever
④ Pilot (around 1960) syringe and inner lever
⑤ Pelican (made in Germany) pump
⑥ Montblanc (made in Germany) pump
⑦ Sheaffer (made in USA) syringe
⑧ Parker (made in USA) A: syringe, B: cartridge pump, C: cartridge
⑨ Parker (made in USA) suction by capillary force

Ink is suctioned using a rubber syringe. The syringe is pushed by pulling up the side lever of the pen. The suction of the syringe is carried out when the side lever returns and syringe inflates (①, ②, ③). ④ has the lever inside the pen and the lever on the back plays the role.

Later in Germany, the suction is made by a pump (⑤, ⑥). Pump is pushed when the bottom of the pen is twisted and it suctions the ink during returning. The pens are partly transparent and the ink motion can be observed.

The Sheaffer (⑦) made in USA looks like a pump but the structure is the syringe. Bottom is pulled out to push the syringe and pushed back to suction the ink.

⑧ is Parker made in USA. This is transition from the syringe type to the cartridge. model and 3 suction types can be used. ⑧A is the syringe type, ⑧B is the cartridge pump type and ⑧C is the cartridge type.

⑨ is also Parker made in USA, but it use new suction by capillary force. This had a problem to reduce suction volume in long use and the pen shifted to the cartridge type.

Donation by Emeritus Prof. Yakichi Higo of Tokyo Institute of Technology

21 Measurement gauge

Balance [1]

Hear hygrometer with thermometer [1]

Maximum minimum thermometer [1]

Fare and rain meter (around 1925) [1]
The weather is visible in the left glass tube.
The liquid inside crystalize depending on the weather.

Portable magnetic compass [1]

Pedometer (1930!' s USA) [1]

Proportional compass [1]

Planimeter (measurement of area)

{1} Donation by Emeritus Prof. Yakichi Higo of Tokyo Institute of Technology

22 Clock

Mechanical discharge lamp display clock driven by AC motor
(1970 Tamura) [1]

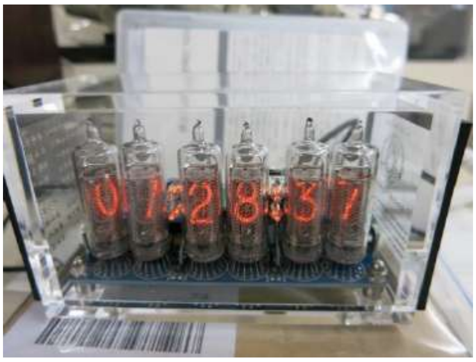
Clock driven by electrical motor
(Tokyo clock) [1]


Tuning fork clock (1974　Seiko) [1]

Tuning fork watch (1960　Bulova Accutron (Switzerland) [2]

Graphic clock
(1985 Citizen) [1]

Pendant quartz watch
(1979Sharp) [1]



Nixy tube clock　(with GPS)
(2015 年　Charonix Design Works)

[1] Donation by Emeritus Prof. Yakichi Higo of Tokyo Institute of Technology
[2] Donation by Mr.Yutaka Kojima in Kojundo Chemical Laboratory

23 Typewriter

Portable typewriter (Before the second world war) [1]
(Prof. Shigeto Tsuru who was a president of Hitotsubashi Univ. used it in Harverd Univ..)

Electrical typewriter (Corona) [1] (Prof. Shigeto Tsuru who was a president of Hitotsubashi Univ. used it.)

[1] Donation by Emeritus Prof. Yakichi Higo of Tokyo Institute of Technology

「世界一の町工場」と呼ばれる清田製作所

【会社メモ】1963年創業。本社・東京都北区。プレス加工によるカメラ・電機通信部品等の製造業でスタートし、82年、電子部門に進出、電子デバイス検査用コンタクトプローブの研究を始めた。86年、国産初シリコンウエハー用４探針プローブの開発に成功し、発展の基盤をつくる。資本金600万円、売上高約１億4000万円（2012年５月期）。従業員16人と社の規模は小さいものの、技術力の高さから「世界一の町工場」と呼ばれる。

世界最小の道具を

最高の技術で

一位の町工場

半導体プローブ

1000分の1の精度

従業員十数人

Evening Newspaper Fuji 2013/1/29

トップ直撃

清田製作所 清田茂男社長（85）

「小さな巨人」の異名をとる半導体プローブ（検査針）のトップメーカー、清田製作所。半導体プローブとは、半導体に電流が正常に流れるかどうかを調べる道具で、1000分の1の精度が求められる。これまでその域に達することができたのは、清田茂男社長を含めて世界で２人。発明大賞など数々の賞に輝く業界の有名人でもある。

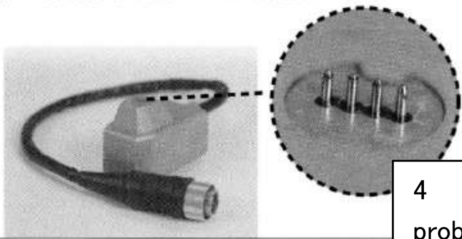
特殊コンタクトプローブ

平成7年4月

科学技術庁長官賞「科学技術振興功績賞」受賞

ケルビン4探針プローブ

昭和61年製品化に成功。世界で2名だけの開発製品



Recording stylus ①

4 point probe ②

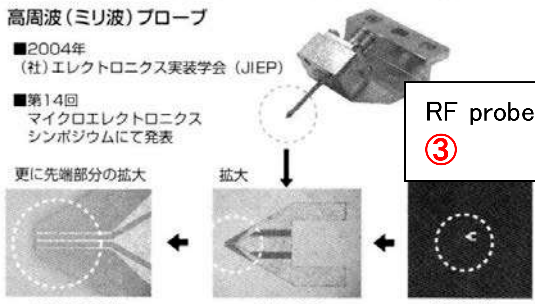
「産・学・官」連携開発製品

GSG ピッチ 20µm 周波数 40GHz 測定 成功

高周波（ミリ波）プローブ

■2004年
（社）エレクトロニクス実装学会（JIEP）

■第14回
マイクロエレクトロニクスシンポジウムにて発表



RF probe ③

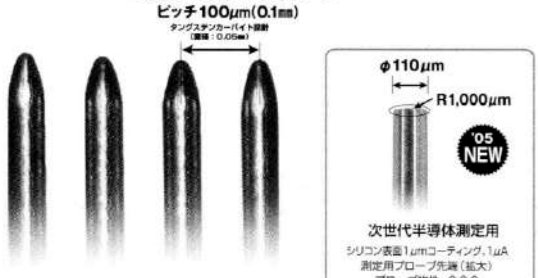
Spring probe ④

Stacked probe ⑤

キヨタ、NTT-AT共同開発製品世界初！

ケルビン100µm4探針プローブ

ピッチ100µm(0.1mm)



次世代半導体測定用

シリコン表面1µmコーティング、1µA測定用プローブ先端（拡大）

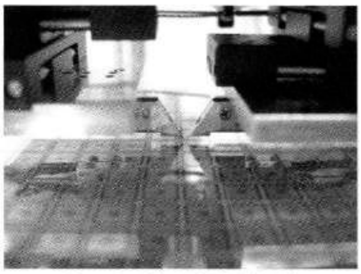
プローブ物性=金合金

特徴:超精密加工

多くの大学研究室で採用

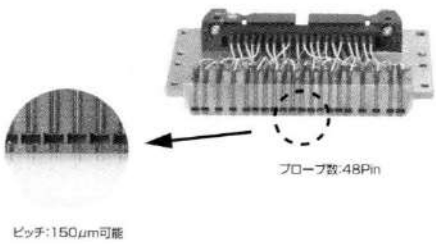
慶應大学、産総研の協力による産学官連携で成功。積層型技術と四探針技術の複合化で実現。

積層型プローブ搭載測定治具

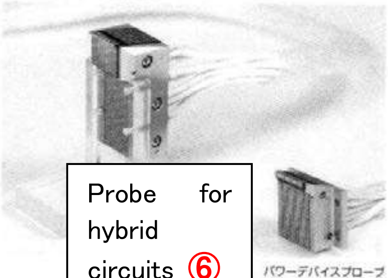


●ファインピッチ/高電流対応可能

ハードディスク　GMR磁気ヘッド対応プローブ



ハイブリッド車用開発プローブ



Probe for hybrid circuits ⑥

G2

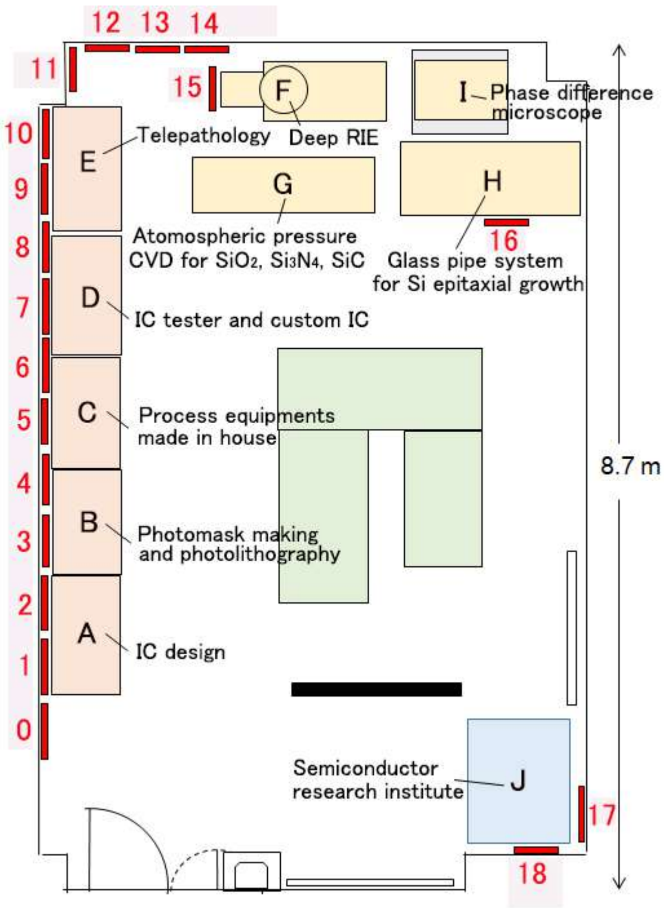

平成十九年春の褒章 伝達式会場 文部科学省

【平成7年】田中真貴紀子科学技術庁長官（中央）と共に


渋沢史料館にて

Kiyota Magfacturing Co. was closed on May 31, 2014 after 50 years operation. All employees and facilities were moved to its contract manufacturing company and “Kiyota probes” have been manufactured there. Kiyota’s technologies are expected to contribute for the future of electronics.

0 In-house IC and equipment room



Poster

0 In-house IC and equipment room
1 Design (1) CAD
2 Design (2) layout
3 Mask making, photolithography
4 Wafer process (1) process sequence, etching
5 Wafer process (2) oxidation, diffusion, CVD
6 Wafer process (3) ion implantation, sputtering
7 IC tester
8 Fabricated custom IC (1) (channel length 10 μm)
9 Telepathology by improved telecommunication
10 Revolution of telemedicine
11 Demonstration of Telepathology by Hi-vision movie
12 Assembly, measurement
13 Fabricated custom IC (2) barrel shifter, integrated capacitive pressure sensor
14 Deep reactive ion etching (Deep RIE) system
15 Effective drawing of process chart
16 Si epitaxial growth and optical observation of defect (Semiconductor research institute)
17 From “Semiconductor Research Institute (SRI)” to “Nishizawa Memorial Research Center”
18 Nishizawa memorial room

In-house IC and equipment room from entrance

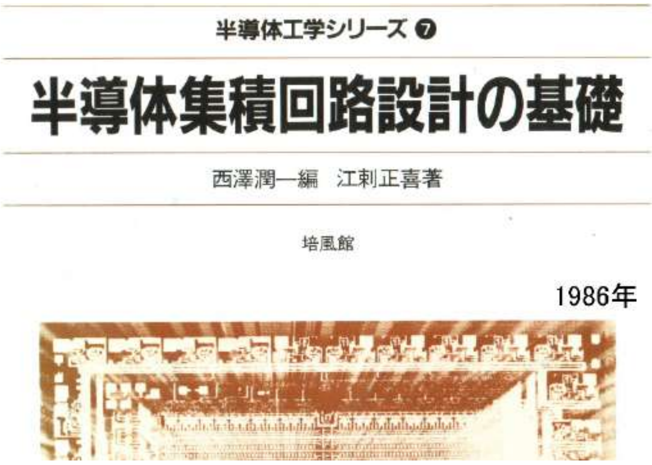
Message from Prof.Nishizawa

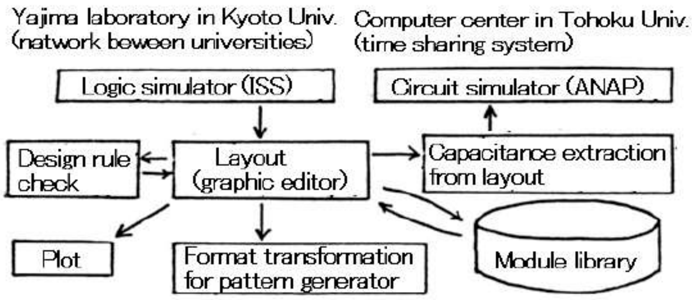
Semiconductor Research Institute and Nishizawa memorial room

In-house IC design, fabrication and test

Glass pipe gas line for Si epitaxial growth system (right), atmospheric pressure CVD system (poly Si, Si_3N_4, SiO_2) (left)

Design and fabrication of CMOS IC using equipment made in-house

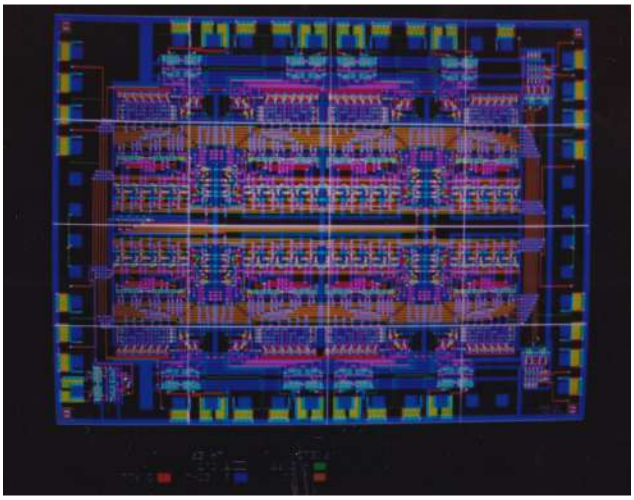




Design flow using CAD programs

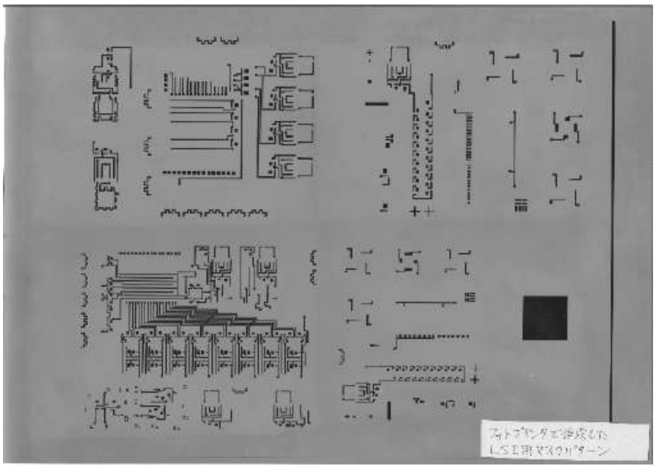
Text book in Japanese "Basics of integrated circuit design" M.Esashi (1986) Baifukan

Graphic display connected to LSI11 (DEC) for LSI design



Layout editor programed by M. Esashi using Fortran

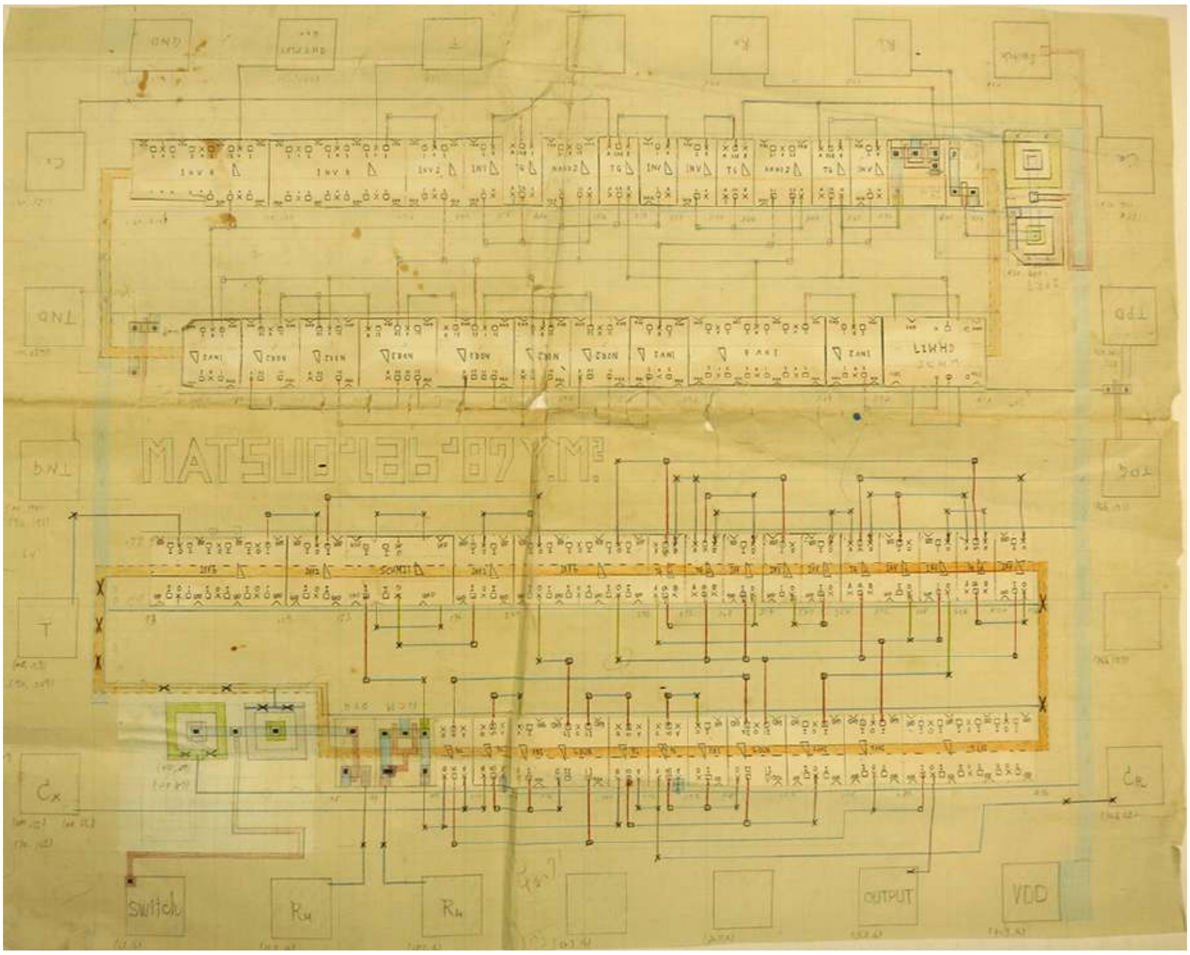
Photo-printer for printing out the layout pattern

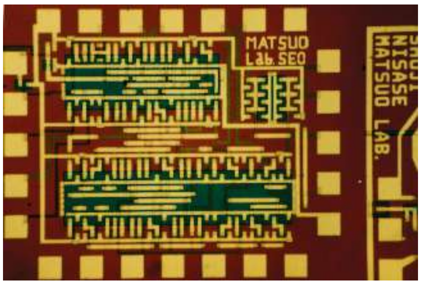


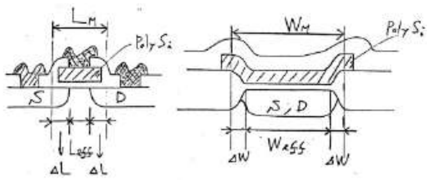
Mask negative printed out on a transparent film

(M. Esashi : Prototyping and Education of LSI in University, J. of the IECE, 68, 1 (1985) 50−52) (in Japanese)
(M. Esashi, A. Komatsu, M. Asibe, M, Ohtomo : Design/Fabrication System for Custom LSI (1) (Overview of the System), (2) (Design Environment), (3) (NMOS process and Evaluation), S58 Convention of the IECE, 401-3 (1983)) (in Japanese)
(M. Esashi, A. Masuda, T. Matsuo : CAD System for LSI Design, Joint Convention of Electrical Academic Societies in Tohoku Region, 2D21 (1984))(in Japanese)

2 Design (2) layout



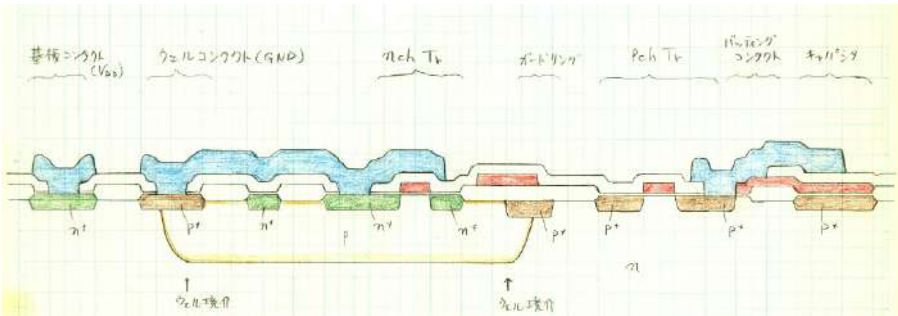


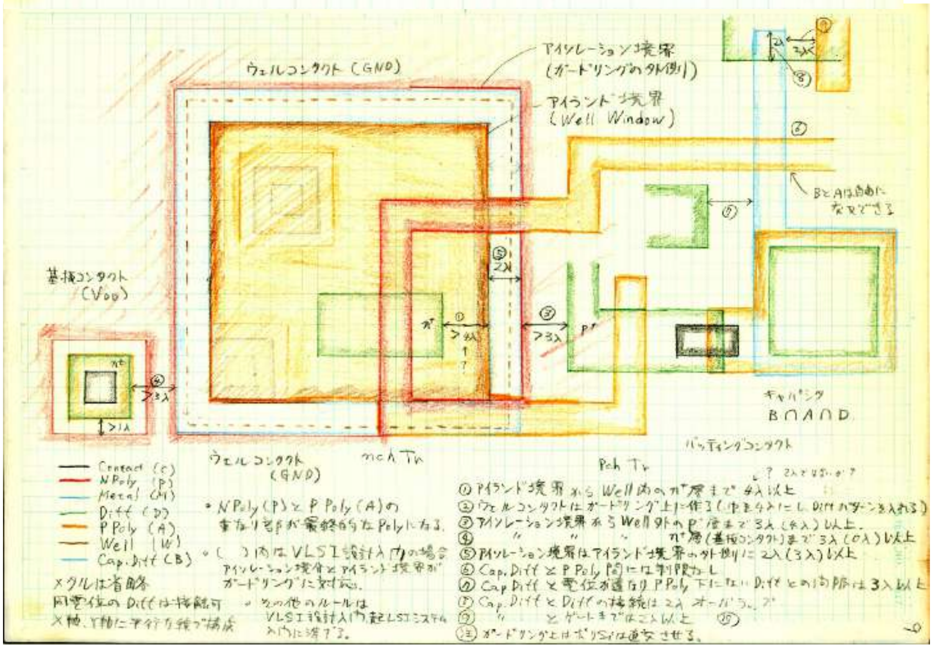


$L_{eff} = L_M - 2\Delta L$ $\qquad W_{eff} = W_M - 2\Delta W$

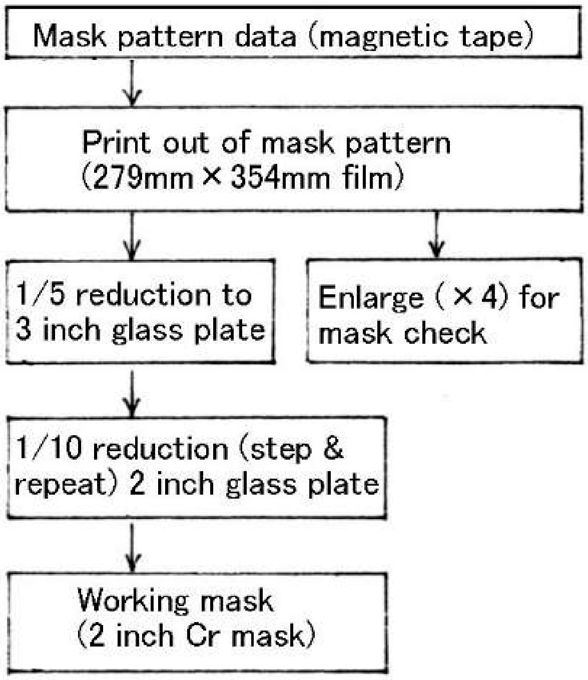
Parameter		Size nMOS	Size pMOS	Unit
Threshold voltage V_T		1.0	-1.2	V
Mobility (maximum) μ_{eff}		373	149	$cm^2V^{-1}sec^{-1}$
Substrate bias effect γ		1.4	0.41	$V^{\frac{1}{2}}$
Channel length modulation λ	$L=5\mu m$	0.056	0.13	V^{-1}
	$L=10\mu m$	0.012	0.022	V^{-1}
	ΔL	1.83	1.7	μm
	ΔW	2.64	2.14	μm
Junction depth of S,D X_j		2.3	2.1	μm
Gate oxide thickness T_{ox}		720	720	Å

Measured SPICE parameter for SPICE simulation
(p-well dose 8×10^{12} atoms/cm^2)



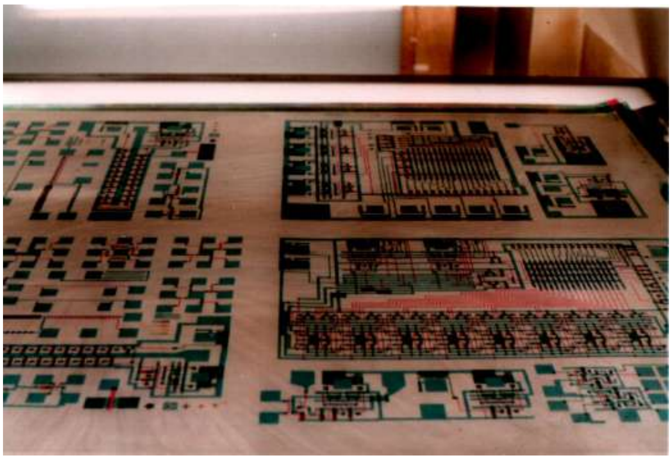


3 Mask making, photolithography



Mask making process

Reduction camera (displayed)



Color key for patter inspection

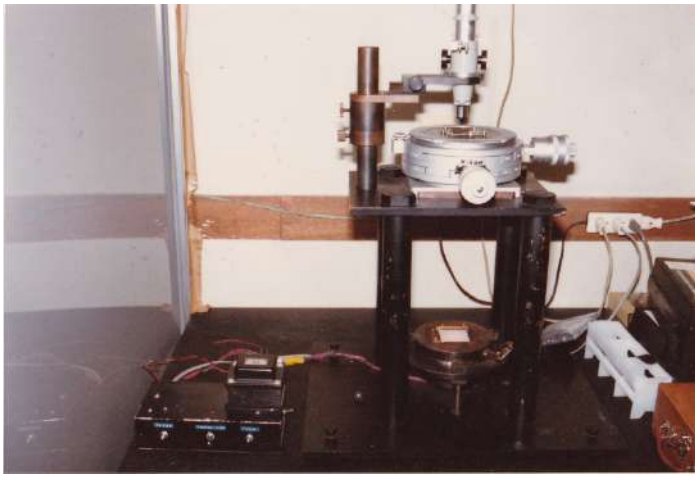
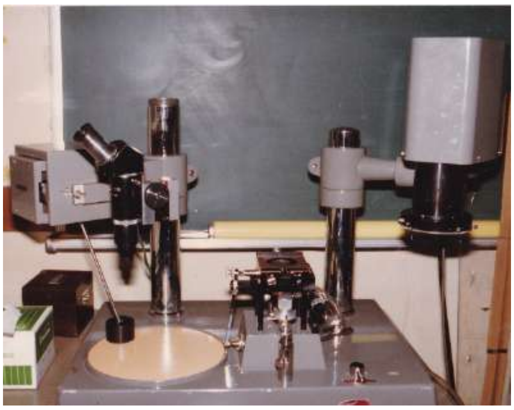
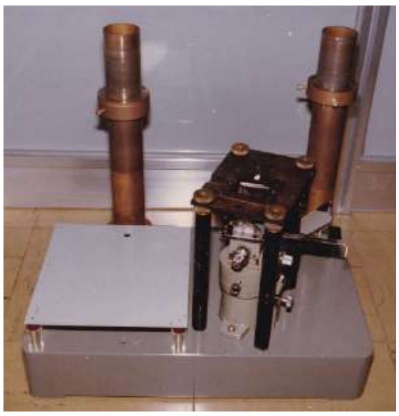


Photo repeater (2nd reduction camera)

Spinner for resist coating and baking tool

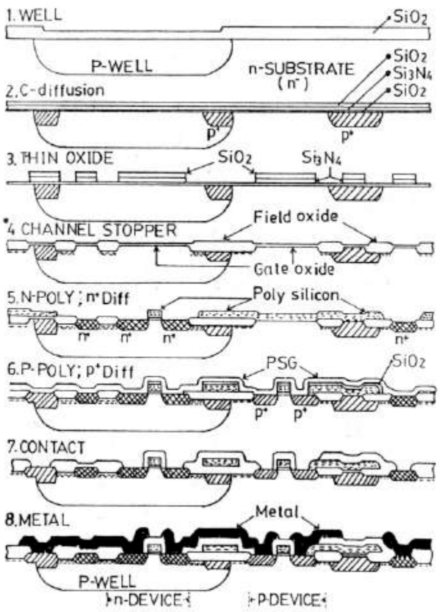


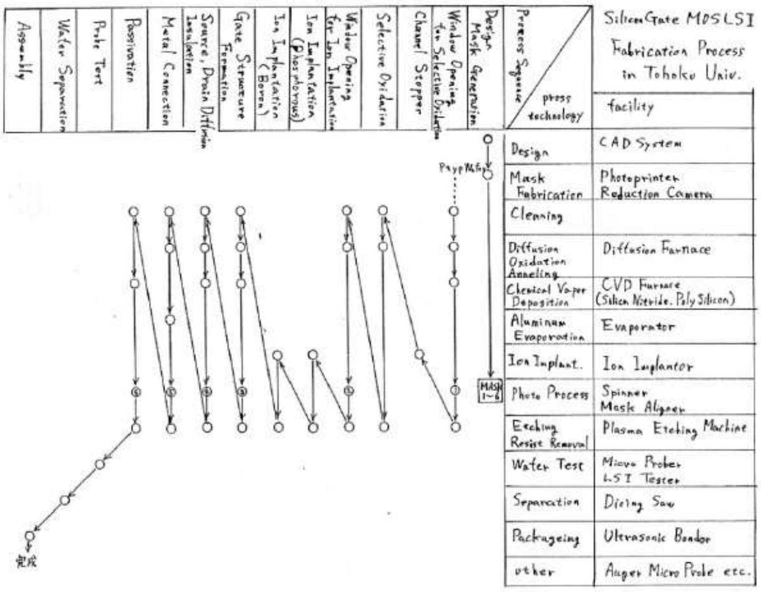
Mask aligner



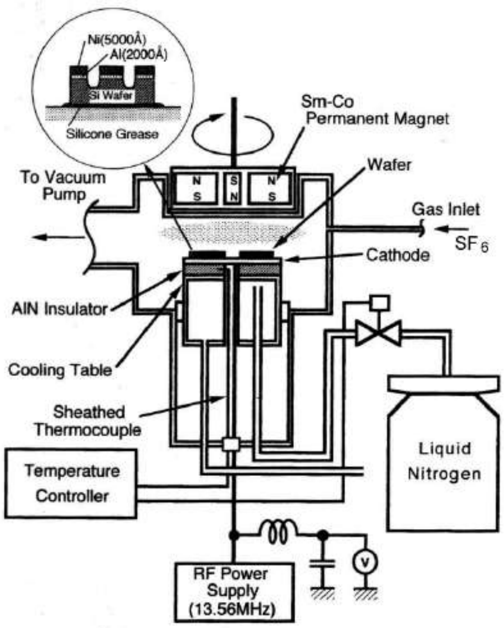
Attachment for double side exposure

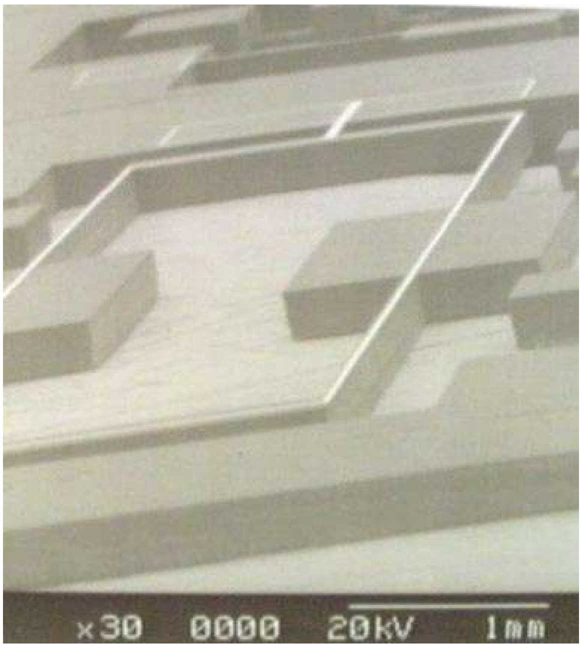
4 Wafer process (1) process sequence, etching





Si EPW etcher, SiN etcher in hot phosphoric acid、Electrochemical Si etcher DI water supply



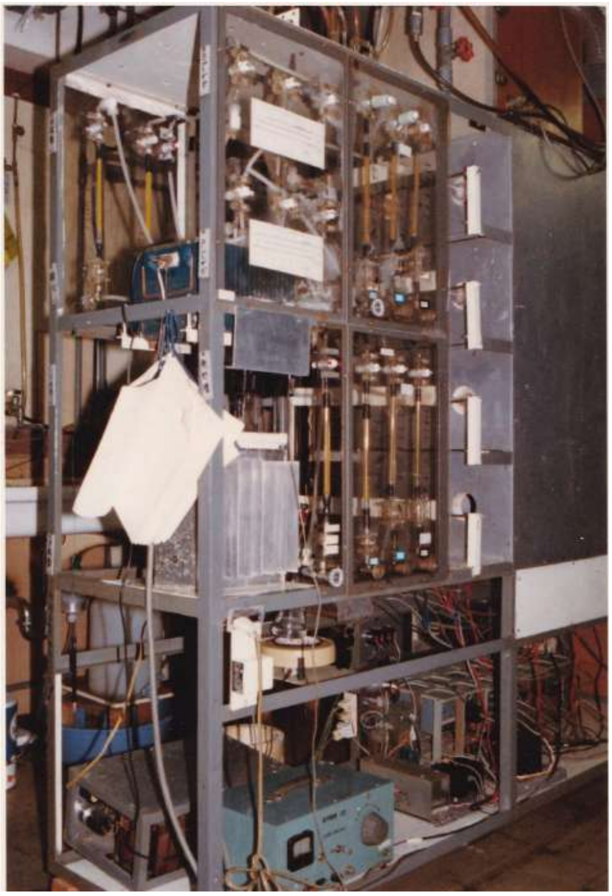


Si deep RIE (Reactive Ion Etching) system (1992) Resonating gyroscope by the deep RIE through Si wafer

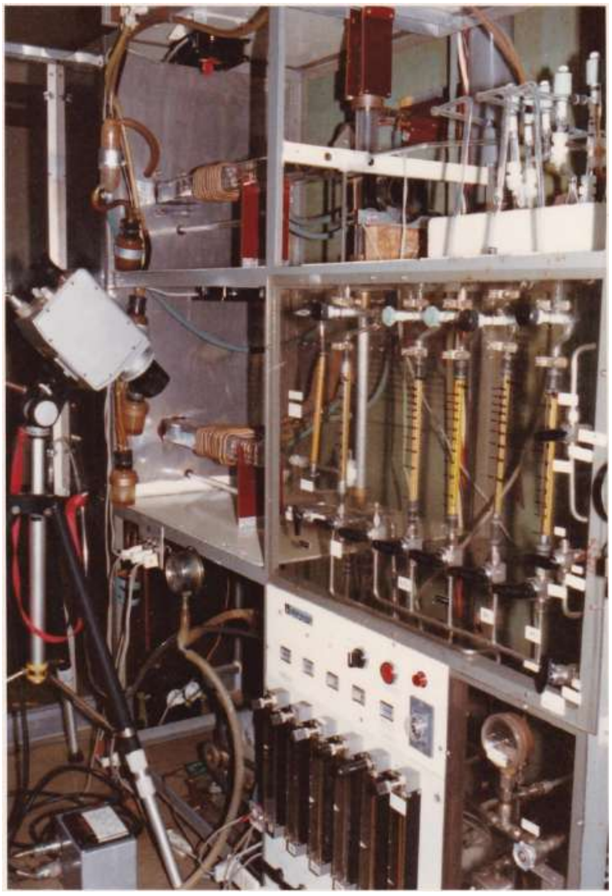
(M.Takinami, K.Minami and M.Esashi : High-Speed Directional Low-Temp. Dry Etching for Bulk Silicon Micromachining, 11th Sensor Symp. (1992) 15-18)

(J.Choi, K.Minami and M.Esashi : Application of Deep Reactive Ion Etching for Silicon Angular Rate Sensor, Microsystem Tech., 2, 4 (1996) 186-199)

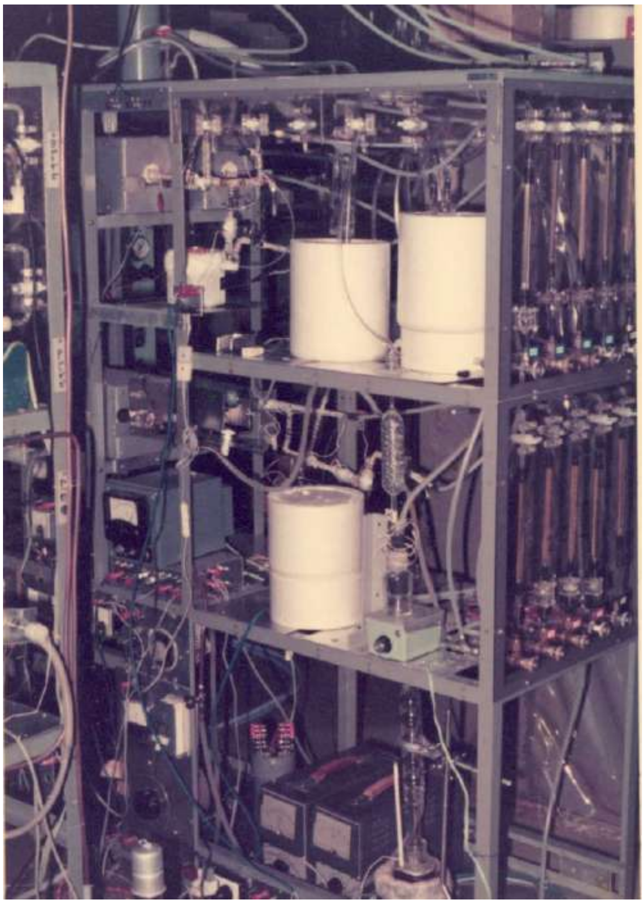
5 Wafer process (2) oxidation, diffusion, CVD



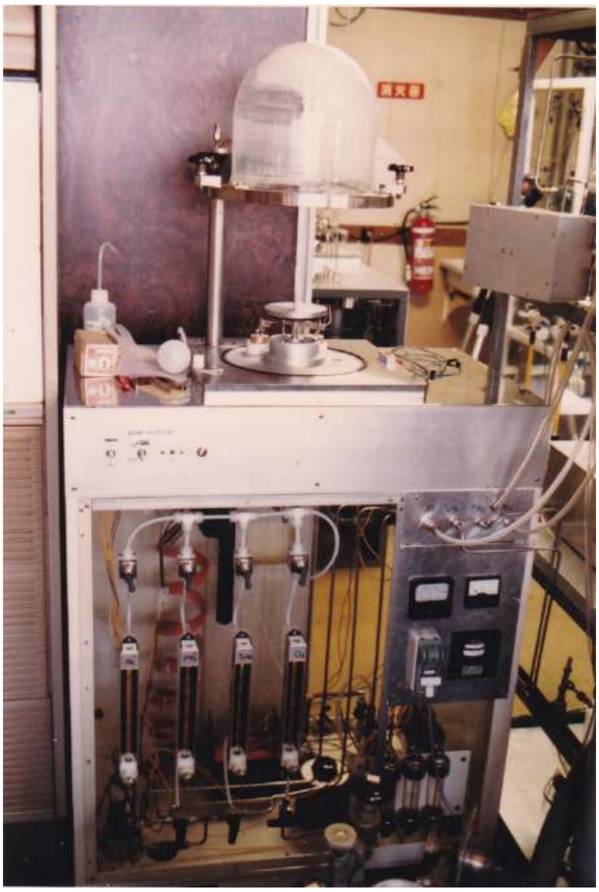
Oxidation diffusion furnace



Atmospheric CVD for Si_3N_4、SiO_2、Poly-Si (displayed)

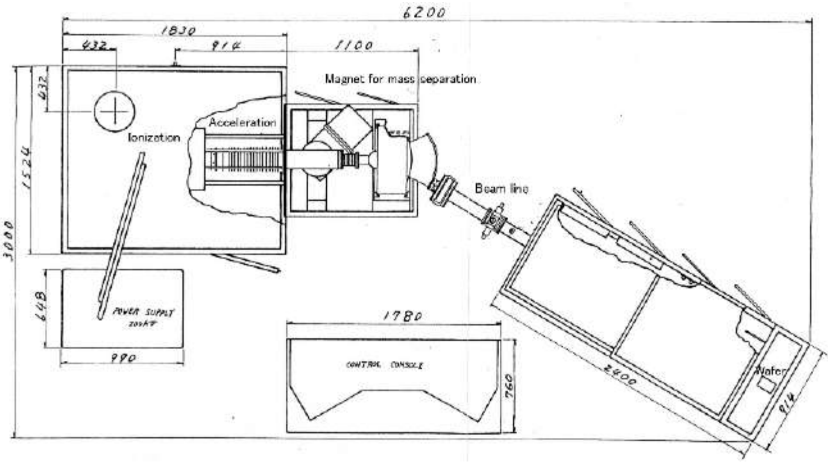


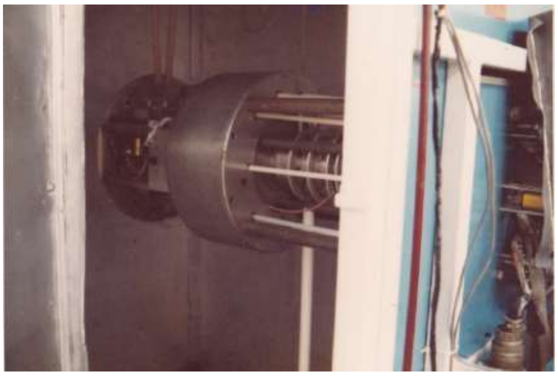
TEOS (tetraethoxysilane) source Al_2O_3–SiO_2 CVD

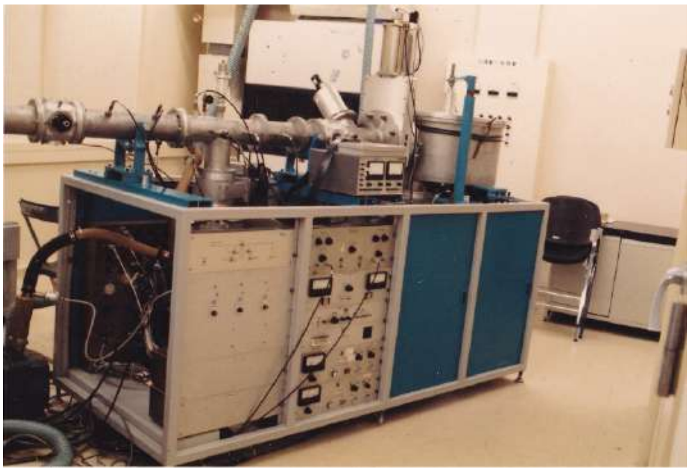


Low temperature CVD for SiO_2 (displayed)

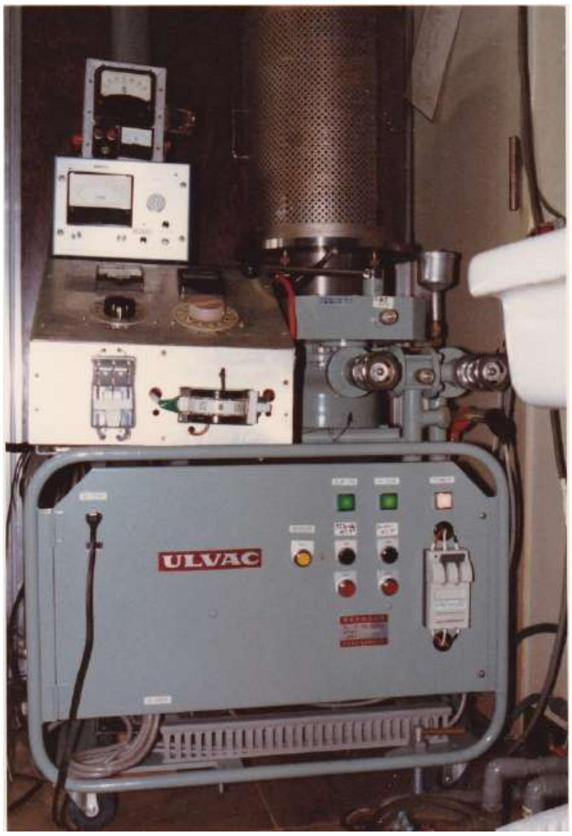
6 Wafer process (3) ion implantation, sputtering

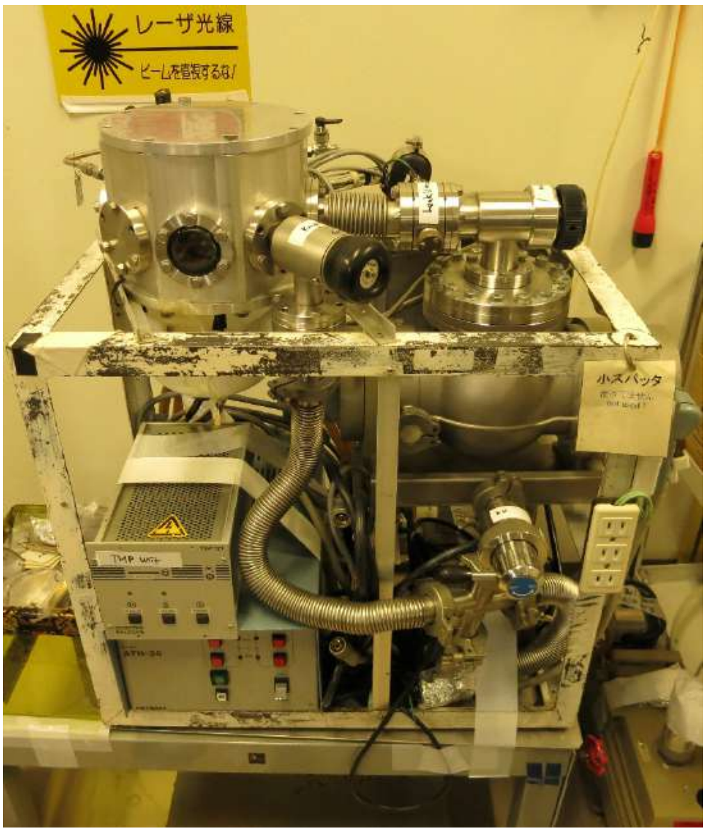






Ion implanter (Accelerator Inc, 200MP second hand)

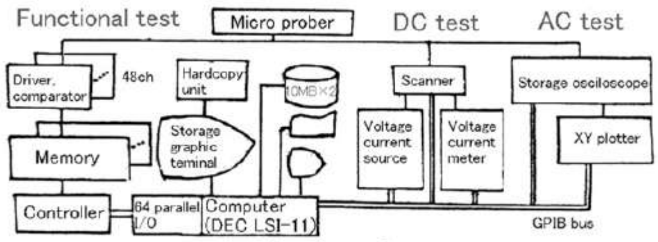




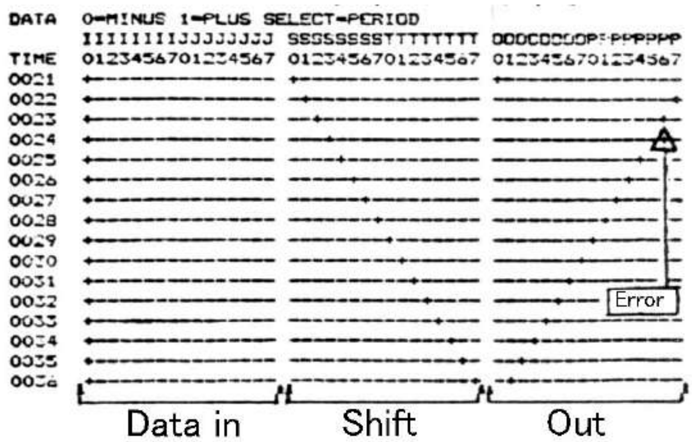
Al, Cr-Cu-Au evaporator

Magnetron sputter deposition

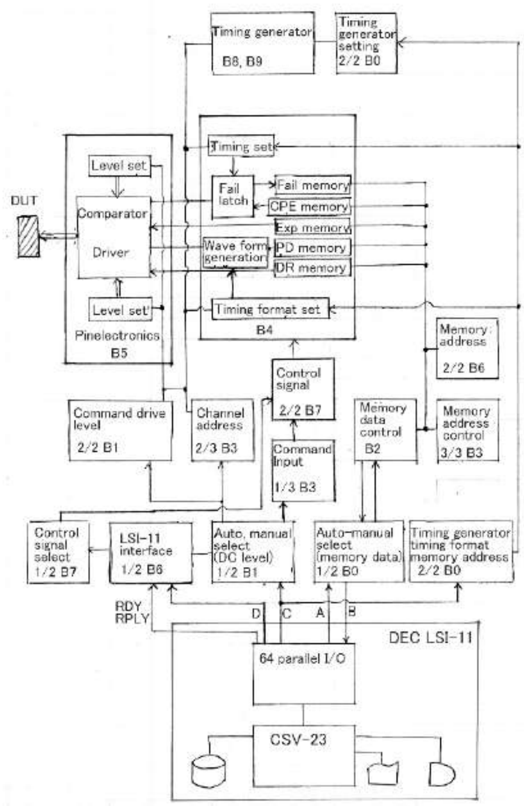
7 IC tester



IC test system

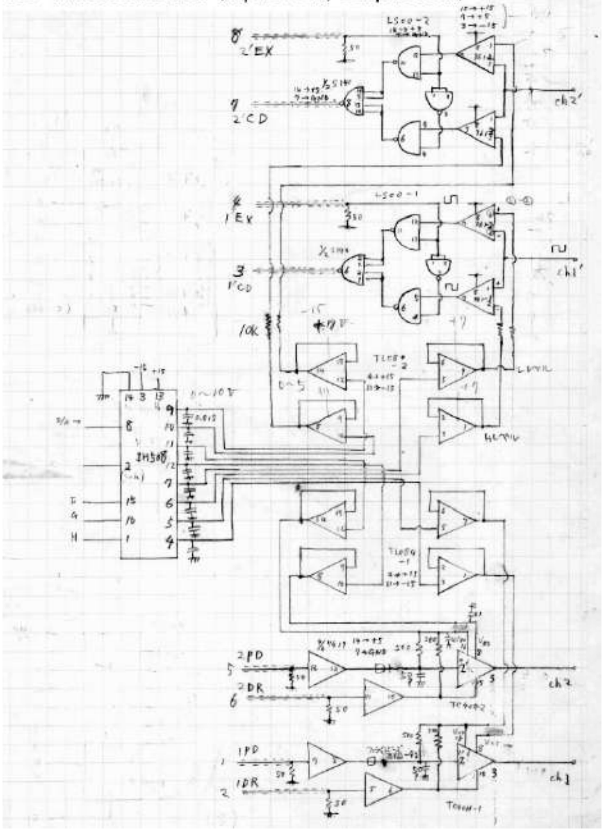


An example of test result of barrel shifter

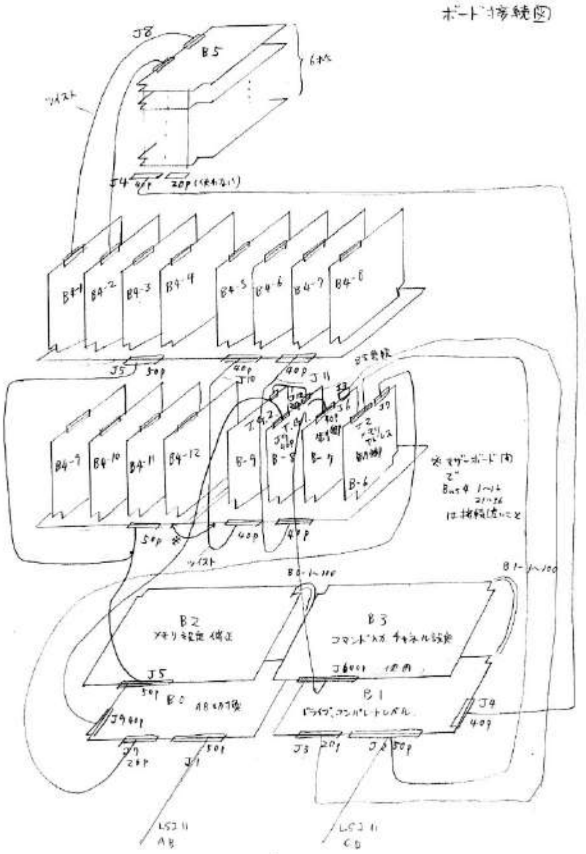


Block diagram of made-in-house IC tester

B5 Pinelectronics (input 2ch, output 2ch)



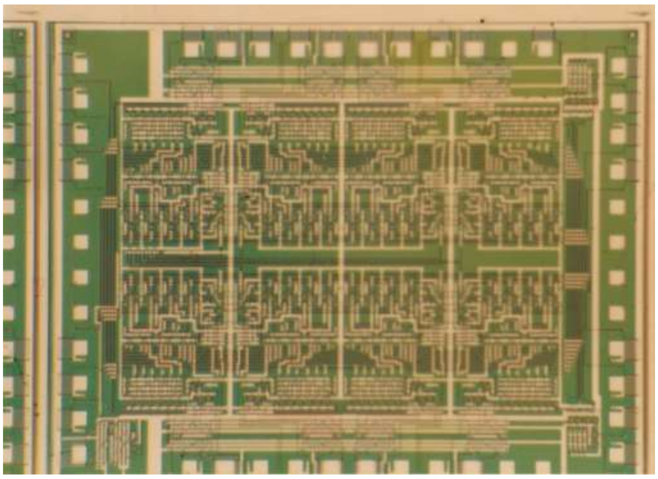
Pin electronics (electrical connection to IC pad)



Connection between boards

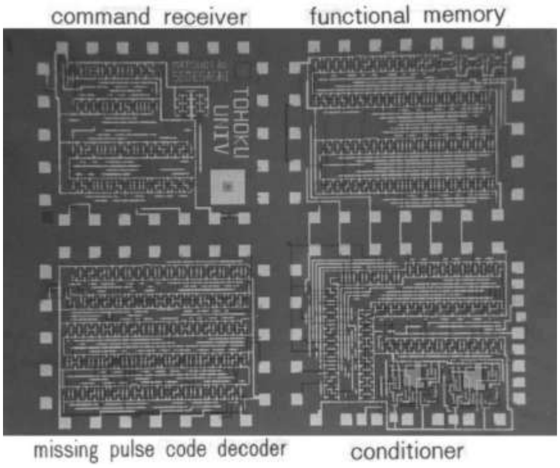
(M. Esashi, M. Ohtomo: Fabrication of Functional LSI Tester, Joint Convention of Electrical Academic Societies in Tohoku Region, 2D21 (1984))(in Japanese)

8 Fabricated custom IC (1) (channel length 10 μm)



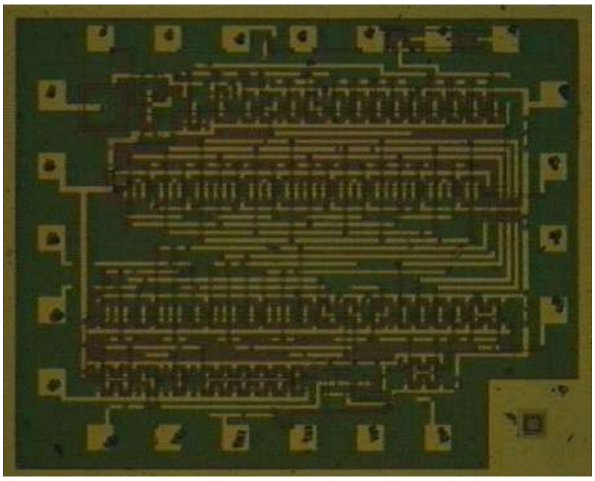
Bit serial parallel image processing IC

(M. Esashi : Basics of integrated circuit design, (1986) Baifukan) (in Japanese)



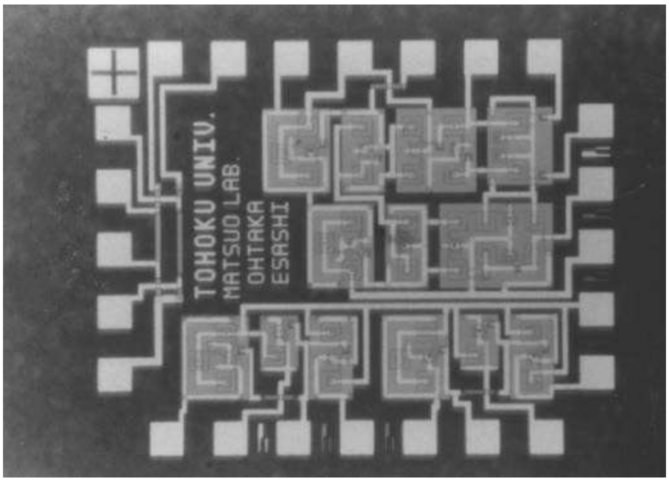
Implantable telemetry IC

(H.Seo, M.Esashi and T.Matsuo : Manufacture of Custom CMOS LSI for an Implantable Multipurpose Biotelemetry System, Frontiers of Medical and Biological Engineering, 1, 4 (1989) 319-329)



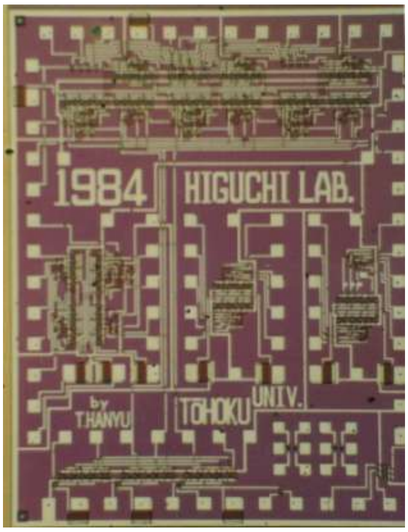
IC for tactile sensor array using common two wires

(M.Esashi and Y.Matsumoto : Common Two Lead Wires Sensing Transducers'91, San Francisco, USA (1991) 330-333)



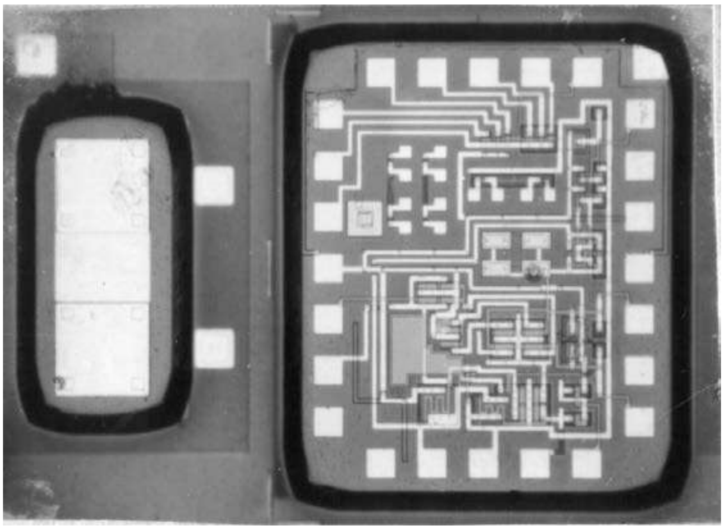
SOS (Si on Sapphire) CMOS OP amp IC for high temperature

(M. Esashi, S. Ohtaka, T.Matsuo : Fabrication of High Temperature Integrated System, Circuit and High Temperature Pressure Sensor, Technical Report IECE, SSD86-57 (1986) 67-74) (in Japanese)



Multi-valued logic IC

(M.Kameyama, T.Haniyu, M.Esashi and T.Higuchi : An NMOS Pipelined Image Processor Using Quaternary Logic, IEEE Int. Solid-State Circuit Conf., San Francisco, USA (1985) 86-87)

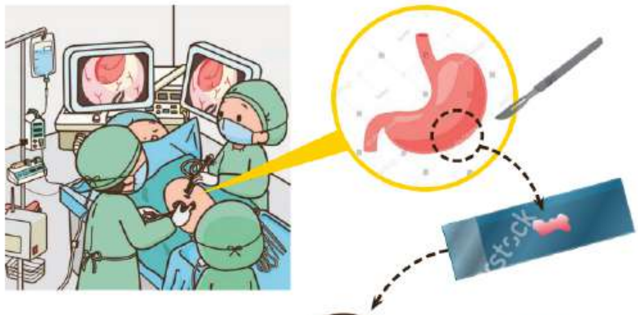


Direct bonded capacitive pressure sensor using switched capacitor IC

(S.Shoji, T.Nisase, M.Esashi and T.Matsuo : Fabrication of an Implantable Capacitive Type Pressure Sensor, The 4th Int. Conf. on Solid State Sensors and Actuators, Tokyo, Japan (1987) 305-308)

9 Telepathology by improved telecommunication

Development of telepathology by improved telecommation

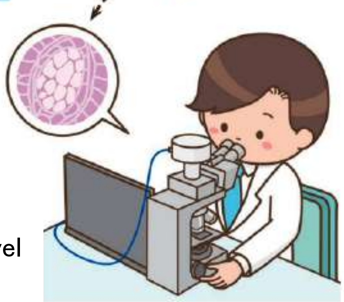


Pathological diagnosis

Making specimens of organ systems and observing it under microscope. Number of pathologist are small compering other specialist of doctors.

Regarding rapid diagnosis

Determine the area for removal during operation. If mistake happens recurrence of malignant tumor which is related to death occurs.
Lack of pathology can be complemented by remote diagnosis.



Telecommunication speed and telepahology

The total digital image data of the pathological specimen can be large Giga byte level volume excepting cross sectional images. Remote diagnosis in the era of low telecommunication speed was carried out by transmitting selected minimum images.

	History of communication network	History of telepathology	Telecommunication speed
1964	Jun-ichi Nishizawa applied patent of optical communicatuion using focused optical fiber		
1970	Corning Ltd (USA) commercialized optical fiber for communication		
1981	Commercialization of optical fiber communication by Nippon Telegraph and Telephone Corp.		
1984		Experiment of telepathology by transmitting still image using analog telephone line	300 bps
1992		Demonstration experiment of telepathology (HD movie + remote operation of microscope) using optical fiber of Tohoku electric power corp. between Tohoku University and Sendai city hospital	178 Mbps (in terms of digital)
1988	Start of ISDN service	Telepathology by transmitting still image using telephone line became popular, Tohoku Univ. – Kesennuma hospital line started in 1994.	64 Kbps
1999	Commercial ADSL internet service frst in Japan		
2001	Authentic optical access (max 10 Mbps) by NTT		
2002	Authentic optical access (max 100 Mbps) by NTT		
2004		Demonstration experiment of telepathology using VGS movie + remote operation of microscope	8 Mbps
2008		Commercialization of telepathology using FHD movie + remote operation of microscope	16 Mbps
2009		Commercialization of WSI (Whole Slide Imaging) in which pathological specimen is digitalized with high magnification	
2010	Experiment using communication satellite (Kizuna) for high speed internet by JAXA	Demonstration experiment of telepathology using communication satellite	

Pathological diagnosis enabled by optical fiber

Diagnosis took time at slow communication era because amount of information was small and transmission took time. Transmission capacity and speed of microscopic image increased by optical fiber in 1992, which enabled remote diagnosis and assured surgery in local hospital. This application of the optical fiber in medicine has been used not only for the pathological diagnosis and teleoperation but also transmission of CT and MRI images and home medical care widely.

10 Revolution of telemedicine

Revolution of temedicine

- Optical fiber of which principle was considered by Prof. Nishizawa enabled high speed communication and started revolution of remote medicine.
- In 1992 which was 10 years before the start of optical communication service, the demonstration of telepathology using analog optical fiber was carried out between Tohoku university hospital and Sendai city hospital supported by Tohoku Electric Power Corp..
- The demonstration by Tohoku university (Sendai International Center) and Sendai city hospital which was carried out in general meeting of the pathology academy in 1992 started practical use of telemedicine using high speed communication in our country.

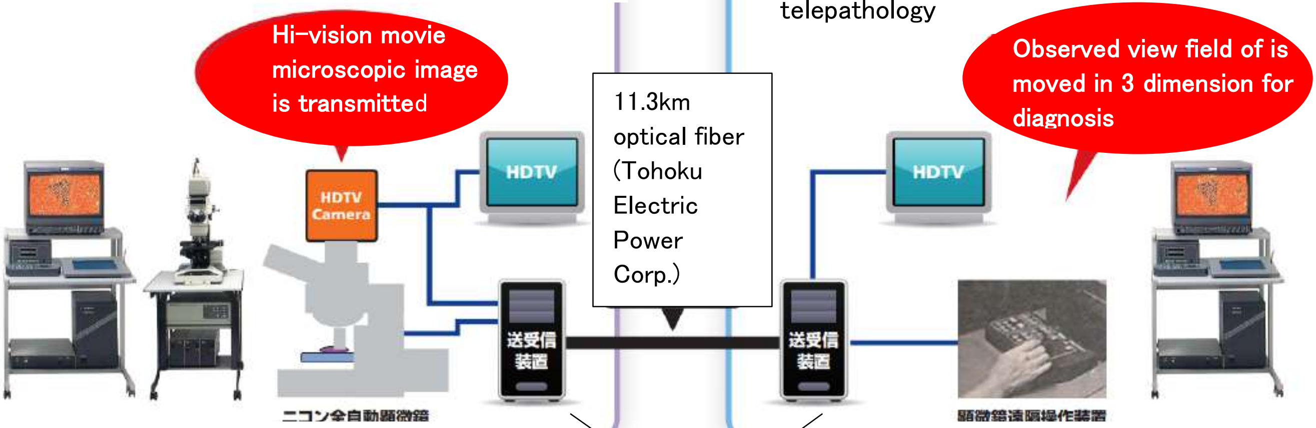
President Nishizawa observing demonstration

Old Sendai city hospital (Itsutsubashi)

Dr. Naganuma transmitting the microscope image

Tohoku university hospital

Dr. Sawai (Tohoku Univ. hospital) carrying out the telepathology



Automatic microscope (Nikon)

Remote operation of microscope

Transmitter and receiver

- Tohoku Electric Power Corp. connected Sendai International Center (300 inch large screen) and Sendai city hospital with optical fiber.
- Nikon Corp. donated microscope.
- Panasonic. Corp. donated transmission equipment.
- Dr. Naganuma (Chief pathology department in Sendai city hospital) transmitted sample images to Prof. Wakasa (Fukushima medical univ.), who explained the system.
- NHK carried out national broadcast of the demonstration by Hi-VISION in realtime.

11 Demonstration of Telepathology by Hi-vision movie

Demonstration of telepathology by Hi-vision movie

Network route of optical fiber used for research

Optical fiber network (11.3km) which connect Tohoku university hospital – old Sendai city hospital (Itsutsubashi) – Sendai international center (Existing optical fiber : 8.4km, New optical fiber : 2.9 km)

Actual exhibition of optical fiber cables attached to electricity distribution lines which inhibit snowfall

(Self-suspended inhibiting snow fall optical fiber cable developed in Tohoku Electric Power Corp.)

● Prehunged type

Hanging wire and cable are unified with polyethylene hanger, which can prevent lateral growth of snow wall and influences of stress to the hanging wire by using slack of the cable.

● Spindle shaped

Hanging wire and cable are unified with polyethylene sheath, which has flat surface.

● Self-suspended spiral (SSS) type with wave-shaped steel pipe.

Cable with wave-shaped steel pipe is wrapped around hanging wire.

● Dual lashing type (SSF type)

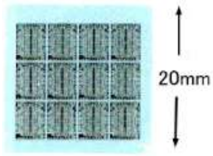
Hanging wire and cable are unified with bind wire.

● Nonmetalic prehunged type

FRP hunging wire and cable are connected with polymer, which don't use metal.

This research was published by New media Ltd. (1994) as "Sendai telepathology research : Proposal of Hi-vision telepathology using optical fiber"

12 Assembly & measurement



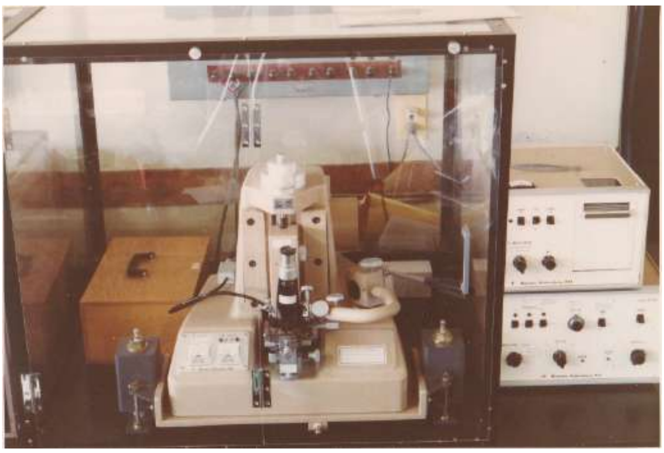
CMOS IC fabricated on a 20mm square wafer

Wafer prober

Dicer

Ultrasonic wire bonder (displayed)

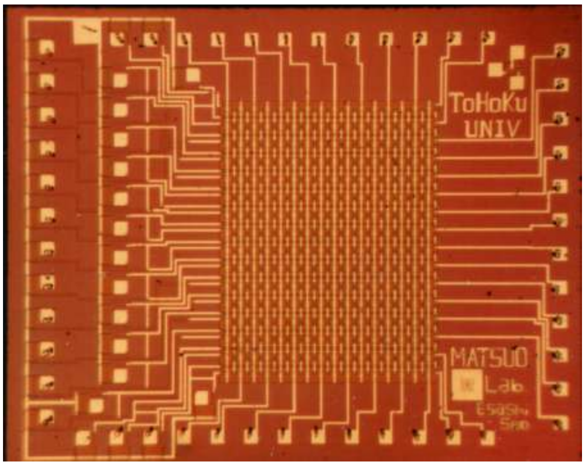
Micro soldering (and connection by conductive paste)



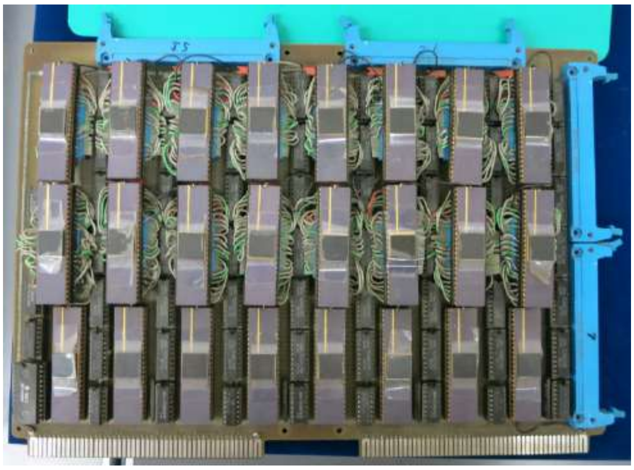
Surface profile meter

Auger electron spectrometer

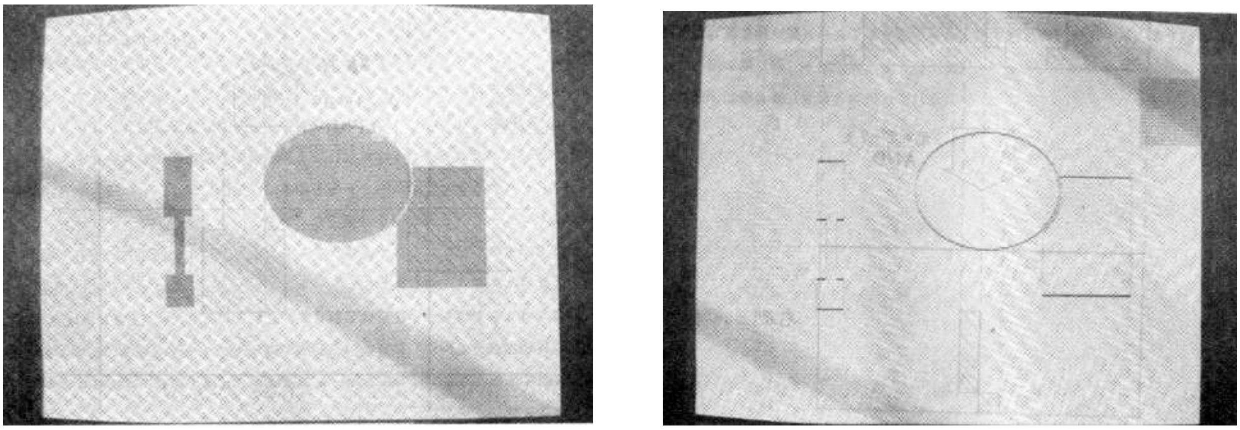
13 Fabricated custom IC (2) barrel shifter, integrated capacitive pressure sensor



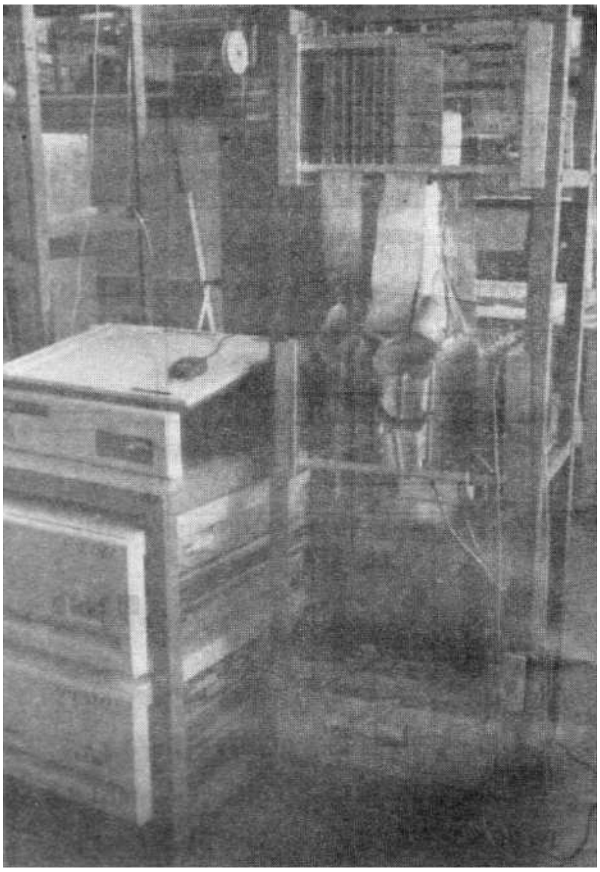
Barrel shifter

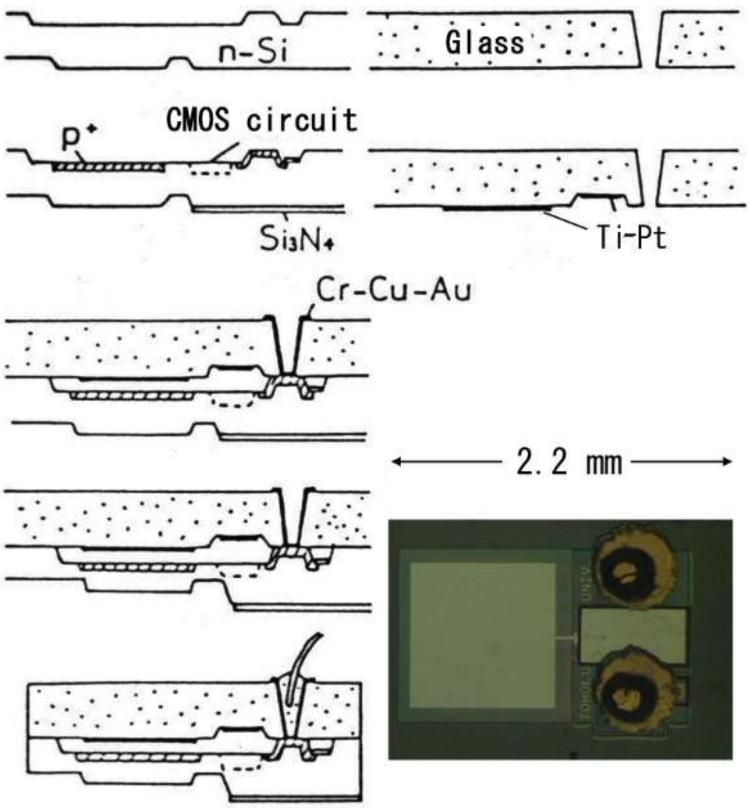


Switching network board using the barrel shifter (displayed)



Example of edge detection using the parallel image processing





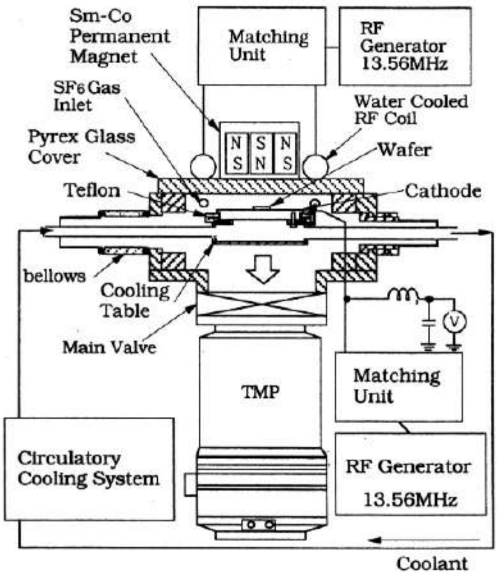
Parallel image processor using the barrel shifter IC (with DEC LSI-11)

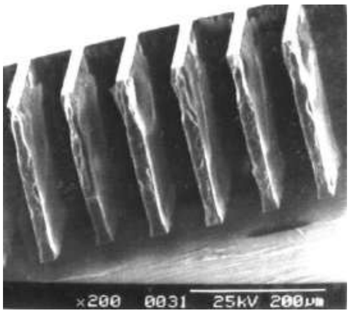
(M. Esashi, T. Matsuo : Workstation for LSI Pattern Design Using Custom LSI, S.59 IECE Convention, 404 (1984) 67-74) (in Japanese)

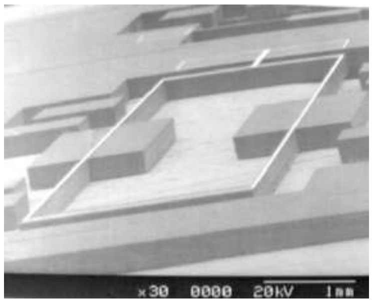
Integrated capacitive pressure sensor

(Y. Matsumoto and M. Esashi : An Integrated Capacitive Absolute Pressure Sensor, Electronics and Communications in Japan, Part 2, 76, 1 (1992) 93-106)

14 Deep reactive ion etching (Deep RIE) system

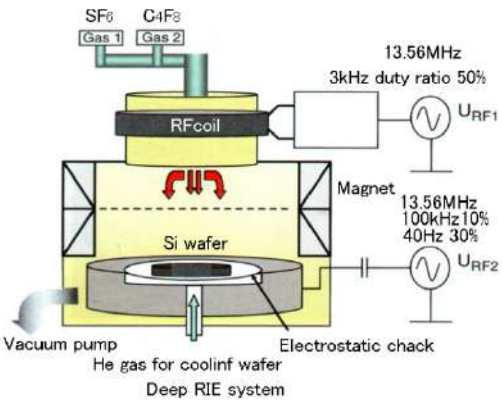


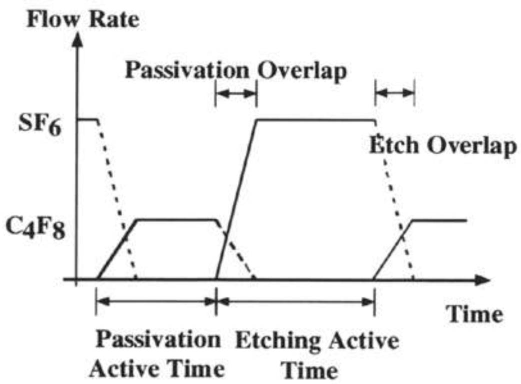




Low temperature Deep RIE system made in Tohoku Univ. and fabricated wafer for gyroscope (right)

(M.Takinami, K.Minami and M.Esashi,11th Sensor Symposium, (1992) 15)

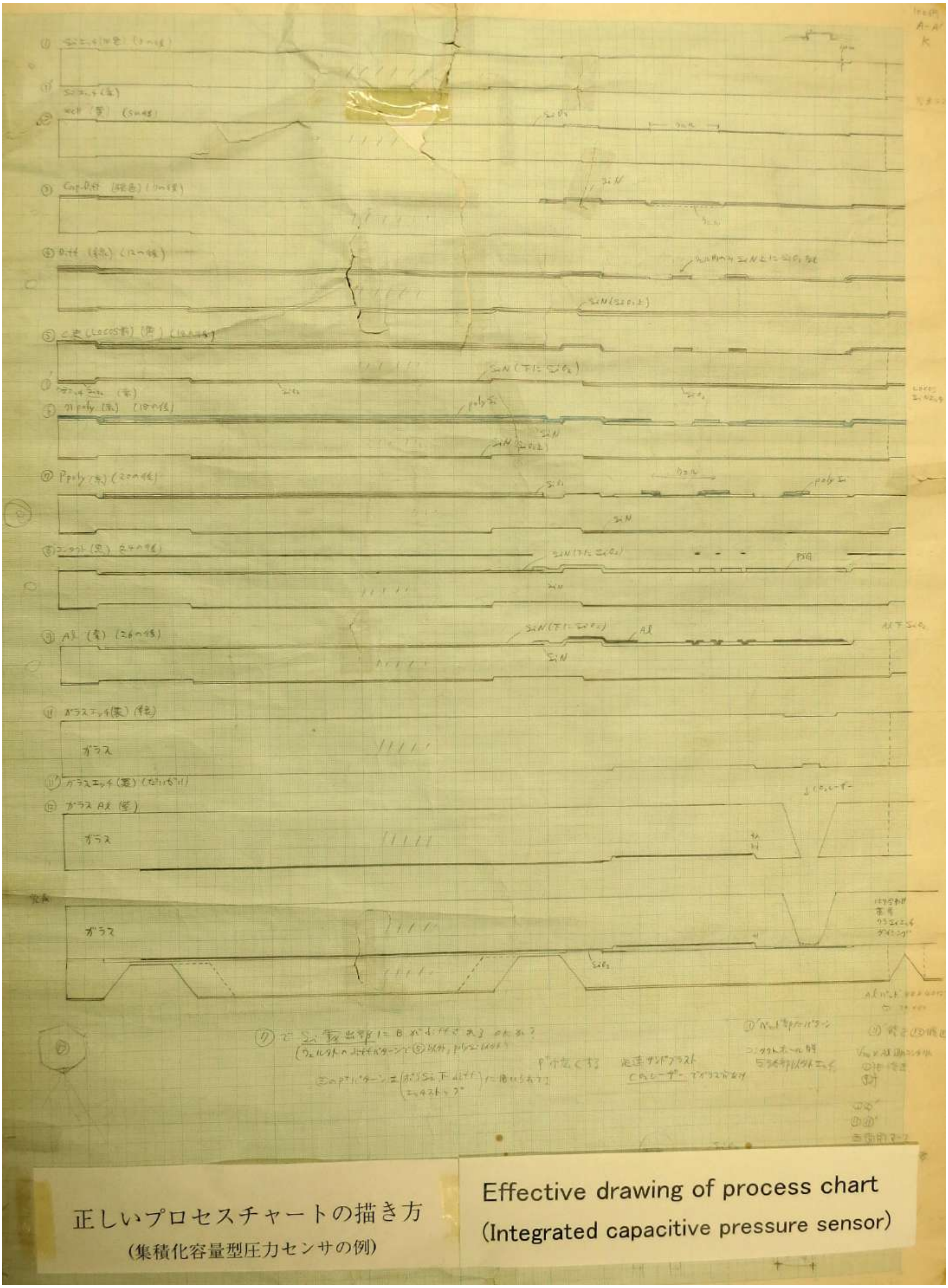




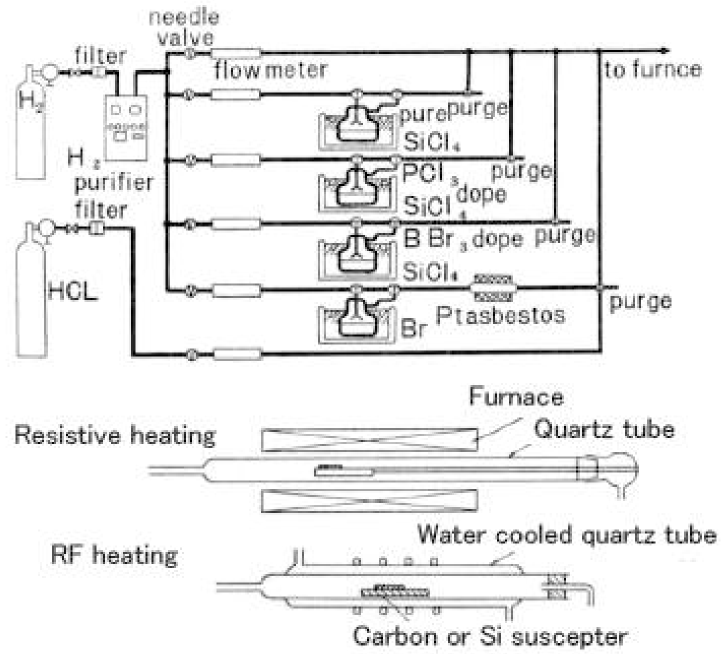
(F.Laermer (R.Bosch), Comprehensive Microsystems, Elsevier (2007) .217)

Deep RIE system displayed (Alcatel), Deep RIE system (Sumitomo Precision Product)

15 Effective drawing of process chart



16 Si epitaxial growth and optical observation of the defects (Semiconductor research institute)



Si gas phase epitaxial growth system (displayed except furnace)

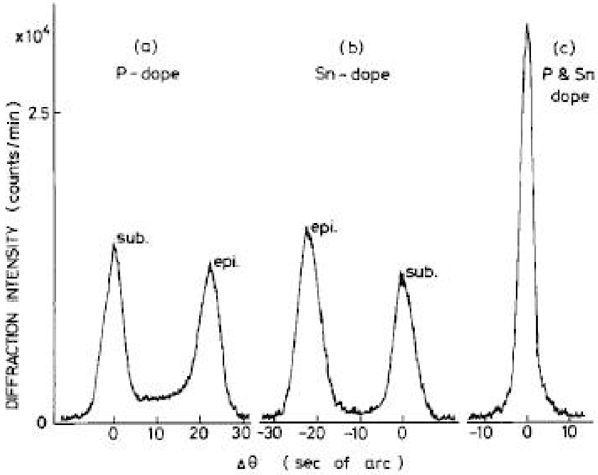
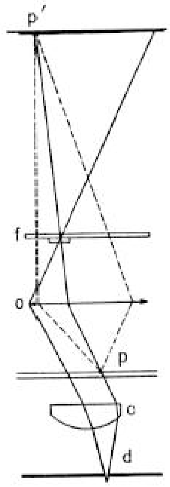


Fig. 10. X-ray rocking curves of $\{(511)^v, -(333)^s\}$ for compensated specimens by simultaneous doping of tin and phosphorus. (*a*) Phosphorus doping; $N_i = 4 \times 10^{19}$ atom/cm^3; $t_f = 10\mu$. (*b*) Tin doping; $N_i = 2 \times 10^{19}$ atom/cm^3; $t_f = 11.5\mu$. (*c*) Simultaneous doping of tin with phosphorus, concentrations of phosphorus and tin are 4×10^{19} atom/cm^3 and 2×10^{19} atom/cm^3, respectively; $t_f = 16\mu$.

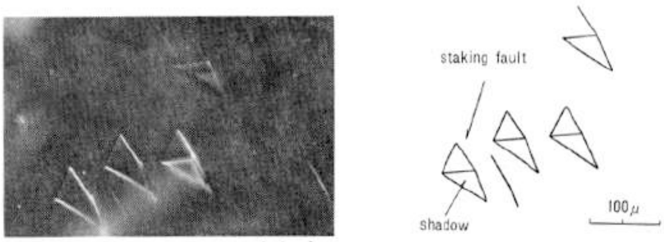
Perfect Crystal Growth of Silicon by Vapor Deposition

Jun-ichi Nishizawa
Research Institute of Electrical Communication, Tohoku University, Sendai, Japan
Takeshi Terasaki
Semiconductor Research Institute, Sendai, Japan
and Kunihiko Yagi and Nobuo Miyamoto
Research Institute of Electrical Communication, Tohoku University, Sendai, Japan



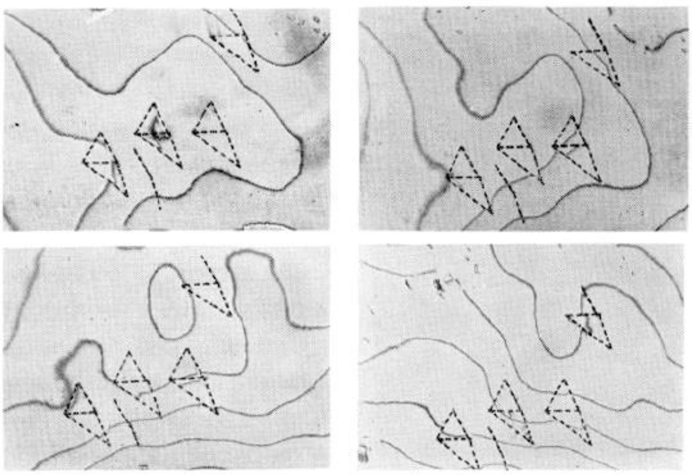
d : Aperture
f : Backside focus of objective lens (phase shift plate)
c : Condensor
p : Subject
o : Objective lens
p′ : Image of subject
Solid line : Direct beam of light
Broken line : difraction light from subject

Principle of phase difference method



(a) Phase contrast image

Phase difference microscope (Reichert MEF)



(b) Multiple reflection interference images (stacking faults are observed)

(K. Terasaki : 5.Optical observation of defects、

Semiconductor research 7 (1971) Kogyo Chosakai)

17 From "Semiconductor Research Institute (SRI)" to "Nishizawa Memorial Research Center"

Semiconductor Research Institute was established in 1961as a pioneer of university-industry cooperation and had been achieved tremendous innovation in microelectronics being supported by member companies.

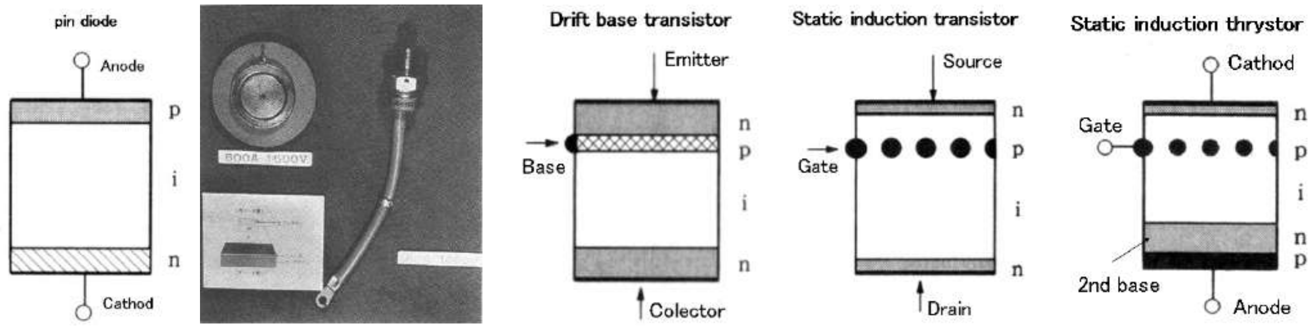
Since 2008 this has been Nishizawa Memorial Research Center in Tohoku university, in which Micro System Integration Center (μSIC) including Hans-on Access Fab. is located.

Semiconductor Research Institute located in Kawauchi, Sendai

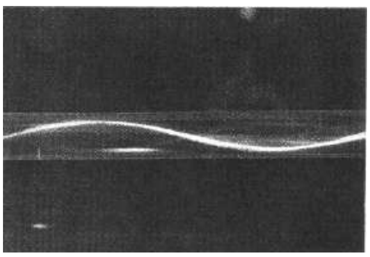
Nishizawa Memorial Research Center

Honorary Director Junichi Nishizawa

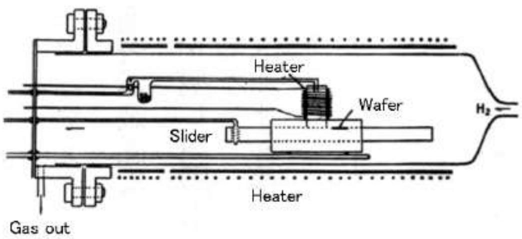
Staffs and students in the Semiconductor Research Institute



From pin diode to Static Induction Transistor and Static Induction Thyristor



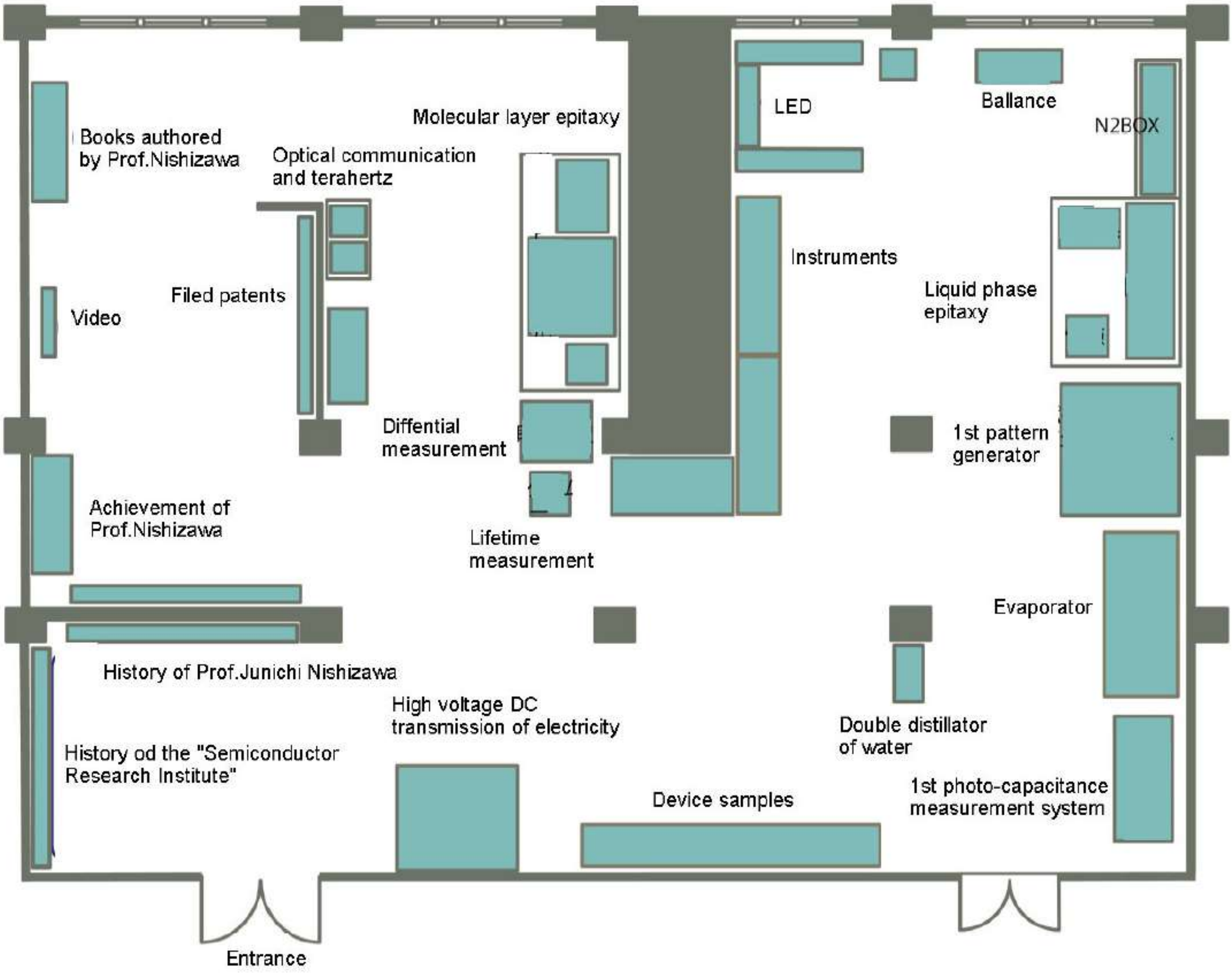
Graded index optical fiber



Liquid Phase Epitaxial growth of InP for high brightness LED

Photocapacitance measurement system

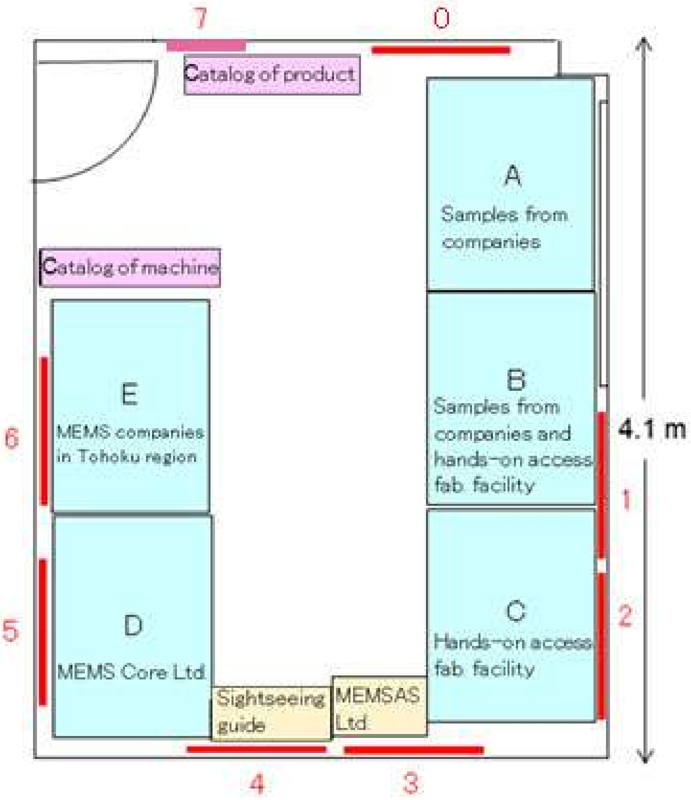
18 Nishizawa memorial room



The "Nishizawa Memorial Room" located in entrance examination center, Tohoku university in Kawauchi, Sendai. The building was used for the Semiconductor Research Institute in which Prof. Junichi Nishizawa developed semiconductor devices and supported semiconductor industry since 1961. (Open 9:00 ~ 16:00 Phone 022-795-4804)

http://www.tohoku.ac.jp/japanese/profile/establishment/01/establishment0107/

Business matching room



Poster

0 Business matching room
1 Hands-on-access fab. (Prof. K. Totsu)
2 Hands-on-access fab. Equipment
3 MEMSAS Inc
4 MEMS CORE Co. Ltd (1)
5 MEMS CORE Co. Ltd (2)
6 MEMS company map in Tohoku region
7 Member companies of MEMS park consortium

View from the entrance

Catalogs of products for business matching

Commercialization of developed equipment (ALD、bonding、CATCVD)

Samples for packaging (Tanaka Kikinzoku Kogyo、NGK, Nikko)

Hands-on access fab.

Nanoimprint, Sandblust, Water laser

Each process steps in the wafer fabrication

MEMSAS Ltd. (Minimal invasive medicine)

Sightseeing information of Sendai city

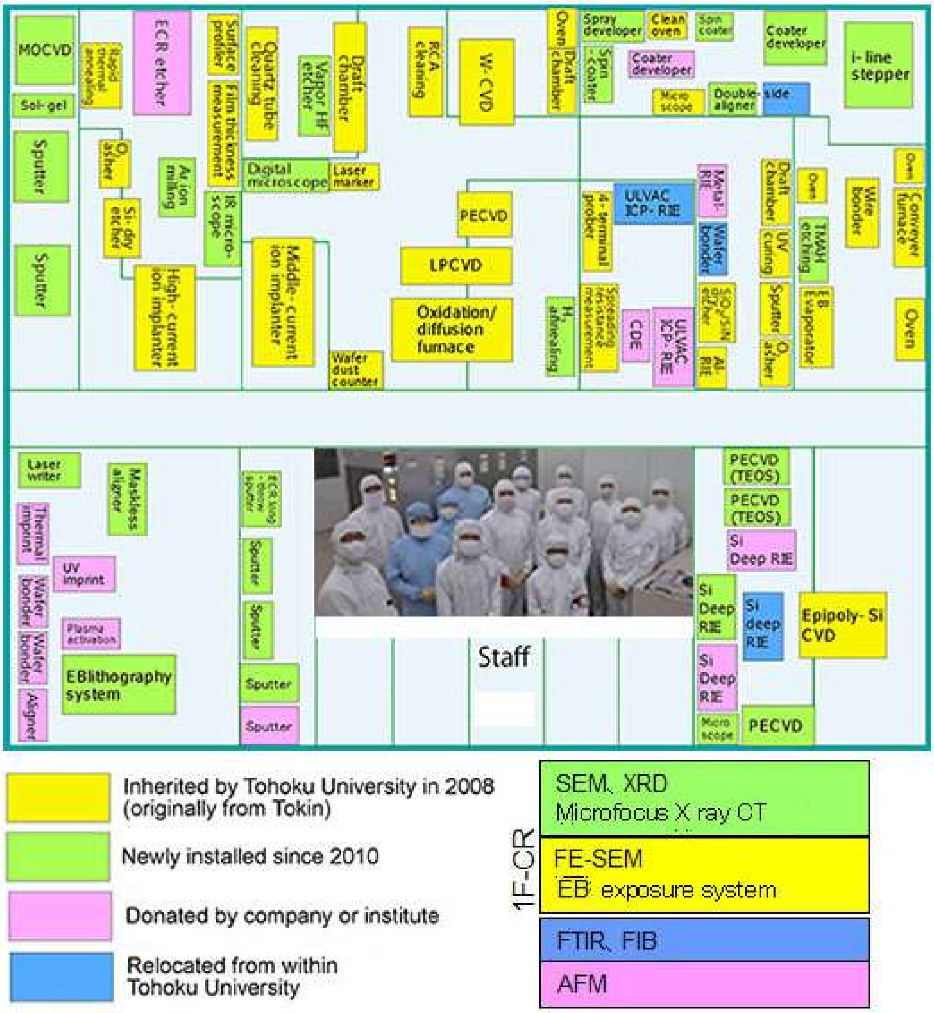
MEMS Core Co. Ltd. (Contract development of MEMS)

MEMS company map in Tohoku resion

1 Hands-on-access fab. (Prof. K. Totsu)

Shared facility for industry to prototype MEMS devices (4 / 6 inch). Companies which cannot prepare their own facility dispatch their employees to operate equipments by themselves. The facility is located in 1800m^2 clean room, which was used for the production of power transistor and newly installed MEMS fabrication equipments. http://www.mu-sic.tohoku.ac.jp/coin/index.html

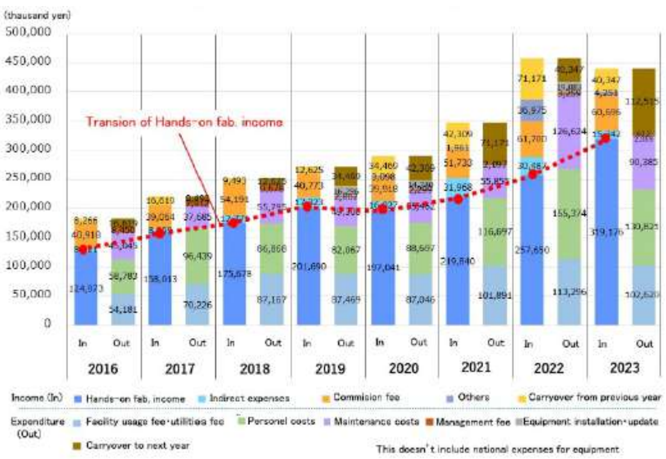
Contact person: Professor Kentaro Totsu Phone 022-229-4113, totsu@mems.mech.tohoku.ac.jp



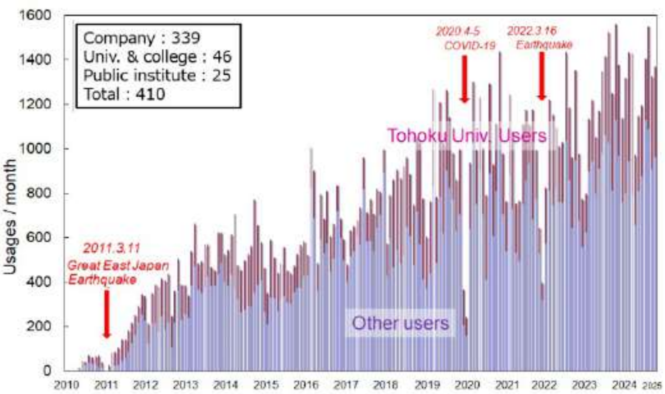
Patterning (I line stepper)

Oxidation, diffusion

Dry etching (DRIE)



Transition of income and expenditures



Transition of user number

2 Hands-on-access fab. Equipment

Draft chamber ~6" HF/HNO$_3$/H$_2$SO4/HCl etc.

Vacuum oven ~6" Yamato DP-31

Brush scrubber ~6" Zenkyo post polishing

Spin dryer 4", 6" SEMITOOL PSC101 x3

Spin dryer ~6" Toho Kasei ZAA-4 x2

Inert oven ~6" Yamato DN63H

UV curing ~4" Ushio UMA-802

Curing oven ~6" Yamato DN43H

Pattern generator ~6" NSK TZ-310 For emulsion / Cr mask making, up to 7inch

Laser writer ~9" Heidelberg instruments DWL2000CE

Spin coater ~6" Actes ASC-4000 x2 Mikasa 1H-DXII x2

Clean oven ~6" Yamato DE62 x2

EB lithography ~6" Elionix ELS-G125S Max130keV, 4nm, up to 6"

Stepper 4", 6" Canon FPA1550M4W g line, 0.65μm, 4inch

Double-side aligner ~6" Suss MA6/BA6 x2

Spray developer ~6" Actes ADE-3000S 8 inch, vacuum/mechanical chuck

Oxidation/diffusion furnace ~6" TEL XL-7

Middle-current ion implanter ~4" 日Nissin ion NH-20SR Max. 180keV, 0.6mA

Annealing ~6" AG Associates AG4100 1000℃

Metal diffusion furnace ~4" Koyo lindberg Model270

Asher ~6" Branson IPC4000 13.56MHz, 600W

Plasma cleaner ~6" Yamato PDC210

Surface planer 4", 8" Disco DAS8920

Water laser ~8" Shibuya LAMICS AQL-1900

Wafer polisher ~6" BN technology Bni52, Bni62

Electroplating ~6" Yamamoto Cu, Ni, Sn, Au

Wafer bonder ~6" Suss SB6e

Dicer ~6" Disco DAD522型

Wire bonder Chip West Bond etc. Al, Au

Reflow furnace ~4" Shinko FB-260H/TE

Laser marker ~4" GSI WM-II

Sand bluster ~6" Shinto

Wafer aligner 8" EVG Smart View

Wafer bonder 8" EVG 520

Epoxy injection chamber 8" EVG 520

UV imprinting ~4" Toshiba machine ST50

Thermal imprinting ~50mm Origin electric Reprine-T50A MAX 650°C, 30kN

TOF-SIMS CAMECA TOF-SIMS IV

FIB ~3" SII SMI9200

AFM ~8" Digital Instruments Dimension3100

LP-CVD ~6" Kokusai SiN, Poly-Si, NSG

熱CVD ~6" Kokusai Epi-Poly Poly-Si, 1100°C

PE-CVD ~6" JPEL VDS-5600 SiN, SiO_2

PE-CVD ~8" Sumitomo MPX-CVD SiN, SiO_2

PE-CVD ~8" Sumitomo MPX-CVD TEOS SiO_2

Sputtering ~6" Anelva SPF-730 8inch target x3 Al, AlSi

Sputtering ~8" Shibaura CFS-4ESII 3inch target x 3 Stage cooling x1, heating x1

Sputtering ~8" Shibaura I-Miller 3inch target x 4, Load lock, Automatic transfer x 10 wafers

W-CVD 4" Applied materials Precision 5000

EB evaporation ~6" Anelva EVC-1501

Automatic sol-gel deposition ~4" Technofine PZ-604

MOCVD ~8" Wacom Doctor-T PZT, up to 8inch

Sputtering (high temp.) 8" Youtec 21-0604

ALD ~6" Technofine ALK-600

ICP－RIE ~6" ULVAC NE-550

Chemical dry etcher (CDE) ~4" Shibaura CDE-7

Si Deep-RIE x4 ~8" Sumitomo MUC-21 SF_6, C_4F_8

Dry etcher ~6" Anelva DEA-506 For SiN, SiO2 etching

Dry etcher 4" Anelva L-507DL For Si etching

Al RIE 4" Shibaura HIRRIE-100 Cl_2, BCl_3

RIE ~6" Ulvac RIH-1515Z Cl2, BCl3, SF6, CF4, CHF3, Ar, O2, N2

ECR etcher 3" Anelva ECR6001 3 inch GaAs, AlGaN, etc

Vapor HF ~8" Sumitomo Primaxx uEtch

KOH･TMAH ~6"

Ar ion milling 6" x 4, 4" x 6 NS, Hakuto 20IBE-C

Wafer dust counter ~6" Topcon WM-3

Film thickness measurement ~6" Nanometric NanoSpec 3000

Surface profiler ~6" Dektak8 Tenchor AlphaStep 500

Depth measurement ~6" Union Hisomet

4-terminal probe ~6"

Spreading resistance measurement Solid State Measurements SSM150

IR microscope ~6" Olympus, Hamamatsu

Laser/white light confocal microscope ~6" Lasertec OPTELICS HYBRID L3-SD

Digital microscope ~8" Keyence and Kunoh

SEM ~12" Hitachi S3700N EDX

FE-SEM Chip Hitachi S5000

Ellipsometry ~6" Photonic lattice SE-101 ULVAC

X-ray micro CT ~6" Comscan techno ScanXmate D160TS110

Ultrasonic microscope ~12" Insight IS350

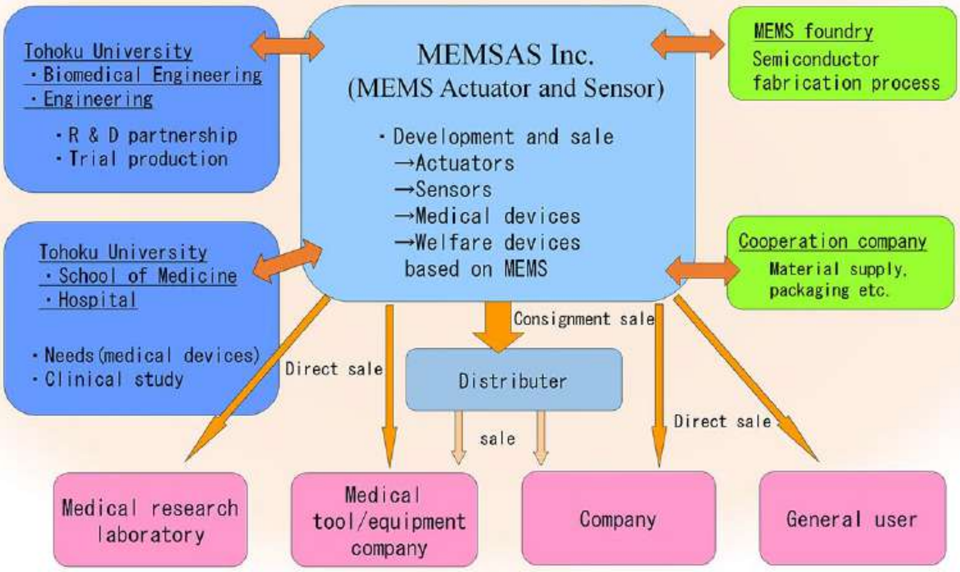
Line-focus-beam acoustic microscope

3 MEMSAS Inc.

MEMSAS Inc.

→Products (sensors and actuators based on MEMS)

→Technical support



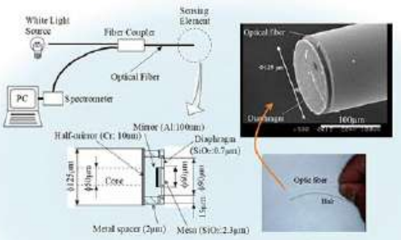
MEMSAS,INC. is the venture company on the purpose of application development, manufacturing consulting, and sales for sensor and actuator which are fabricated based on MEMS(Micro Electro Mechanical Systems) technology. We have developed the tip of catheters equipped with small movement mechanism for minimally invasive instruments that performs inspection and medical treatment safely by controlling the movement and micro pressure sensor(which is very thin like hair) from outside. By applying small movement mechanism, we also have developed 2-Dimensional tactile display (Pin Display) for visually impaired persons. Concerning basic research and development, we actively utilize the research environment of Tohoku University by conducting an animal experiment and evaluating the trial production for medical instruments in Graduate school of Biomedical engineering, Tohoku University.

About MEMSAS

Name :	MEMSAS Inc. http://www.memsas.co.jp
Established :	September 29th, 2004
Location :	#1003, 1-6-22, 1 ban-cho Aoba-ku Sendai-shi Miyagi, Japan, 980-0811
Board Members :	Representative director: Kazuya Kato Director: Masayoshi Esashi, Yoichi Haga, Tadao Matsunaga, Kentaro Totsu Corporate auditor: Nobui Mishina

Products

Sensors based on MEMS

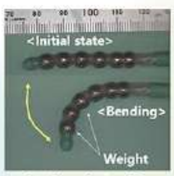


Ultra-thin fiber optic pressure sensor

For the purpose of local pressure measurement in a very narrow space, ultra-miniature fiber-optic pressure sensor of 125μm in diameter has been developed.

Thin diaphragm which is bonded at a tip of the optical fiber is deformed by applying a pressure, and the deformation changing is measured interferometrically. In particular, fiber-optic pressure sensors have the advantages of not only high potential of miniaturization but also applicability to use in such electromagnetically harsh environments as in an operating room in a hospital.

Actuators using Shape Memory Alloy (SMA)

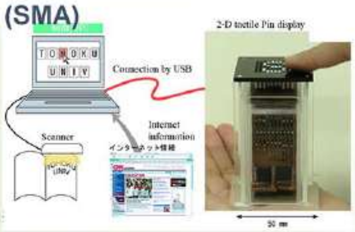


Active bending mechanism for ileus tubes

Ileus tube is used for the ileus treatment. Bending mechanism utilizing SMA actuator, which is assembled at a tip of the tube, can make pylorus passing easy.

Active bending electronic endoscope

For inspection and treatment inside of the small intestine Disposable endoscope has been developed by combining small electrical imager and bending mechanism using SMA actuator.



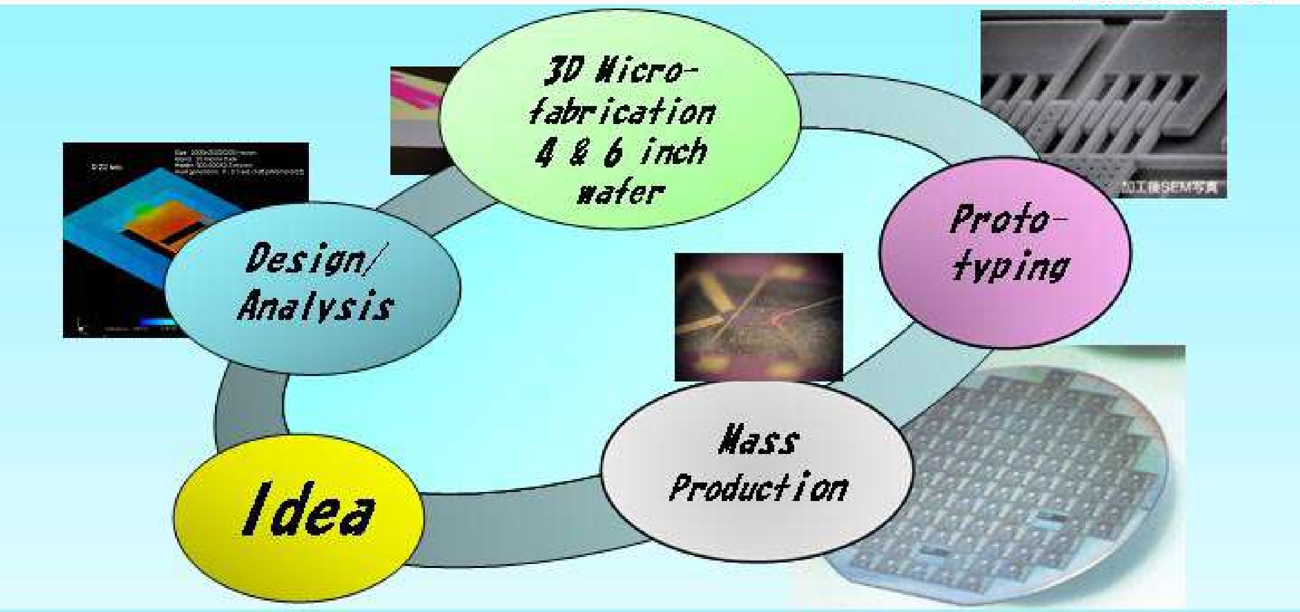
2-D tactile pin display

Two-dimensional tactile pin display has been developed for visually impaired people. Character and graphic information is dynamically displayed by an array of pins in up and down positions. The contraction of SMA micro-coil actuators moves the pins up and down, and latch mechanism using a permanent magnet accurately positions the pins in an up or down state without any feedback control.

Turn the Idea into Product

Always with you

MEMS CORE



Company Profile

Name : MEMS-CORE Co.Ltd.
Capital : 60,000,000 JPY   Foundation : Dec. 2001
CEO : Koji Homma
Address : 3-11-1 Akedouri Izumi-ku Sendai Miyagi, 981-3206, JAPAN
Web site : www.mems-core.com   Tel.: +81-22-777-8717

Company Policy

We support your development of new devices by our Q-TAT process.
We totally support from feasibility study to mass-production.
Our intimate relation with Universities and Laboratories helps us.

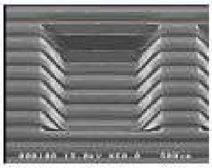
Core Technology


Deep RIE

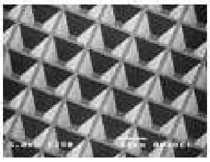

stealth dicing

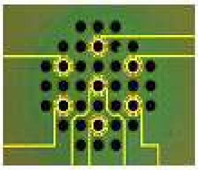

TSV

sacrificial layer etching

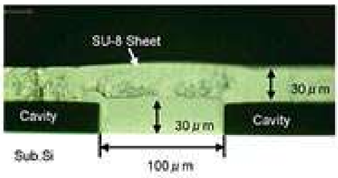

Dry film resist


Bonding


Wet etching


Metalization


Cantilever

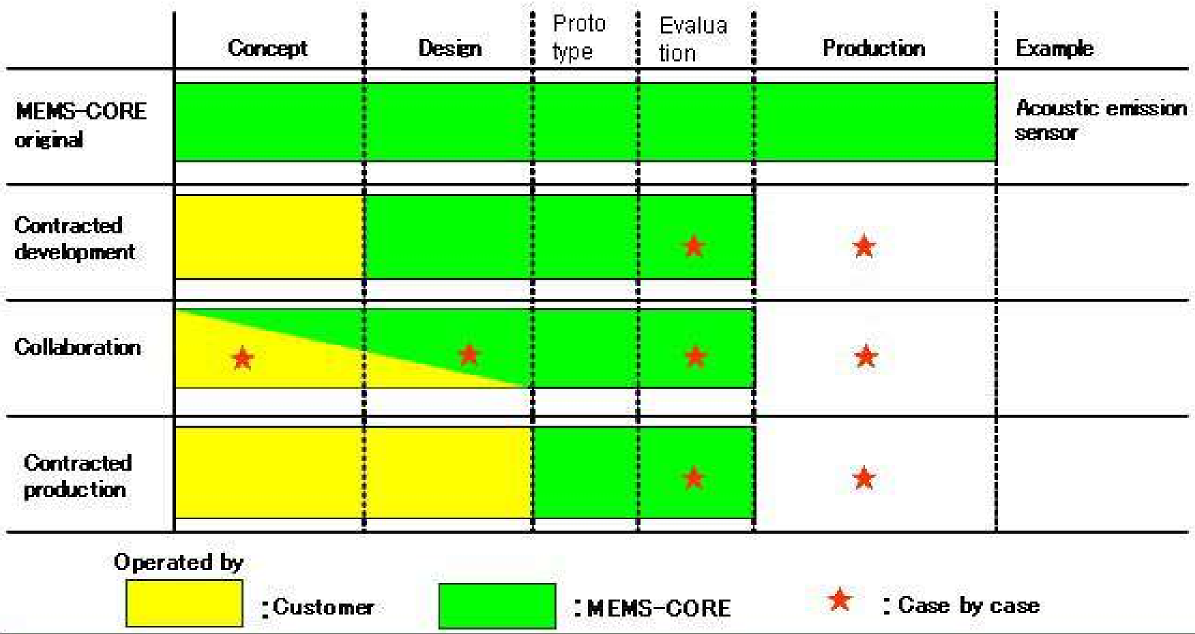


Laminating

Process Menu at MEMS-CORE

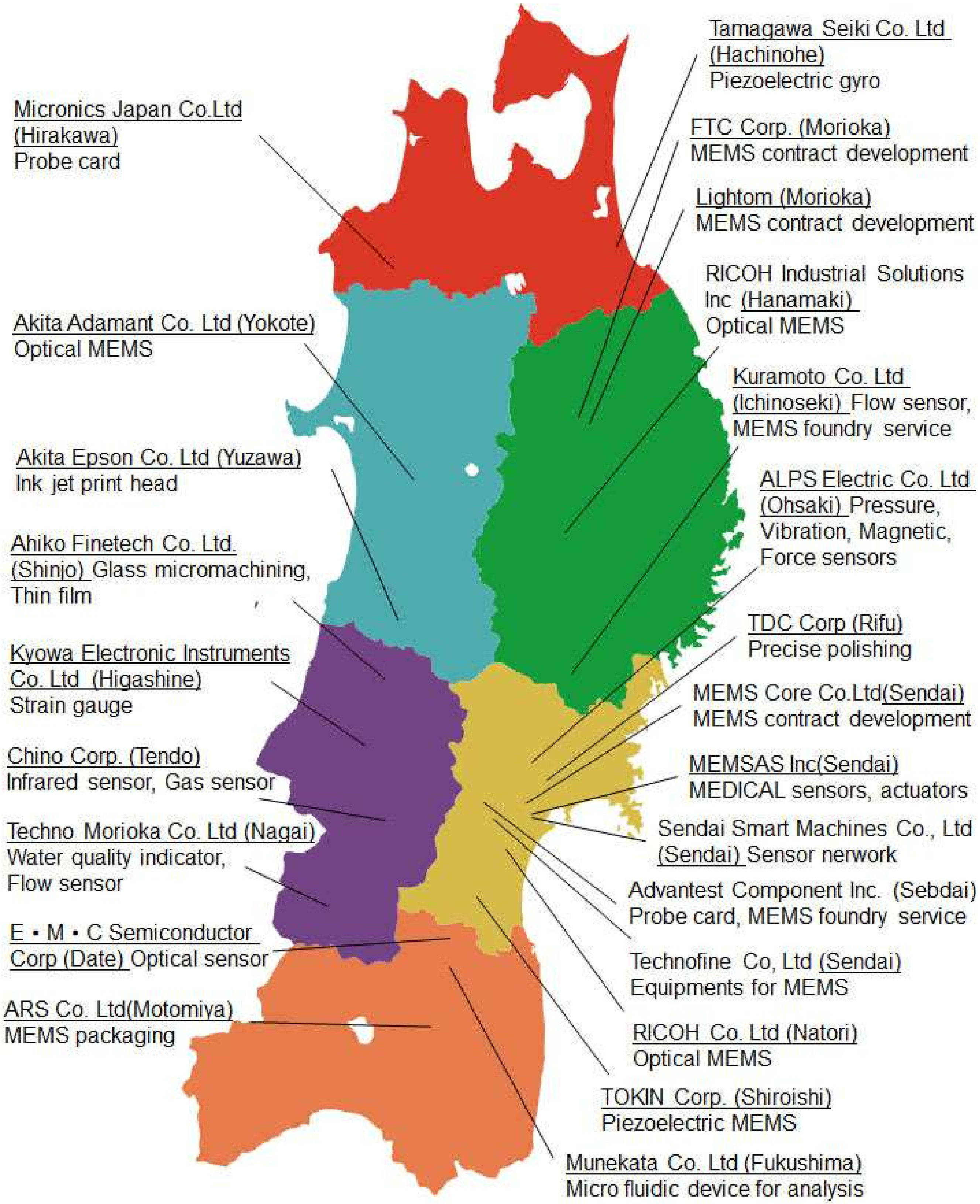
item	Process	Material/Equipment
Film deposition	Dielectrics (SiO_2, NSG, PSG)	Oxidation furnace, P-TEOS Atmospheric Pressure-CVD
	Metal (Au, Pt, Cr, Ti, Cu, W *et al*)	Sputtering, EB evaporation, Electro-plating
Photo-lithography	Resist Coat /Bake Exposure	Spin coater, Bake oven, Hot-plate Sus MA6, Double side aligner,
	Photomask making	CAD (CoventorWare™), Pattern generator
Etching	Dry etching (SiO_2, Si, Metals)	Deep RIE, RIE, Sacrificial Etching, XeF_2 Si etching Ion milling, O_2 plasma asher
	Wet etching	TMAH, HF-NH_4F, Metal wet etching
Bonding	Wafer bonding	Anodic bonding, Thermal bonding
Dicing Packaging	Wafer dicing	Blade dicer, Leaser dicer(Stealth)
	Die bonding, Wire bonding	Die bonder, Wire bonder
Polishing	Wafer polishing	Chemical mechanical polisher, Cleaner
Measurement Inspection		Measurement microscope, Leaser microscope, SEM, Stress monitor Sheet resistance, Surface profiler, Optical thickness measurement
Miscellaneous	Cleaning, Surface treatment	UV/O_3, HMDS

Foundry service/Collaboration scheme



MEMS-CORE Co. Ltd., e-mail; info@mems-core.com
URL: http://www.mems-core.com/ TEL: +81-22-777-8717 FAX+81-22-777-8718

MEMS company map in Tohoku region

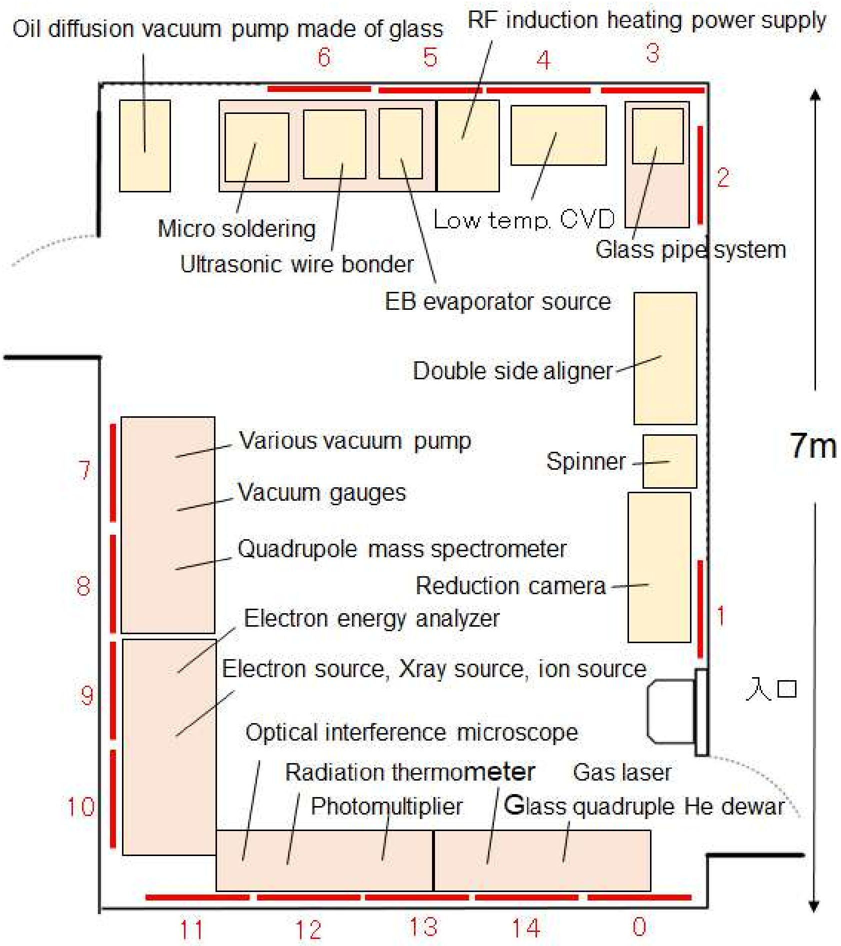


MEMS
PARK CONSORTIUM

Advantest Laboratories Ltd.
Advantest Component Corp.
Advantest Technologies Co., Ltd.
Ahiko Finetec Co., Ltd.
ALPS ALPINE CO., LTD.
EV Group Japan KK
Ushio Inc.
SPP Technologies Co., Ltd.
Orbray Co., Ltd.
Koken Ltd.
Citizen Watch Co., Ltd,
SHIBAURA MECHATRONICS CORP.
SCHOTT Japan Corp.
Sumitomo Precision Products CO., LTD.
Tsuken Electric Ind. Co., Ltd.
TDC Corp.
TECNISCO, LTD.
Tokyo Electron Ltd.
TOKYO PHKA KOGYO CO., LTD.
TOKYO KEIKI INC.
Tohoku Economic Federation
NAITO SENSEI KOGYO CO., LTD.

Nagase & Co., Ltd.
Nabtesco Corp.
NAMICS CORP.
NIDEC COMPONENTS CORP.
Nippon Kayaku Co., Ltd.
Nippon Signal Company Ltd.
Nihon Dempa Kogyo Co., Ltd.
Niterra Co., Ltd.
PARKER CORP.
Panasonic Industry Co., Ltd.
Hamamatsu Photonics K.K.
Hitachi High-Tech Corp.
FUJI ELECTRIC CO., LTD.
Fujikura Kasei Co., Ltd.
HOKURIKU ELECTRIC
INDUSTRY CO., LTD.
Mitsubishi Electric Corp.
Murata Manufacturing Co., Ltd.

0　Mini tech museum



poster

0　Mini tech museum
1　Fabrication of photomask
2　Photoresist coating, patterning and etching
3　Wafer process (oxidation, diffusion, ion implantation)
4　Chemical vapor deposition (CVD) and RF induction heating
5　Physical vapor deposition (PVD (evaporation、sputtering))
6　Assembly (dicing, wire bonding, soldering) and test
7　Vacuum pump (rotary pump, turbo molecular pump, diffusion pump, ion pump, cryopump)
8　Vacuum gauges and quadrupole mass spectrometer
9　Xray photoelectron spectroscopy (XPS)
10 Auger electron spectroscopy (AES)
11 Optical microscope for measurement
12 Various measurement method other than optics
13 Gas laser, photomultiplier and radiation thermometer
14 A liq.^{4}He / liq.N_2 cryostat Dewer by double−

Layout of exhibition and poster

Tech museum located in San Jose (west coast USA) before was used to show the fabrication sequence for integrated circuit. Our mini tech museum shows how the integrated circuit is fabricated as well. In addition to the fabrication sequence components for equipment are exhibited.

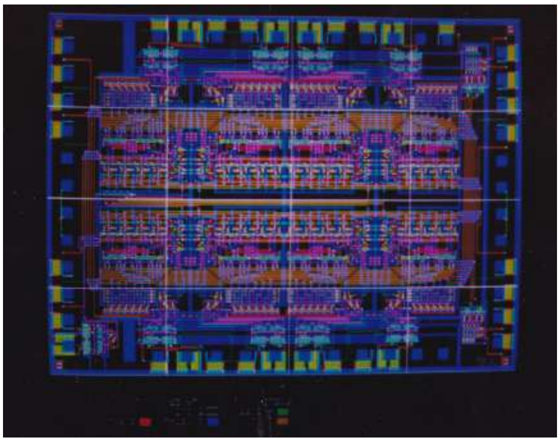
Tech museum (at present)

Mini tech museum 1

Mini tech museum 2

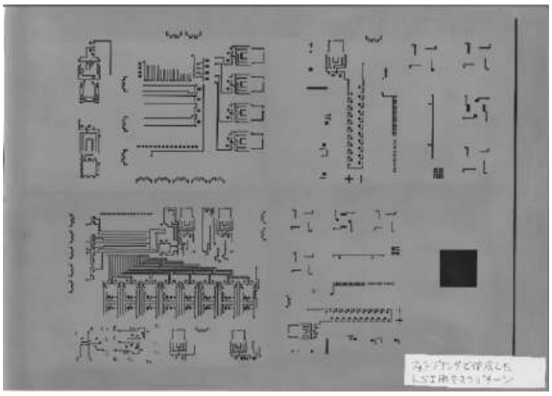
1 Fabrication of photomask

Patterning system for layout design
(Minicomputer PDP11)

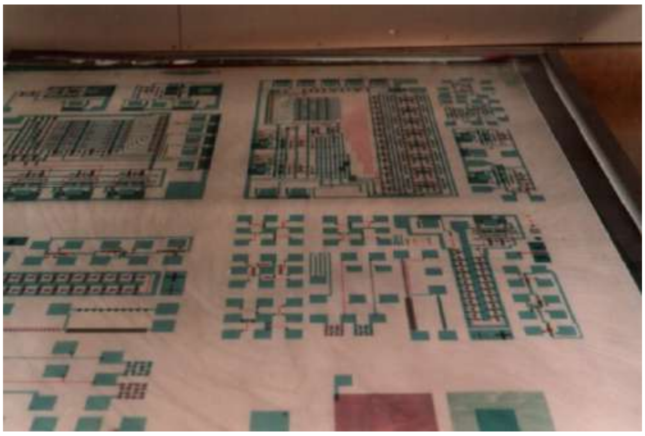


Layout (Graphic editor was made by Fortran)

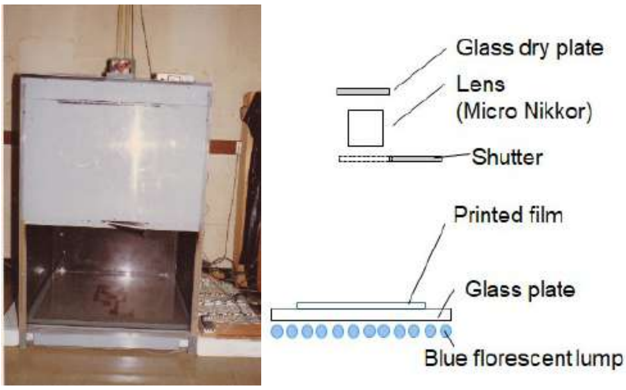
Photo printer for output



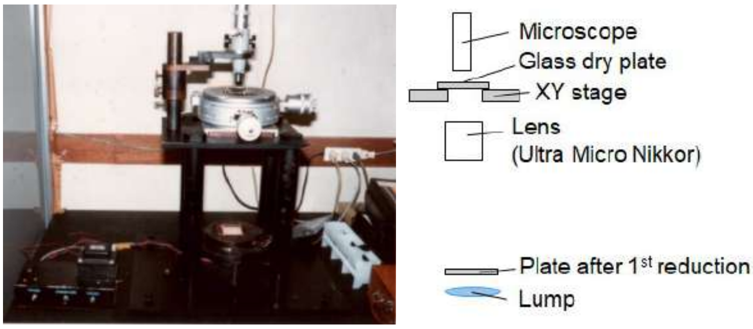
Printed transparent film



Patterns of each layers are checked



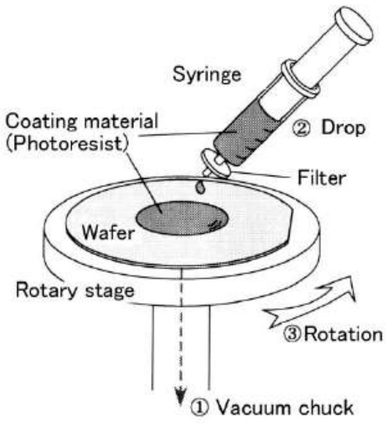
1/20 reduction camera (exhibited)



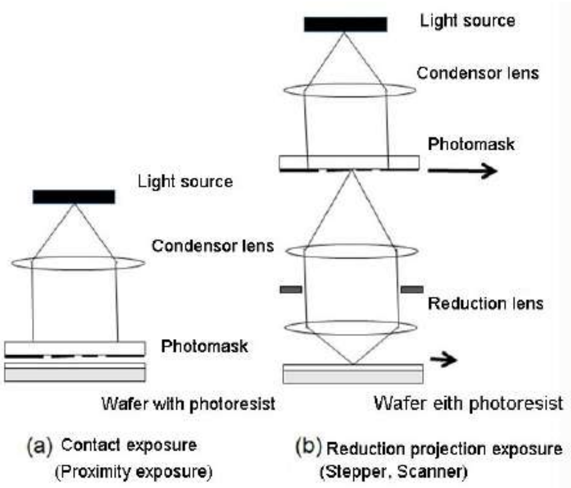
1/10 reduction camera for repeated pattern

Mask making room

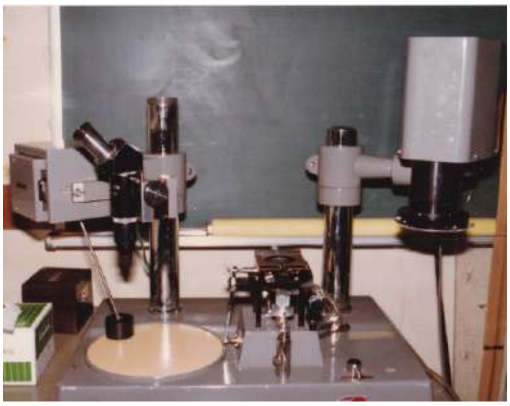
2 Photoresist coating, patterning and etching

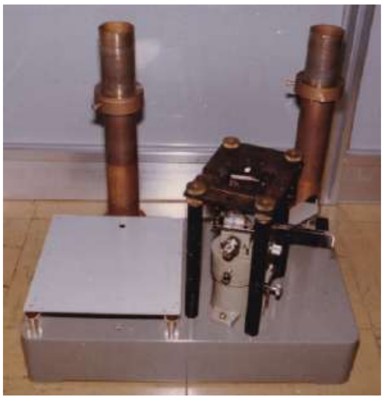


Spin coater (exhibited)



Principles of exposure systems

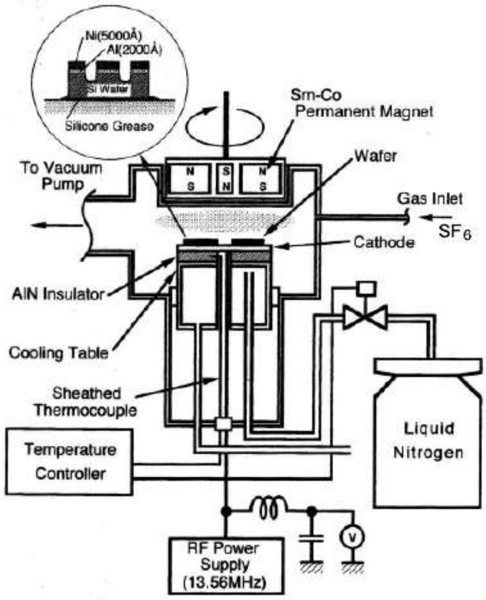


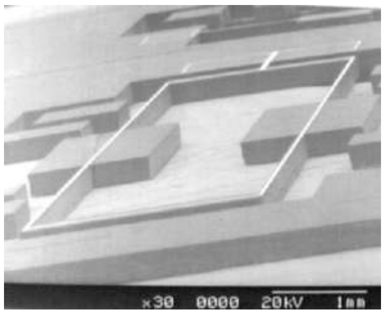


Contact exposure system and modified double side system

Double side exposure system (exhibited)

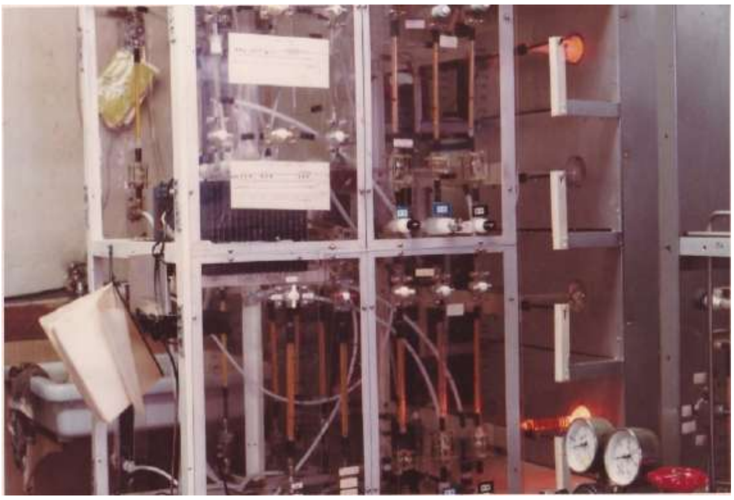
Wet etching (Si_3N_4)



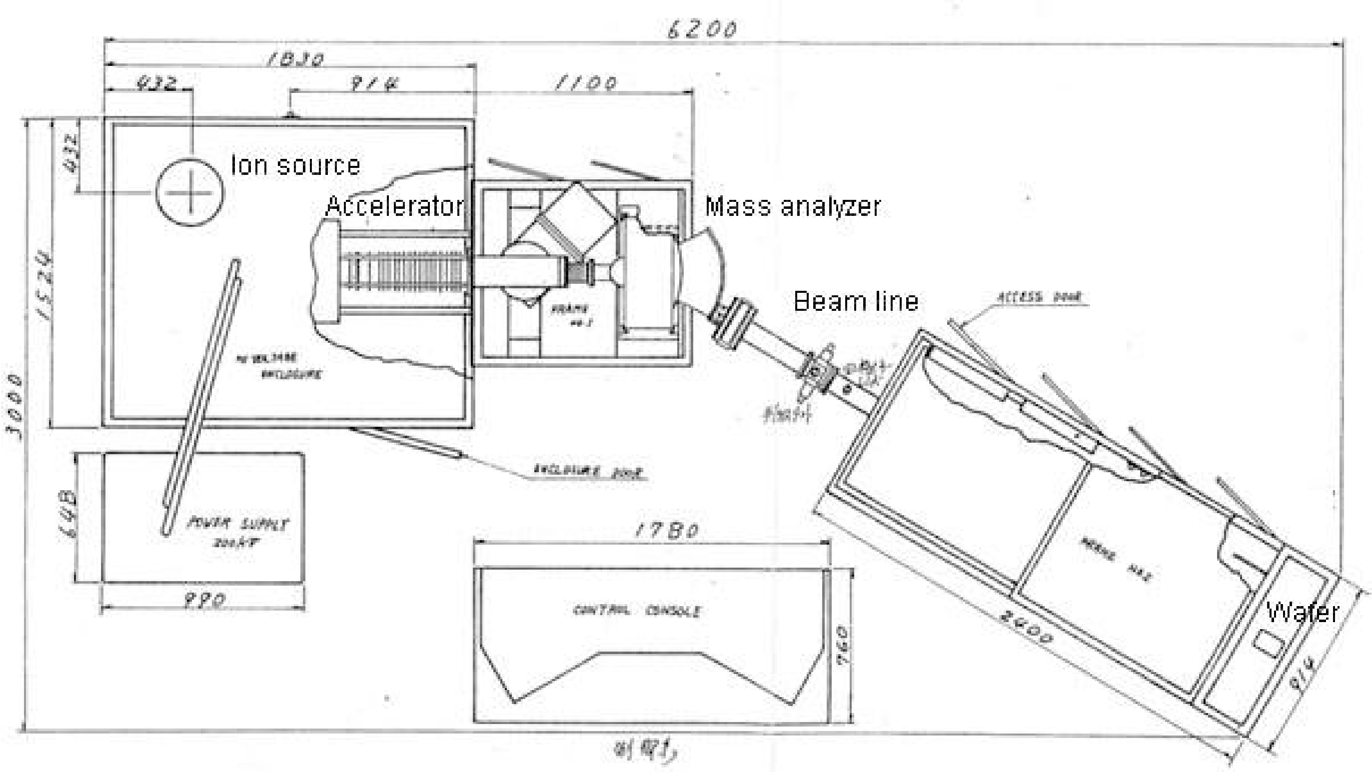


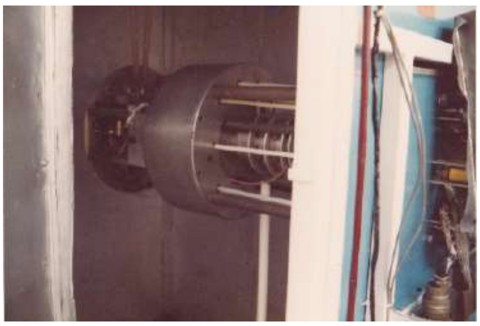
Dry etching (Si reactive ion etching (DRIE))

3 Wafer process (oxidation, diffusion, ion implantation)



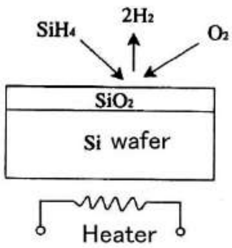
Oxidation diffusion furnace (Liquid source BCl_3, $POCl_3$)   Glass pipe line (exhibited)



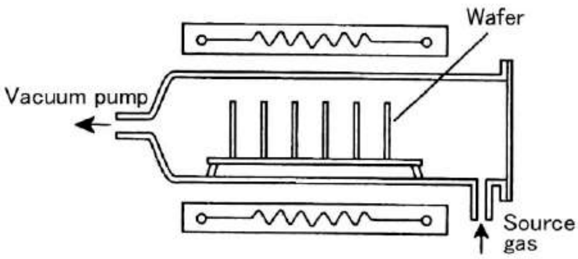


Ion implanter (Accelerator Corp. 200kV)

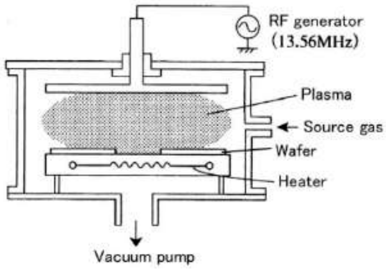
4 Chemical vapor deposition (CVD) and RF induction heating



Principle of chemical vapor deposition



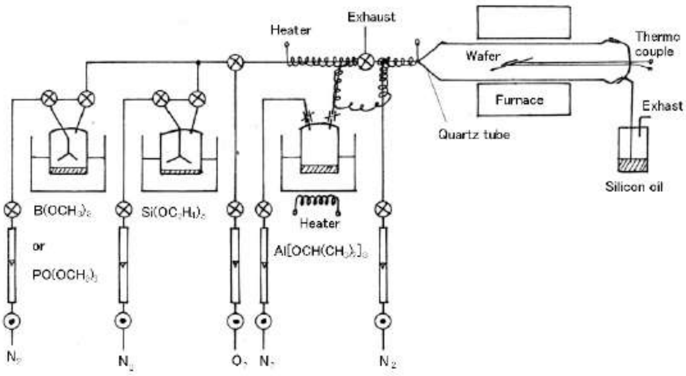
Low pressure (LP) CVD

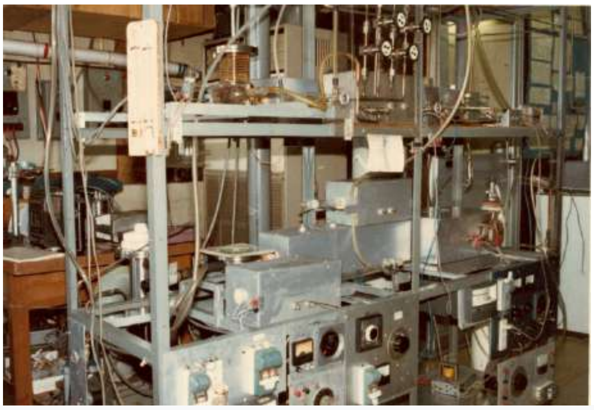


Plasma CVD

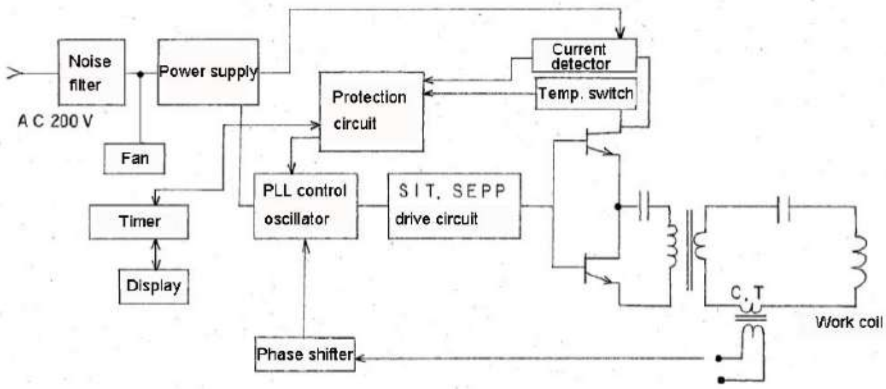
RF heating poly Si, SiO_2 CVD (top)
Infrared heating Al_2O_3, Ta_2O_5 CVD (bottom)

Low temperature SiO_2CVD (exhibited)



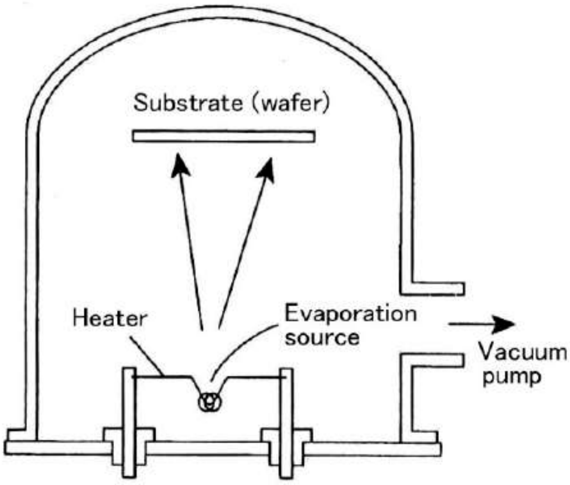


Organic liquid source (Tetraethoxysilane TEOS etc.) P_2O_5–SiO_2, B_2O_3–SiO_2, Al_2O_3–SiO_2 CVD

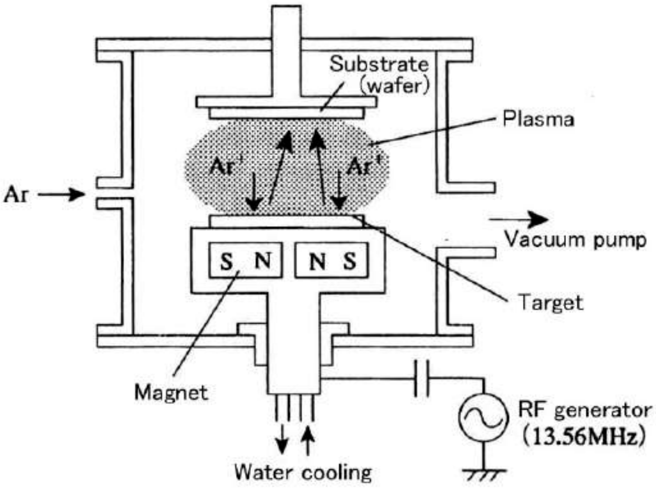


Oscillator for RF inductive heating using SIT (static induction transistor) (Tokin)(exhibited)

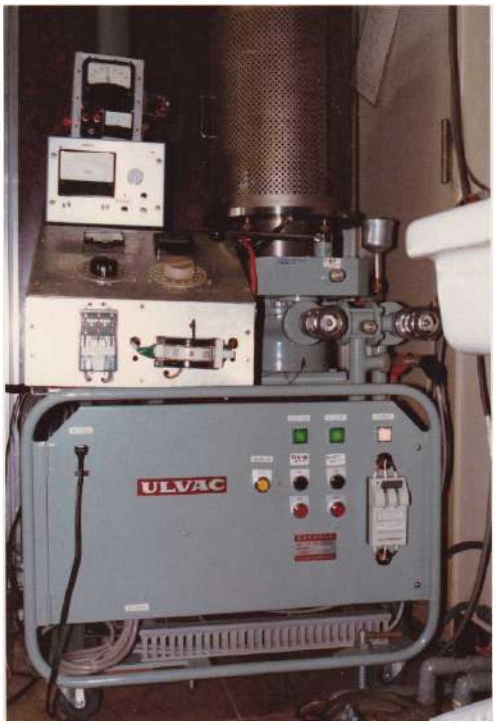
5 Physical vapor deposition (PVD (evaporation、sputtering))



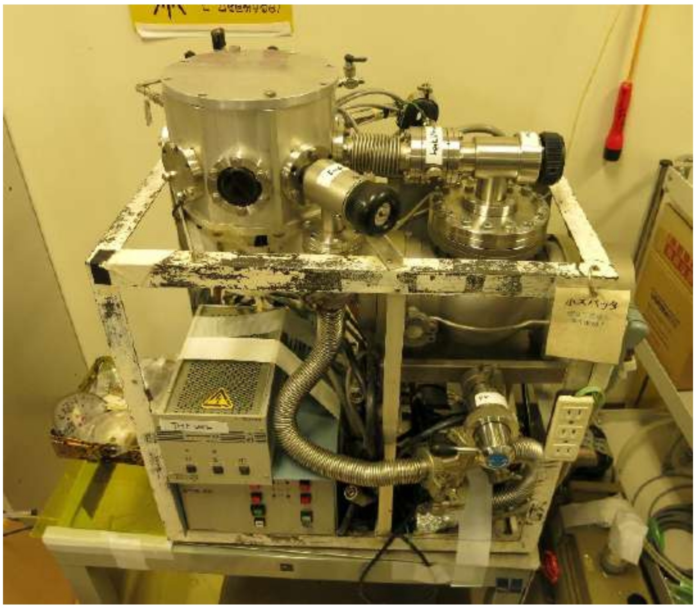
Principle of evaporation



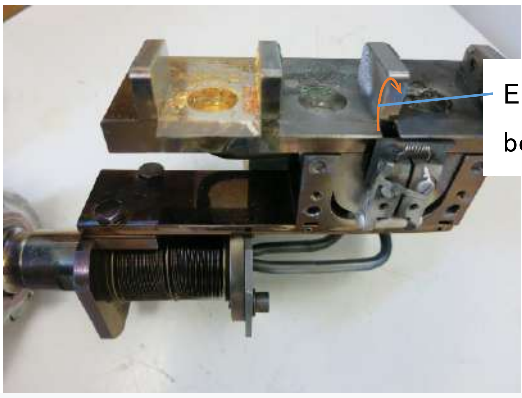
Principle of sputter deposition



Evaporator



Sputtering machine



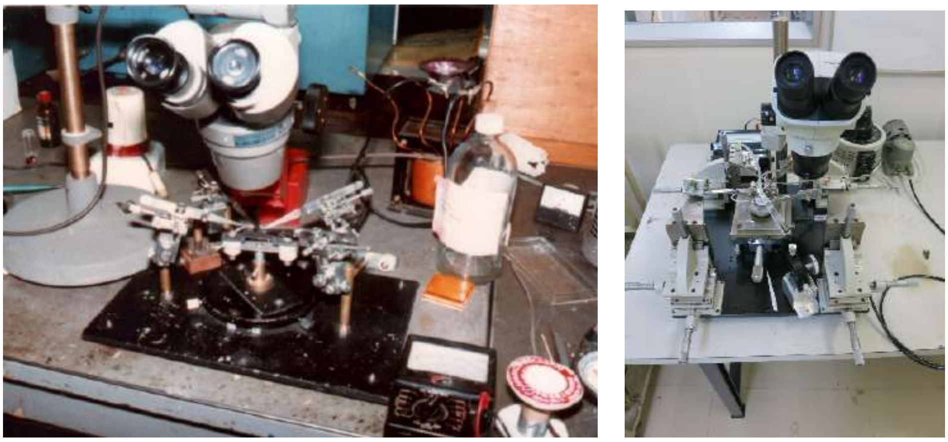
Electron beam evaporor (exhibited)

Parylene (Polyparaxylylene) deposition

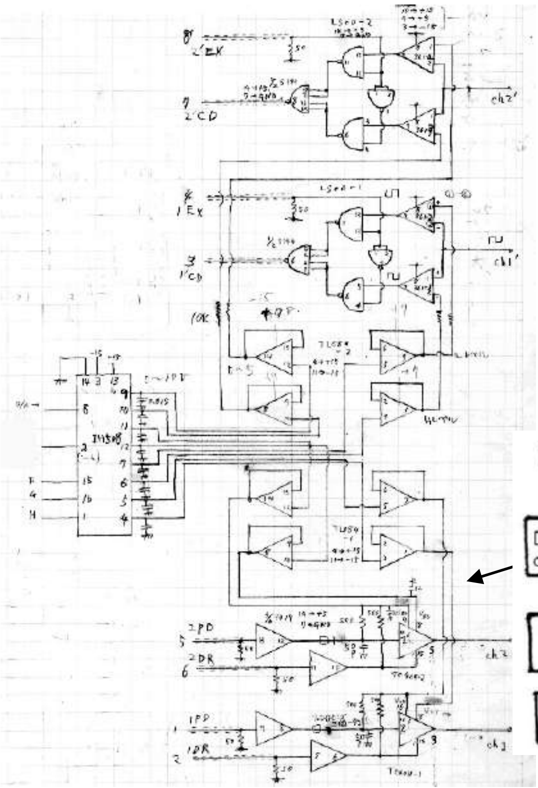
6 Assembly (dicing, wire bonding, soldering) and test

Dicing machine (chip separation from wafer)

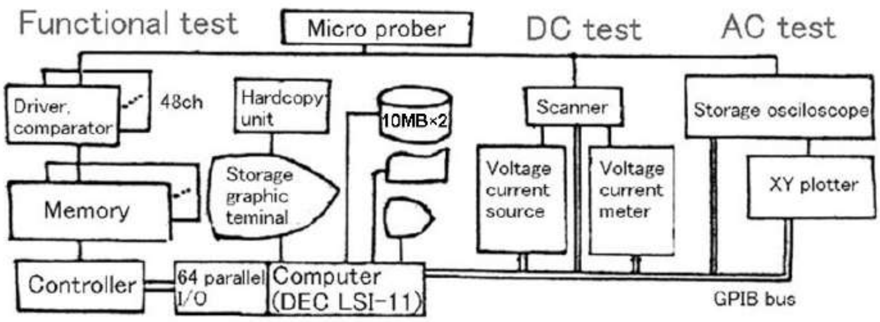
Ultrasonic wire bonder (exhibited)



Micro soldering machine using cream solder (right exhibited)



Microprober for testing

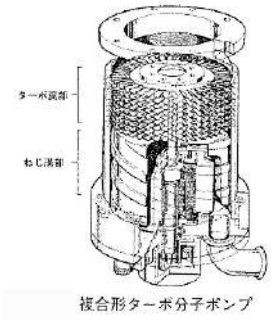


Pin electronics for IC tester (2ch)

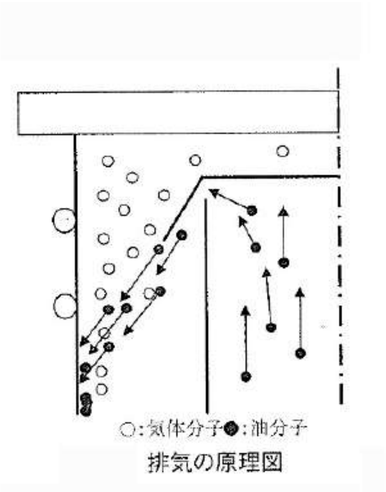
IC test system

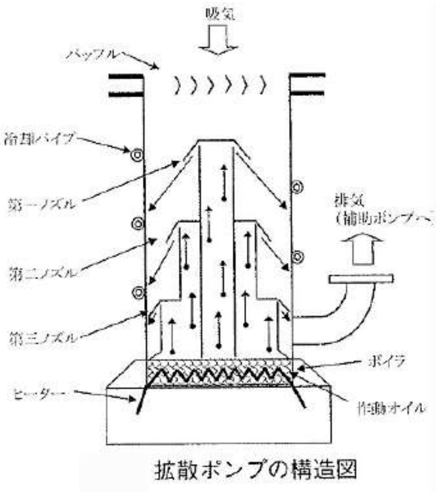
7 Vacuum pump (rotary pump, turbo molecular pump, diffusion pump, ion pump, cryopump)

Rotary roughing pump

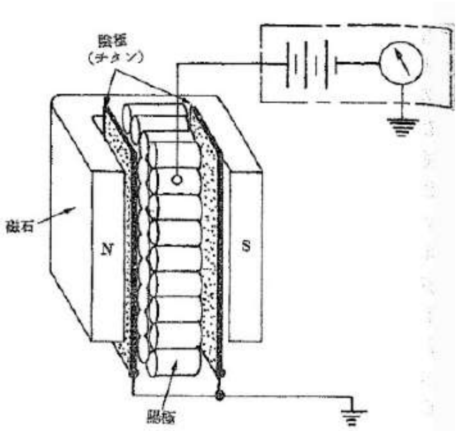


Turbo molecular pump

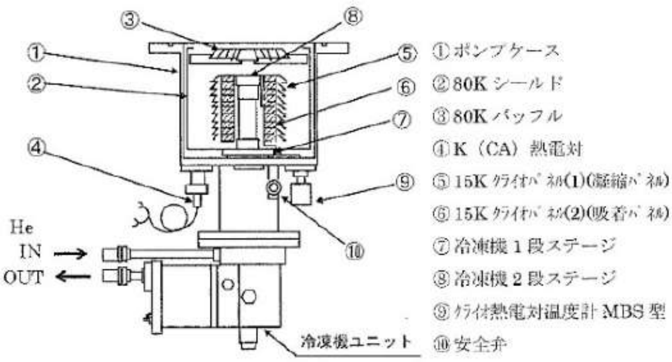




Oil diffusion pump (principle) and photograph of which K. Kumano made

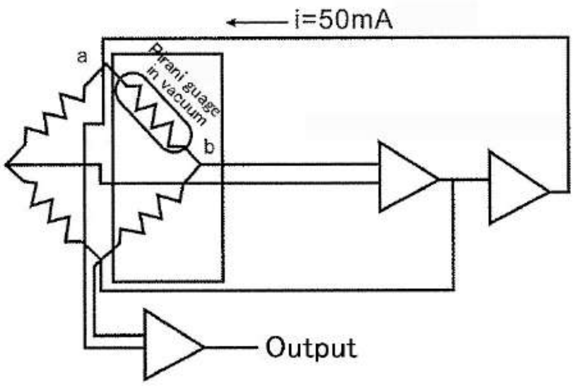


Ion pump (principle and photograph)

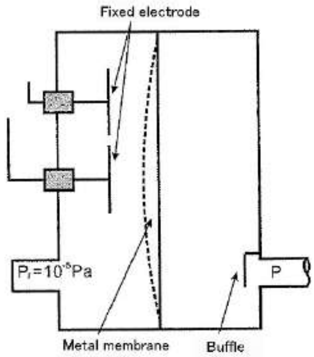


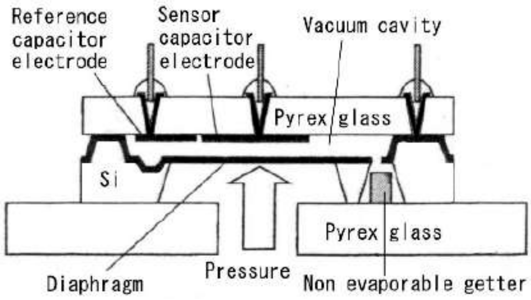
Cryopump (principle and photograph)

8 Vacuum gauges and quadrupole mass spectrometer



Pirani gauge (exhibited)



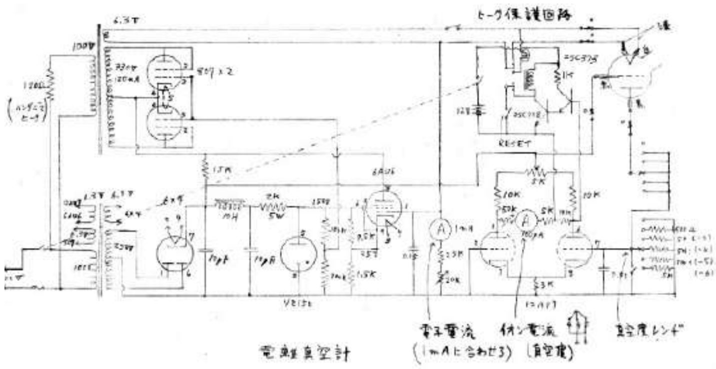


Diaphragm vacuum gauge (left exhibited)

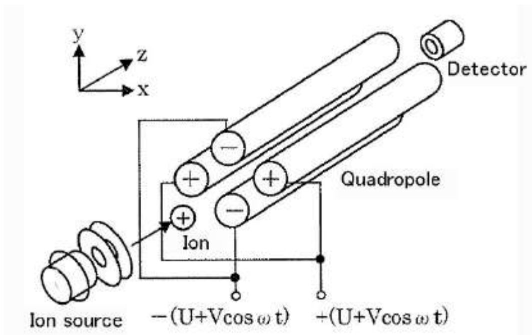
Thermal electron emission from heater

Molecules are ionized by electron

Ion current is detected by anode

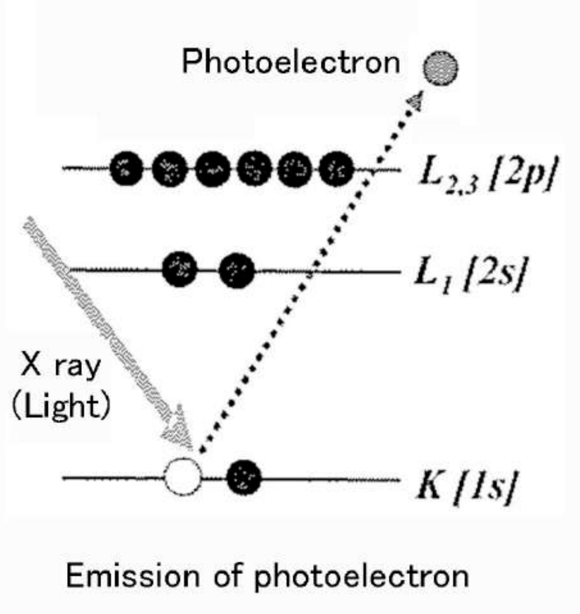


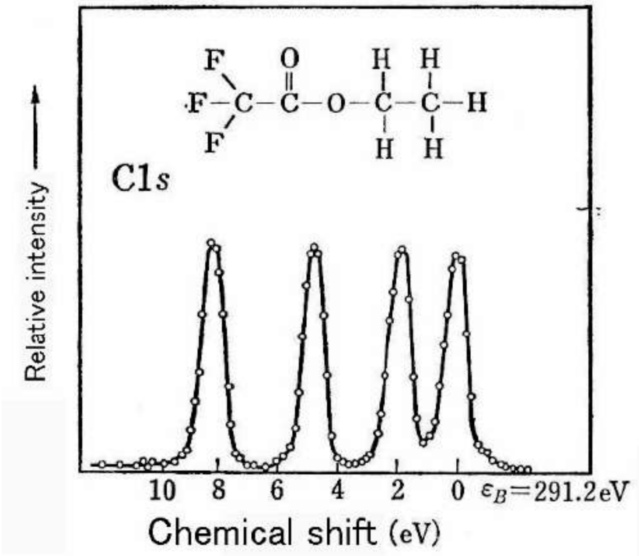
Ionization vacuum gauge (exhibited) and circuit



Quadrupole mass spectrometer (exhibited)

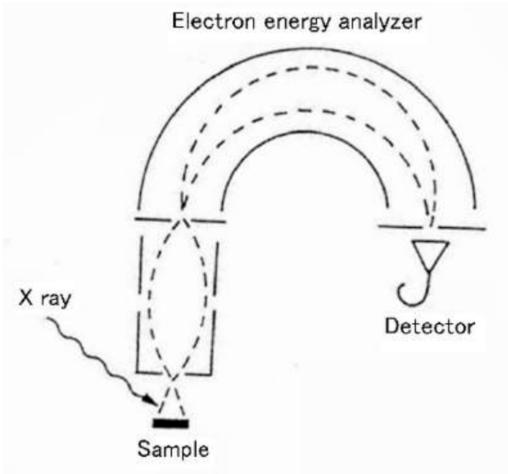
9 X ray photoelectron spectroscopy (XPS)



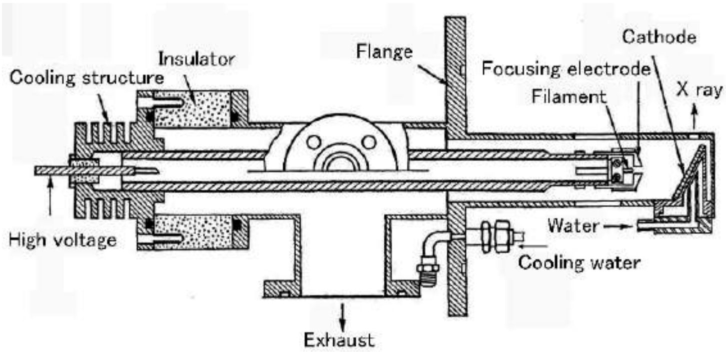


Principle

Example of X ray photoelectron spectroscopy (C1s spectrum of trichloroacetic acid) (K.Siegbahn : J. Electr. Spectry, 5, 3 (1974))

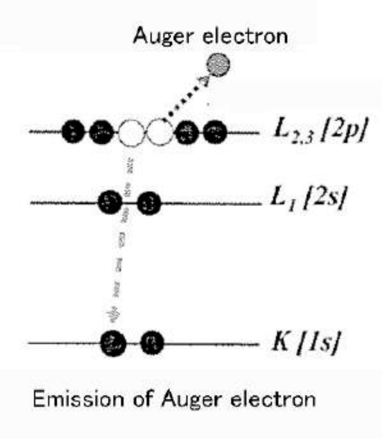


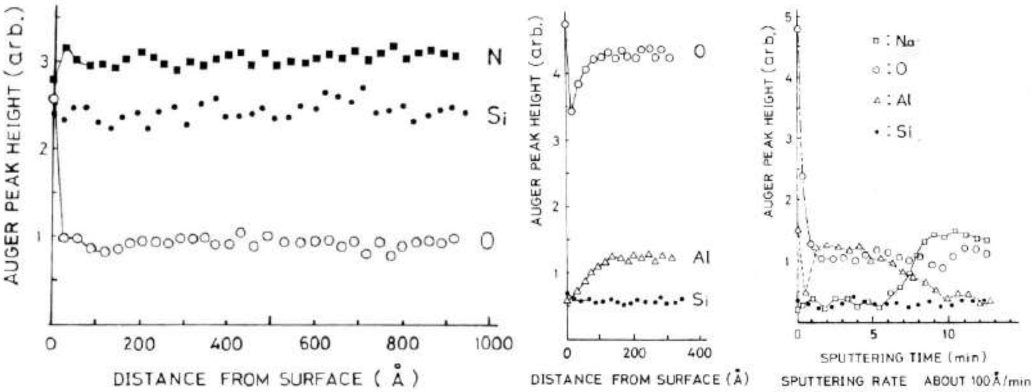
X ray photoelectron spectroscopy using hemispherical electron energy analyzer (exhibited)



Xray source (exhibited) and its structure

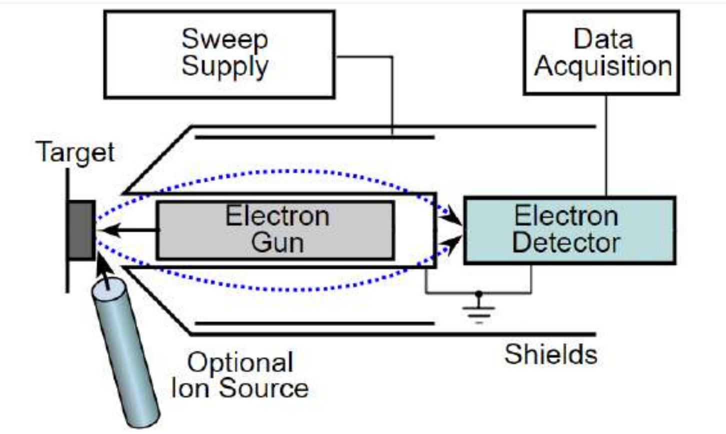
10 Auger electron spectroscopy (AES)



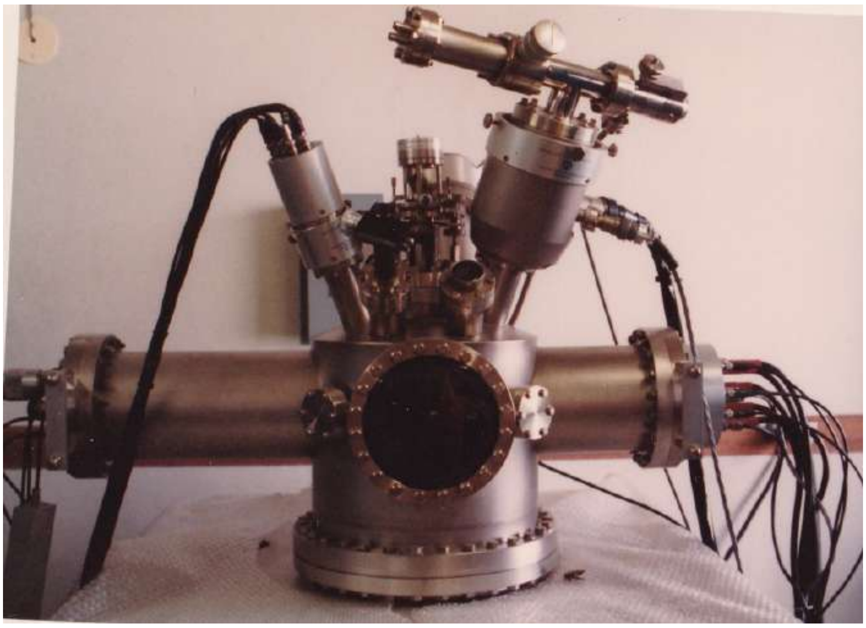


pH Si_3N_4 pNa Al_2O_3 pK Na doped Al_2O_3

Principle Examples of AES (Semiconductor ion sensor (ISFET) surface)

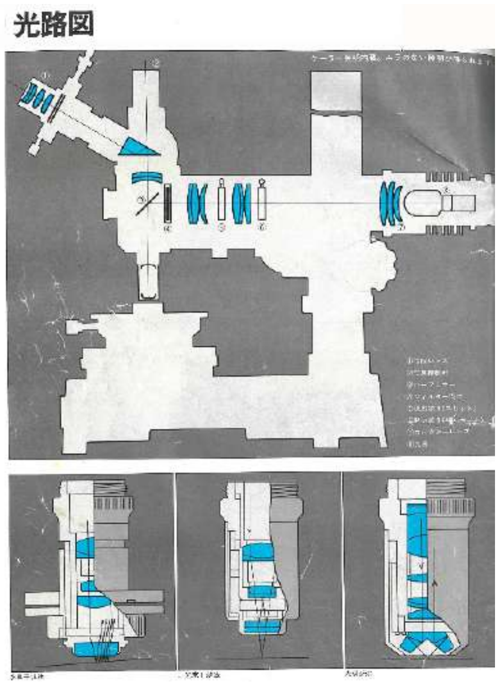


Cylindrical Mirror **Analyzer** (CMA) for AES (exhibited)

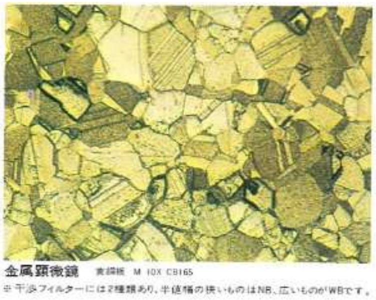


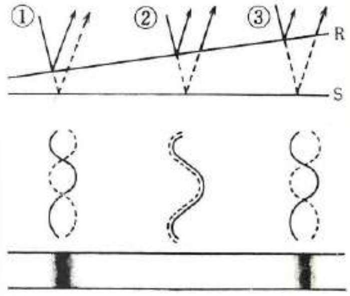
XPS (left) and AES (right) using the cylindrical Mirror **Analyzer** (CMA)

11 Optical microscope for measurement



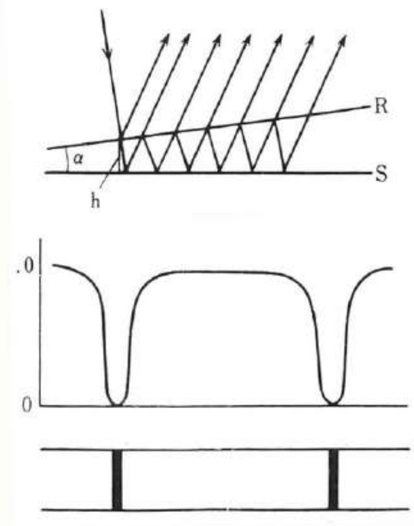
Multiple interference | Two beam interference | Light section method



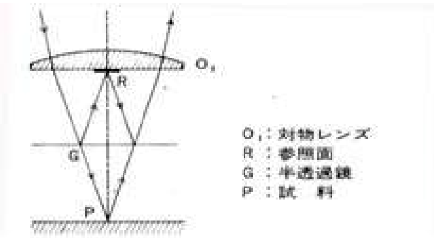


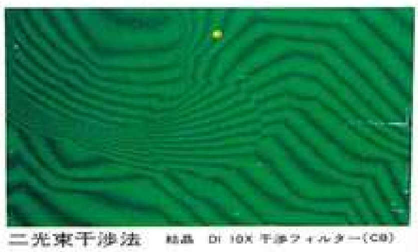
Principle of optical interference

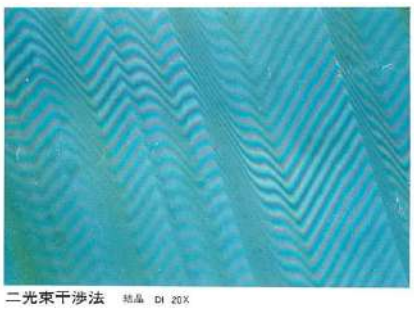
Surface finish microscope (Nikkon), Optical microscope, Optical interference



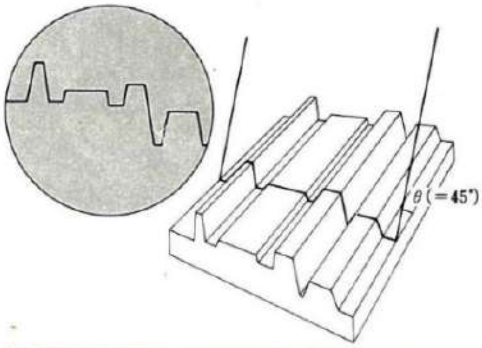
Multiple interference

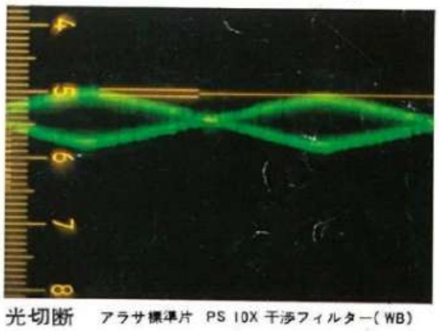






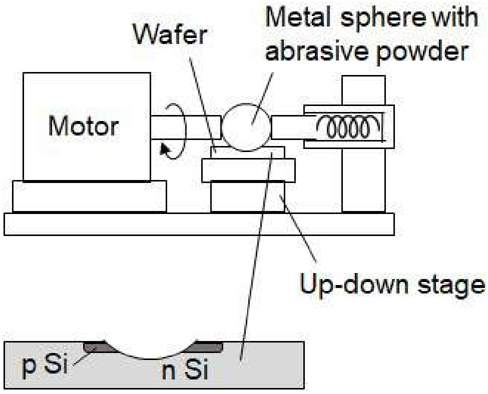
Two beam interference



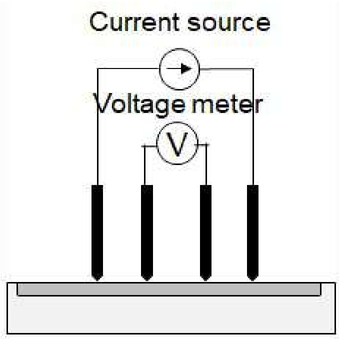


Light section method

12 Various measurement method other than optics

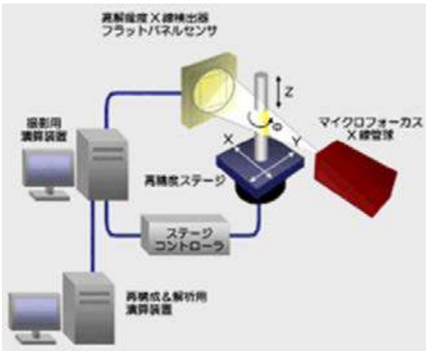


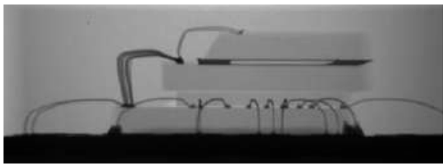
p Si is colored to measure depth after polishing in round shape by spherical drill



Measurement of sheet resistance by 4 probes

Atomic force microscope (AFM) (Park Systems NX-20)





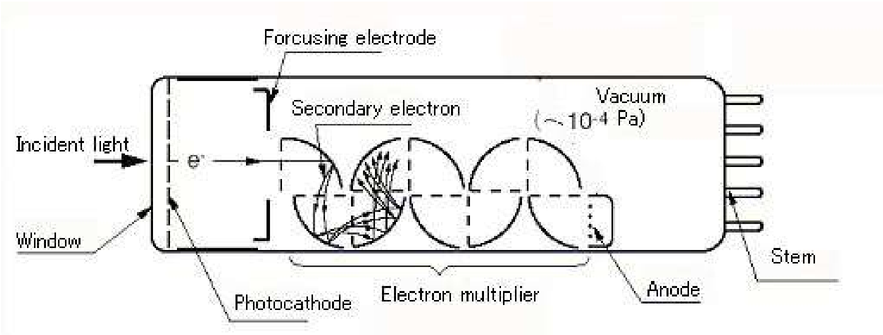
Micro X ray CT (used in clean room 1F) and cross-sectional image of 3D accelerometer

Scanning electron microscope (SEM)

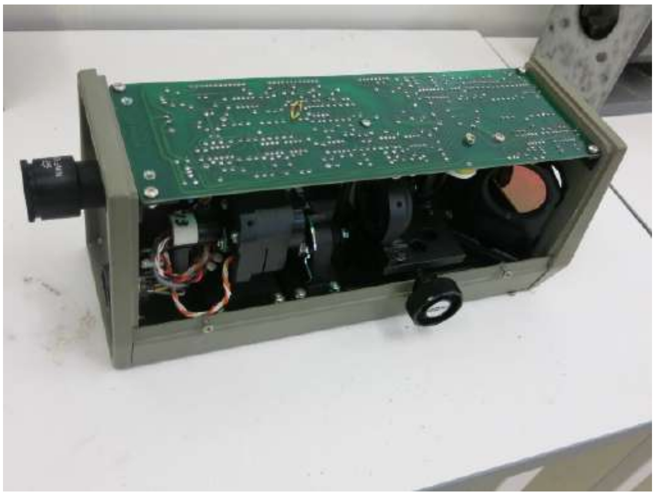
X ray diffraction

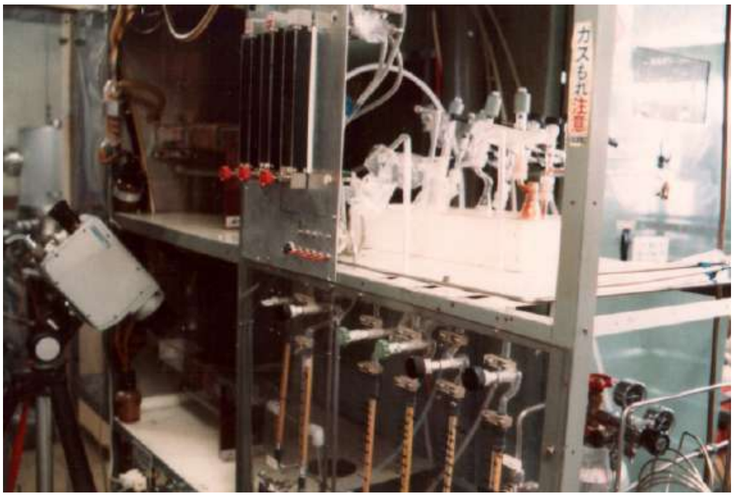
13 Gas laser, photomultiplier and radiation thermometer

Gas laser (laser tube (top), CO_2 laser (bottom)) (exhibited)



Photomultiplier





(Infrared) radiation thermometer and its application

14 A liq.^{4}He / liq.N_2 cryostat Dewer by double-duplex glass tubing (since 1973)

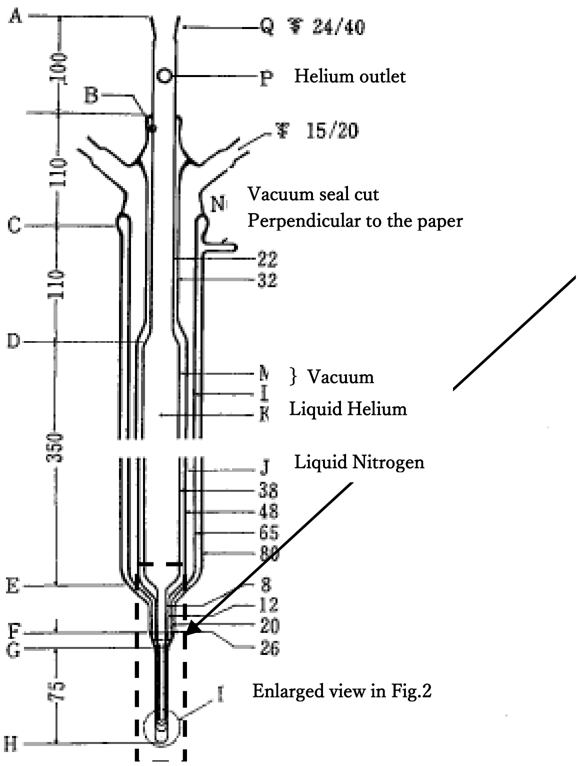
History of the development of lab-use glass equipment in Tohoku University can be going back in the same year as of the campus start. Together with the nurturing program of glass blow specialist and thanks in the collaboration with researchers, a lot of unique glass apparatus was made in the campus.

A liq.^{4}He / liq. N_2 cryostat, integrated as a single Dewer, was developed at Chemical Research Institute of Non-Aqueous Solutions, Tohoku University (later Institute of Multidisciplinary Research for Advanced Materials, Tohoku University) and tailored to specific research needs. Key to realize the cryostat Dewer lies in knowhow about Quartz/ Pylex glass blow joint tubing thinned to about 0.6mm thick. Multi-stage Quartz / Pyrex glass joint enabled the production of various type of glass cryostats, which were applied to low-temperature experiments such as infrared and UV-visible absorption spectroscopy, ESR spectroscopy, and AC magnetic susceptibility measurements.

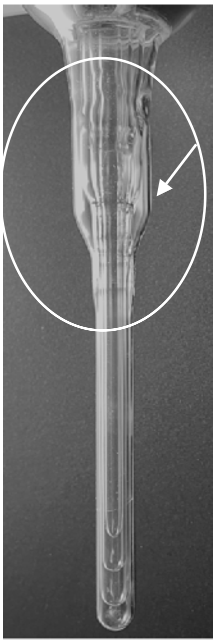
The helium Dewar on display was crafted around 1984 by Zenjiro Matsumura for X-band ESR. It consists of four Quartz / Pyrex blown joint glass tubes, located in the reduced diameter region of the cylindrical body. There innermost quartz tube, served as liq. ^{4}He reservoir in the X-band cavity, has a small 5 mm diameter, which reduce helium consumption and assures a long measurements time.

Double-duplex glass tube Helium cryostat Dewar Designed for long time measurement with minimal liquid Helium consumption

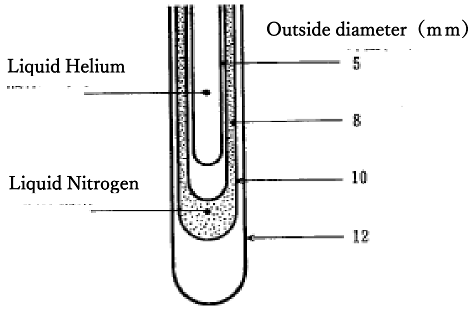
cons



Insert-Type Liquid Helium Cryostat. All dimensions are in mm; glass tube diameters refer to outer dimensions.″



Each quartz/Pyrex glass joint sections are set by glass blow with vertical offset. Both the cavity quartz wall and vacuum gap are ~0.5 mm thick, ensuring a compact structure.



Quartz quadruple tube insertion section

The quartz tube is polished to thin, then the glass is joined.

Ref.; Matsumura et al, Rev. Sci. Inst., 45, 596 (1976)