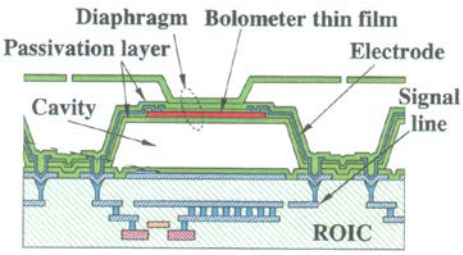
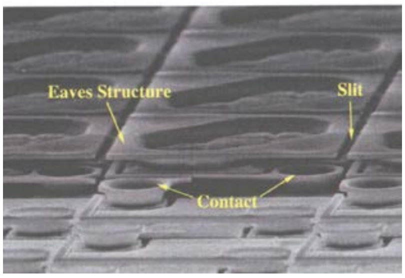
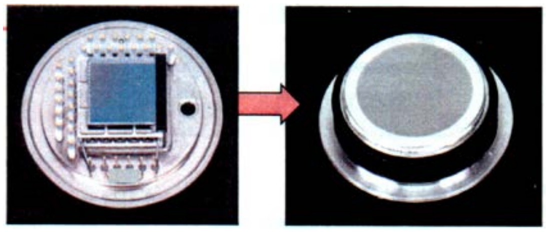
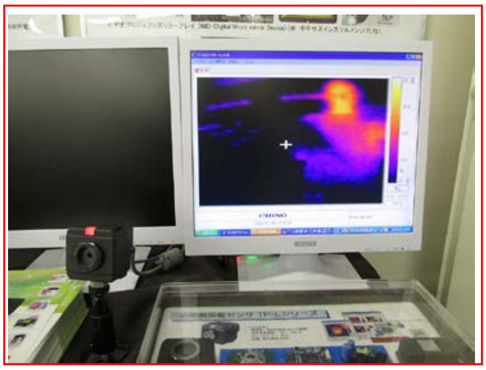
A1 Infrared sensor, imager

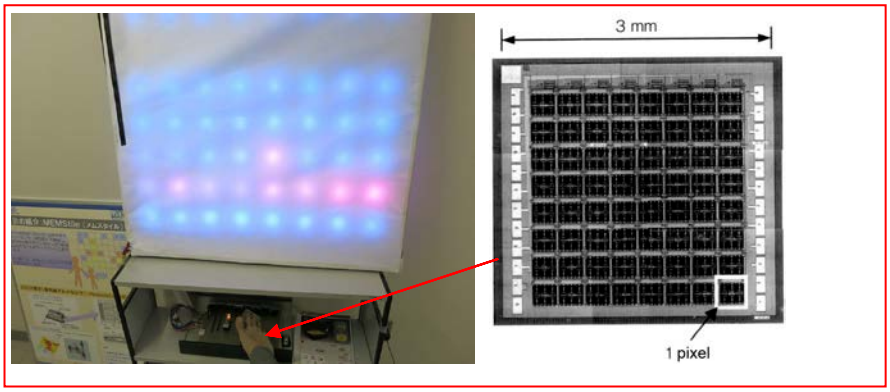






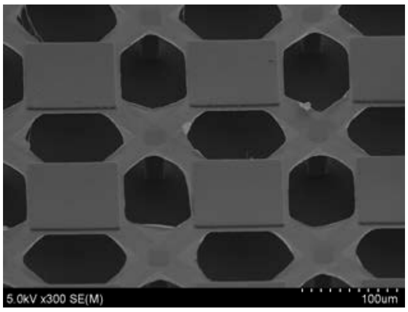
640×480 Thermal infrared imager using VO_2 bolometer (NEC) (S.Tohyama, Optical Engineering, **45** (2006) 14001)

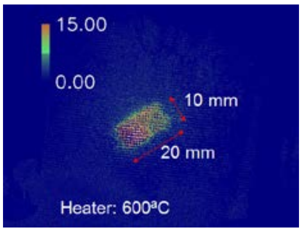


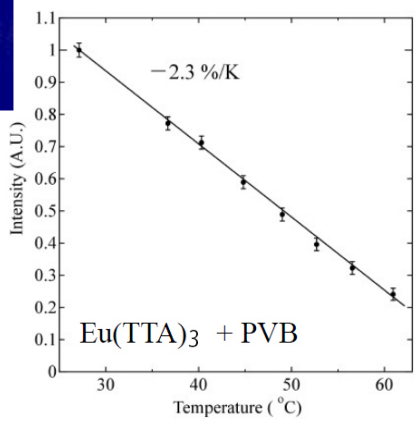


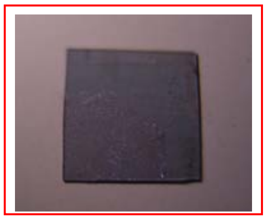
Compact thermal image sensor (Chino)

8×8 Thermopile infrared sensor (Panasonic) (displayed in corridor Card N!)

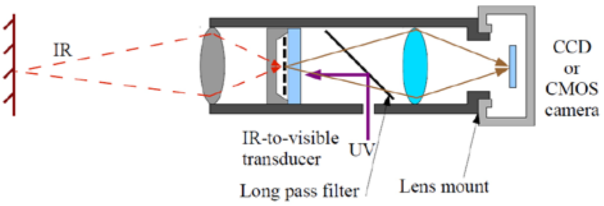




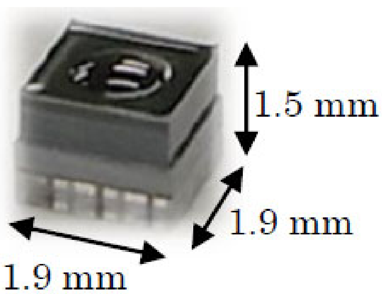


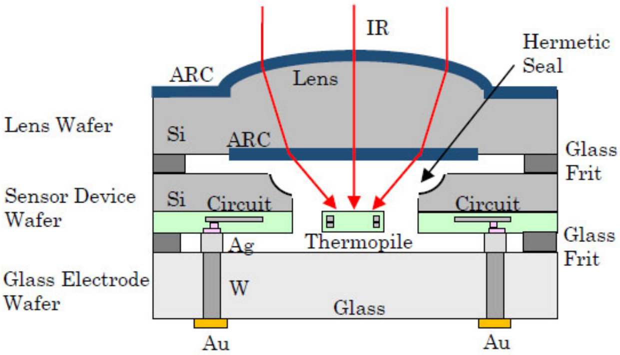


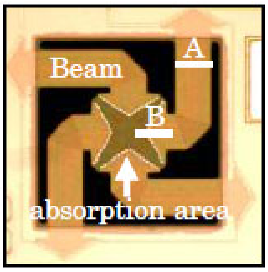
IR–to–visible transducer



Thermal imaging method using temperature sensitive luminescent material $Eu(TTA)_3$
(T.Tsukamoto, M.Esashi and S.Tanaka, J. of Micromechanics and Microengineering, 23, 11 (2013) 114015)

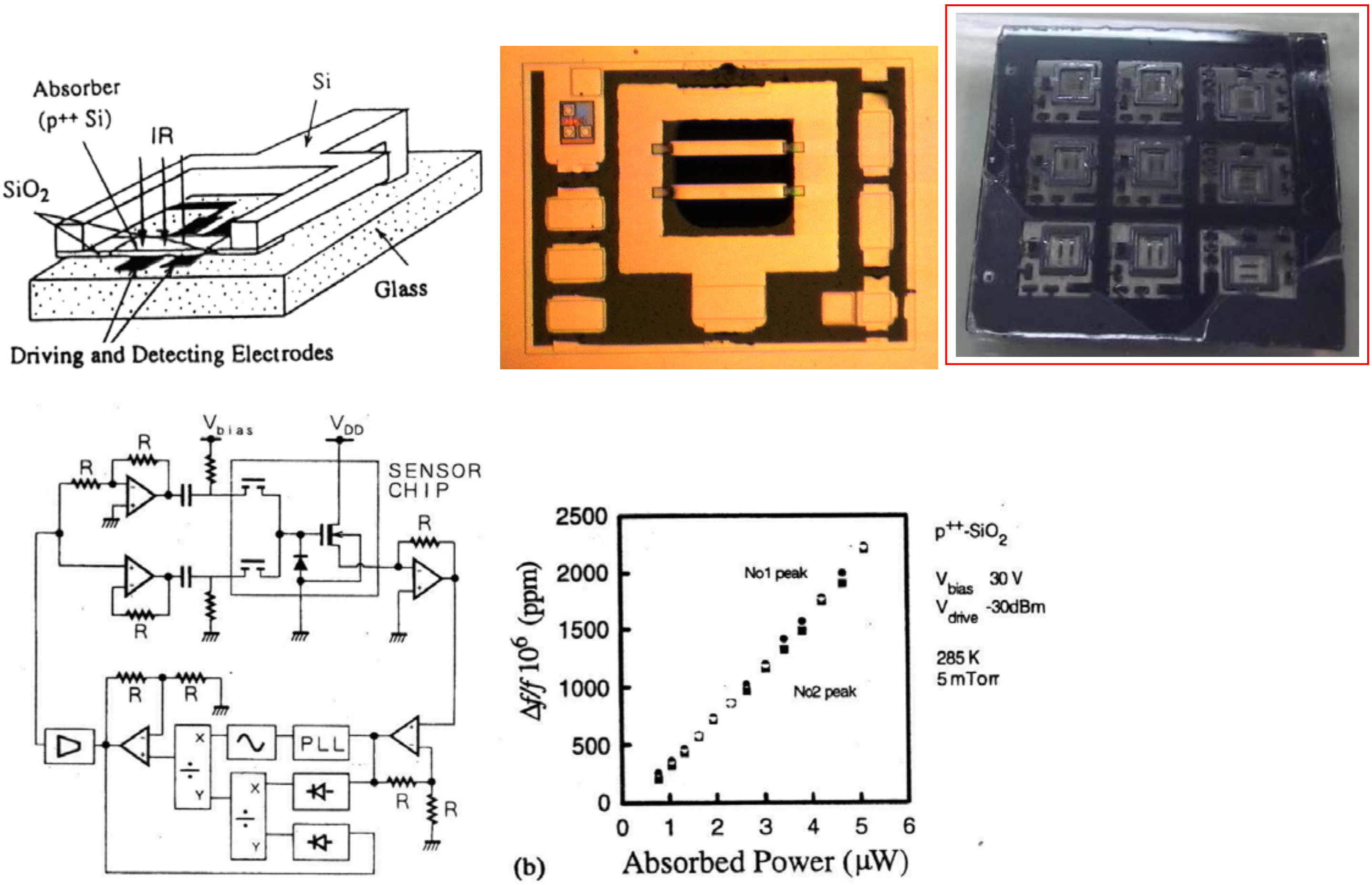






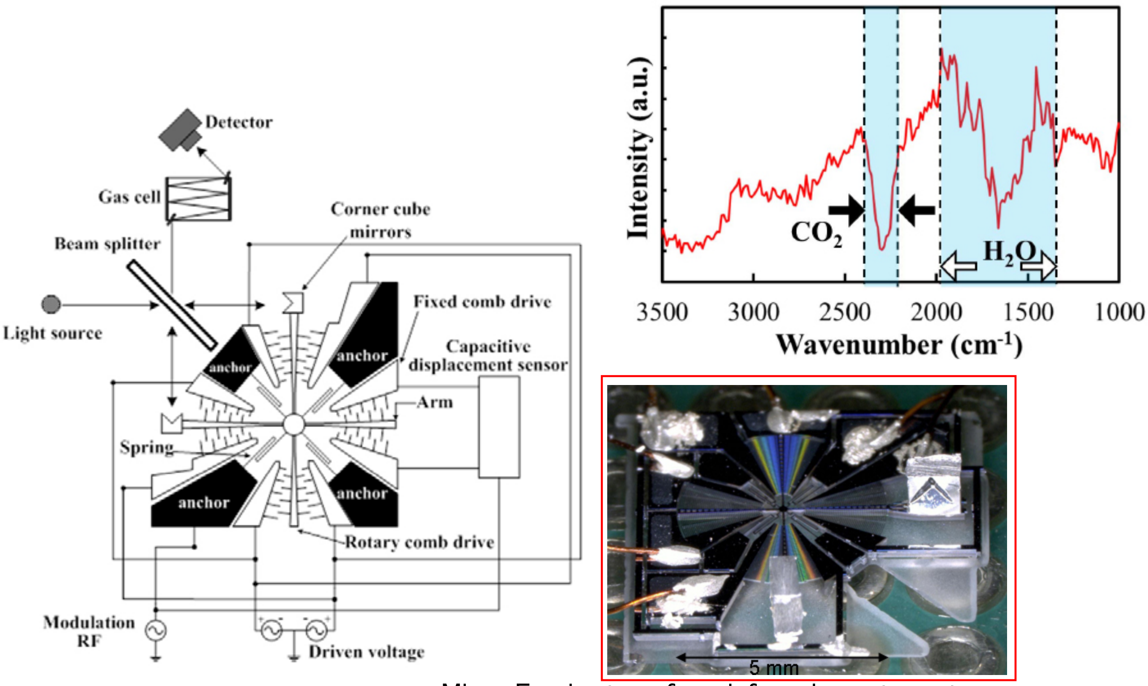
Ultra–small infrared temperature sensor using thermopile integrated with Si lens (Ricoh)
(H.Noguchi, H.Watanabe et.al, 31th Sensor Symposium (2014) 21pm1–B1)

A2 Infrared sensor



Resonant infrared sensor

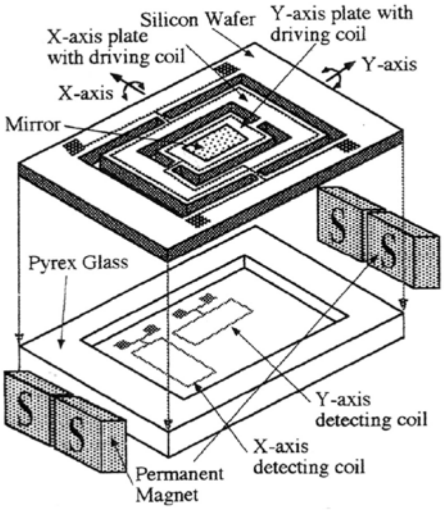
Reference : C.Cabuz, S.Shoji, K.Fukatsu, E.Cabuz, K.Minami and M.Esashi, Fabrication and Packaging of a Resonant Infrared Sensor Integrated in Silicon, Sensors and Actuators A, 43 (1994) pp.92-99

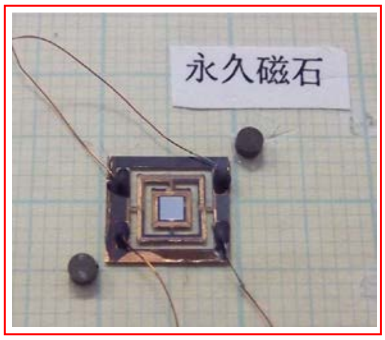


Micro Fourier transform infrared spectrometer

Reference : Y.-M. Lee, M. Toda, M.i Esashi, and T. Ono, Micro wishbone interferometer for Fourier transform infrared spectrometry, J. of Micromechanics and Microengineering, 21 (2011) 065039

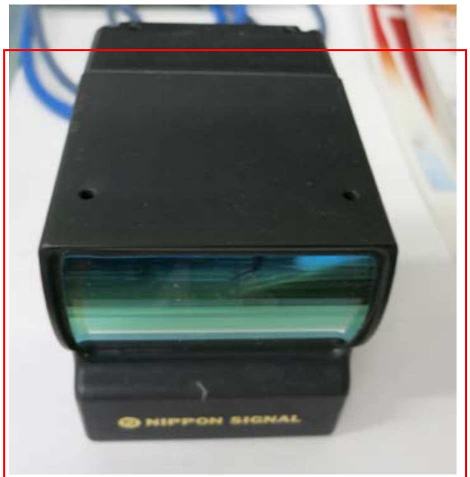
A3 # 2 axis galvano optical scanner

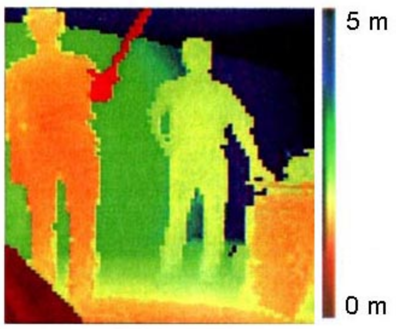




2 axis galvano optical scanner　(Tohoku Univ. – Japan Signal)

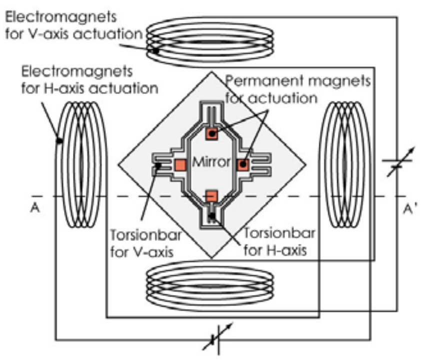
Reference : N.Asada, H.Matsuki, K.Minami and M.Esashi : Silicon micromachined two-dimensional galvano optical scanner, IEEE Trans. on Magnetics, 30 (1994) pp.4647-4649

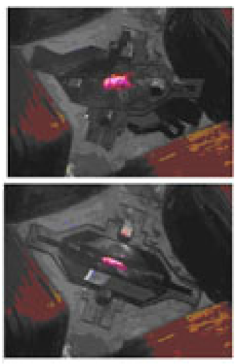


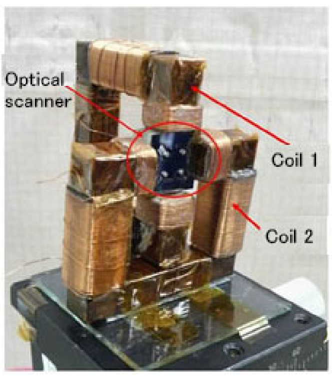


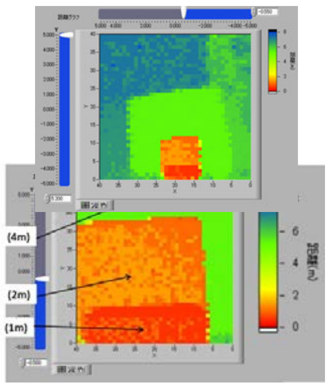
Ranging imager system "Eco scan" (Japan Signal) applied for platform door in railway station

Reference : T.Ishikawa, H.Inomata : Laser Ranging Sensor Using MEMS Optical Scanner "ECO SCAN"、Japan Signal Technical Report、33, 1, pp.41-46 (2009)







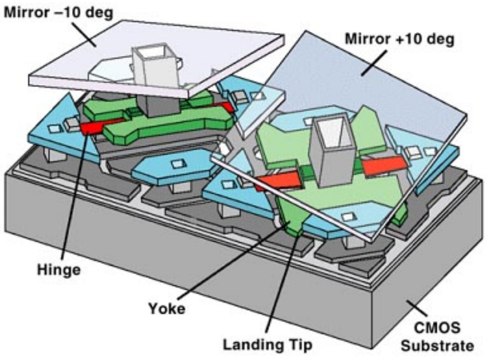


Electromagnetic non-resonance large scan-angle 2-axes optical scanner　　Zooming function

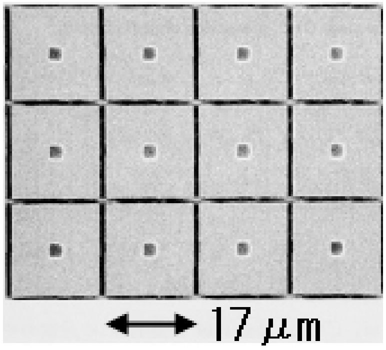
Reference :　W.Makishi, Y.Kawai and M.Esashi : Magnetic Torque Driving 2D Micro Scanner with a Non-Resonant Large Scan Angle, Trans. on IEEJ, 130-E, 4 (2010) 135-136

A4 DMD (Digital Micromirror Device) (TI (Texas Instruments), USA)

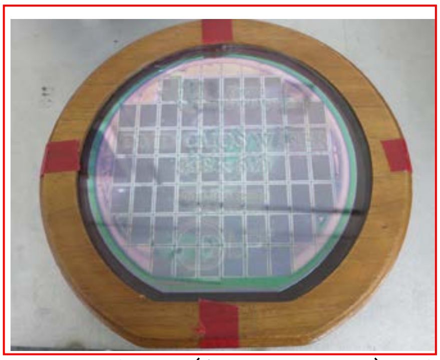
Electrostatically actuated mirror array is fabricated on CMOS chip for video projectors and digital cinema.
Binary pulse width modulation called DLP (Digital Light Processing) is used for gray scale sensation.
Amorphous metal of Al_3Ti is used for the hinge to solve the fatigue.

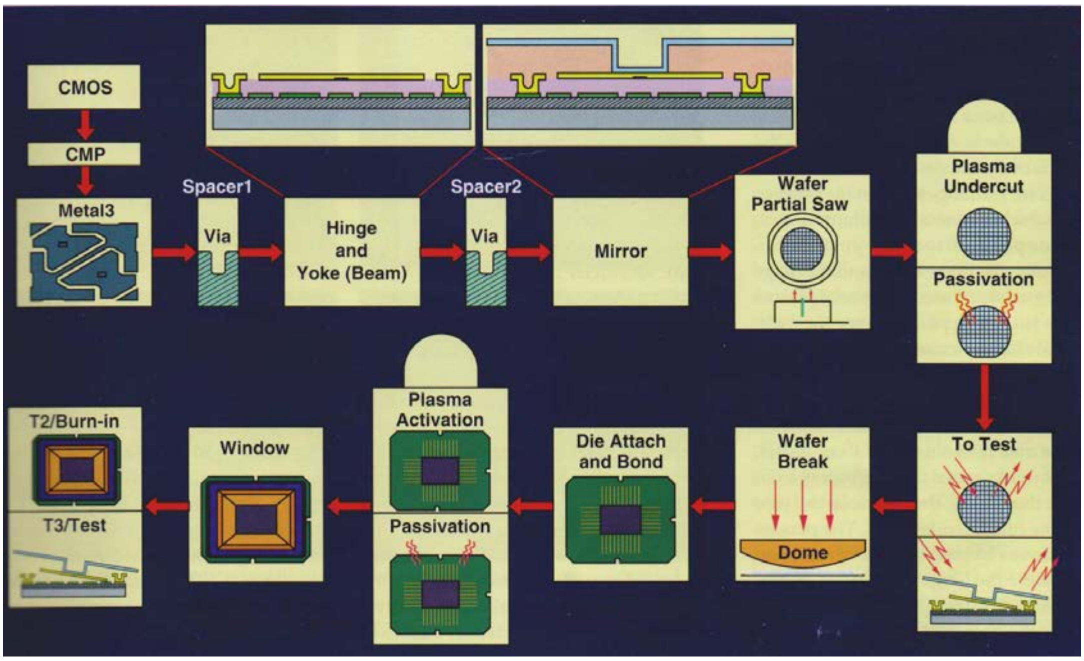


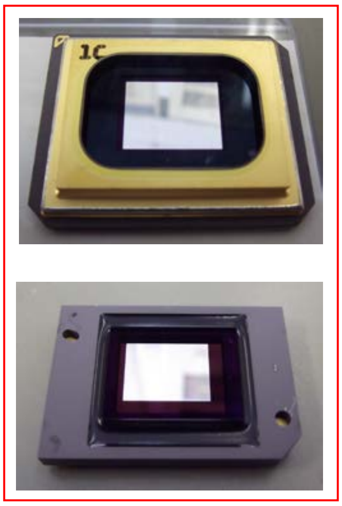
Principle of the movable mirror



Photograph of the mirror array

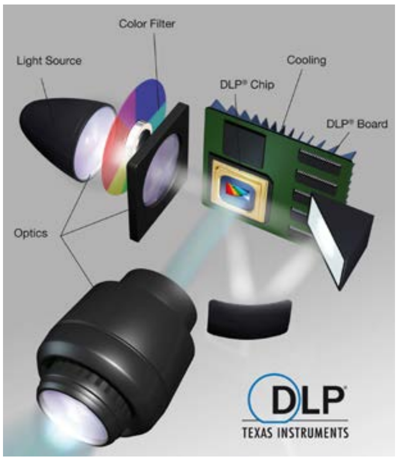

DMD on 6 inch (15cm diameter) wafer





DMD process flow

References : P.F.Van Kessel, L.J.Hornbeck, R.E.Meier and M.R.Douglass: A MEMS-based projection display, Proc. of the IEEE, 86, 8 (1998) 1687-1704

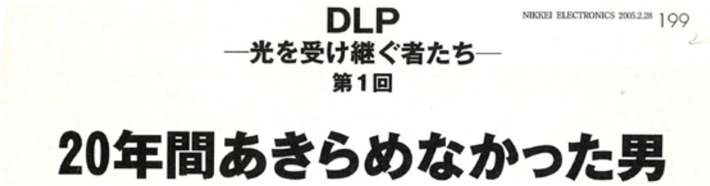


Video projector

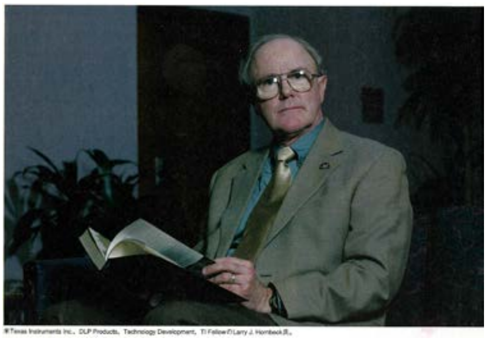
Digital cinema

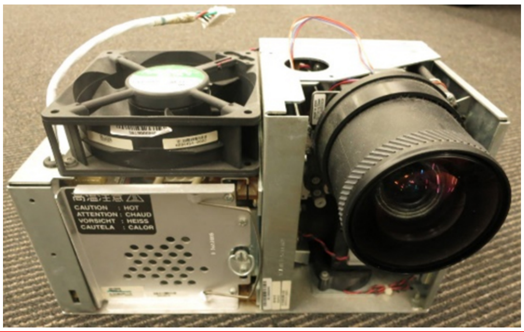

DLP Pico projector for mobile use

A5　Digital cinema using DMD (Digital Micromirror Device)


DLP
—光を受け継ぐ者たち—
第1回
NIKKEI ELECTRONICS 2005.2.28 199
20年間あきらめなかった男

Man who didn’t give up for 20 years





Video projector using DMD in 1995

DLP (no.1－ no.6) , Nikkei Electronics, 2005.2.28 – 2005.5.9 (in Japanese)　http://www.dlp.com/jp/
https://www.ti.com/about-ti/newsroom/news-releases/2015/2015-02-09-texas-instruments-fellow-larry-j--hornbeck--phd--wins-the-oscar-.html

Texas Instruments Fellow Larry J. Hornbeck, PhD, Wins the Oscar®

Academy Award® of Merit (Oscar® statuette) presented to DLP® chip inventor for his contribution, converting a 100-year-old industry to digital cinema technology

DALLAS, Feb. 9, 2015 /PRNewswire/ -- Larry J. Hornbeck, PhD, the inventor of the digital micromirror device (DMD) or DLP® chip, the technology that led to the design and development of DLP Cinema® display technology from Texas Instruments (TI) (NASDAQ: TXN), has been awarded an Academy Award® of Merit (Oscar® statuette) for his contribution to revolutionizing how motion pictures are created, distributed and viewed. The industry's conversion from 35-mm motion picture film to digital cinema is nearly complete worldwide, with DLP Cinema technology now powering more than eight out of 10 digital movie theatre screens.

DLP Cinema technology gives viewers consistent brightness and color-accurate images compared to 35-mm motion picture film. The technology not only makes it easier for studios to package and distribute movies, but also enables audiences to experience the true vision of the creators of the content.

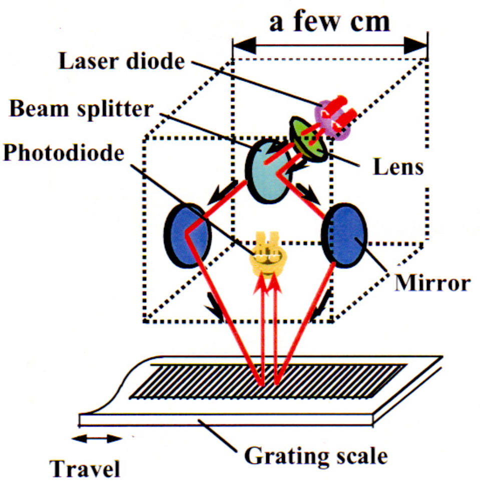
As a result of Hornbeck's invention, for more than two decades, award-winning TI DLP® product innovations have solved some of the world's most complex display and light-control issues in the personal electronics, industrial and automotive markets with powerful, flexible, programmable optical chipsets based on DLP technology.

Development of the DLP chip began in TI's Central Research Laboratories in 1977 when Hornbeck first created "deformable mirrors" to manipulate light in an analog fashion. But the analog technology consistently fell short of expectations. It was not until 1987 that he invented the DMD, the breakthrough technology that would become known as the DLP chip. During the mid-1990s, TI established the DLP Cinema team, chartered to develop a digital projector that could match the quality of 35-mm motion picture film.

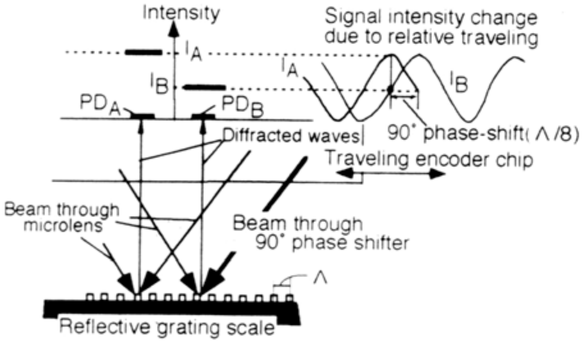
After years of testing and perfecting, the resulting technology made its public debut in 1999, when "Star Wars: Episode 1 – The Phantom Menace" was released as the first full-length motion picture shown with DLP Cinema technology. Over the subsequent 15 years, the cinema industry has nearly completed the conversion from film projectors to digital cinema projectors. Today, digital projectors powered by DLP Cinema technology are installed in more than 118,000 theatre screens around the globe, according to TI.

"It's wonderful to be recognized by the Academy. Following the initial inventions that defined the core technology, I was fortunate to work with a team of brilliant Texas Instruments engineers to turn the first DMD into a disruptive innovation," said Hornbeck, who has 34 U.S. patents for his groundbreaking work in DMD technology. "Clearly, the early and continuing development of innovative digital cinema technologies by the DLP Cinema team created a definitive advancement in the motion picture industry beyond anyone's wildest dreams."

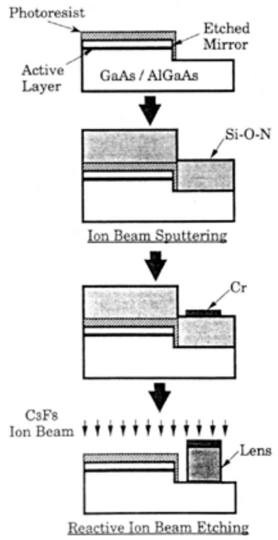
A6 Optical encoder (NTT)



Principle of conventional optical encoder

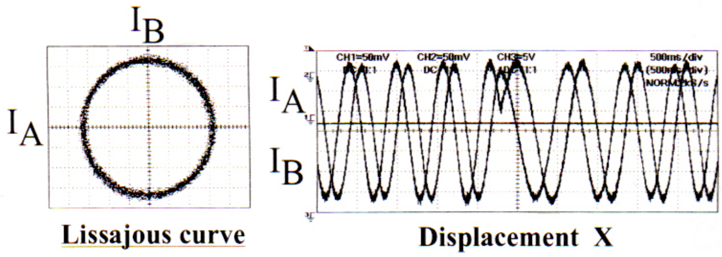


Principle of the developed optical encoder



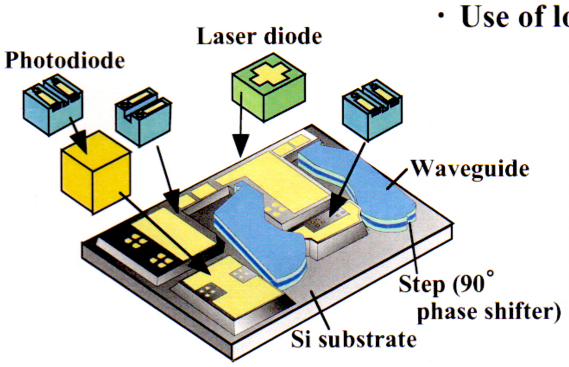
Fabrication of etched mirror

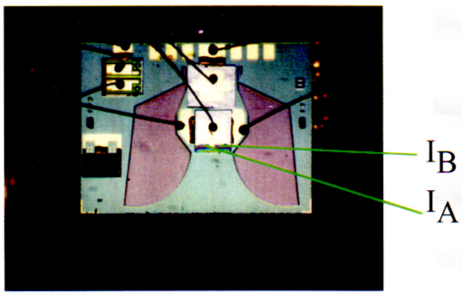
One revolution of Lissajous curve corresponds to displacement of 0.8 or 1.6 μm.

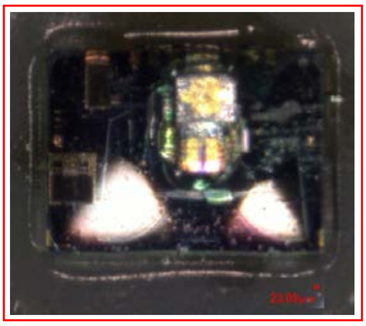


Measurement of displacement

- **Accurate bonding on silicon substrate**
- **Use of long-life optical elements (LD, PD)**

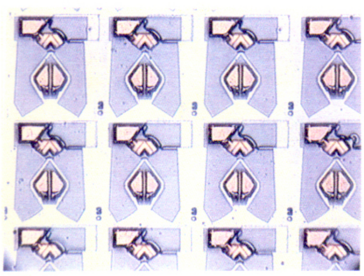


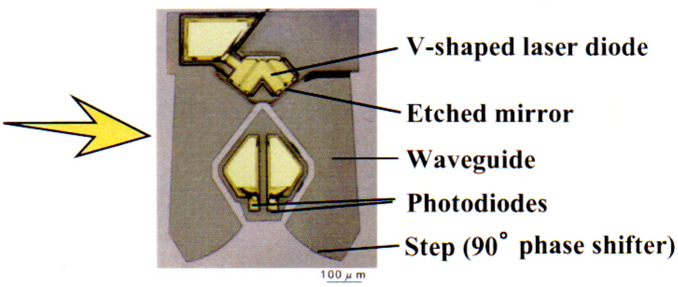


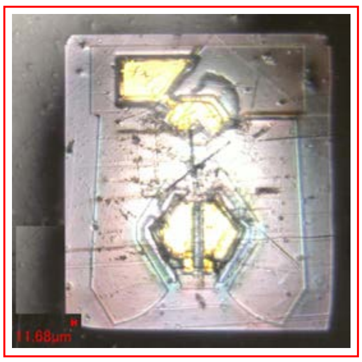


Hybrid method (assembly)

- **4000 chips fabricated using batch process on 2-inch GaAs substrate**



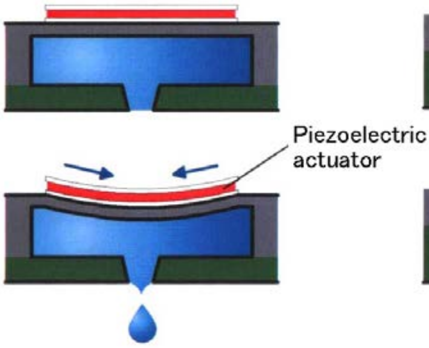




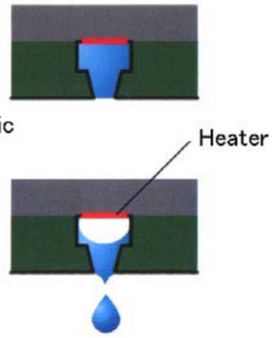
Monolithic method

Reference : R.Sawada, O.Ohguchi, K.Mise and M.Tsubamoto, Fabrication of Advanced Integrated Optical Micro-encorder Chip, IEEE MEMS'94 (1994) pp.337-342

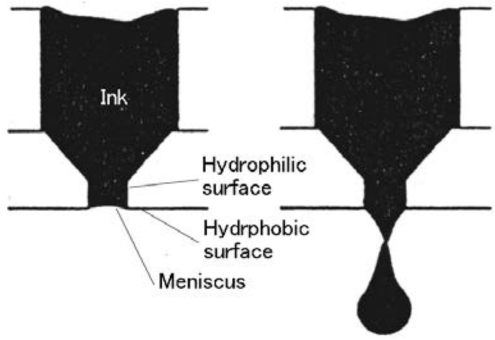
A7 Piezoelectric, thermal inkjet printer head



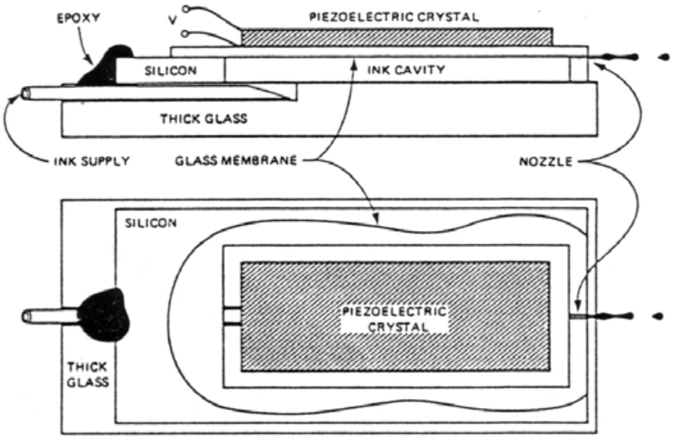
Piezoelectric type
(EPSON, XAAR)



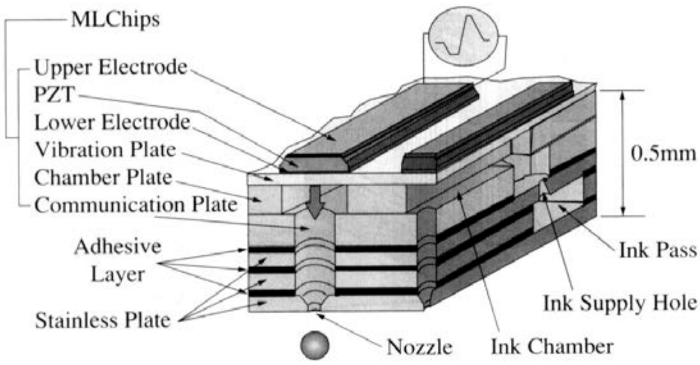
Thermal type
(CANON. HP, Lexmark, XEROX)



Principle of ink droplet ejection



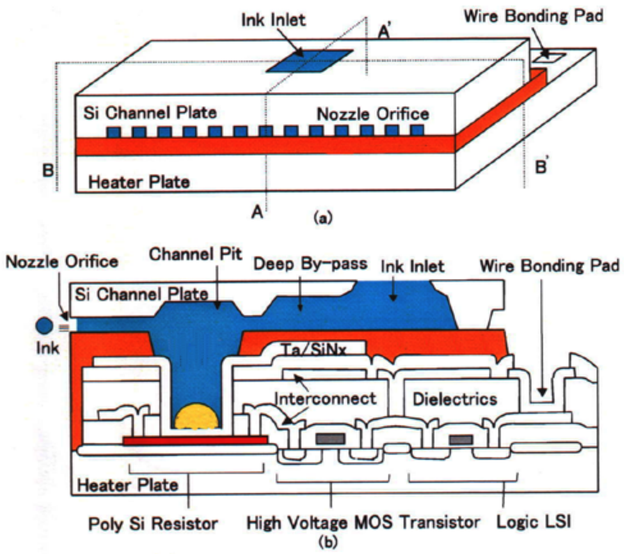
On demandPiezoelectric Ink-jet print head



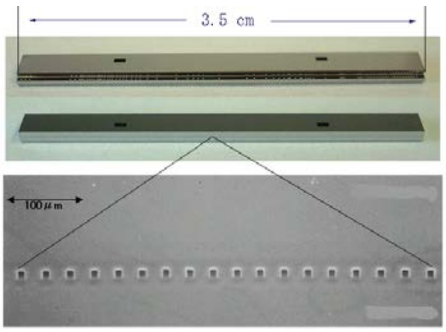
Piezoelectric Ink-jet print head (Seiko Epson)

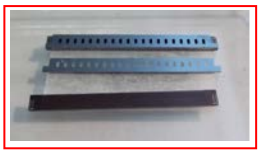
Reference : K.P.Petersen, Fabrication of an Integrated, Planar Silicon Ink-Jet Structure, IEEE Trans. on Electron Devices, ED-26 (1979) pp.1918-1920

Ink-jet Head (Seiko Epson), 2003 MEMS Technology Outlook (2003) pp.71-74



Structure

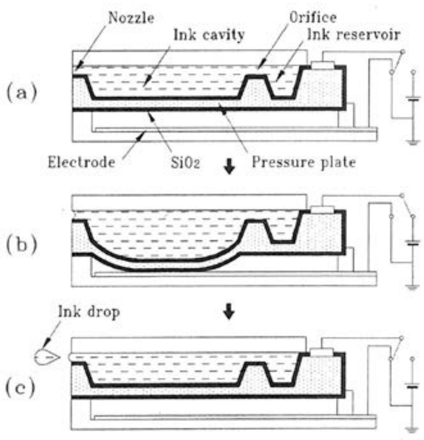




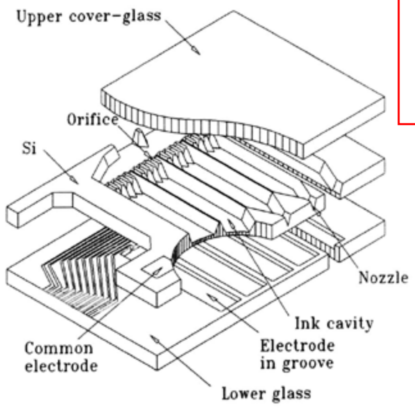
Nozzle

Reference : M.Murata, M.Kataoka, R.Nayve, A.Furugawa, Y.Ueda, T.Mihara, M.Fujii and T.Iwamori (Fuji Xerox), High Resolution Long Array Thermal Ink Jet Printhead with On-chip LSI Heater Plate and Micromachined Si Channel Plate, IEICE Trans. Electronics, E-84-C (2001) pp.1792-1800

A8 Electrostatic inkjet printer head



Principle

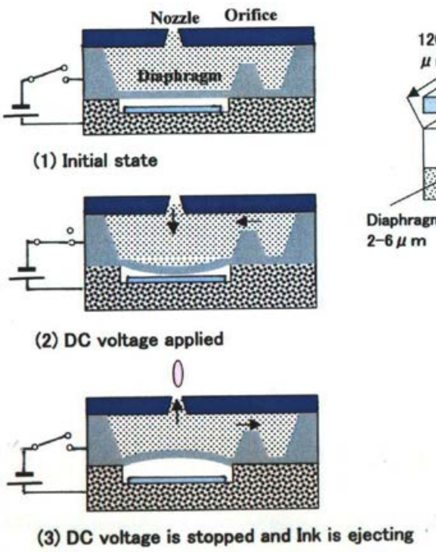


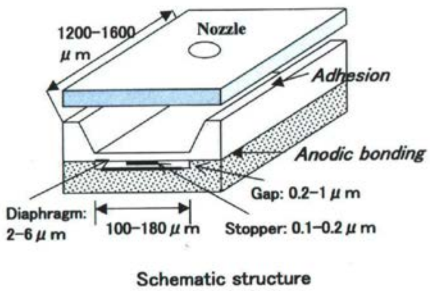
Structure

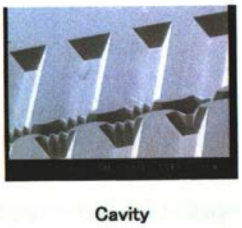
Ink tank – head assembly

Electro static printer head (Seiko Epson)

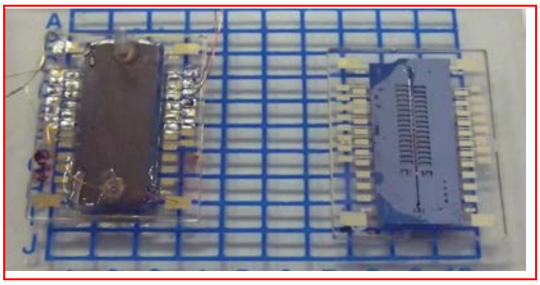
Reference : S.Kamisuki, T.Hagata, C.Tezuka, Y.Nose, M.Fujii and M.Atobe, A Low Power, E;ectrostatically-driven Commercial Inkjet Head, Proc. of IEEE MEMS (1998) pp.63-68



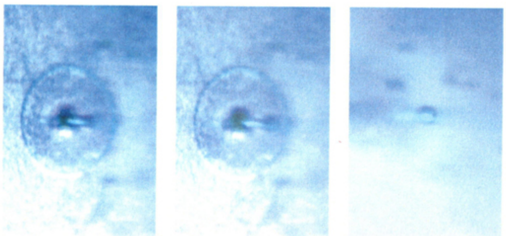




Cavity

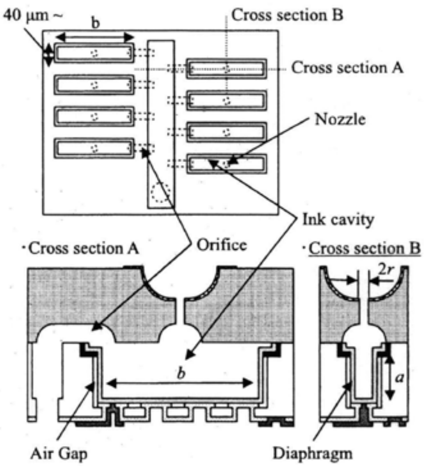


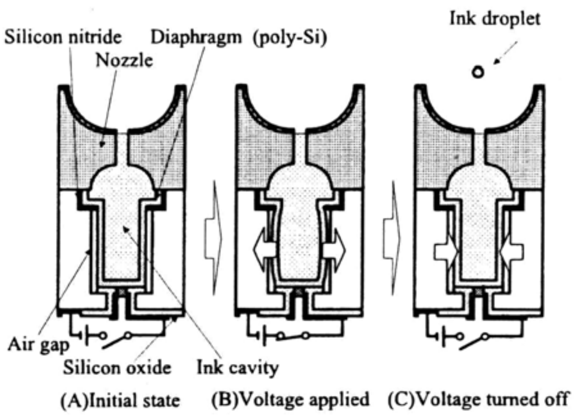
Ink head

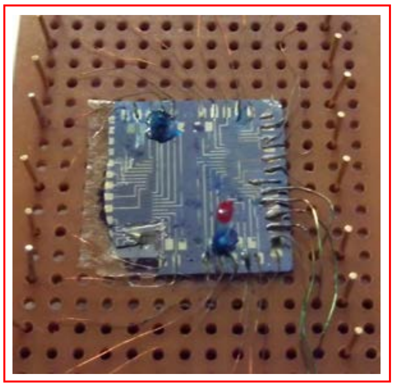


Principle Structure and nozzle photograph Strobe observation of the ink ejection

Electrostatic inkjet printer head for high speed low power line printer (Tohoku Univ. — Sony)



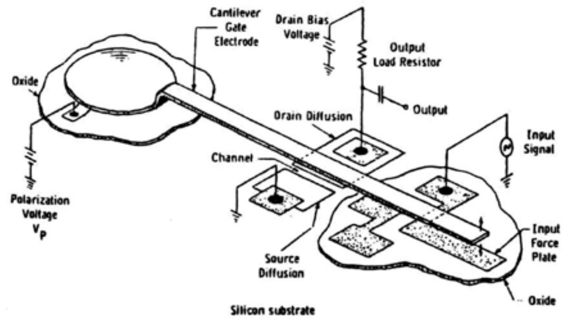


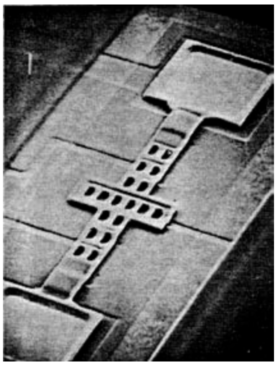


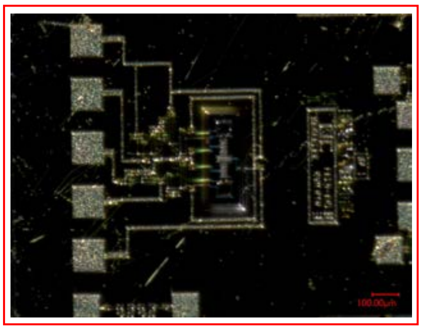
Electrostatic inkjet printer head with vertical diaphragms

Reference : T.Norimatsu, S.Tanaka and M.Esashi, Vertical Diaphragm Electrostatic Actuator for a High Density Ink Jet Printer Head, Trans. IEE ofJapan, 125-E (2005) pp.350-354

A9 MEMS resonator (USA)



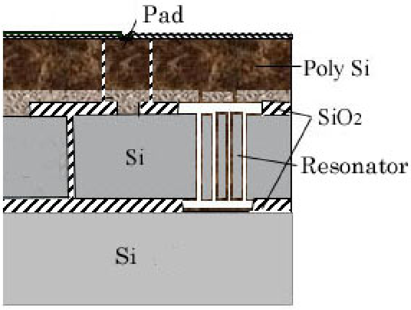


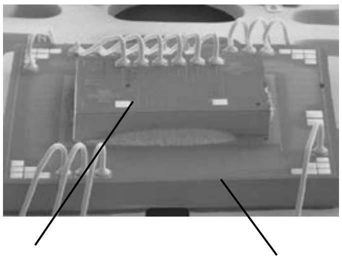


Resonant gate transistor (Westing house) **Resonant micro-bridge** (U.C.Berkeley)

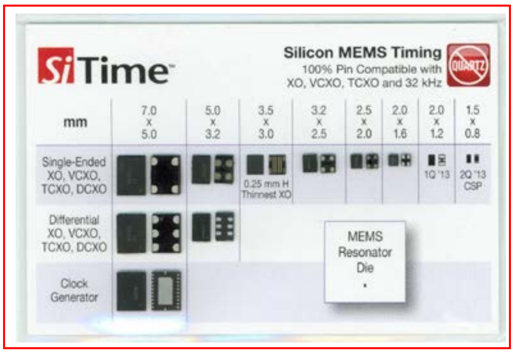
Reference : H.C.Nathanson et.al. The resonant gate transistor, IEEE Trans. on Electron Devices, ED-14 (1967) 117-133

R.T.Howe and R.S.Muller, Resonant-Microbridge Vapar Sensor, IEEE Trans. on Electron Devices, ED-33 (1986) pp.499-506

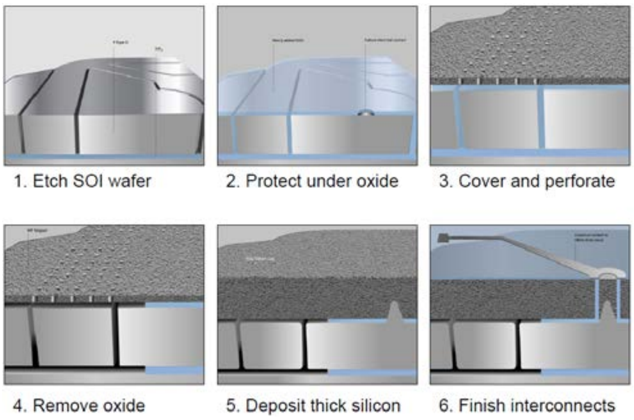


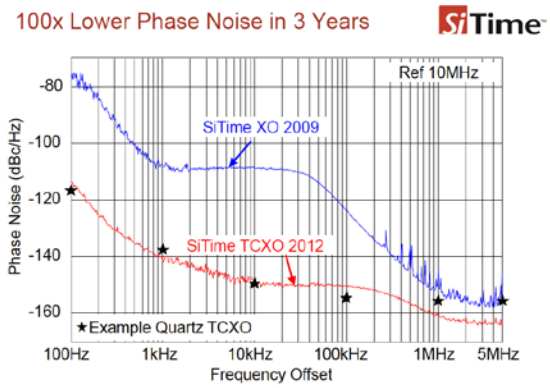


MEMS resonator chip Circuit chip



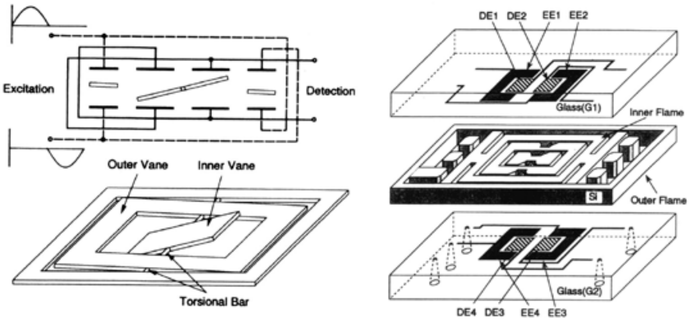
MEMS oscillator (SiTime)

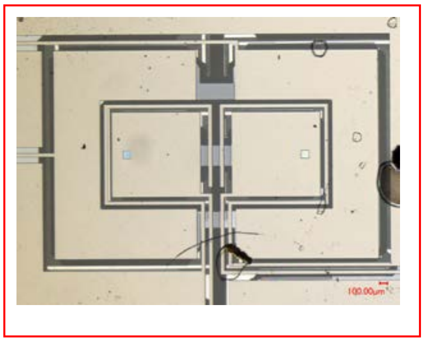




Reference : M.Lutz, A.Partridge, P.Gupta, N.Buchan, E.Klassen, J.McDounald and K.Petersenand, MEMS Oscillators for High Volume Commercial Applications, Technical Digest of Transducers' 07 (2007) pp.49-52

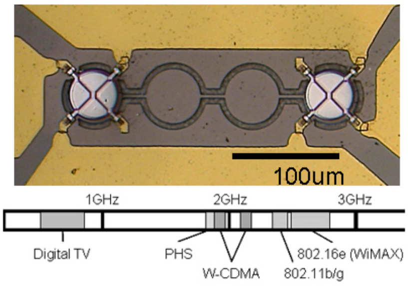
A10 MEMS resonator（disk, Lamb etc.)

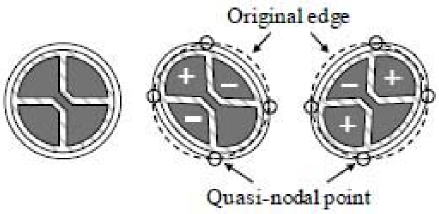


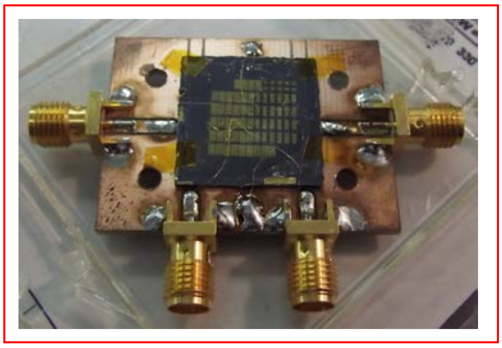


Packaged high Q MEMS trsonator (Tohoku Univ. – Shimazu)

Reference : K.Yoshimi, K.Minami, Y.Wakabayashi and M.Esashi, Packaging of Resonant Sensors, Technical Digest of the 11th Sensor Symposium(1992) pp.35–38

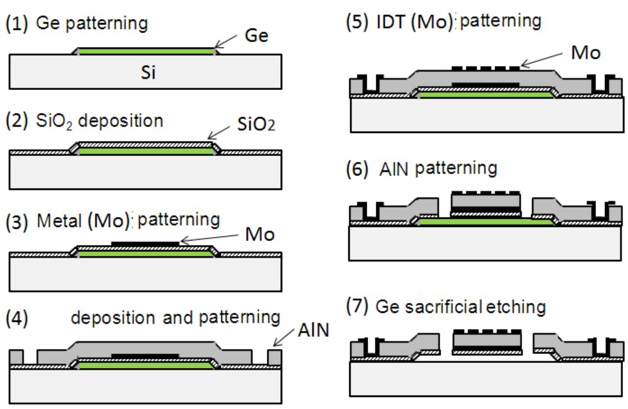


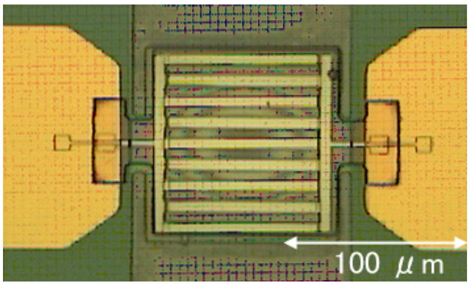


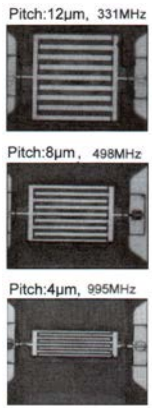


Micro disk resonator（Tohoku Univ. – NICT）

Reference :T.Matsumura, M.Esashi, H.Harada and S.Tanaka : Multi-band Radio-frequency Filter Fabricated Using Polyimide-based Membrane Transfer Bonding Technology, J. of Micromech. Microeng., 20, 9 (2010) 095027(9pp)

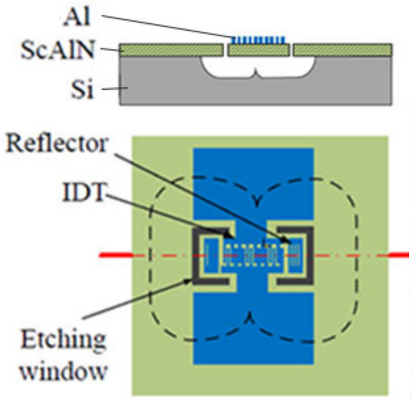


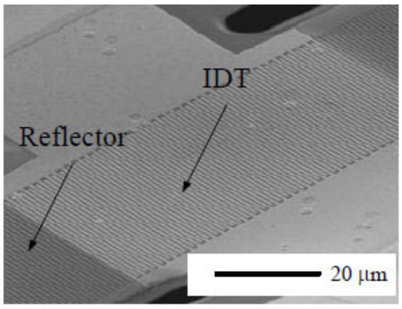


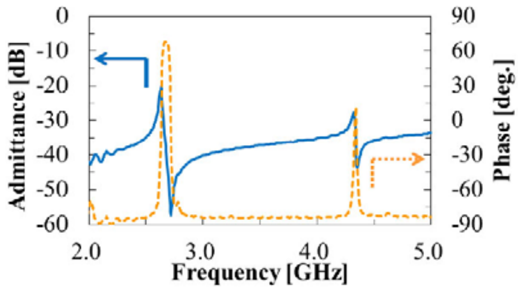


Lamb wave resonator (Tohoku Univ. – Japan Denpa)

Reference : K.Hirano, M.Esashi and S.Tanaka, Aluninum Nitride Lamb Wave Resonator Using Germanium Sacrificial Layer, 2nd International Workshop on Piezo-devices Based on Latest MEMS Technologies (2008) pp.111–117



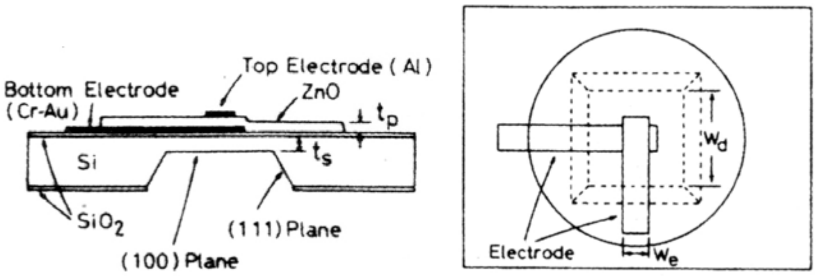




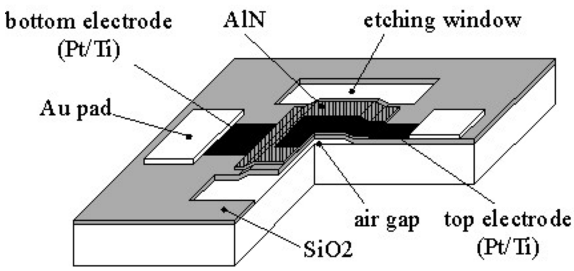
Lamb wave resonator using Sc–AlN,

Reference : A.Konno et.al ::ScAlN Lamb Wave Resonator in GHz Range Released by XeF_2 Etching, 2013 IEEE Ultrasonics Symposium 2013 1378–1381)

FBAR (Film Bulk Acoustic Resonator)



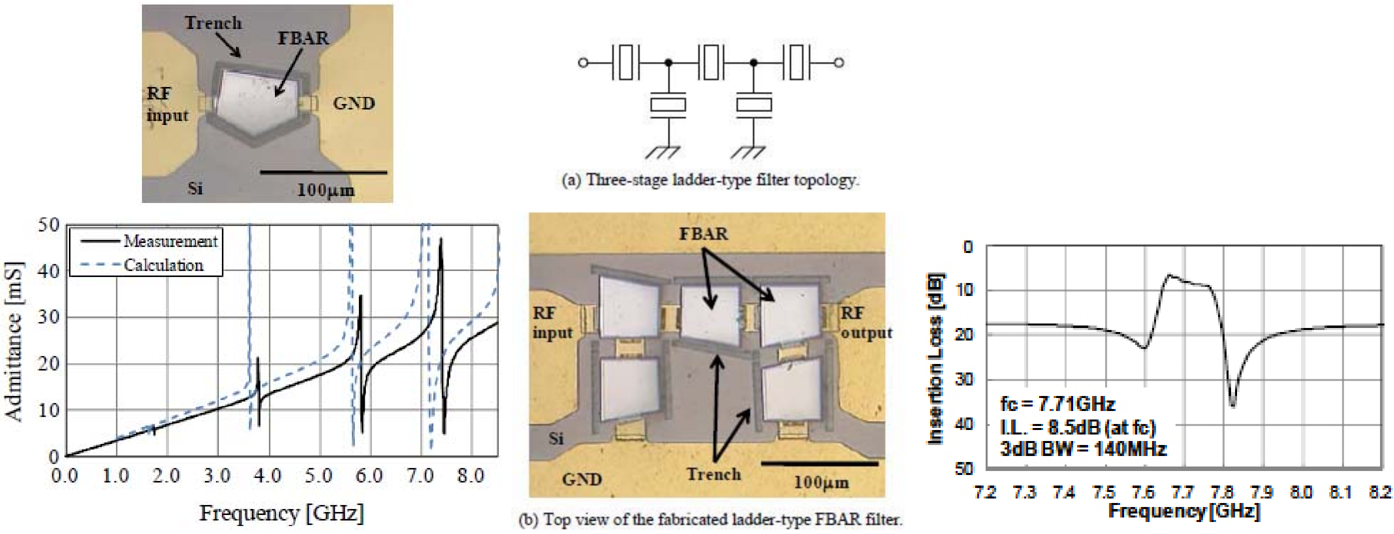
FBAR (S. Nakamura, Tohoku Univ.)



FBAR

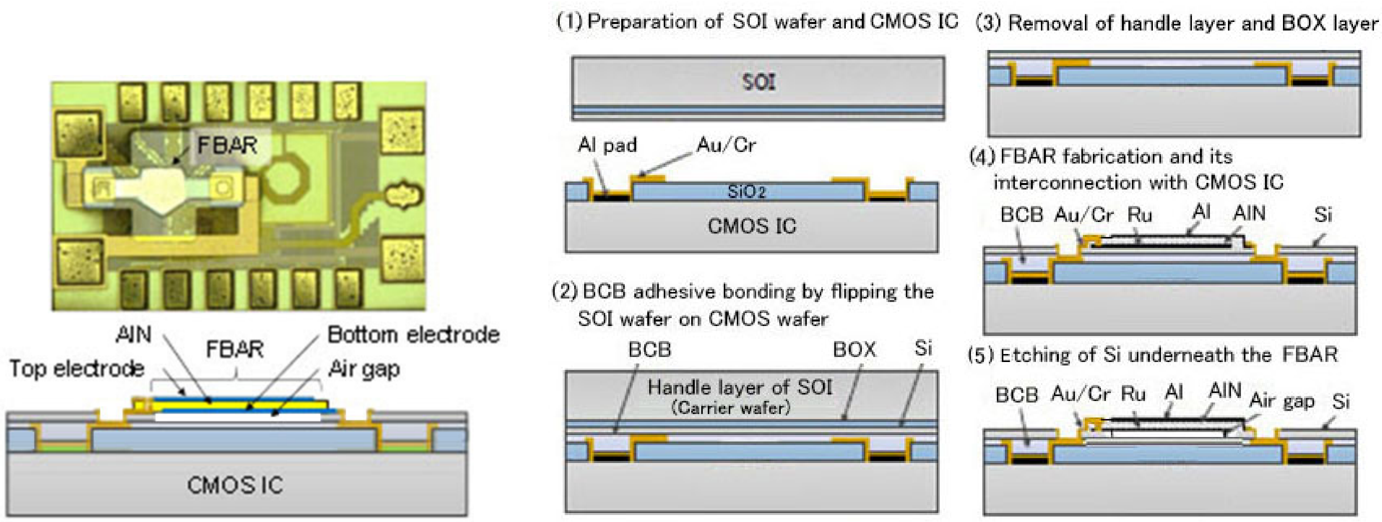
Reference : K.Nakamura, H.Sasaki and H.Shimizu, A Piezoelectric Composite Resonator Consisting of a ZnO Film on an Anisotropically Etched Silicon Substrate, Proc. of 1st Symp. On Ultrasonic Electronics (1980), Jap. J. of Applied Physics, 20(1981) Supplement 20-3, pp.111-114

M.Hara, J.Kuypers, T.Abe and M.Esashi, Surface Micromachined AlN Thin Film 2GHz Resonator for CMOS Integration, Sensors & Actuators A, 117 (2005) pp.211-216



FBAR (Film Bulk Acoustic Resonator) (Tohoku Univ. – NICT)

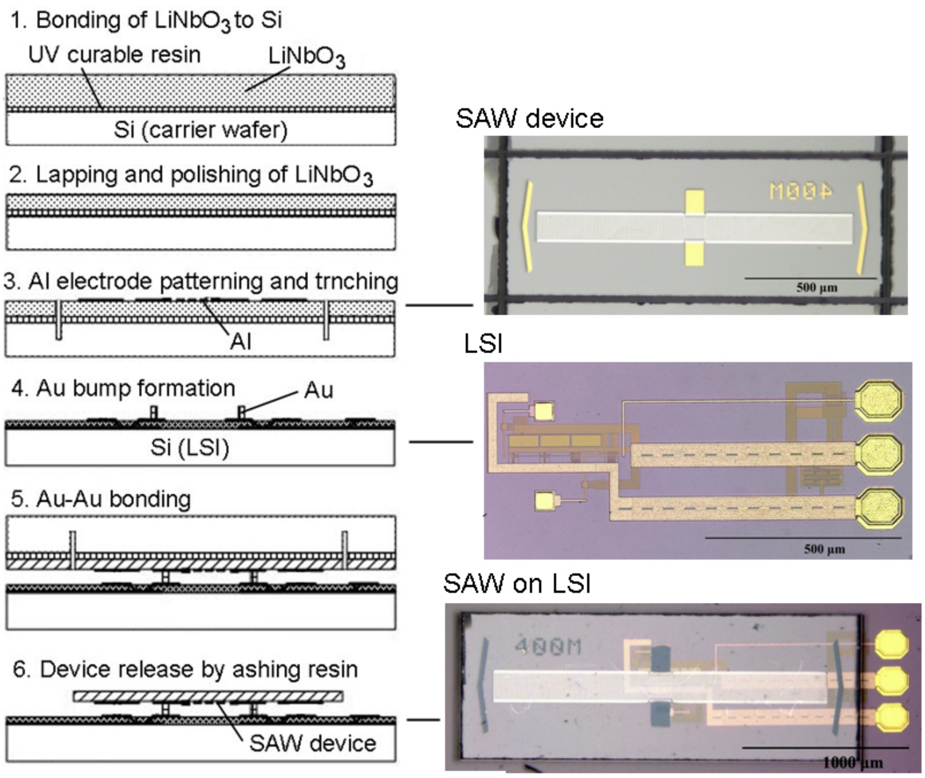
Reference : T.Matsumura, M.Esashi, H.Harada and S.Tanaka, Multi-band Radio-frequency Filter Fabricated Using Polyimide-based Membrane transfer Bonding Technology, J. of Micromech. Microeng., 20 (2010) 095027(9pp)

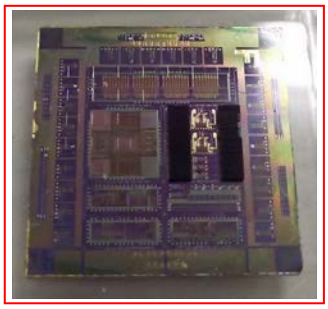


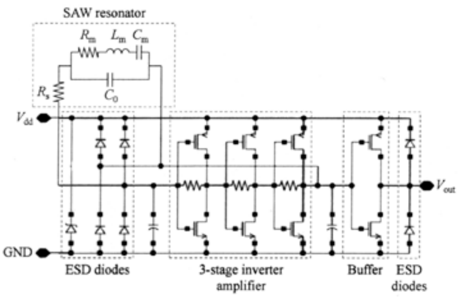
FBAR(film bulk acoustic resonator) fabricated on LSI

Reference : Kochhar et. al, 2012 IEEE Internl. Ultrasonic Symp. (2012) 1047

A12 SAW device on LSI (surface acoustic wave device on LSI)

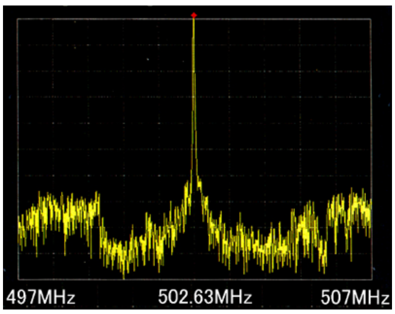




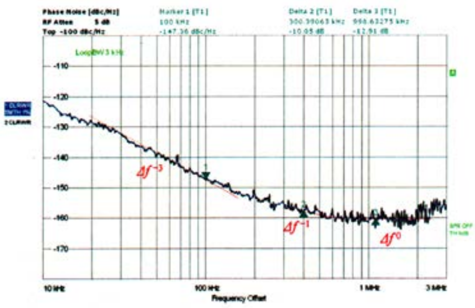


Fabrication process

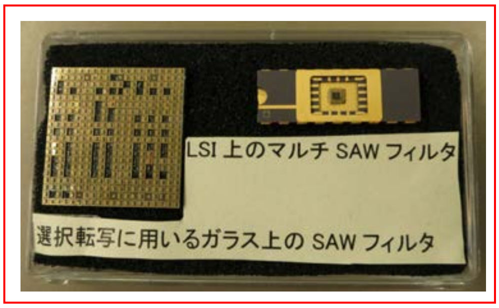
CMOS circuit



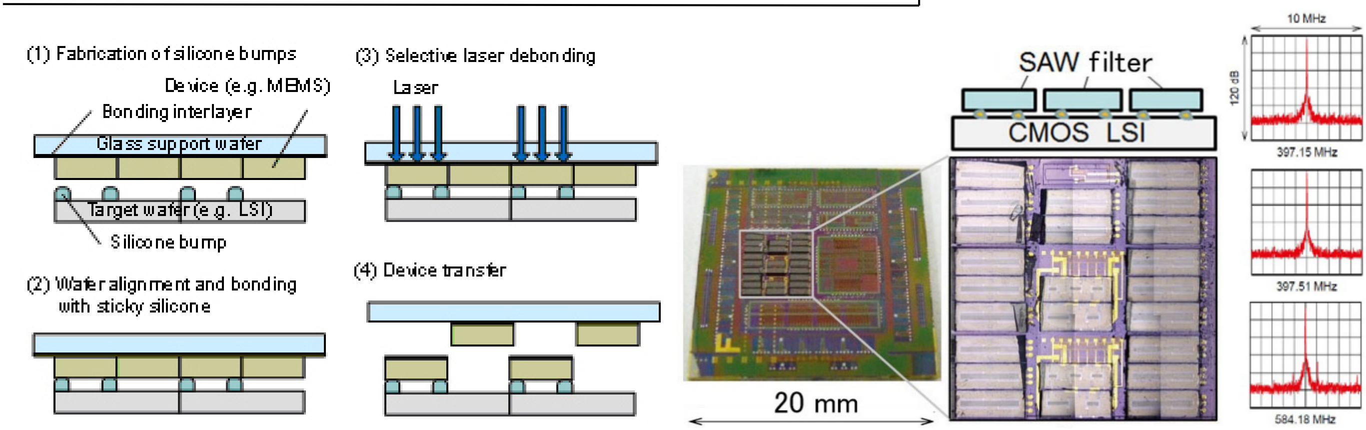
Oscillation spectrum



Jitter characteristics



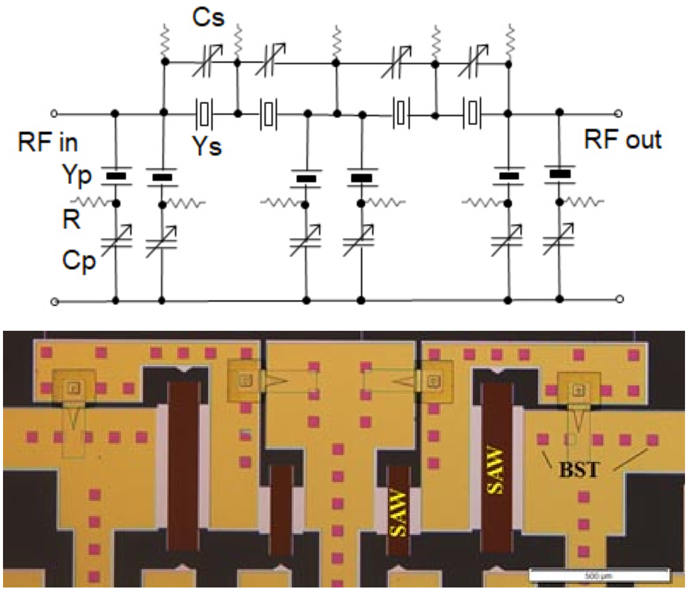
Reference : K.D.Park, M.Esashi and S.Tanaka, Preparation of Thin Lithium Niobate Layer on Silicon Wafer for Wafer–level Integration of Acoustic Devices and LSI, Trans. of IEE in Japan, 130–E (2010) pp.236–241



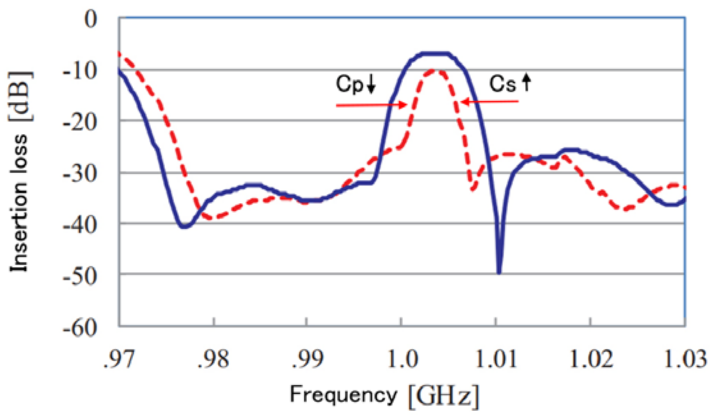
Multi SAW filter using selective transfer process

Reference ; S. Tanaka, M. Yoshida, H. Hirano and M. Esashi, Lithium Niobate SAW Device Hetero–transferred onto Silicon Integrated Circuit Using Elastic and Sticky Bumps, 2012 IEEE International Ultrasonics Sympsium (2012) p.1047

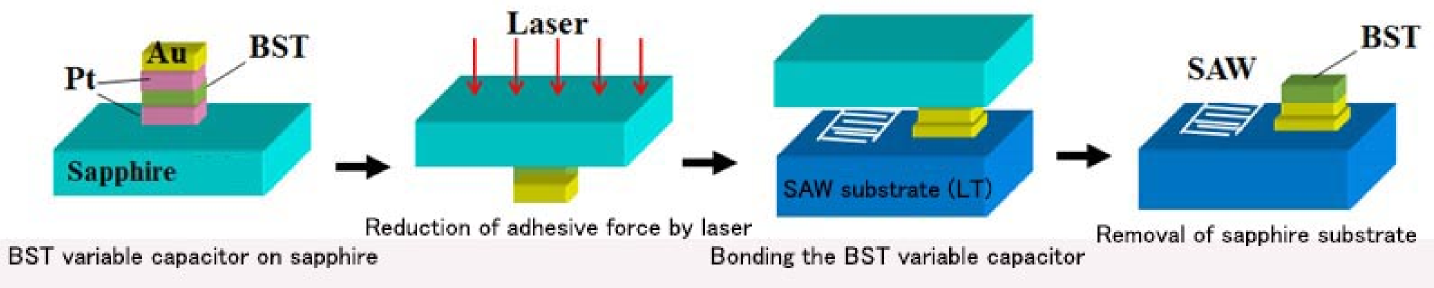
A13 Tunable SAW filter using variable capacitor



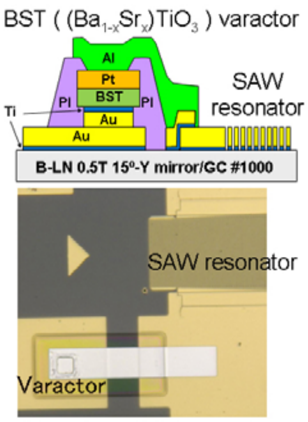
Principle and photograph



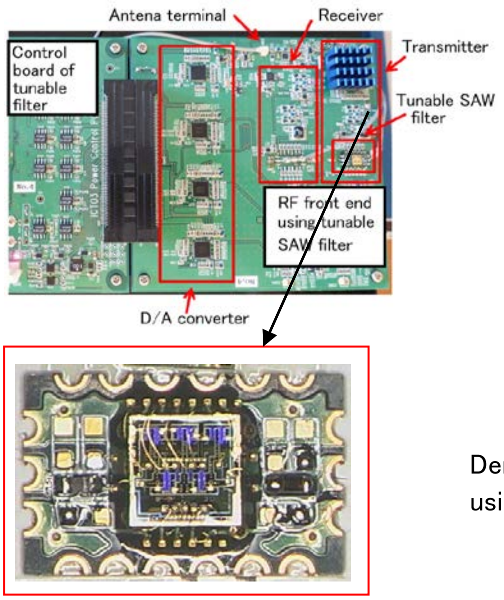
Chracteristics

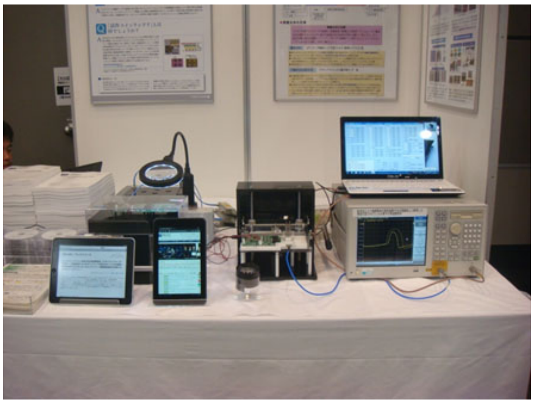


Fabrication process of variable capacitor using BST($(Ba_{1-X}Sr_X)TiO_3$)



Transferred BST varactor
(Tuning ratio of 1.6 at 3 V)





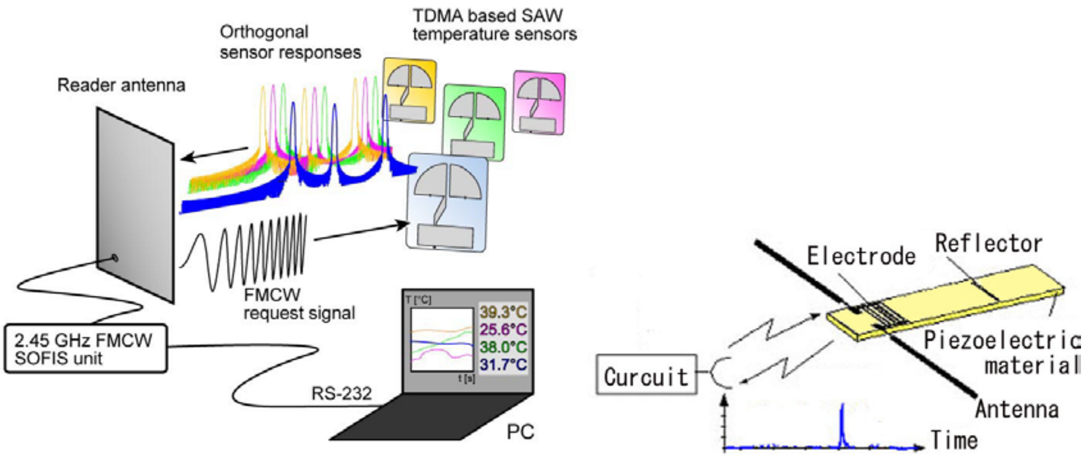
Demonstration of wireless communication system using cannel of digital TV in case of emergency

Reference : Hideki Hirano et.al, Bandwidth-tunable SAW Filter Based on Wafer-level Transfer-integration of $BaSrTiO_3$ Film for Wireless LAN System using TV White Space, Proc. IEEE Ultrason. Symp., USA (2014) 803-806

Reference : H.Hirano, T.Kimura, I.P.Koutsaroff, M.Kodato, K.Hashimoto, M.Esashi and S.Tanaka, Integration of BST Varactors with Surface Acoustic Wave Device by Film Transfer Technology for Tunable RF Filters , J. of Micromech. Microeng., 23, 2 (2013) 025005 (9pp)

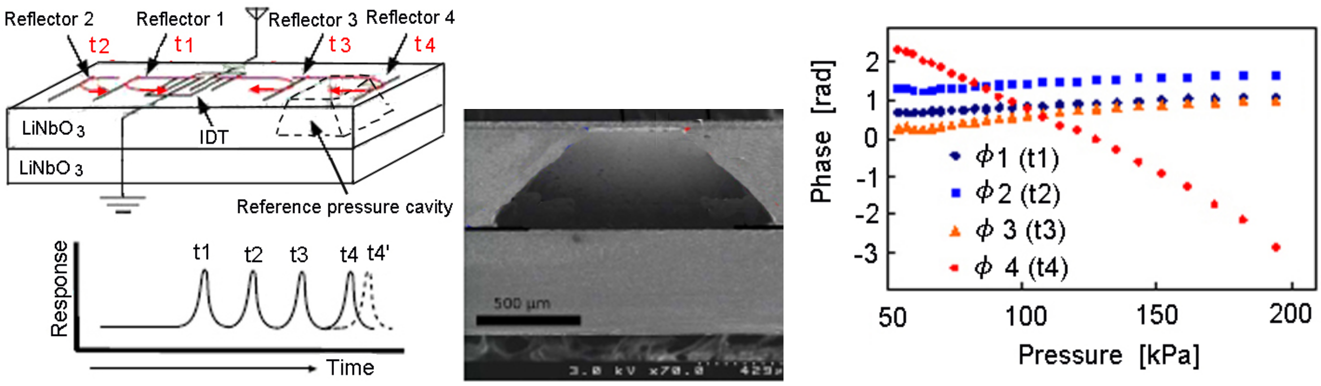
A14 SAW passive wireless sensor

(Strategic Information and Communication R&D Promotion Program (SCOPE) 2006FY – 2008FY)



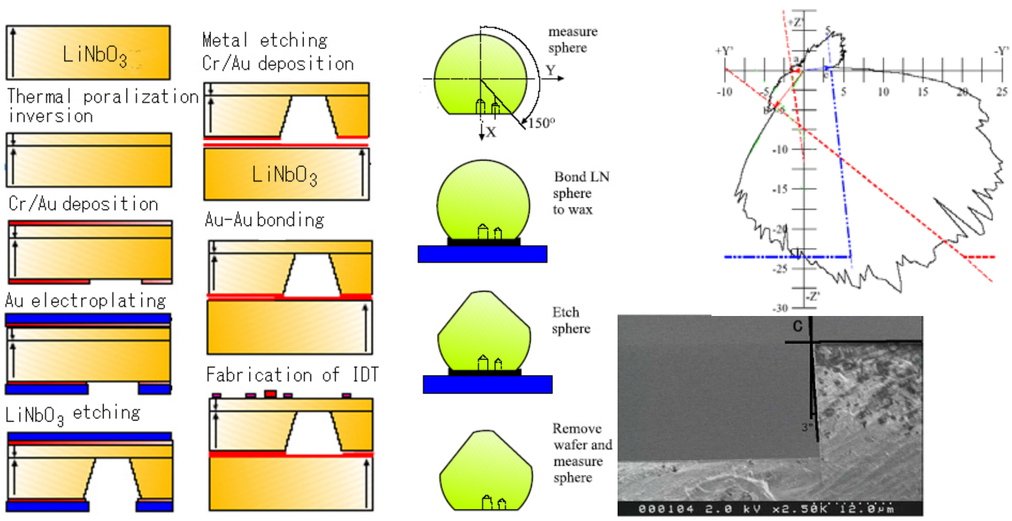
Principle of SAW passive wireless sensor

Reference : J. H. Kuypers, L. M. Reindl, S. Tanaka and M. Esashi, Maximum Accuracy Evaluation Scheme for Wireless SAW Delay Line Sensors, IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, 55 (2008) pp.1640–1652



Application to tire pressure monitor (Tohoku Univ. – Nissan motor)

Reference : S.Hashimoto, J.H.Kuypers, S.Tanaka and M.Esashi, Design and Fabrication of Passive Wireless SAW Sensor for Pressure Measurement, Trans. IEE of Japan, 128-E (2008) pp.231–234



Selective etching and simulation of anisotropic etching of $LiNbO_3$

Reference : A. B. Randles, M. Esashi and S. Tanaka, Etch Stop Process for Fabrication of Thin Diaphragms in Lithium Niobate, Jap. J. of Applied Physics, 46 (2007) pp.L1099–L1101

A.B.Randles, M.Esashi and S.Tanaka, Etch Rate Dependence on Crystal Orientation of Lithium Niobate, IEEE Trans. on Ultrasonics, Ferroelectrrics, and Frequency Control, 57 (2010) pp.2372–2380