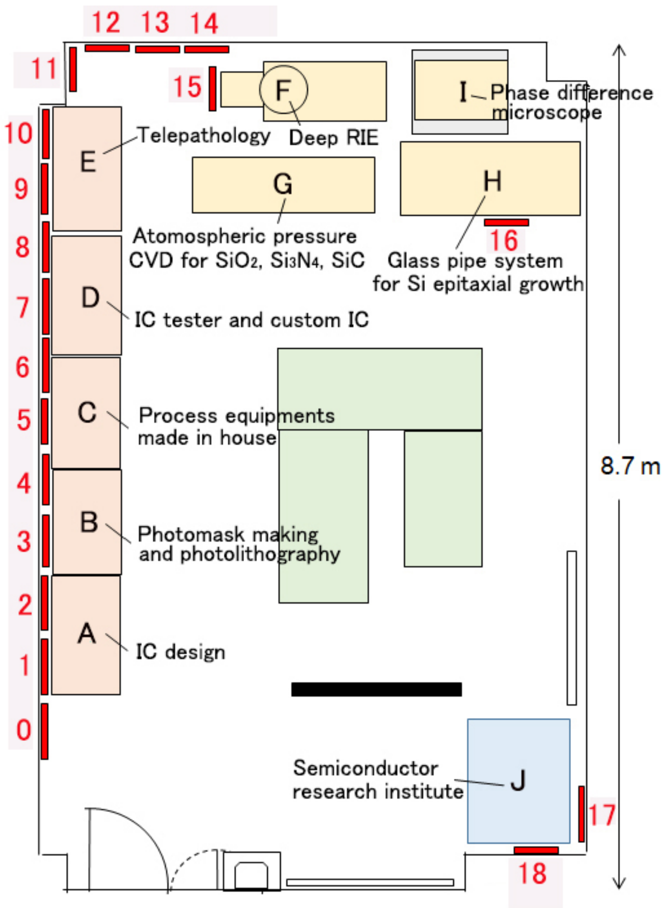
0 In-house IC and equipment room



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

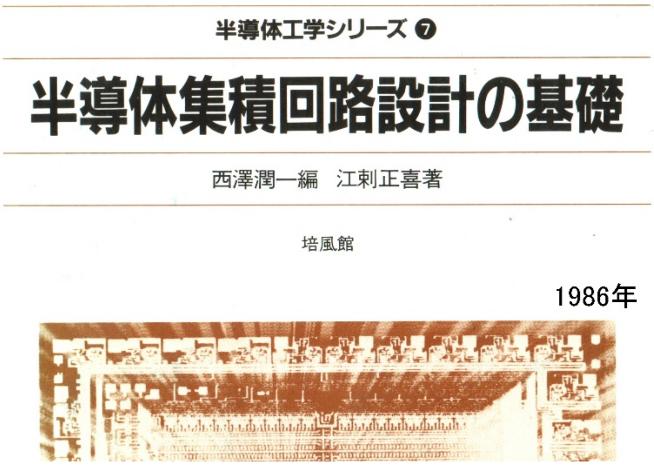
Message from Prof.Nishizawa

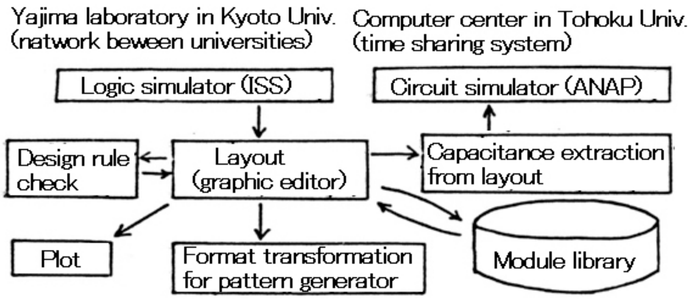
Semiconductor Research Institute and Nishizawa memorial room

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

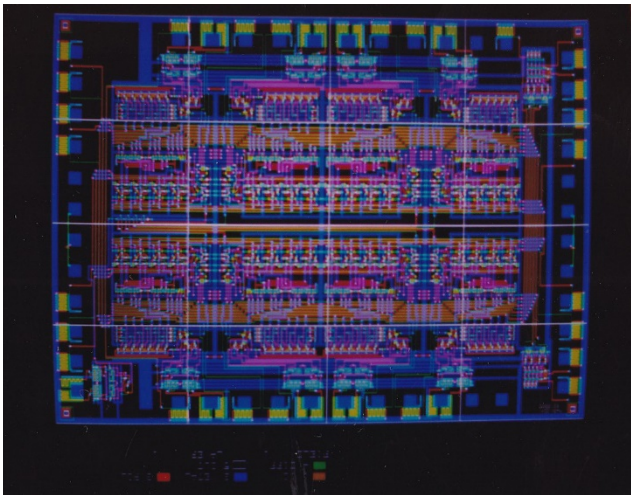




Design flow using CAD programs

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

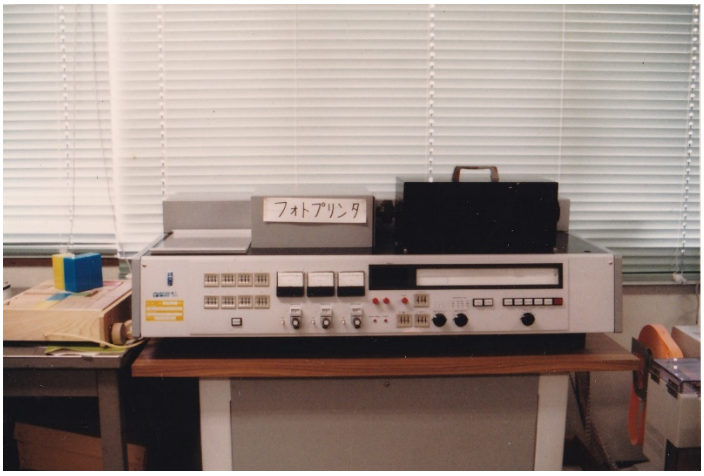
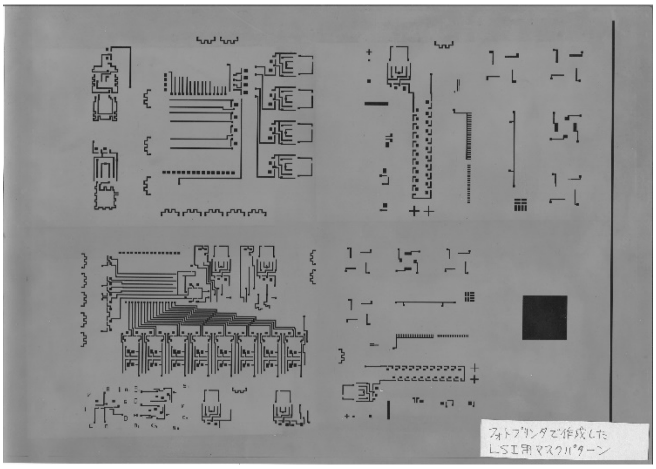


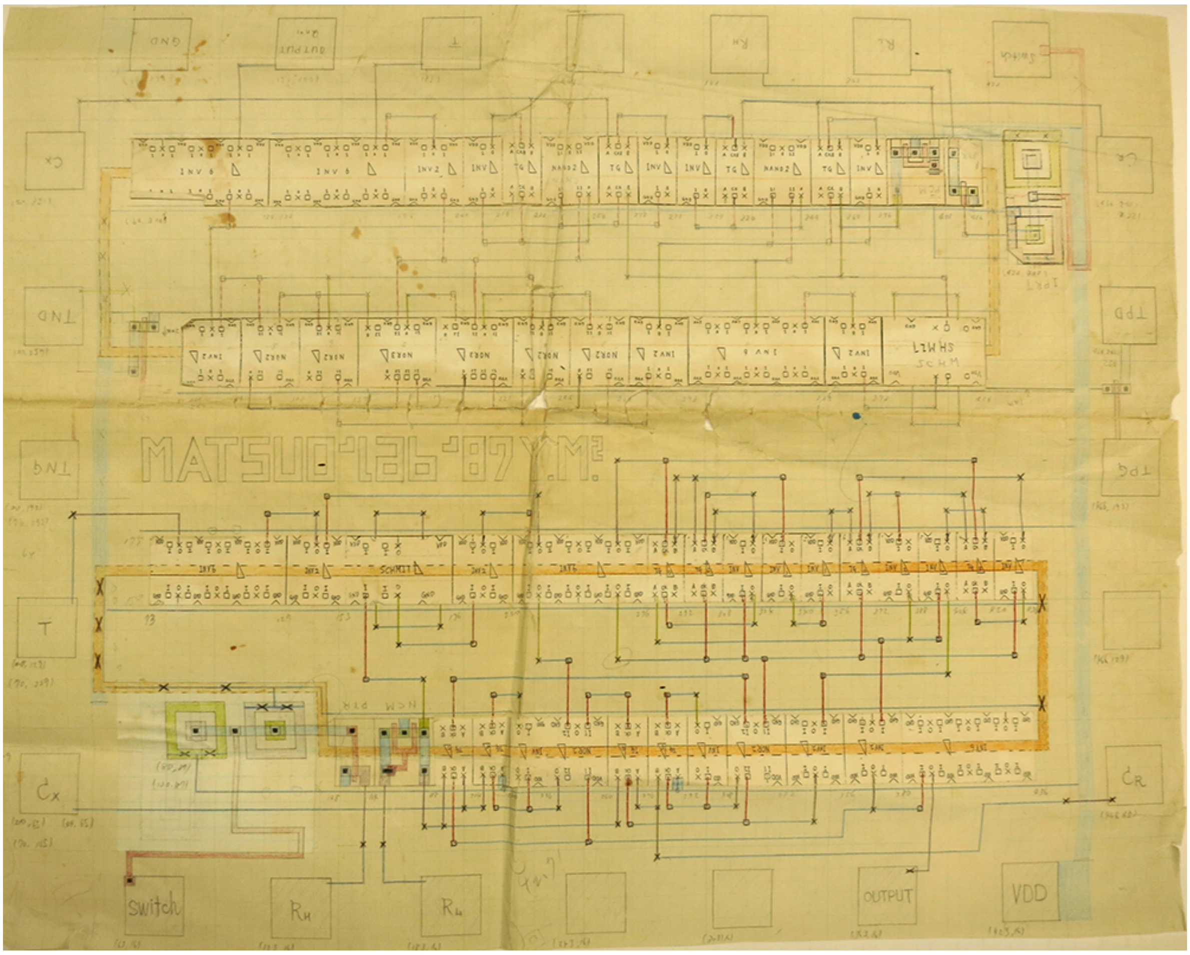
Photo-printer for printing out the layout pattern

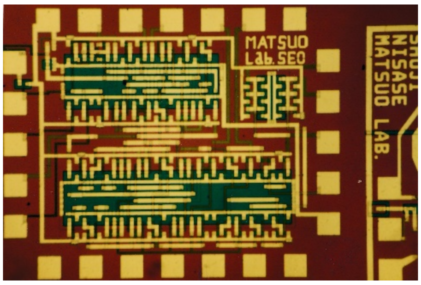


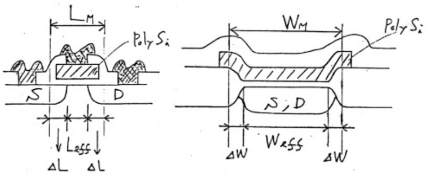
Mask negative printed out on a transparent film

(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



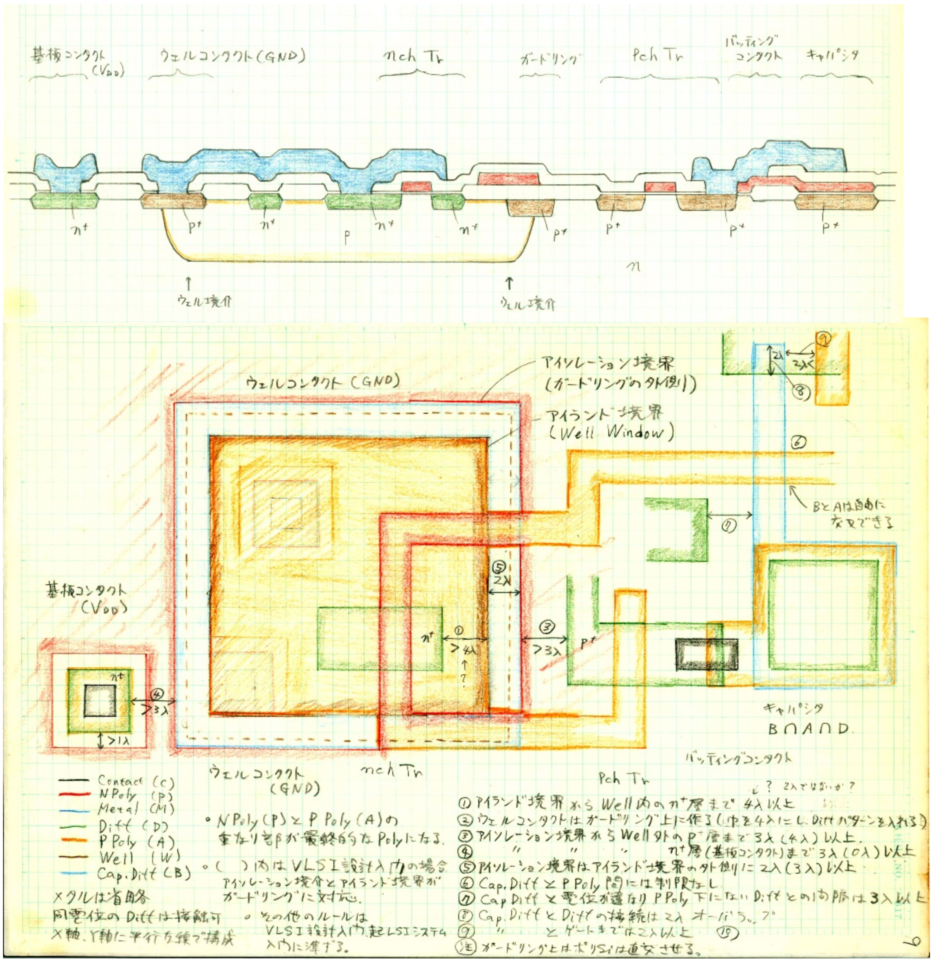




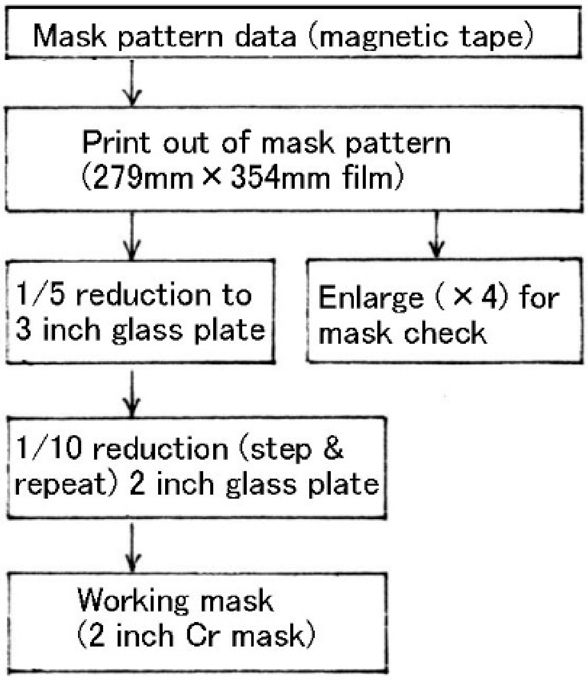
$L_{eff} = L_M - 2\Delta L$ $\quad W_{eff} = W_M - 2\Delta W$

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=5μm	0.056	0.13	V^{-1}
	L=10μm	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/cm²)

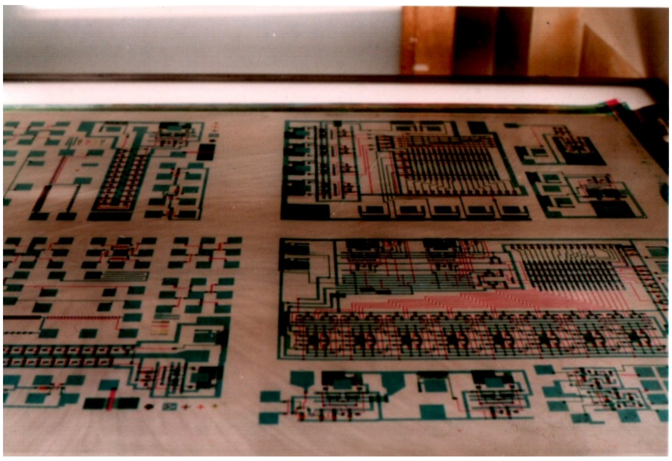


3 Mask making, photolithography



Mask making process

Reduction camera (displayed)



Color key for patter inspection

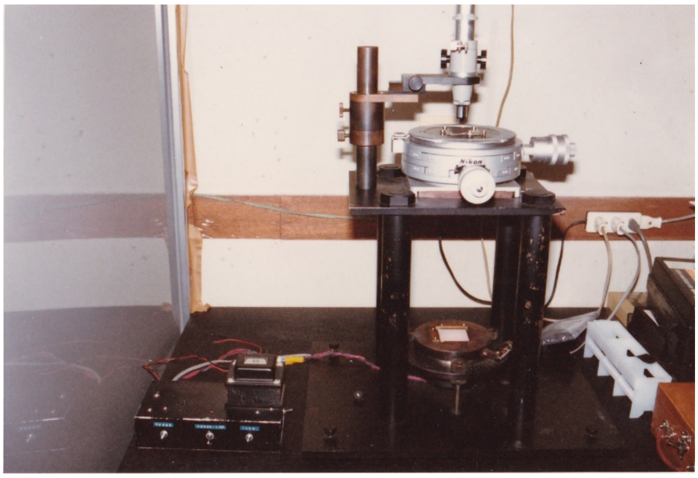
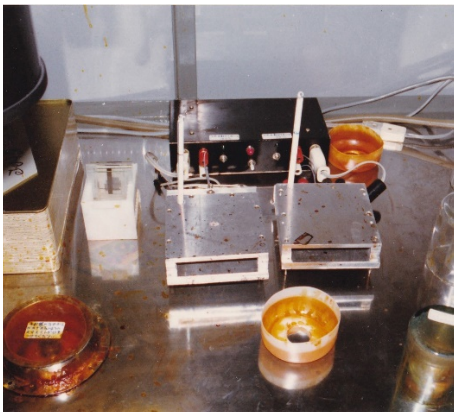
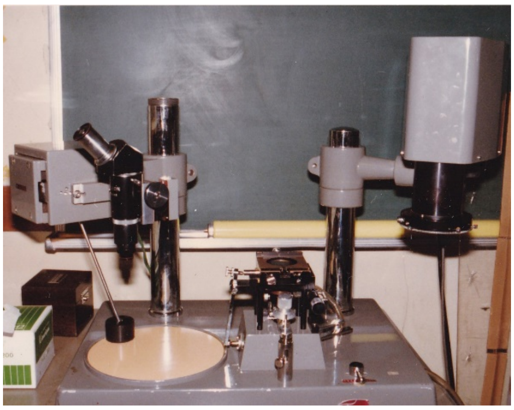


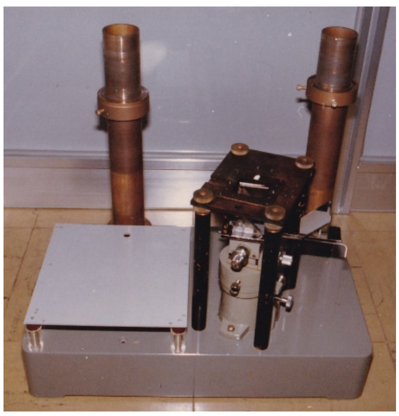
Photo repeater (2nd reduction camera)



Spinner for resist coating and baking tool

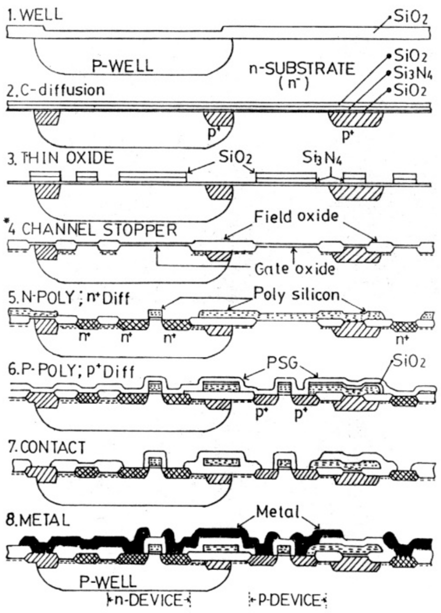


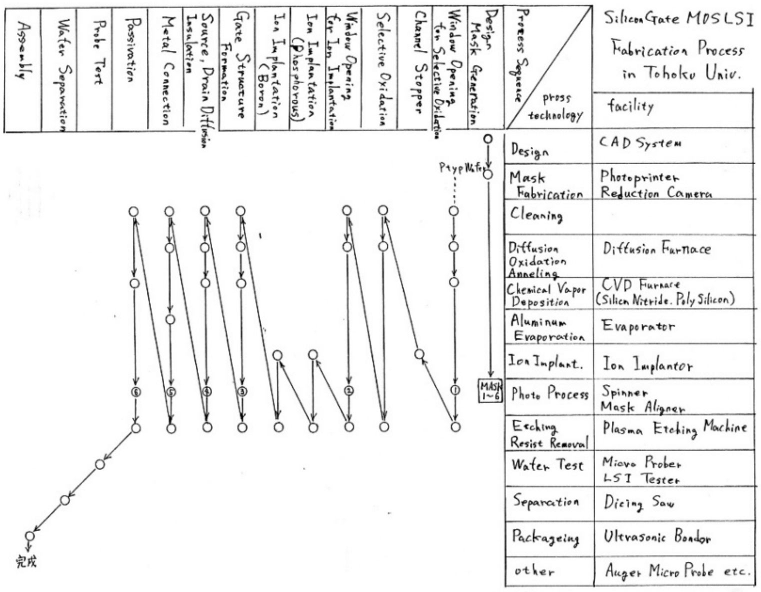
Mask aligner

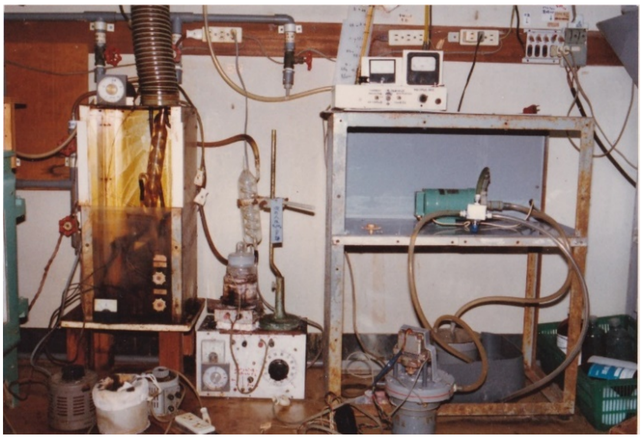


Attachment for double side exposure

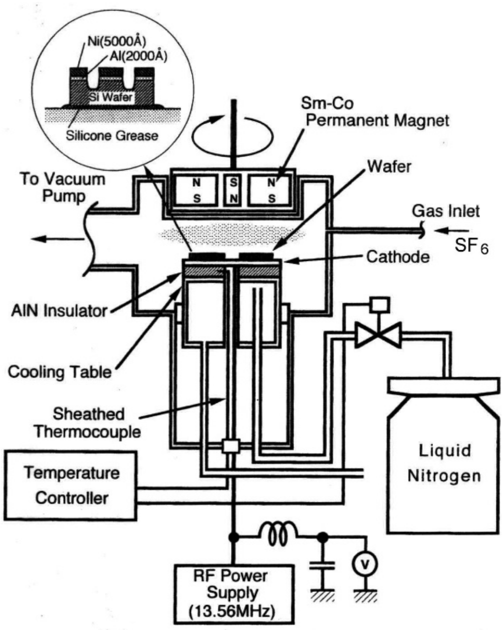
4 Wafer process (1) process sequence, etching

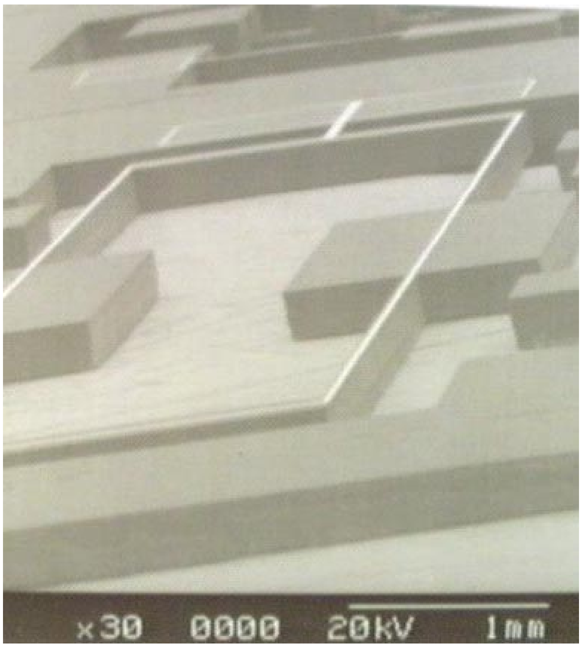






Si EPW etcher, SiN etcher in hot phosphoric acid、Electrochemical Si etcher DI water supply



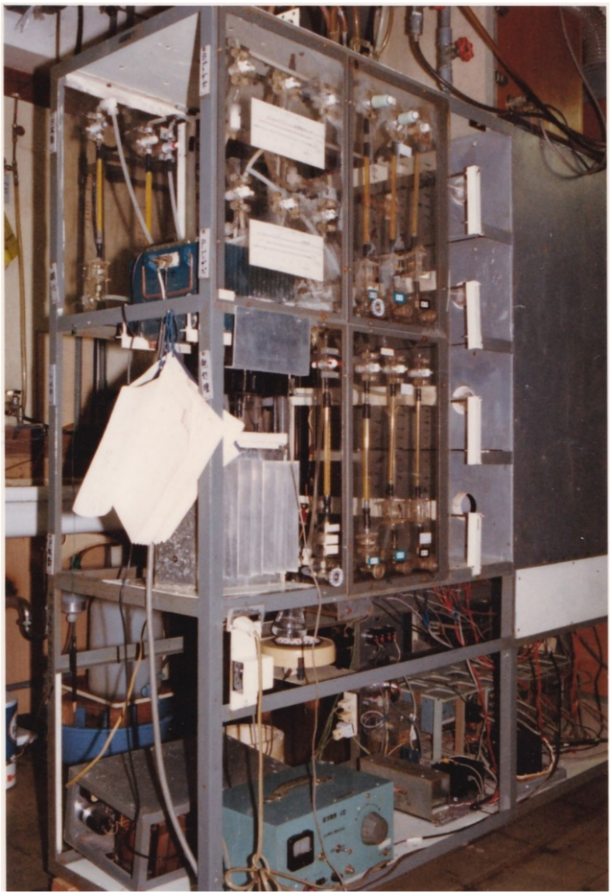


Si deep RIE (Reactive Ion Etching) system (1992) Resonating gyroscope by the deep RIE through Si wafer

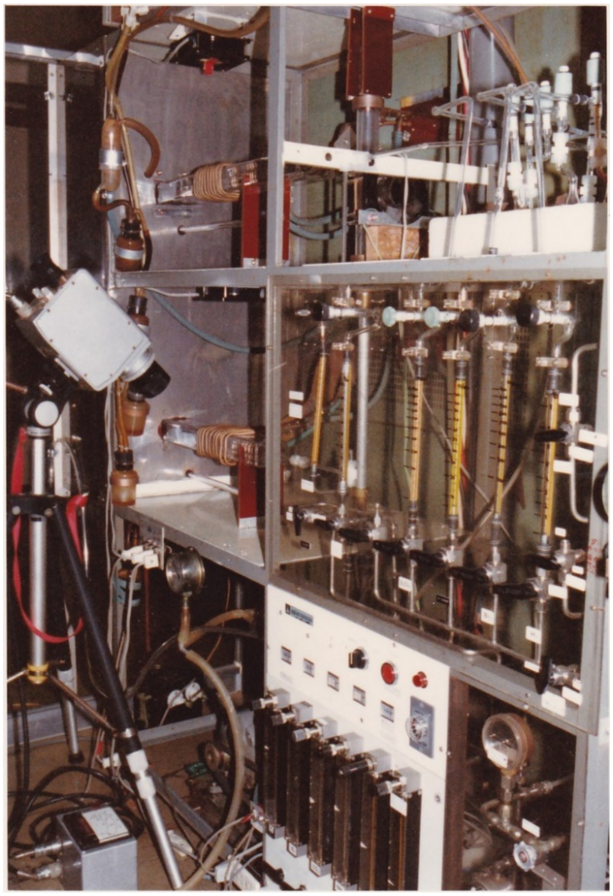
(M.Takinami, K.Minami and M.Esashi : High-Speed Directional Low-Temp. Dry Etching for Bulk Silicon Micromachining, 11th Sensor Symp. (1992) 15-18)

(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)

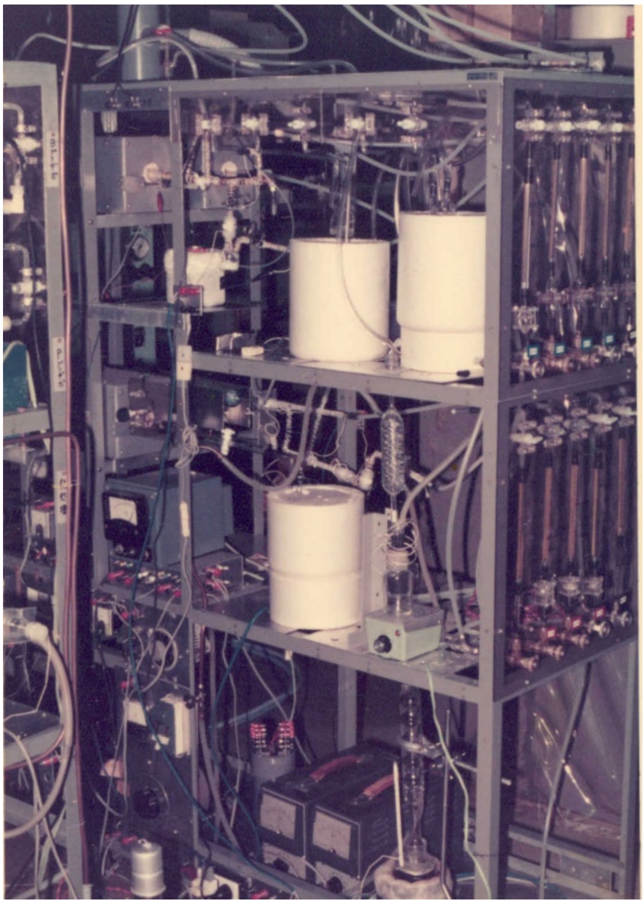
5 Wafer process (2) oxidation, diffusion, CVD



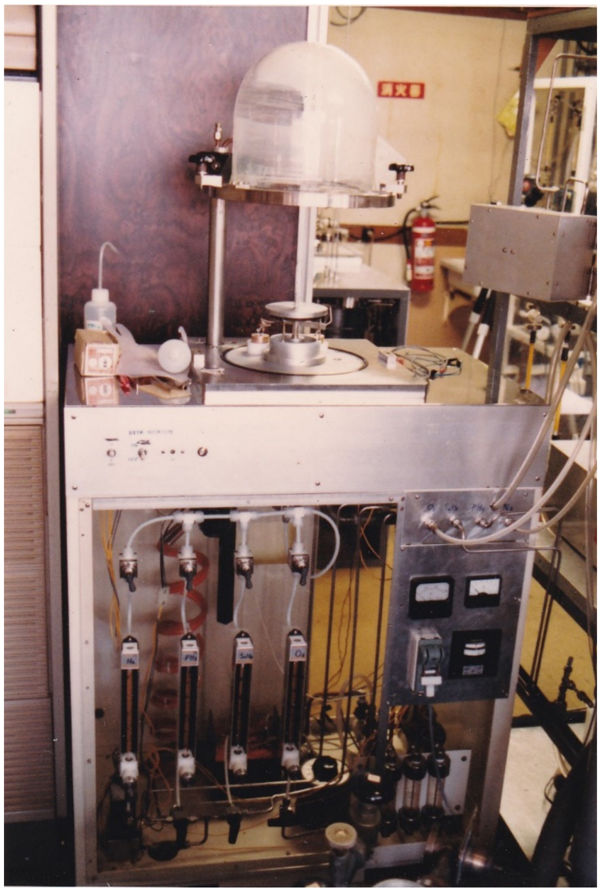
Oxidation diffusion furnace



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

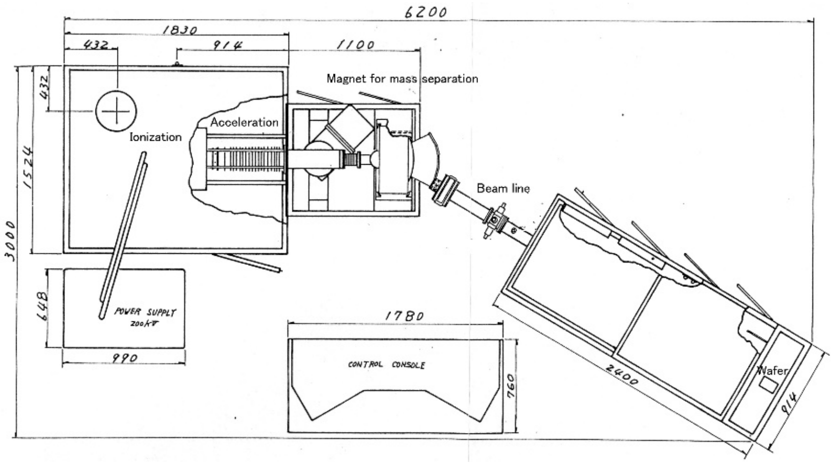


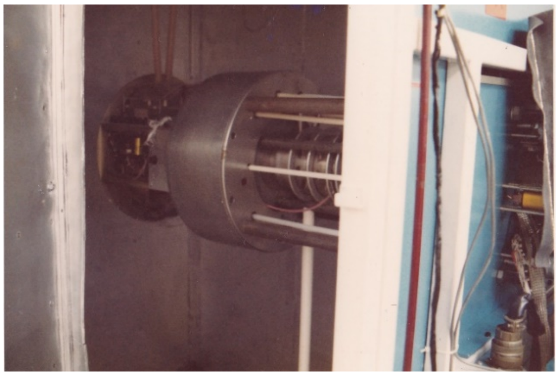
TEOS (tetraethoxysilane) source Al_2O_3–SiO_2 CVD

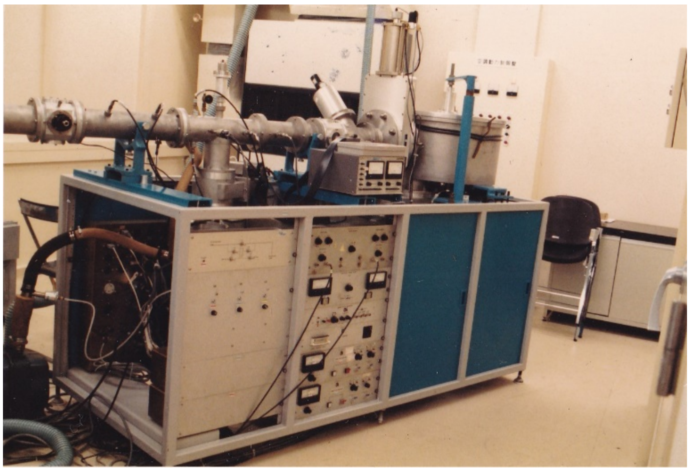


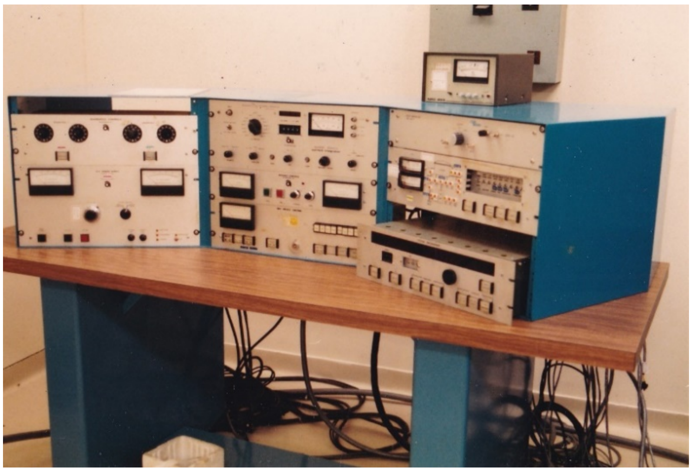
Low temperature CVD for SiO_2 (displayed)

6 Wafer process (3) ion implantation, sputtering

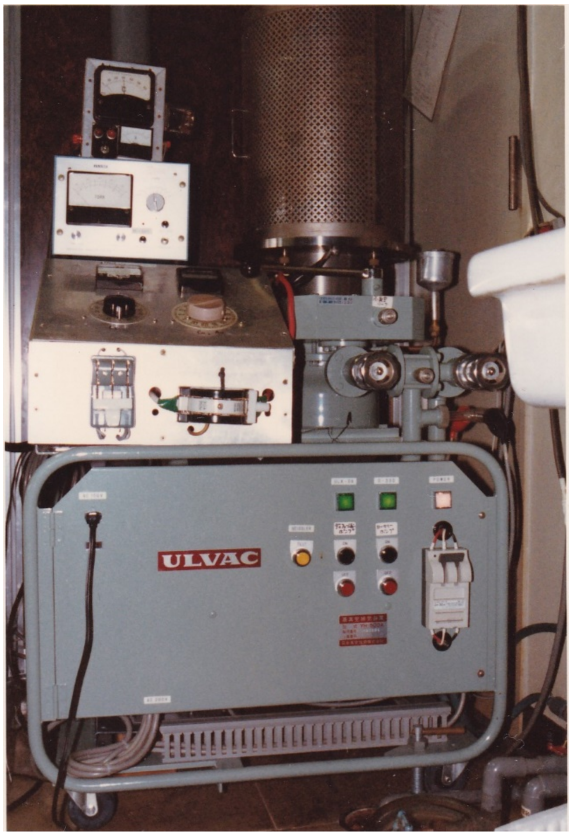




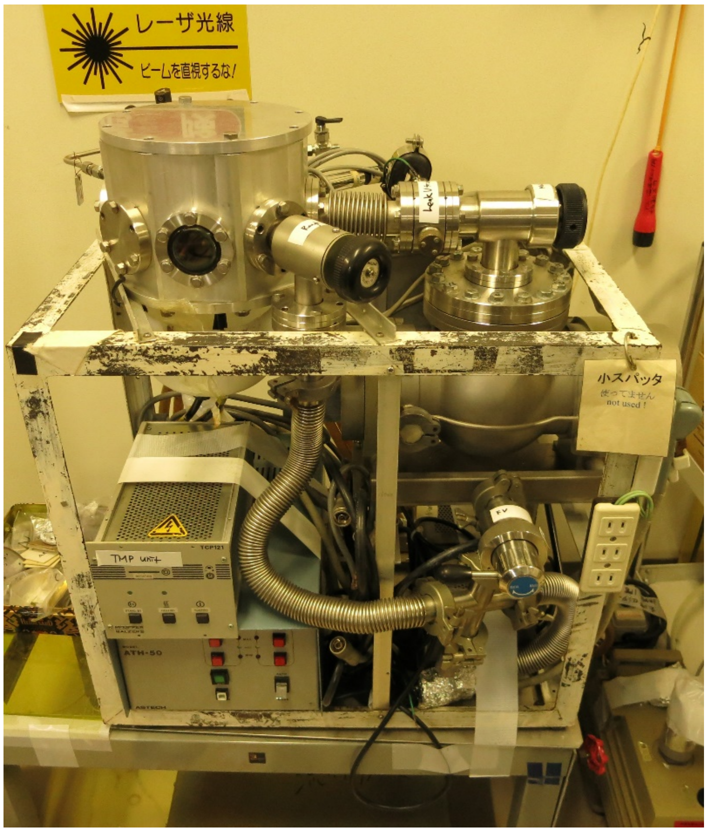




Ion implanter (Accelerator Inc, 200MP second hand)

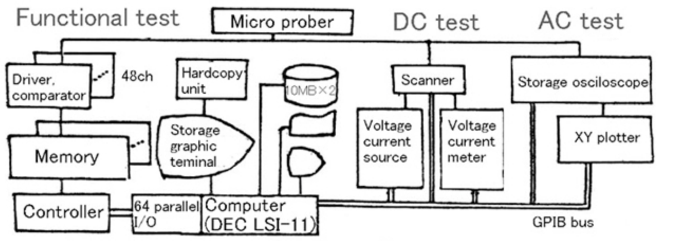


Al, Cr–Cu–Au evaporator

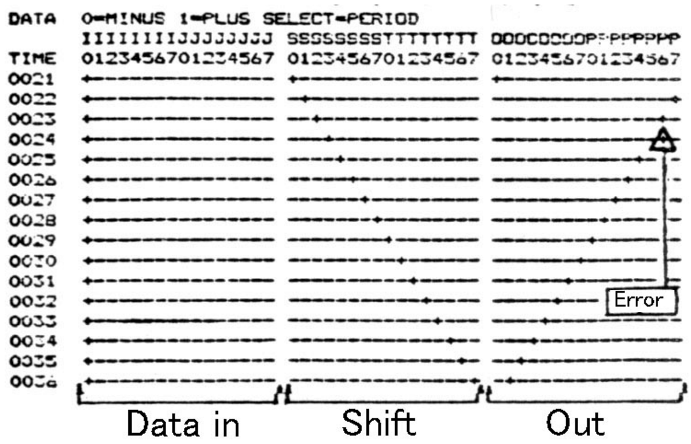


Magnetron sputter deposition

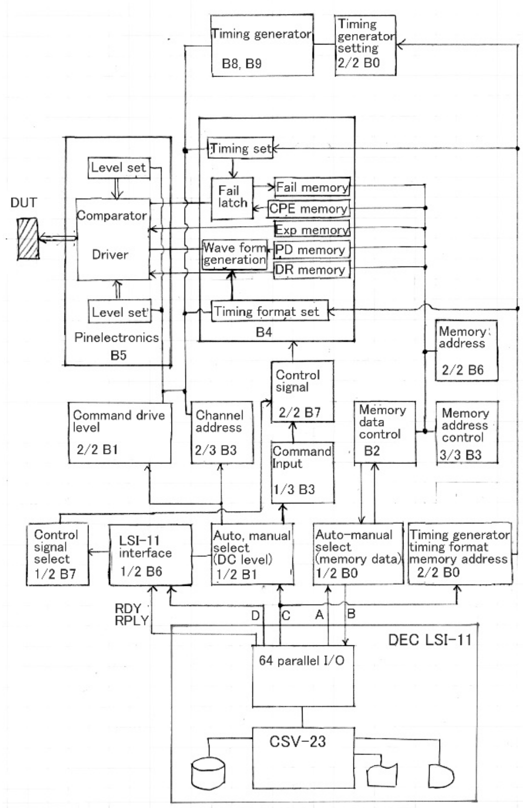
7 IC tester



IC test system

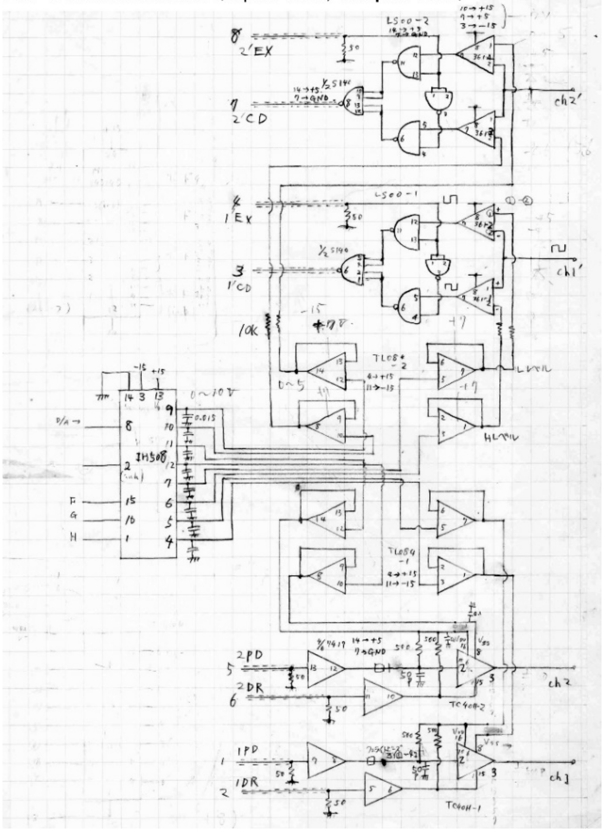


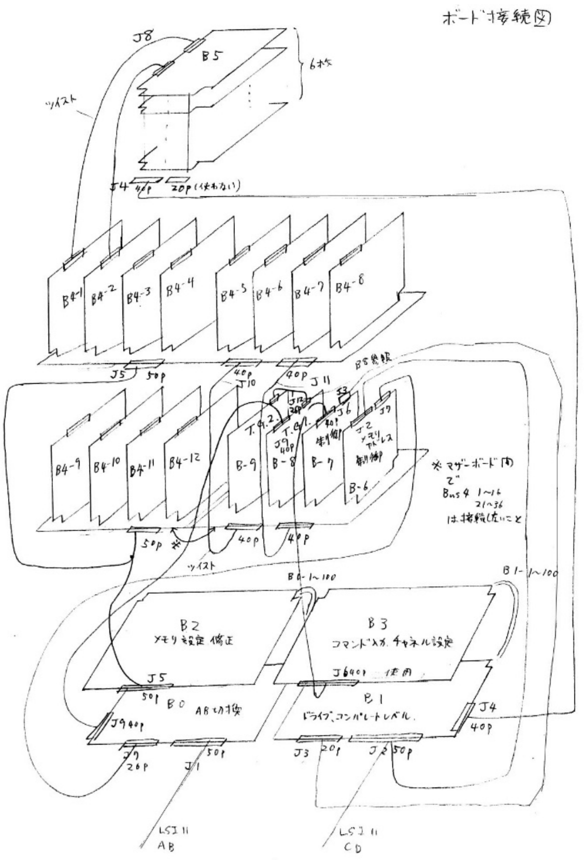
An example of test result of barrel shifter



Block diagram of made-in-house IC tester

B5 Pinelectronics (input 2ch, output 2ch)

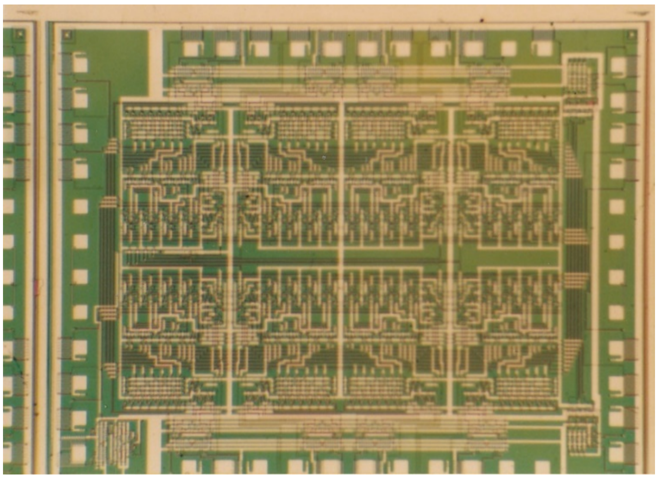

Pin electronics (electrical connection to IC pad)



Connection between boards

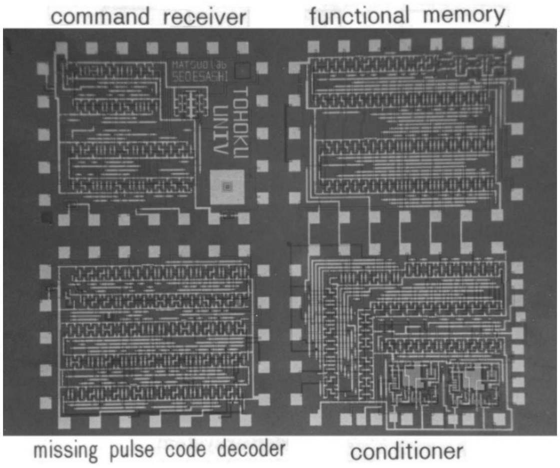
(M. Esashi, M. Ohtomo: Fabrication of Functional LSI Tester, Joint Convention of Electrical Academic Societies in Tohoku Region, 2D21 (1984))(in Japanese)

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



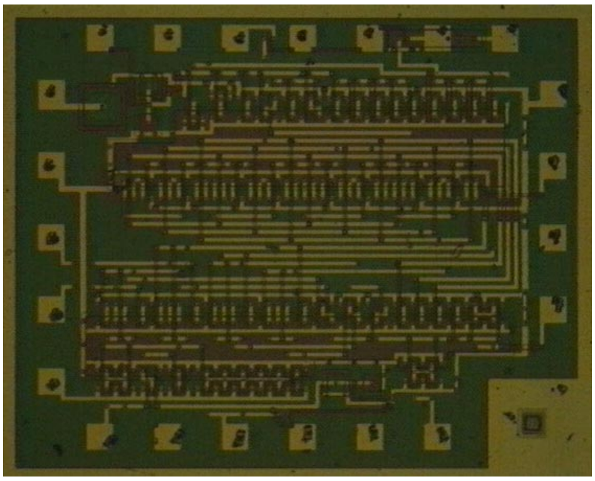
Bit serial parallel image processing IC

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



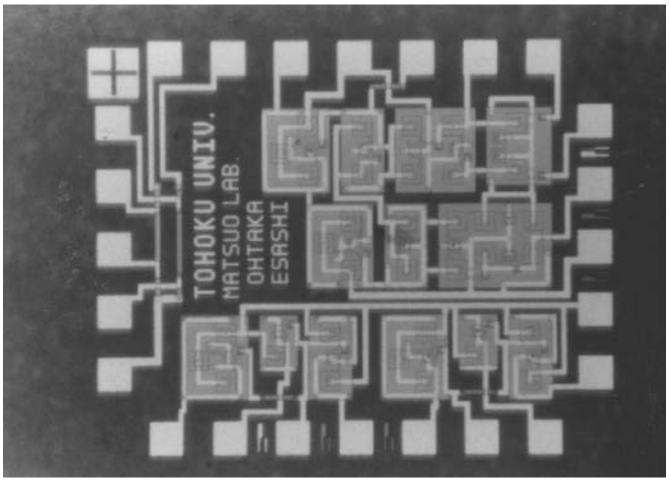
Implantable telemetry IC

(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)



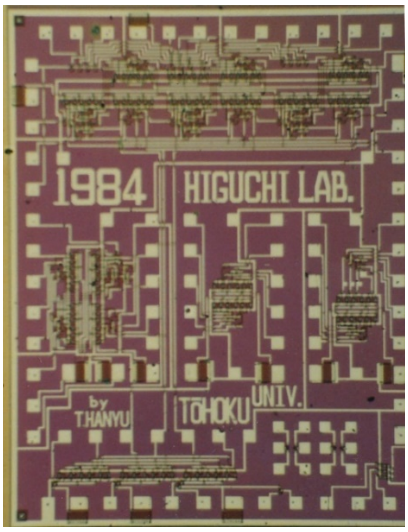
IC for tactile sensor array using common two wires

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



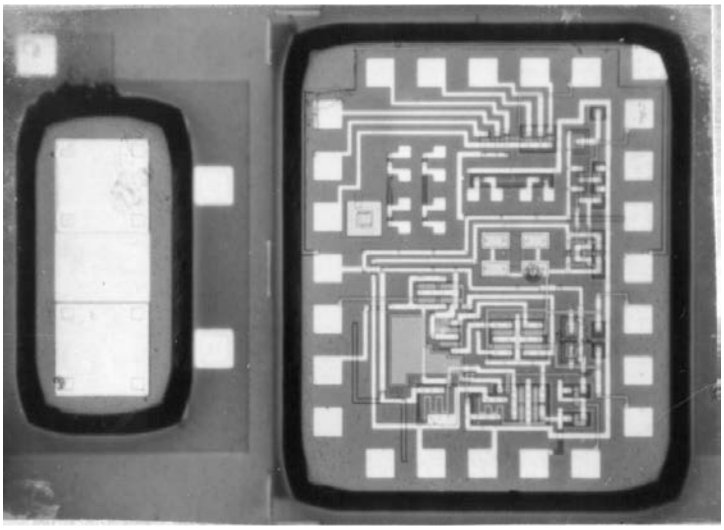
SOS (Si on Sapphire) CMOS OP amp IC for high temperature

(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)

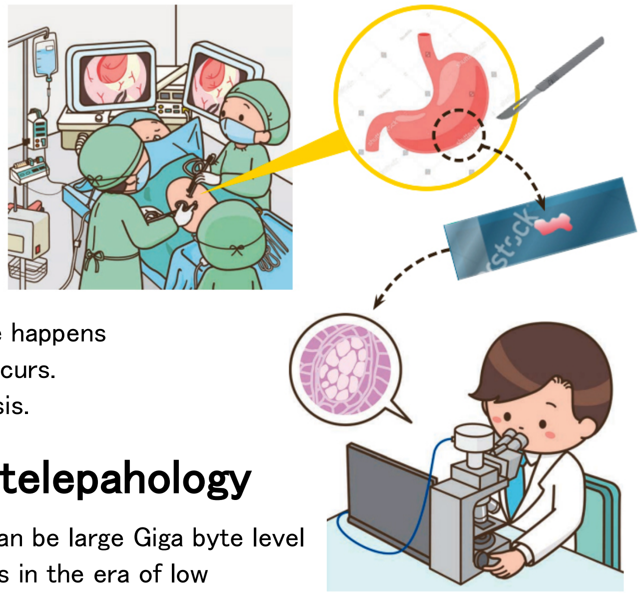


Direct bonded capacitive pressure sensor using switched capacitor IC

(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.

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.

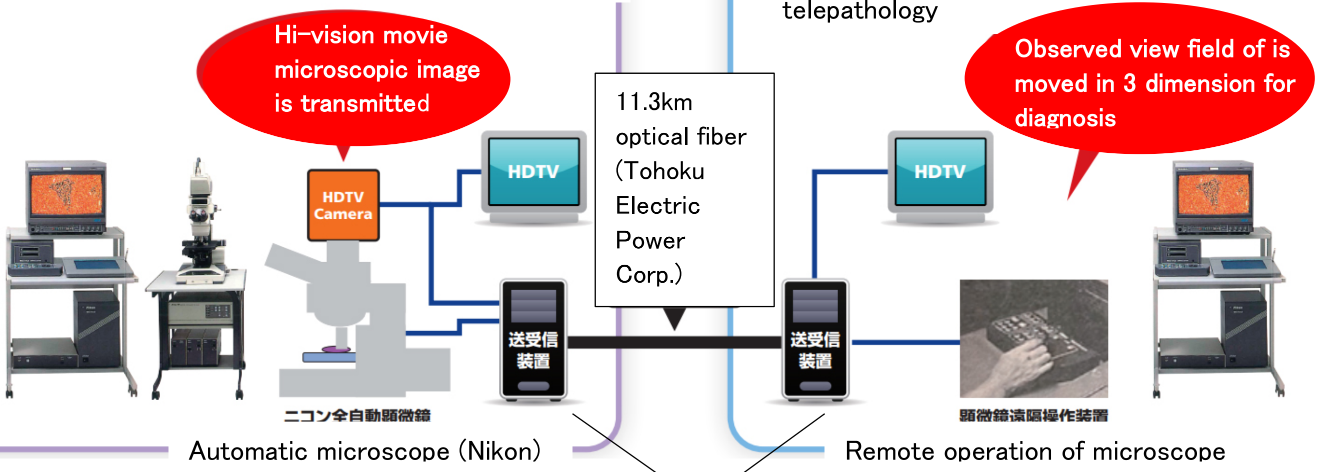
President Nishizawa observing demonstration

Old Sendai city hospital (Itsutsubashi)

Dr. Naganuma transmitting the microscope image

Tohoku university hospital

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



- 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.

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)

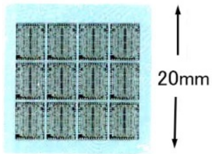
Hanging wire and cable are unified with bind wire.

- Nonmetalic prehunged type

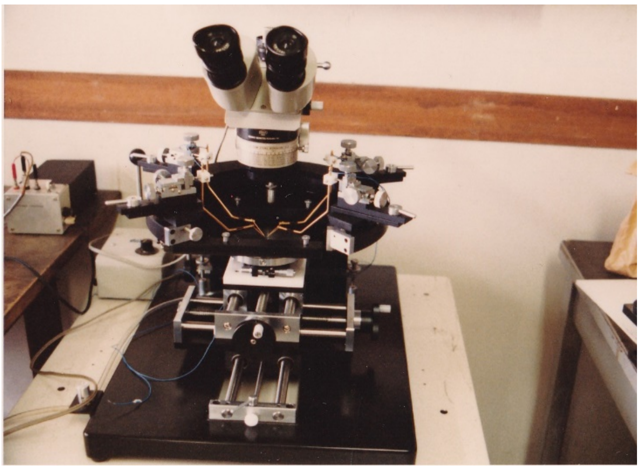
FRP hunging wire and cable are connected with polymer, which don't use metal.

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

12 Assembly & measurement



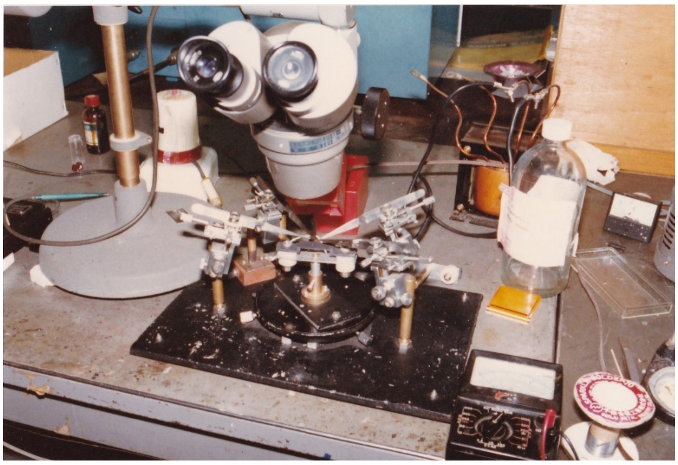
CMOS IC fabricated on a 20mm square wafer



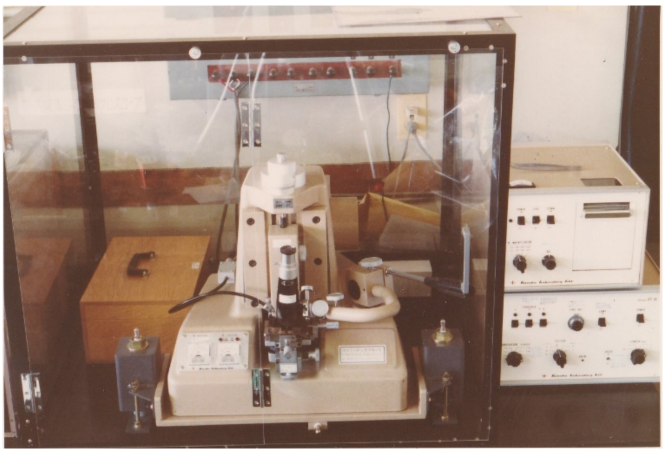
Wafer prober

Dicer

Ultrasonic wire bonder (displayed)



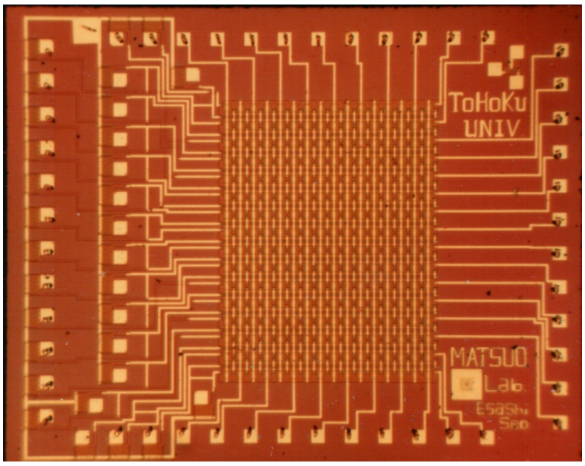
Micro soldering (and connection by conductive paste)



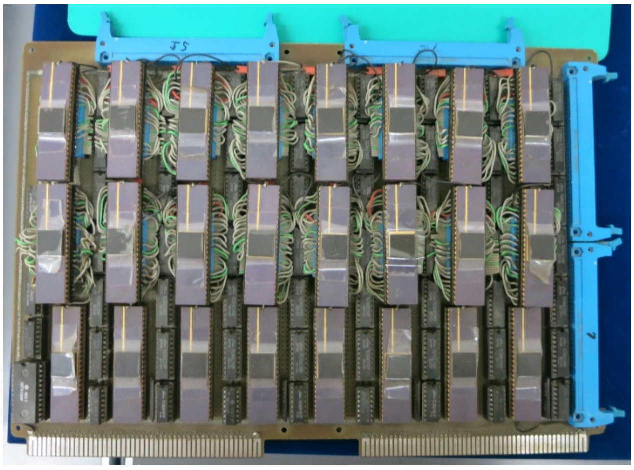
Surface profile meter

Auger electron spectrometer

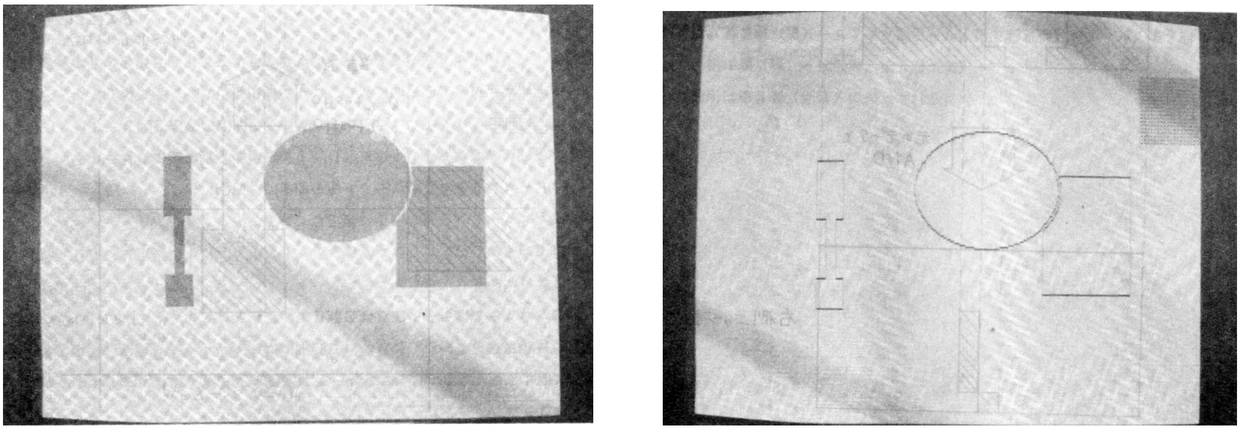
13 Fabricated custom IC (2) barrel shifter, integrated capacitive pressure sensor



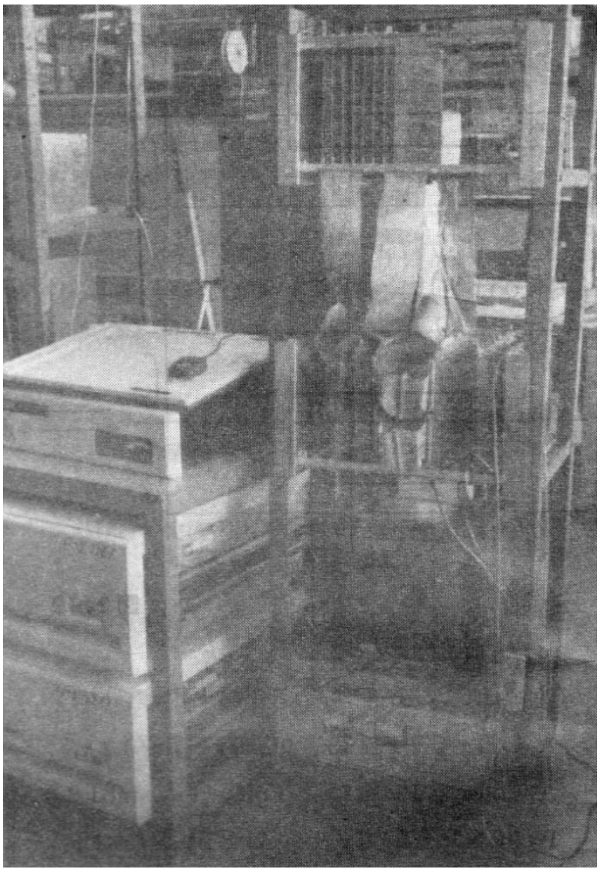
Barrel shifter



Switching network board using the barrel shifter (displayed)

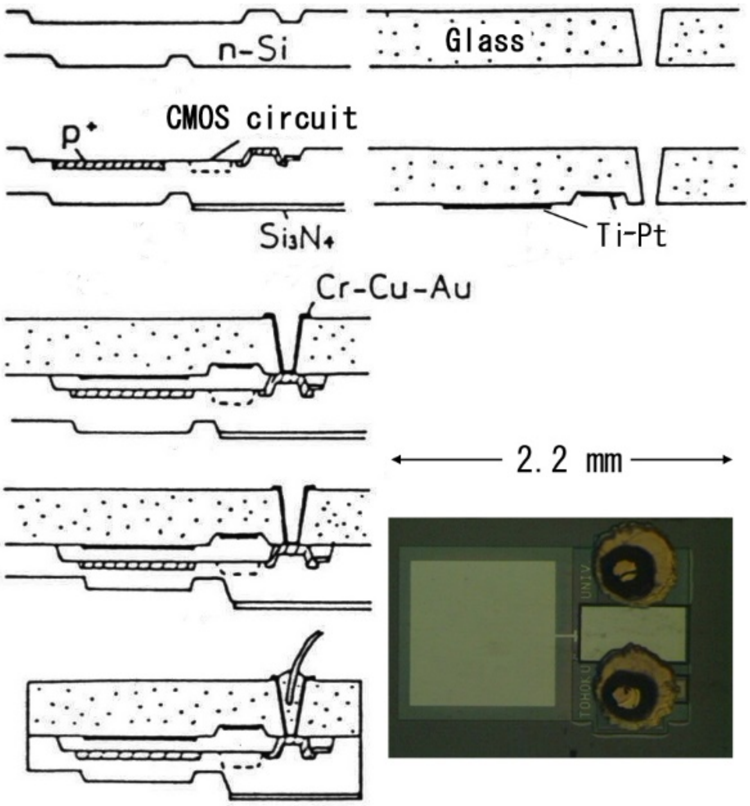


Example of edge detection using the parallel image processing



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

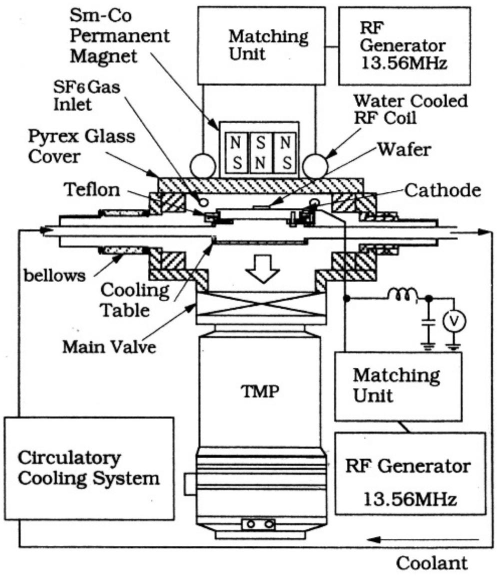
(M. Esashi, T. Matsuo : Workstation for LSI Pattern Design Using Custom LSI, S.59 IECE Convention, 404 (1984) 67-74) (in Japanese)

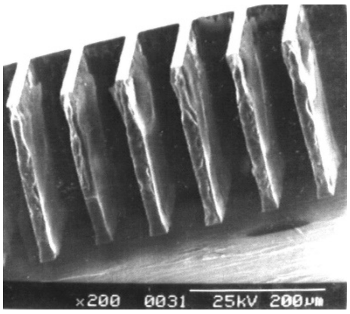


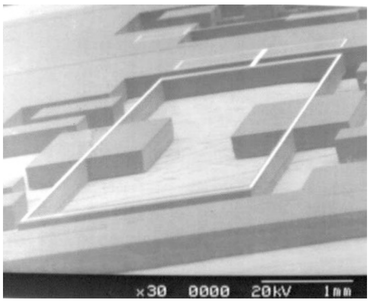
Integrated capacitive pressure sensor

(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

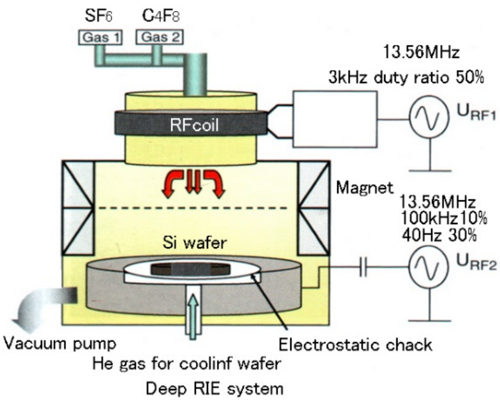


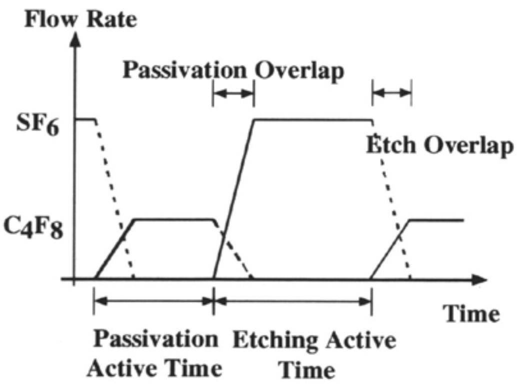




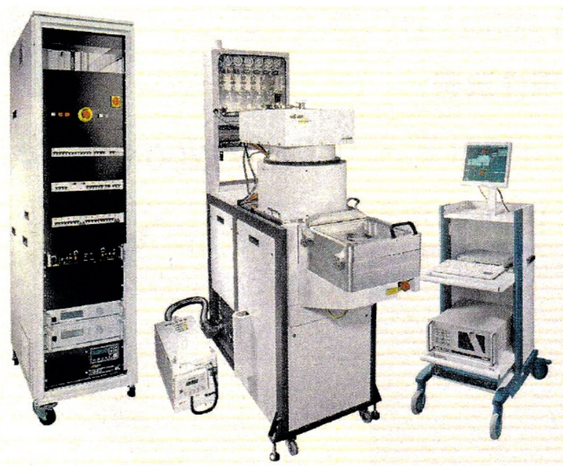
Low temperature Deep RIE system made in Tohoku Univ. and fabricated wafer for gyroscope (right)

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



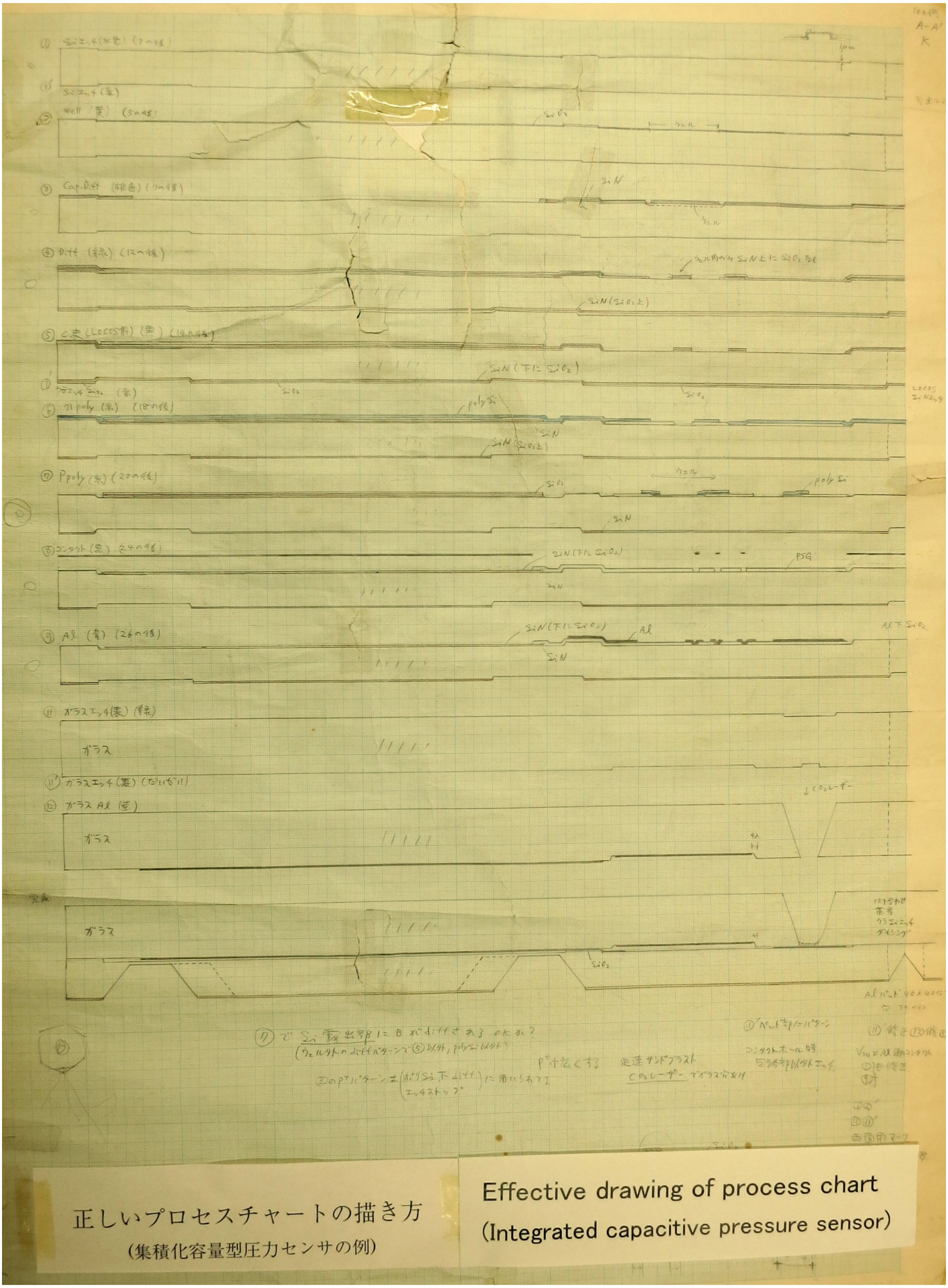


(F.Laermer (R.Bosch), Comprehensive Microsystems, Elsevier (2007) .217)

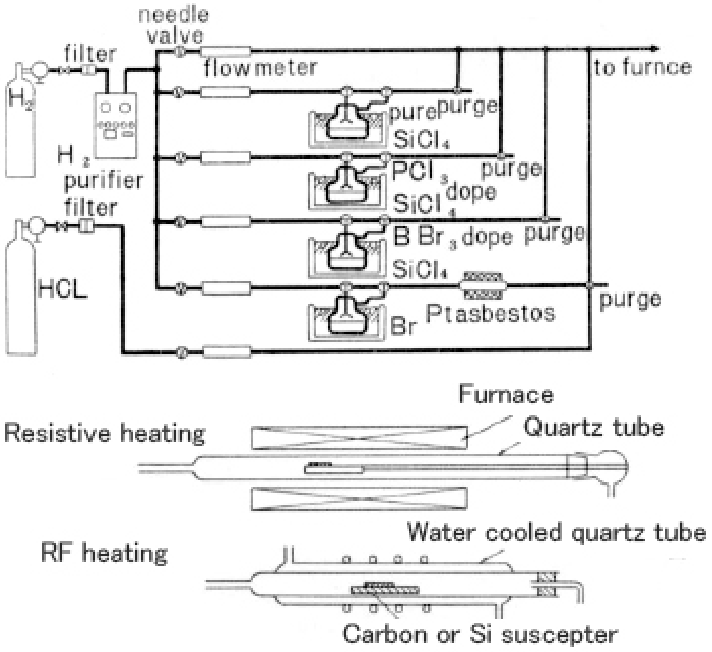


Deep RIE system displayed (Alcatel), Deep RIE system (Sumitomo Precision Product)

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)

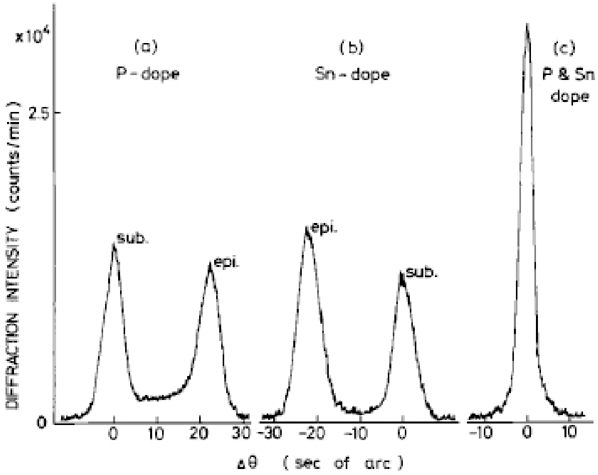
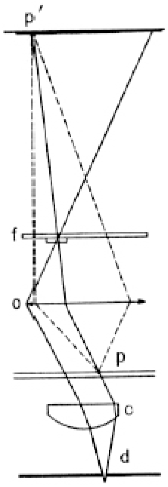


Fig. 10. X-ray rocking curves of {(511)^v, —(333)^s} for compensated specimens by simultaneous doping of tin and phosphorus. (a) Phosphorus doping; $N_i = 4 \times 10^{19}$ atom/cm^3; $t_f = 10\mu$. (b) Tin doping; $N_i = 2 \times 10^{19}$ atom/cm^3; $t_f = 11.5\mu$. (c) Simultaneous doping of tin with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

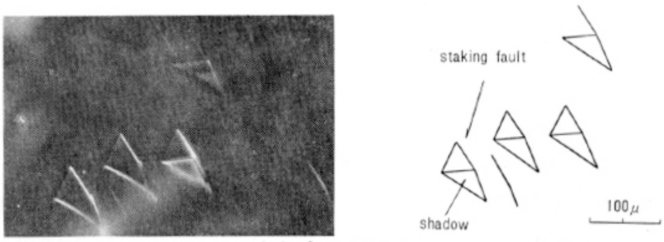
Perfect Crystal Growth of Silicon by Vapor Deposition

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

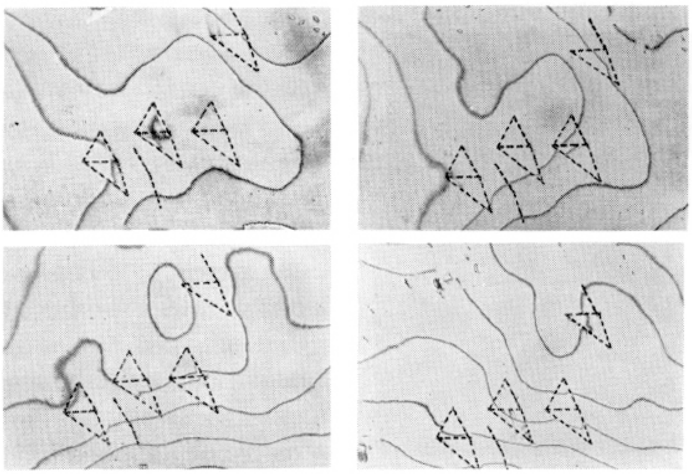


d : Aperture
f : Backside focus of objective lens (phase shift plate)
c : Condensor
p : Subject
o : Objective lens
p′ : Image of subject
Solid line : Direct beam of light
Broken line : difraction light from subject

Principle of phase difference method



(a) Phase contrast image



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

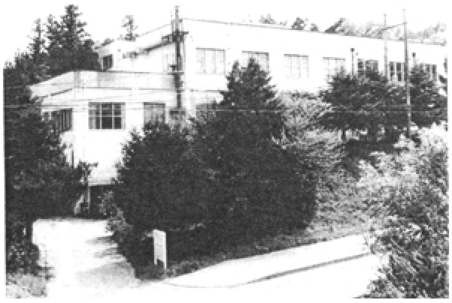
Phase difference microscope (Reichert MEF)

(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.

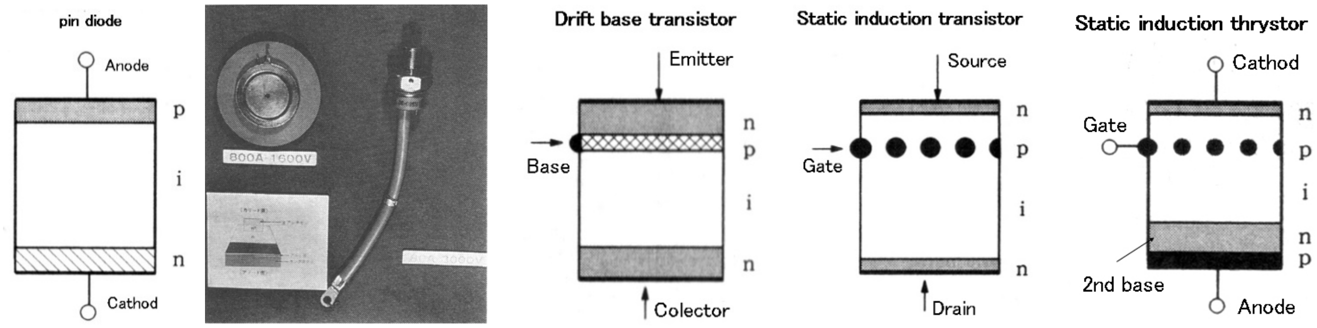


Semiconductor Research Institute located in Kawauchi, Sendai

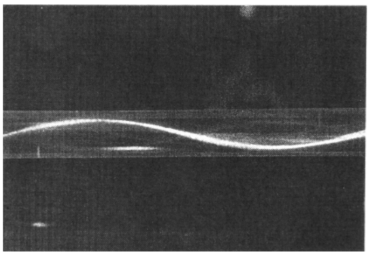
Nishizawa Memorial Research Center

Honorary Director Junichi Nishizawa

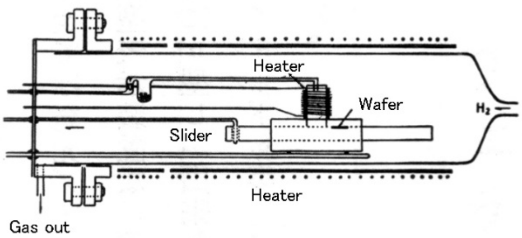
Staffs and students in the Semiconductor Research Institute



From pin diode to Static Induction Transistor and Static Induction Thyristor



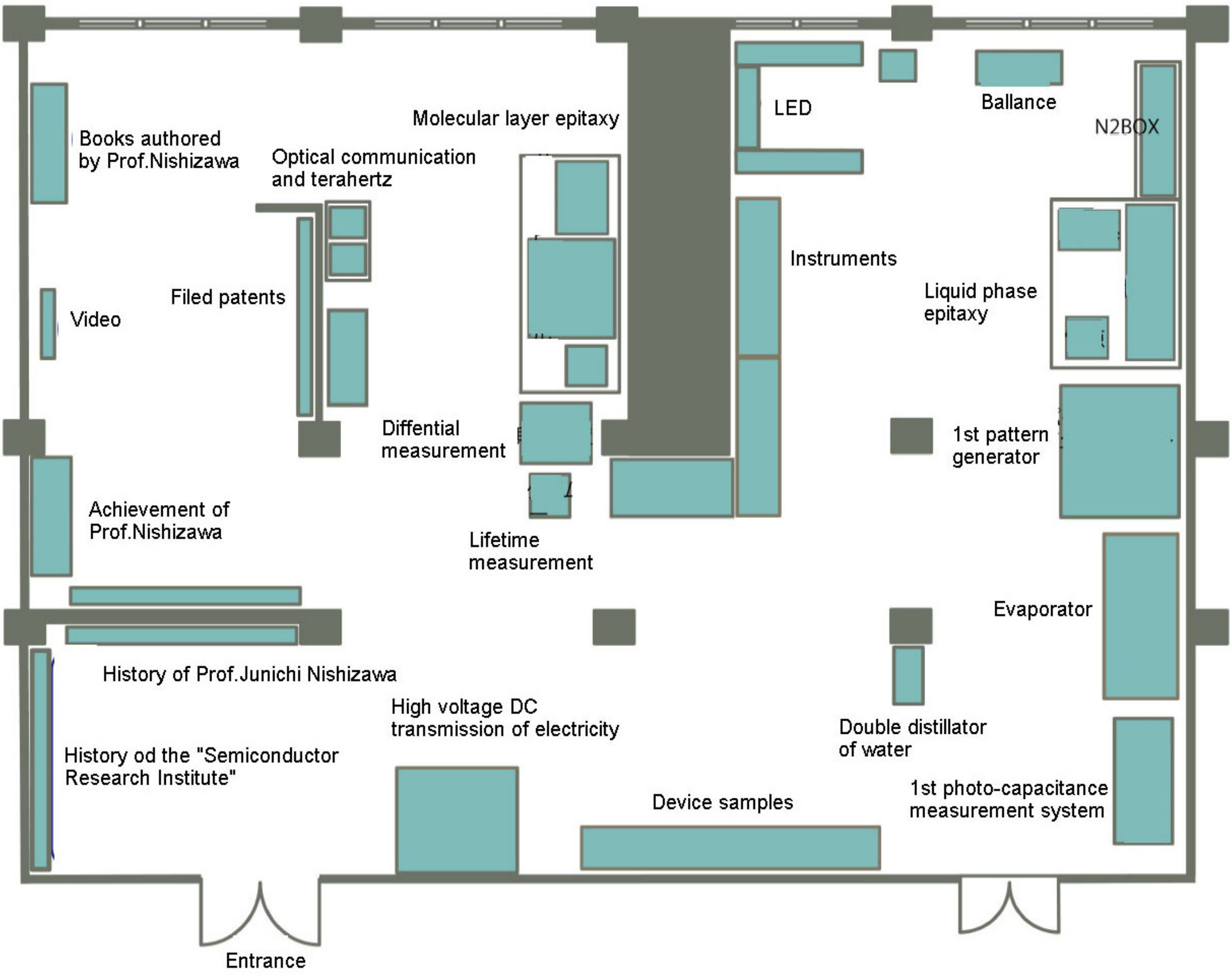
Graded index optical fiber



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/