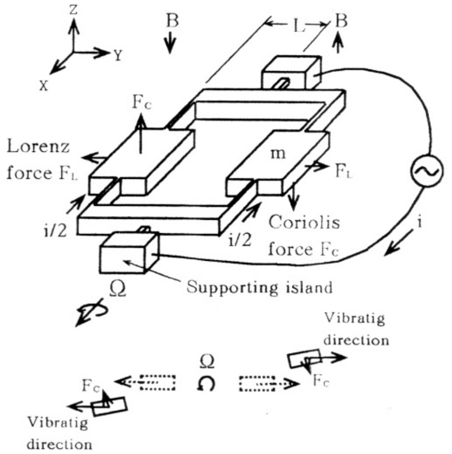
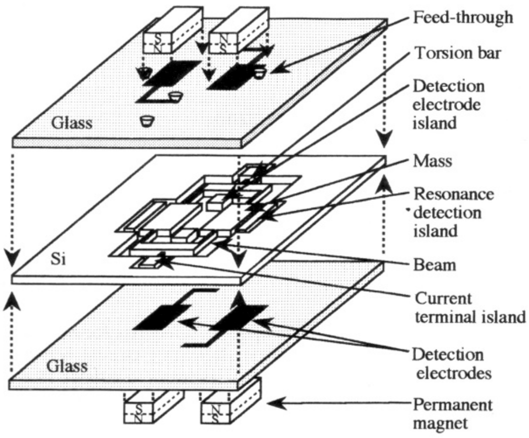
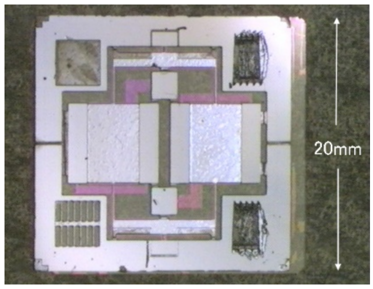
C1 Electromagnetically driven resonating gyroscope

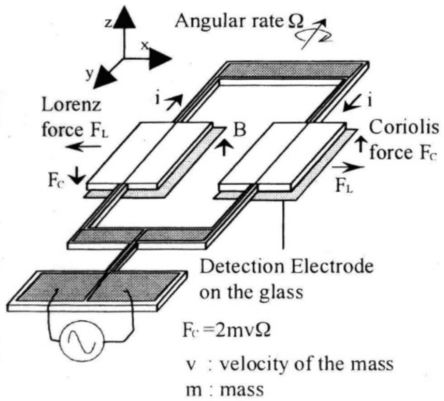


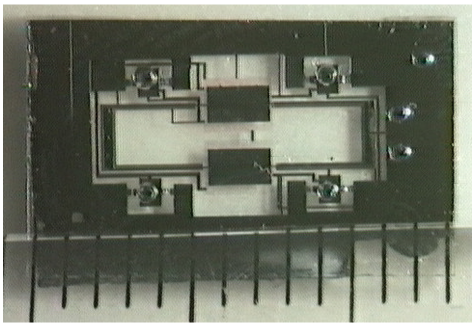
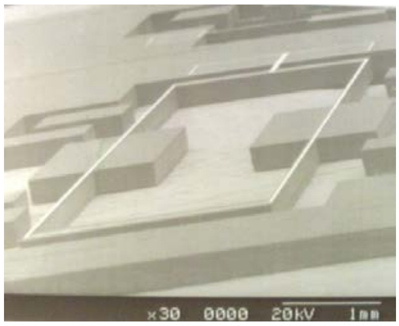




Electromagnetically excited capacitive sensing gyro by anisotropic etching of (110) Si (Tohoku Univ. – Toyota Motor)

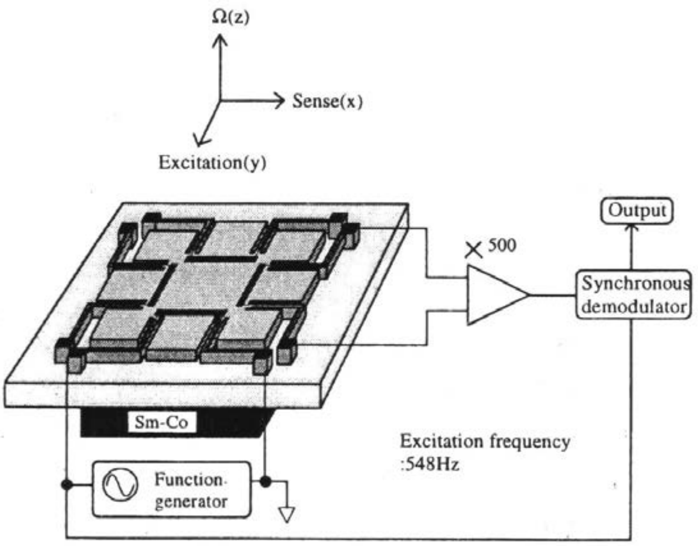
Reference : M.Hashimoto, C.Cabuz, K.Minami and M.Esashi, Silicon Resonant Angular Rate Sensor Using Electromagnetic Exitation and Capacitive Detection, Micro System Technologies'94 (1994) pp.763-772

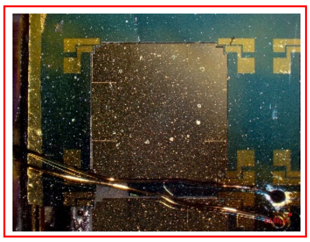
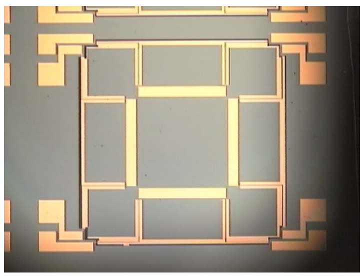


Electromagnetically excited capacitive sensing gyro by Deep RIE

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

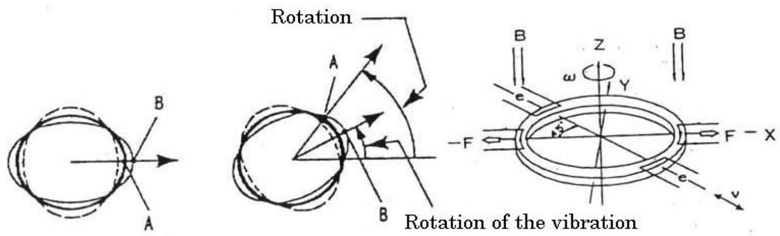


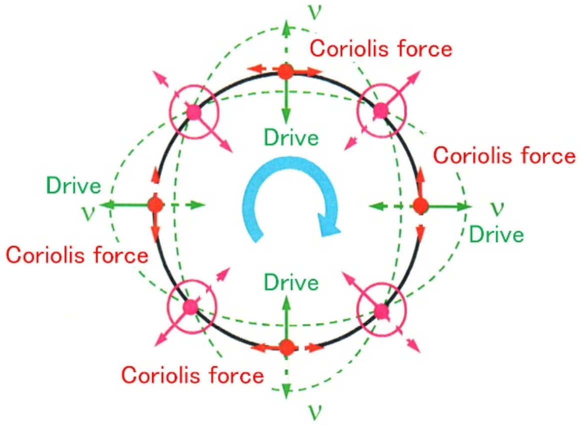




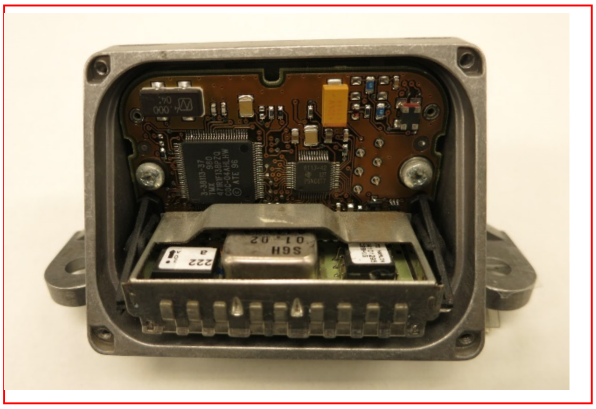
Electromagnetically excited and electromotive voltage sensing resonating gyro for Z-axis

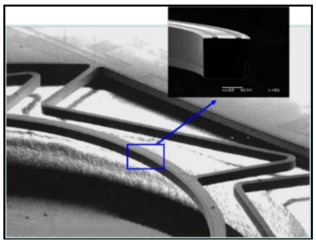
Reference : J.-J. Choi, K.Minami, M.Esashi, Electromagnetical Excitation and Induced Electromotive Voltage Sensing Silicon Angular Rate Sensor, Trans. IEE of Japan, 118-E (1998) pp.641-646

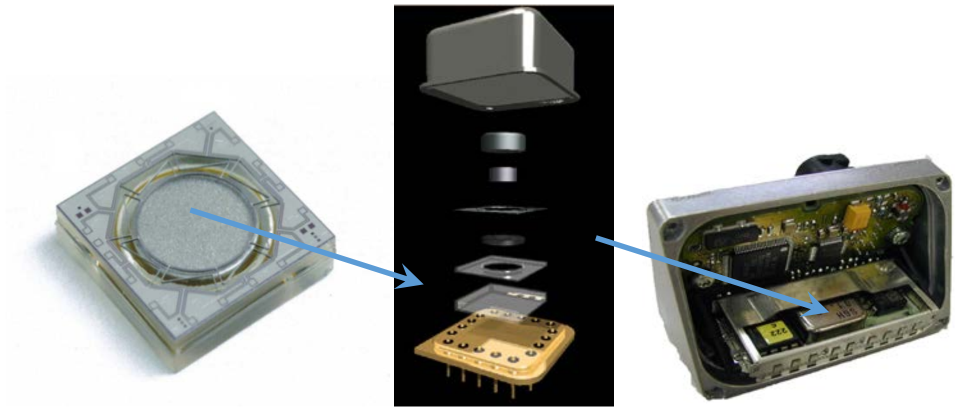
C2 Silicon ring gyroscope

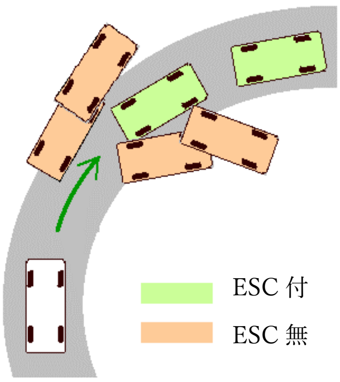




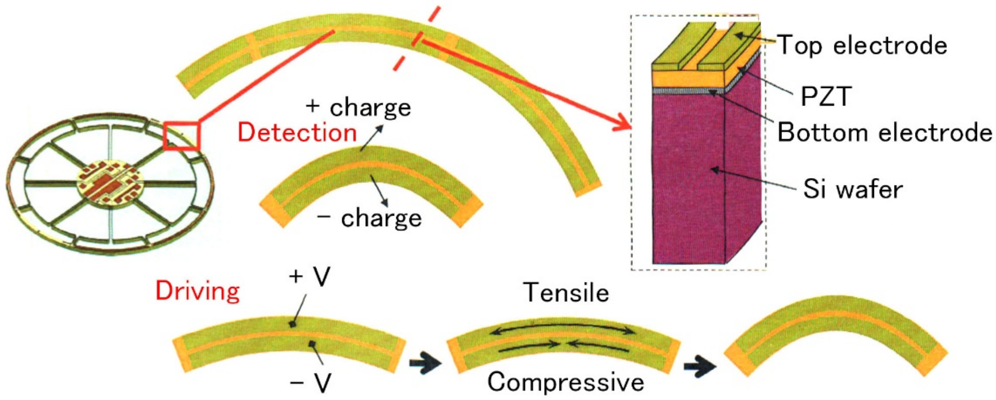


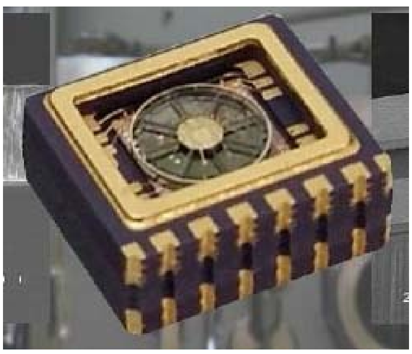






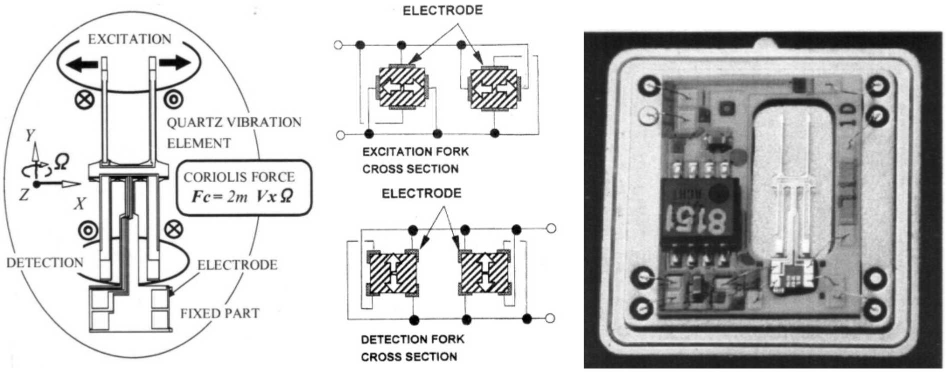
Electromagnetic Si vibrating ring gyroscope ESC（Electronic Stability Control）





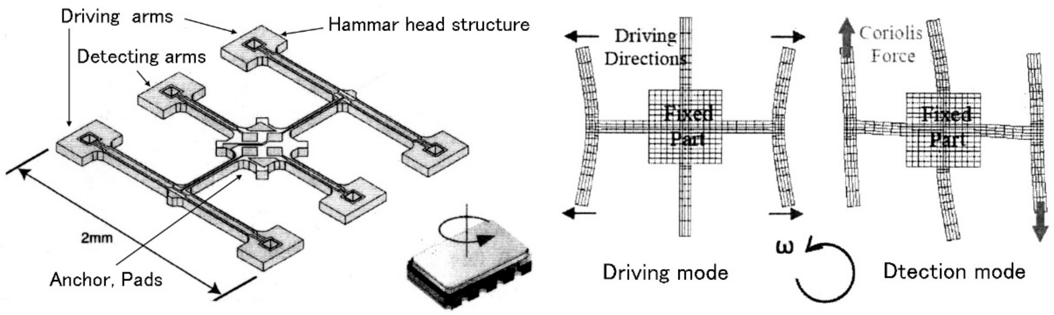
Piezoelectric Si vibrating ring gyroscope

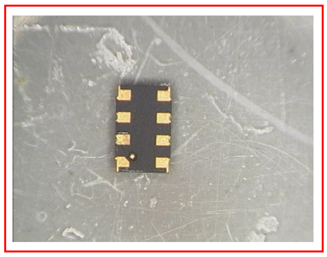
C3 Piezoelectric gyroscope



Quartz resonating gyro (Toyota Central Research Laboratory)

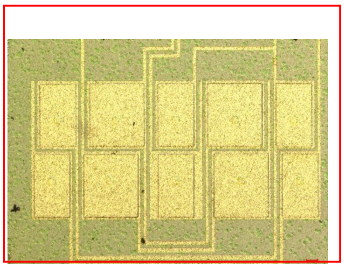
Reference : Y.Nonomura, M.Fujiyoshi, Y.Omura, K.Tsukada, M.Okuwa, T.Morikawa, N.Sugitani, S.Satou, N.Kurata and S.Matsushige, Quartz rate gyro sensor for automotive control, Sensors and Actuators A, 110 (2004) pp.136–141

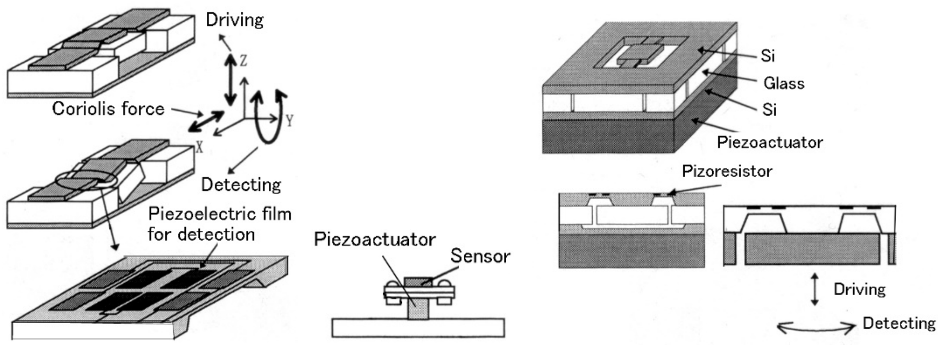


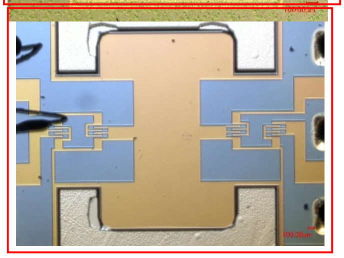


Quartz rate gyro (Epson Toyokom)

Reference : T.Kikuchi, Miniturized Quartz Vibratory Gyrosensor, 4th Intnl. Symp. On Acoustic Wave Devices for Future Mobile Communication Systems (2010) pp.51–55

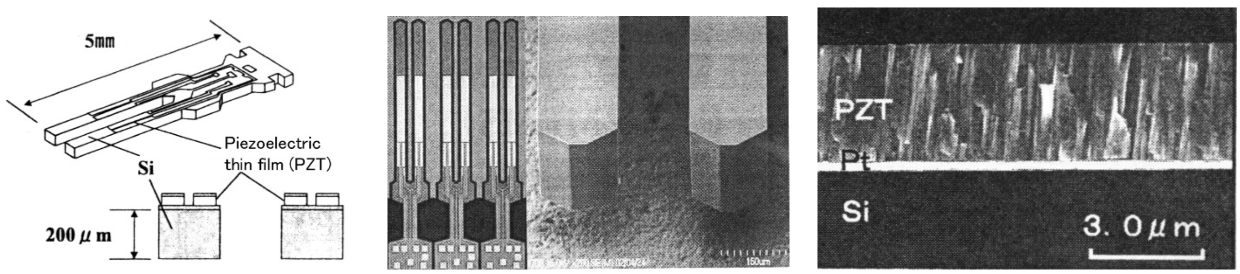






Piezoelectric rate gyro (Tohoku Univ. – Toyota Motor)

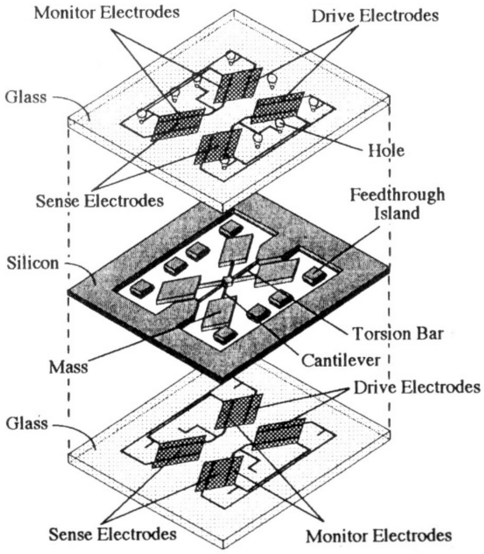
Reference : M.Nagao, K.Minami and M.Esashi, Silicon Angular Rate Sensor Using PZT Thin Film, Sensors and Materials, 11 (1999) pp.31–39

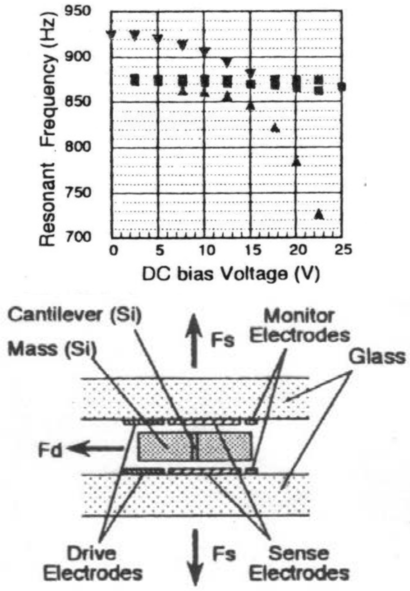


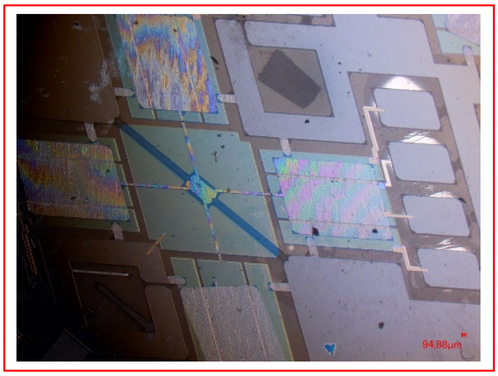
Piezoelectric angular rate sensor (Matsushita Electric Industry)

Reference : R.Takayama, E.Fujii, T.Kamada, A.Murata, T.Hirasawa, A.Tomozawa, S.Fujii,H.Torii, K.Murata, Preparation of <001> Oriented Thin Films and the Applications to Micro Pizoelectric Devices, Trans. of IEE in Japan, 127–E (2007) pp.553–557

C4 Electrostatically driven capacitive sensing gyroscope

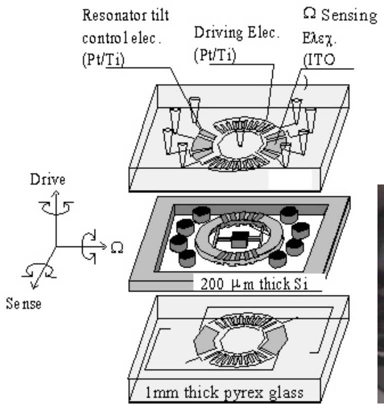


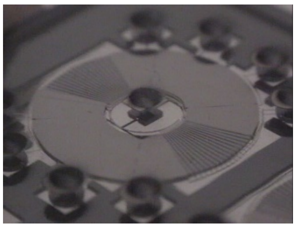


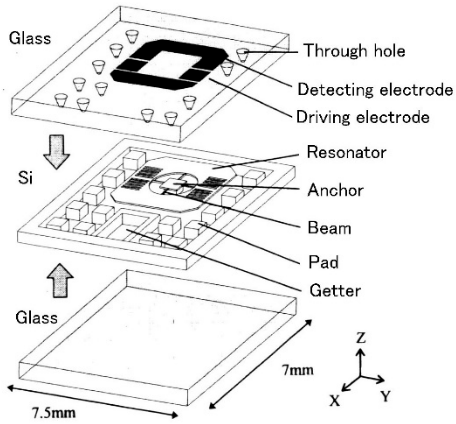


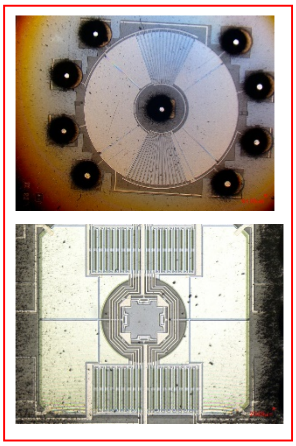
Electrostatically driven capacitive sensing gyro with electrostatic frequency tuning (Tohoku Univ. – Panasonic)

Reference : M.Yamashita, K.Minami and M.Esashi, An X-shaped Tuning Fork Type Resonant Gyroscope by Silicon Micromachine Technology, Micro System Technologies'96 (1996) pp.385-390



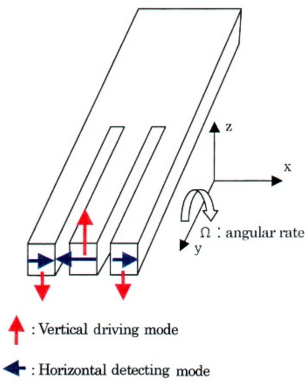


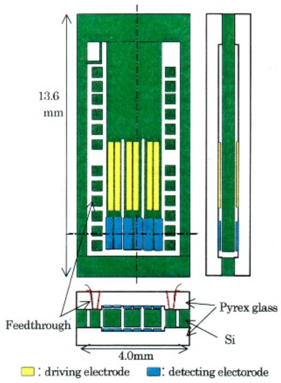




Electrostatically driven capacitive sensing gyro with rotating resonance
(Tohoku Univ. – Ford Motor)(Tohoku Univ. – Toyota Motor)

Reference : J.-J. Choi, R.Toda, K..Minami and M.Esashi, Silicon Angular Resonance Gyroscope by Deep ICPRIE and XeF_2 Gas Etching, Proc.of the Micro Electro Mechanical Systems'98 (1998) pp.322-327
M.Nagao, K.Minami and M.Esashi, A Silicon Micromachined Angular Rate Sensor, Trans. of IEE in Japan, 118-E (1998) pp.212-217





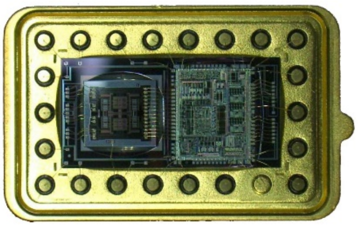
Trident-type Tuning Fork Gyro (Tohoku Univ. – ALPS Electric)

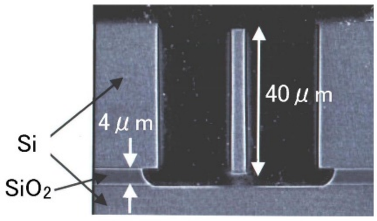
Reference : M.Abe, E.Shinohara, K.Hasegawa, S.Murata and M.Esashi Trident-type Tuning Fork Silicon Gyroscope by the Phase Difference Detection, Proc. of the Micro Electro Mechanical Systems'2000 (2000) pp.508-513

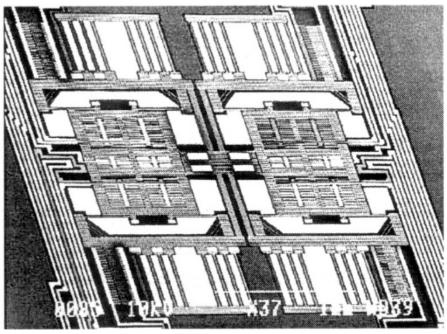
C5 Yaw rate, acceleration sensor (Toyota Motor)

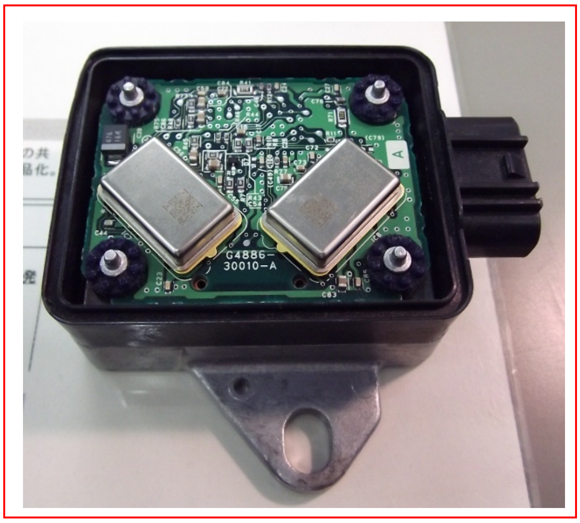
1992–1997

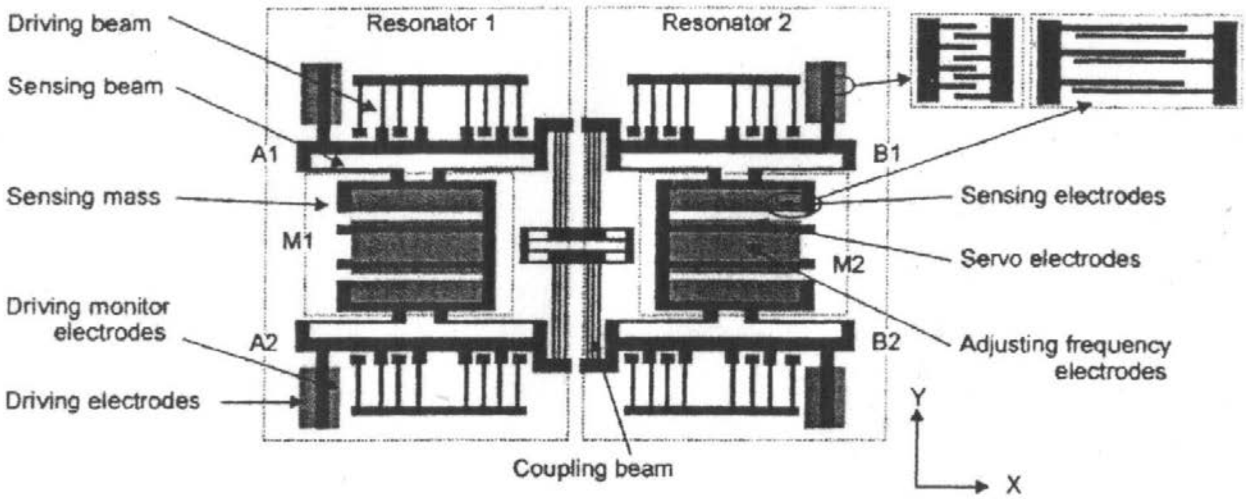
Two researchers from Toyota stayed in Tohoku University for collaborative development of resonating gyroscope

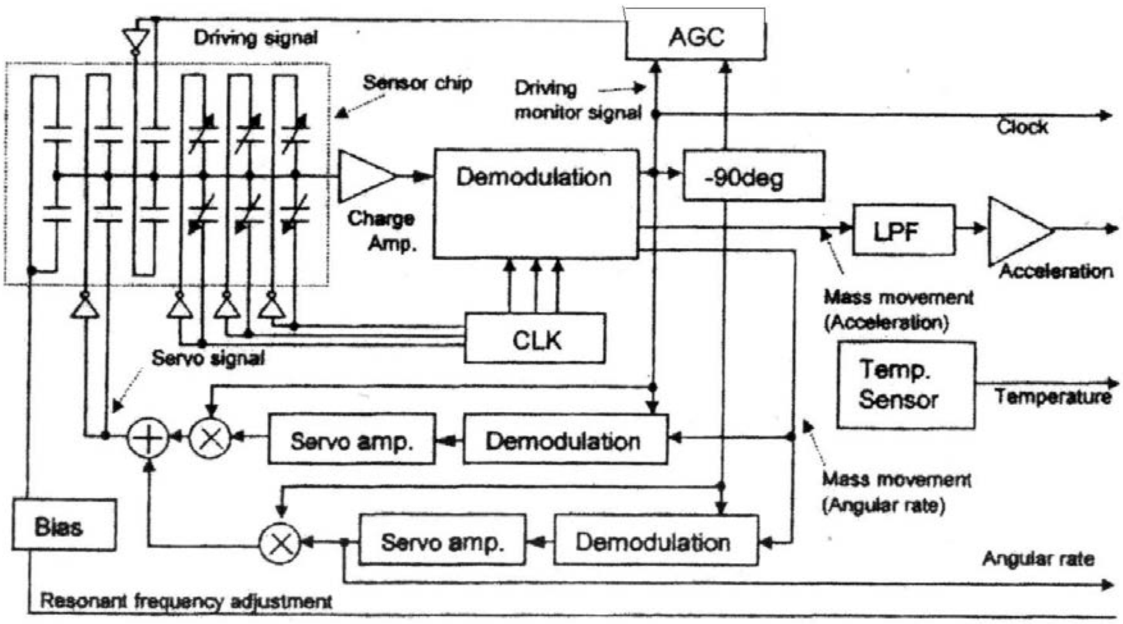






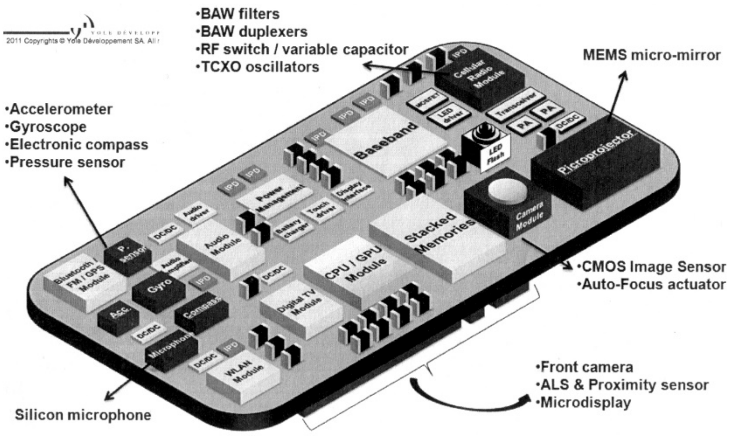




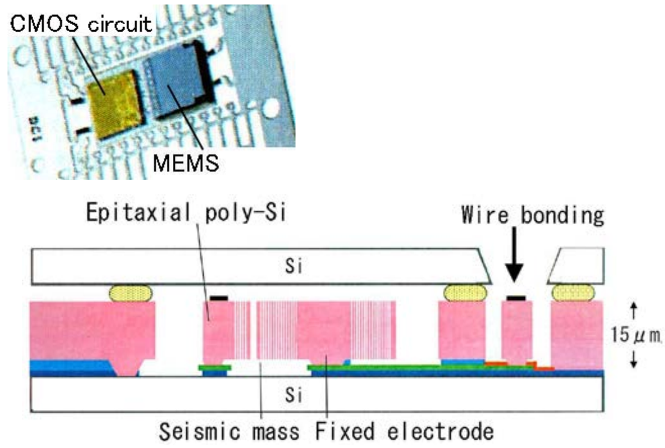


Reference : M.Nagao, H.Watanabe, E.Nakatani, K.Shirai, K.Aoyama and M.Hashimoto: A silicon micromachined gyroscope and accelerometer for vehicle stability control system, 2004 SAE World Congress, 2004-01-1113 (2004)

C6 Accelerometer and gyroscope for automobile and smartphone

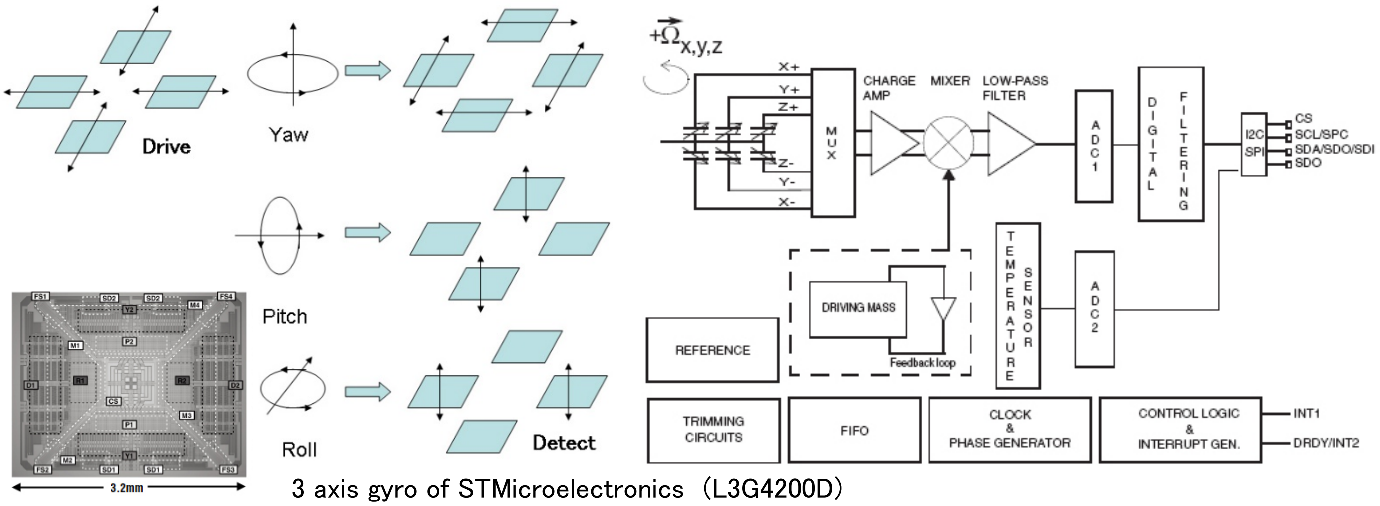


MEMS in mobile equipments (Yole Development)



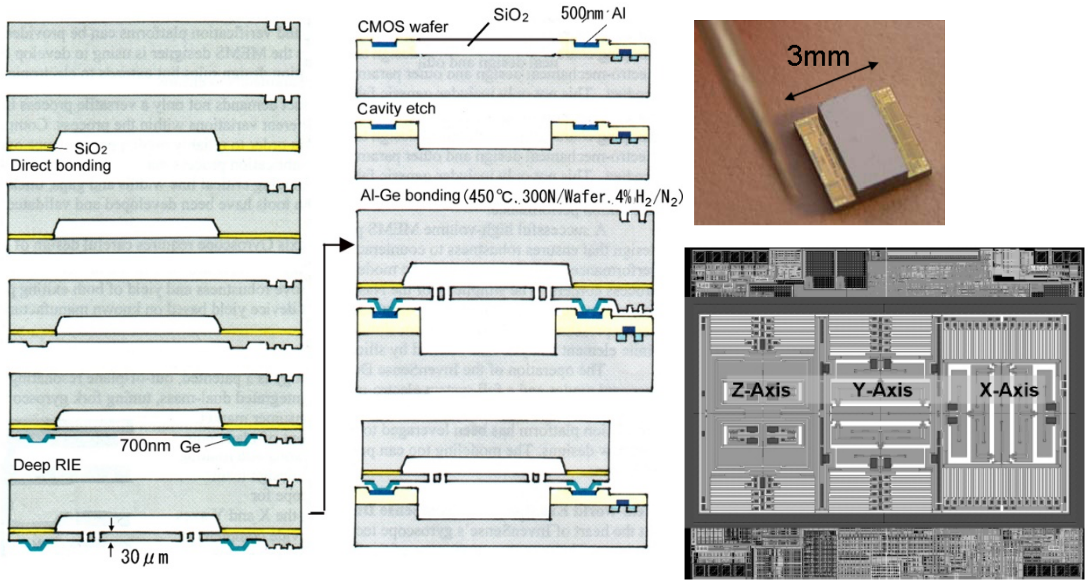
Accelerometer of STMicroelectronics

Reference : H.Noguchi, Latest Developments on MEMS Inertial Sensors and Its Applications, SEMI Technology Symposium 2008, Makuhari, p.45 (2008)



3 axis gyro of STMicroelectronics (L3G4200D)

Reference : L.Prandi, C.Caminada, L.Coronato, G.Cazzaniga, F.Biganzoli, R.Antonello and R.Oboe, A Low-power 2-axis Digital-output MEMS Gyroscope with Single Drive and Multiplexed Angular Rate Readout, ISSCC 2011. (2011) pp.104-105

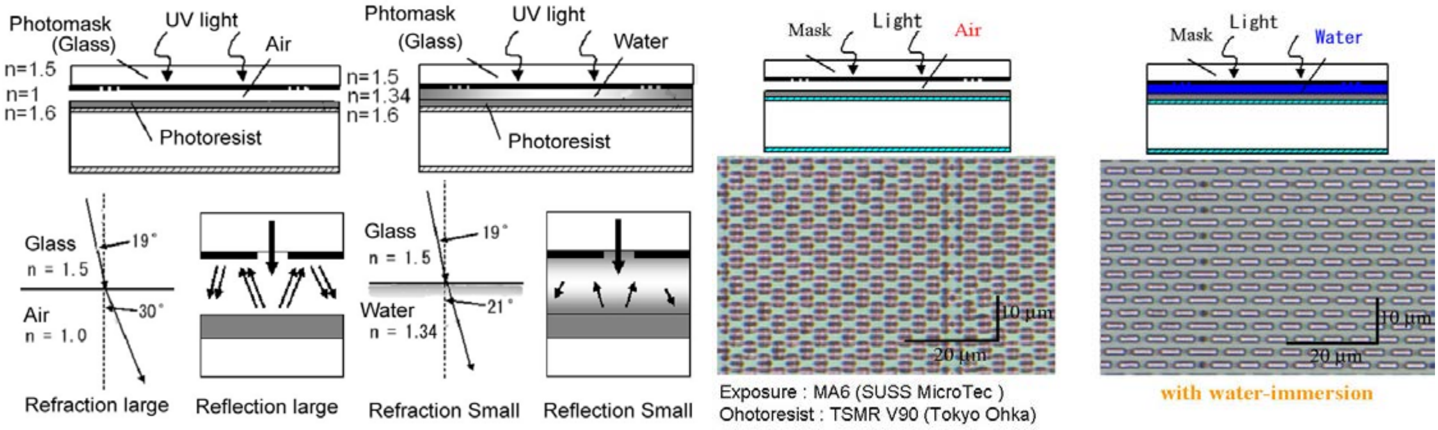


Gyro of Invensense

Reference : J.Seeger, M.Lim and S.Nasiri, Development of High-performance, High-volume Consumer MEMS Gyroscopes, Solid-State Sensors, Actuators and Microsystems Workshop, (2010), p.61

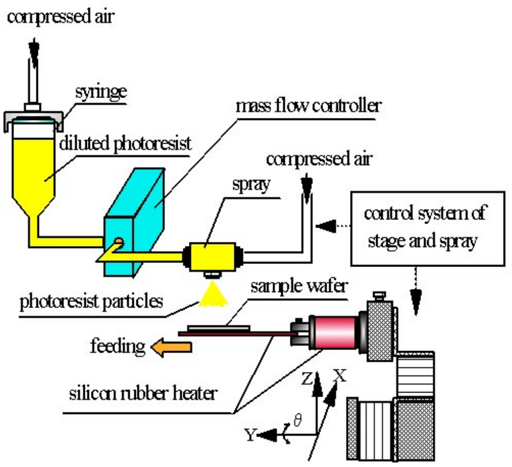
1axis angular rate sensor (Gyroscope)
2 axes accelerometer
Donated by Akebono brake Industry Corp. Ltd..

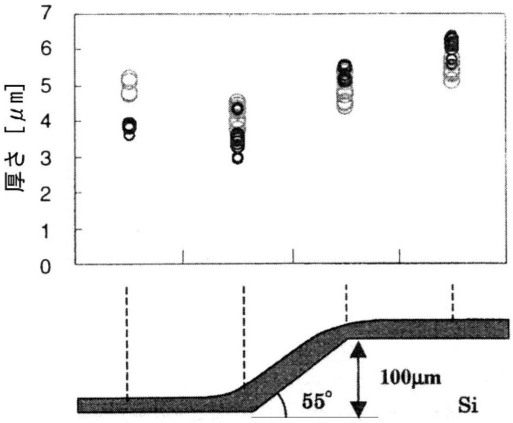
Patterning



Liquid immersion contact lithography

Reference : K.-S.Chang, S.Tanaka and M.Esashi, A Micro-Fuel Processor with Trench-Refilled Thick Silicon Dioxide for Thermal Isolation Fabricated by Water-immersion Contact Photolithography, J. of Micromech. Microeng., 15 (2005) pp.S171-S178

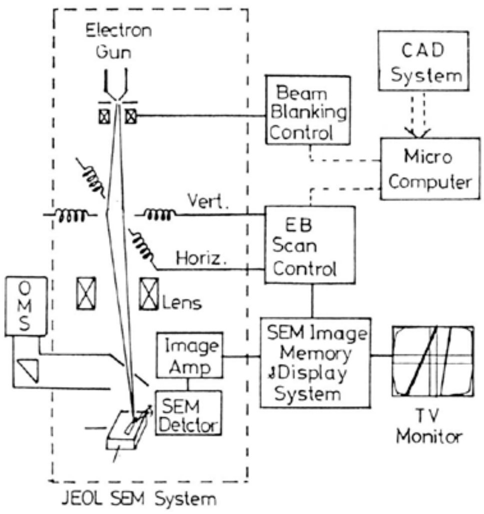


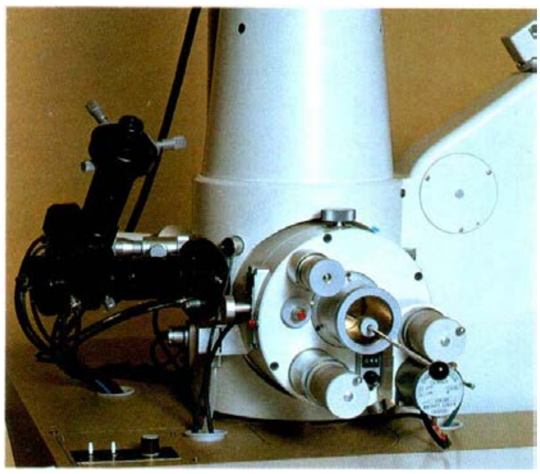


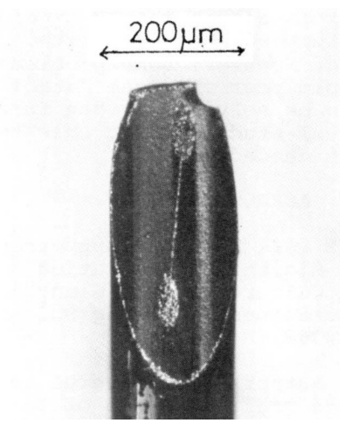
Resist spray coater

Usio

Reference : V.K.Singh, M.Sasaki, K.Hane and M.Esashi, Flow Condition in Resist Spray Coating and Patterning Performance for Three-Dimensional Photolithography over Deep Structures, Jpn. J. Appl. Phys., 43 (2004) pp.2387-2391



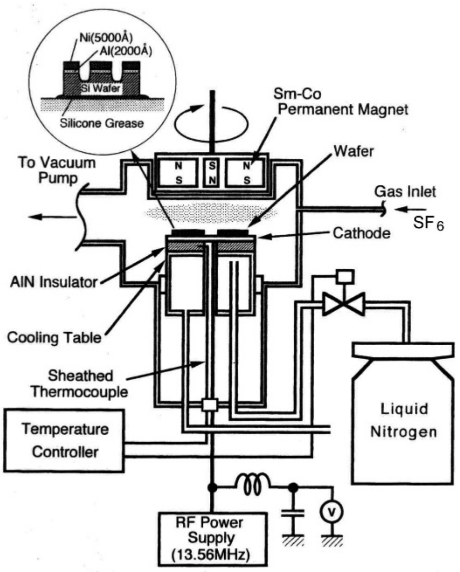




Electron beam exposure system for alignment without mark

Reference : S.Shoji, M.Esashi and T.Matsuo, A New Three-Dimensional Lithographic Technique and its Applications to the Fabrication of Micro Probe Sensors, Digest of Technical Papers, The 4th Int. Conf.on Solid State Sensors and Actuators (1987) pp.91-94

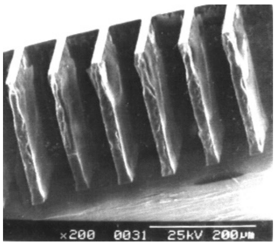
C8 Etching (Deep RIE, XeF_2 Etching, Thickness Monitor during Etching)



Wet anisotropic etching of (110) Si
(thickness 200 μm, width 25/50/100 μm)

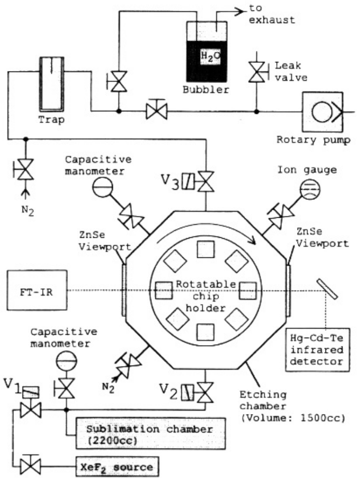
Si Deep RIE
(thickness 200 μm, wafer temp. −120℃)

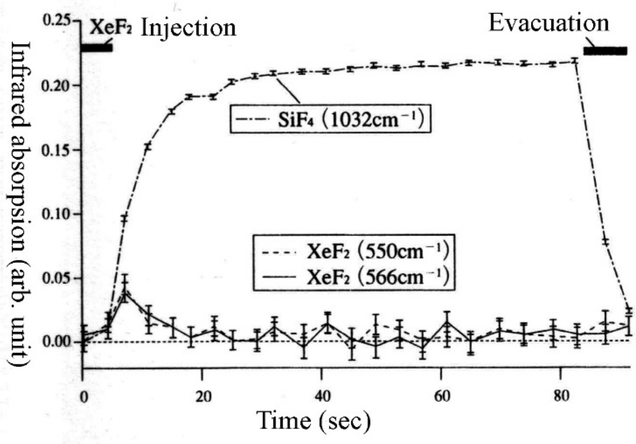
Polyimide RIE
(Thickness 80 μm, O_2 gas)



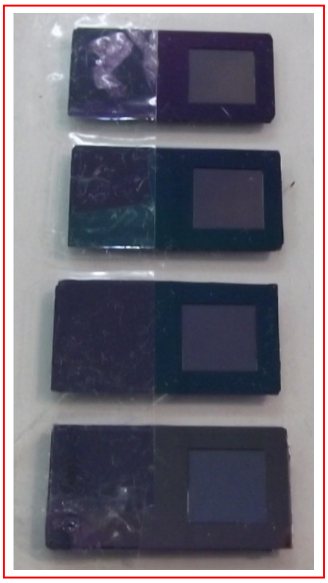
Deep RIE

Reference : M.Takinami, K.Minami and M.Esashi : High-Speed Directional Low-Temperature Dry Etching for Bulk Silicon Micromachining, Technical Digest of the 11th Sensor Symposium (1992) pp.15-18



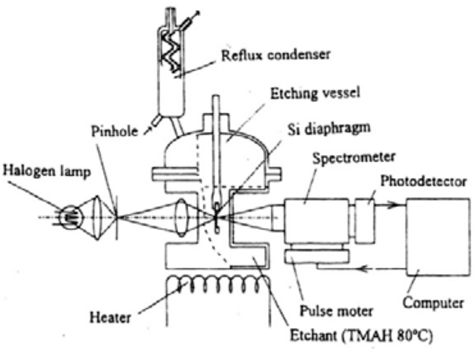


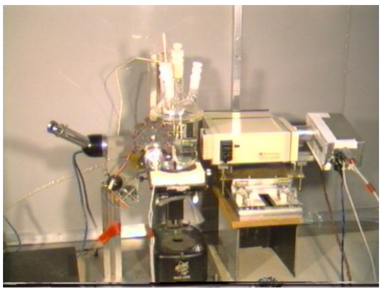
Si dry etching with XeF_2

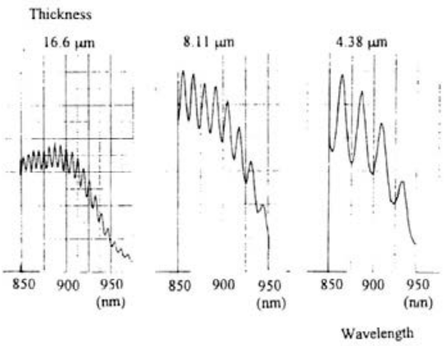


Reference : R.Toda, K.Minami and M.Esashi, Thin Beam Bulk Micromachining Based on RIE and Xenon Difluoride Silicon Etching, Sensors and Actuators, A66 (1998) pp.268-272

Thickness 2/3/5/7 μm from the top



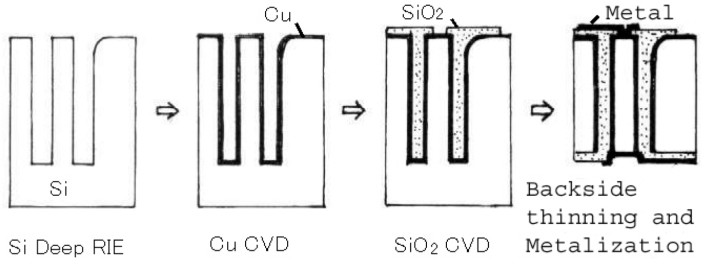


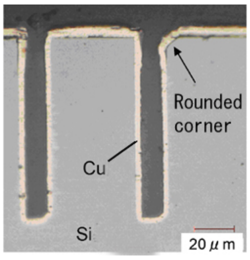


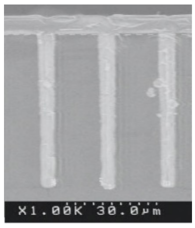
Thickness monitor during wet etching

Reference : K.Minami, H.Tosaka and M.Esashi, Optical in-situ Monitoring of Silicon Diaphragm Thickness during Wet Etching, J. of Micromechanics and Microengineering, 5 (1995) pp.41-46

C9 Deposition

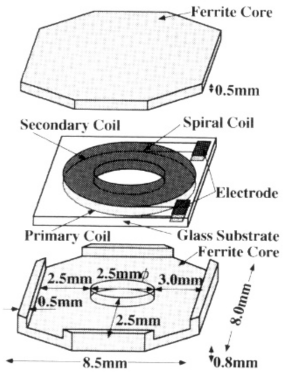


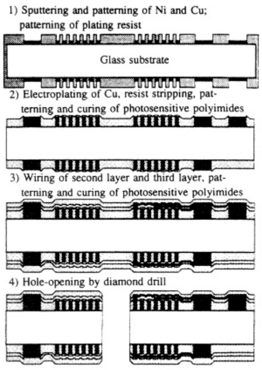


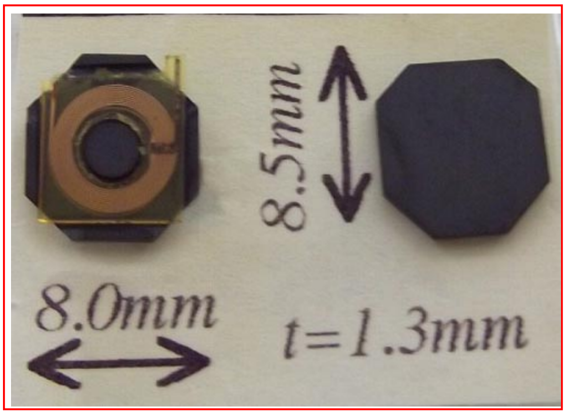


Electrical interconnection through Si wafer for high speed signal, Cu conformal CVD Ozone TEOS SiO_2 CVD
(Tohoku Univ. – Sharp Inc.) (Trench refill)

Reference : M.Sumikawa and M.Esashi, Electrical interconnection through Si wafer for high speed signal , 19th Electronic packaging Convention (2005) pp.117-118

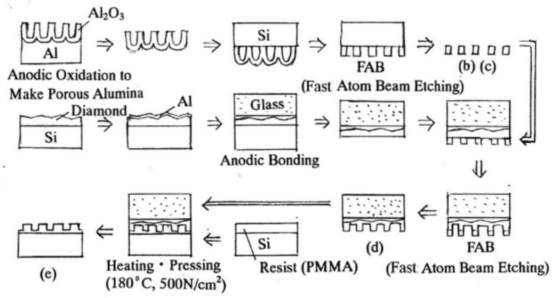




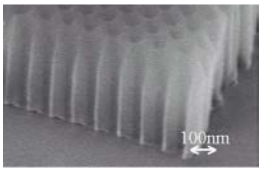


Planar transformer using electroplated coil (Tohoku Univ. – Japan Signal)

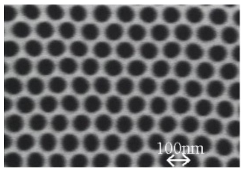
Reference : N.Asada, H.Matsumoto and M.Esashi, A Fail-Saif Logic Operator Using an Insulated Planar Transformer, Trans. of IEE in Japan, 114-A (1994) pp.255-259



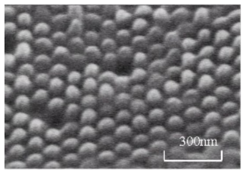
Nanoimprint using diamond mold



(b)

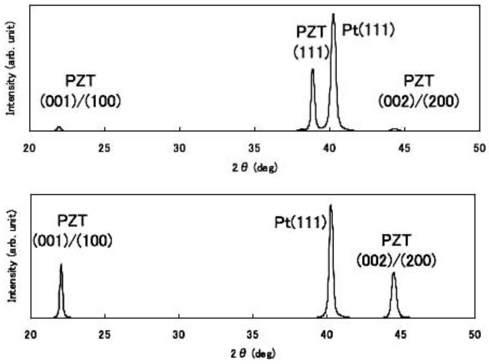


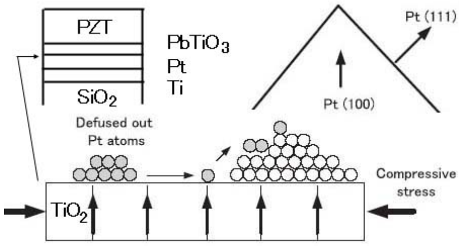
(c)

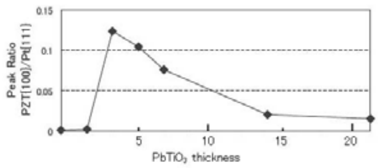


(d)

Reference : T.Ono, C.Konoma, H.Miyashita, Y.Kanamori and M.Esashi, Pattern Transfer of Self-Ordered Structure with Diamond Mold, Jpn. J. Appl. Phys., 42, Part 1 (2003) pp.3867-3870



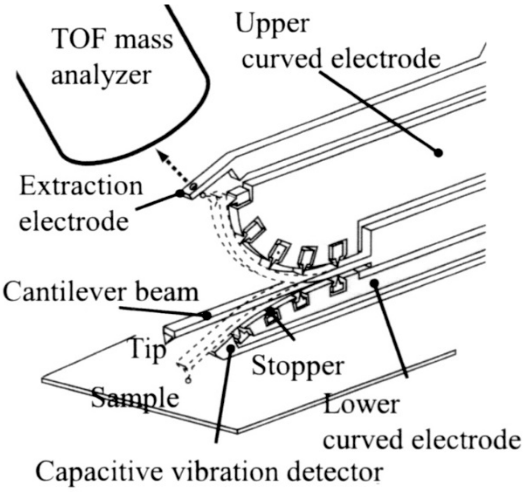


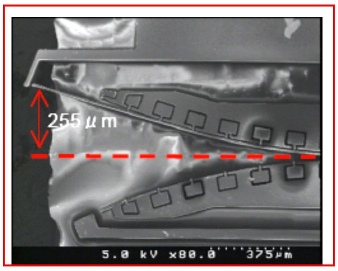


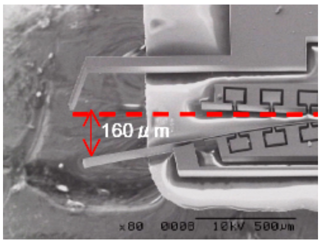
(100) oriented PZTfilm by LD MO (Liquid Delivery Metal Organic) CVD (Tohoku Univ. – Japan Signal)

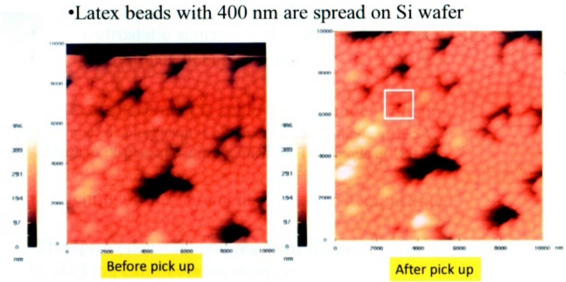
Reference : H.Matsuo, Y.Kawai, S.Tanaka and M.Esashi, Investigation for (100)-/(001)-Oriented $Pb(Zr,Ti)O_3$ Films Using Platinum Nanofacets and $PbTiO_3$ Seeding Layer, Jap. J. Appl. Phys, 49 (2010) 061503

C10 Probe for scanning probe microscope (SPM)

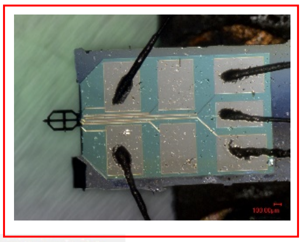




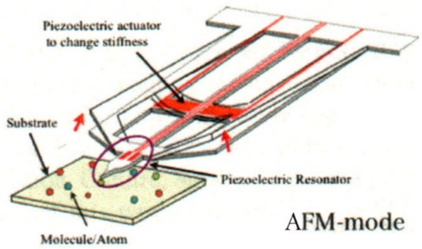


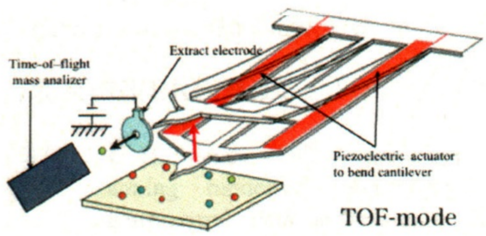


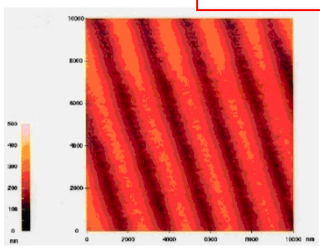
Electrostatically driven probe for Time-of-flight Scanning Force Microscopy



Reference : C.Y.Shao, Y.Kawai, M.Esashi and T.Ono, Electrostatic Actuator Probe with Curved Electrodes for Time-of-flight Scanning Force Microscopy, Review of Scientific Instruments, 81 (2010) 083702

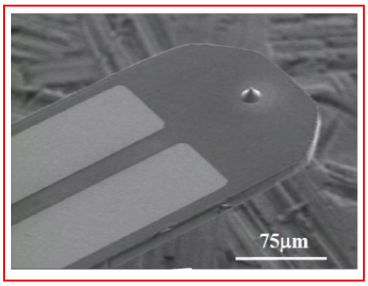


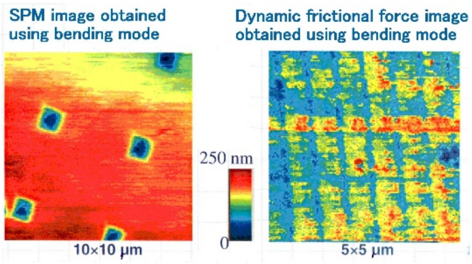




Piezoelectric driven probe for Time-of-flight Scanning Force Microscopy

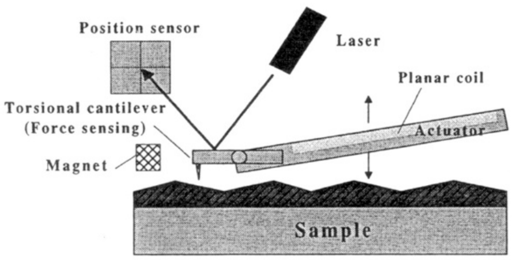
Reference : Y.Kawai, T.Ono, M.Esashi, E.Meyer and C.Gerber, Resonator Combined with a Piezoelectric Actuator for Chemical Analysis by Force Microscopy, Rev. of Sci. Instru., 78 (2007) 063709(4pp)

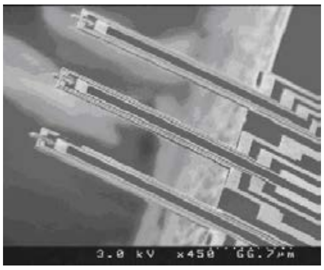


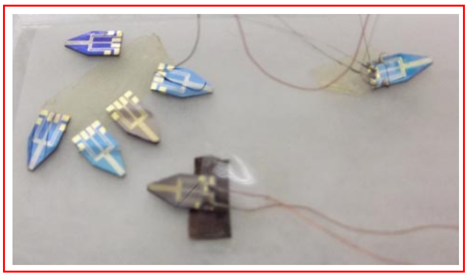


Quartz AFM probe

Reference : A.Takahashi, M.Esashi and T.Ono, Quartz-crystal Scanning Probe Microcantilevers with a Silicon Tip Based on Direct Bonding of Silicon and Quartz, Nanotechnology, 21 (2010) 405502(5pp)



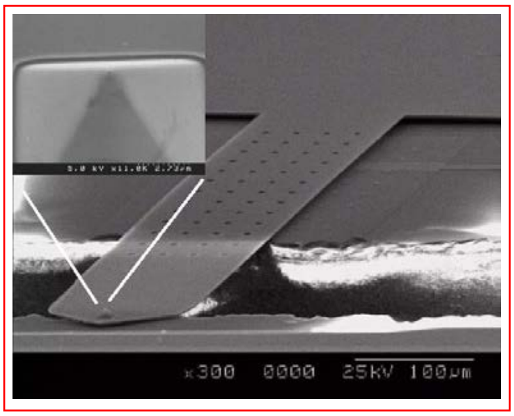


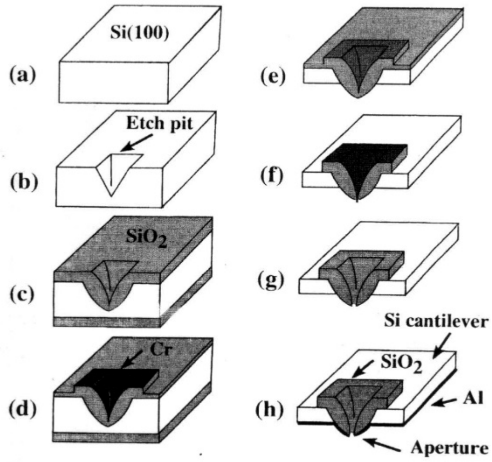


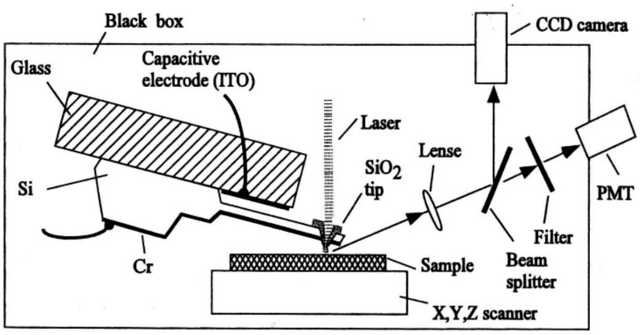
Electromagnetically driven AFM probe

Reference : D.W.Lee, T.Ono and M.Esashi, High-Speed Imaging by Electro-Magnetically Actuated Probe with Dual Spring, J. of Microelectromechanical Systems, 9 (2000) pp.419-424

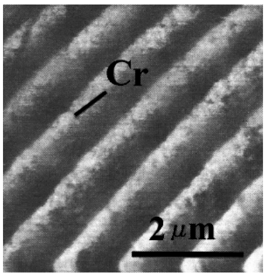
C11 Near-field optical probe and bow-tie antenna







AFM



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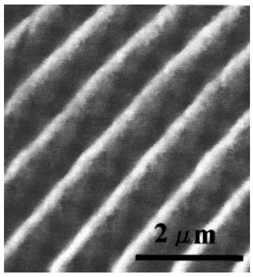
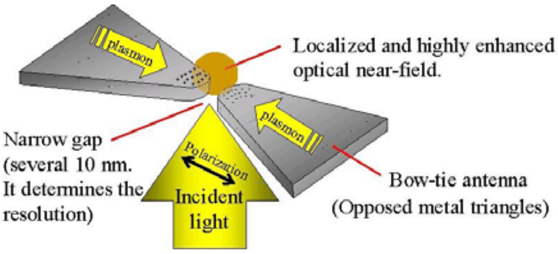
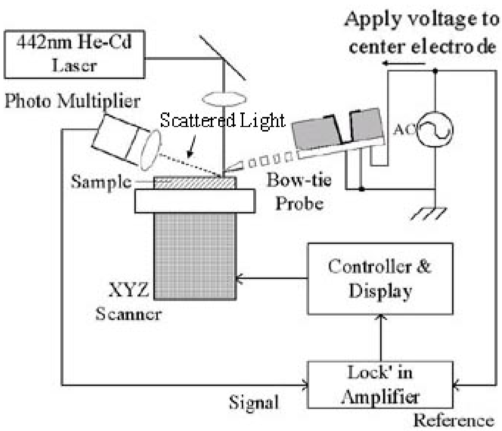
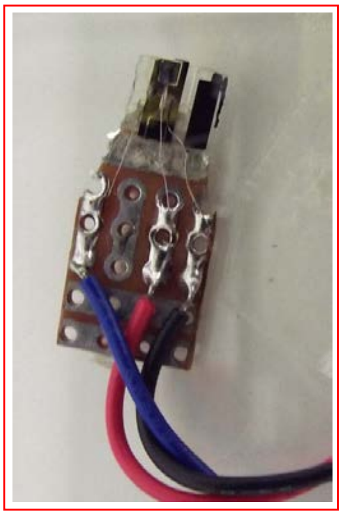


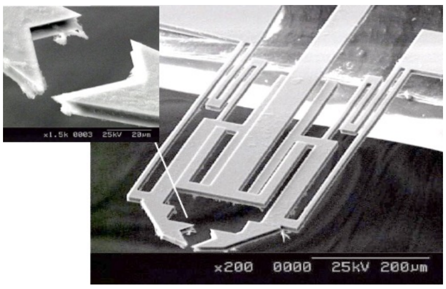
Probe for Near-field Scanning Optical Microscopy

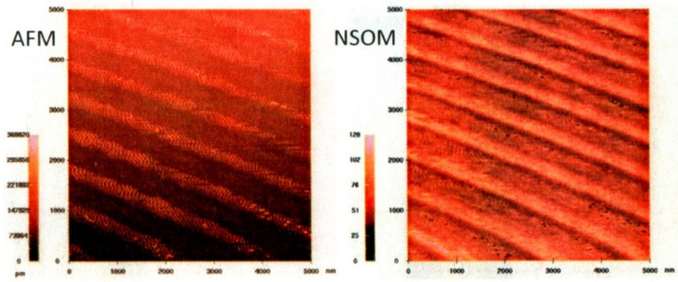
Reference : P.N.Minh, T.Ono and M.Esashi, Microfabrication of Miniature Aperture at the Apex of SiO_2 Tip on Silicon Cantilever for Near-field Scanning Microscopy, Sensors and Actuators, A80 (2000) pp.163-169







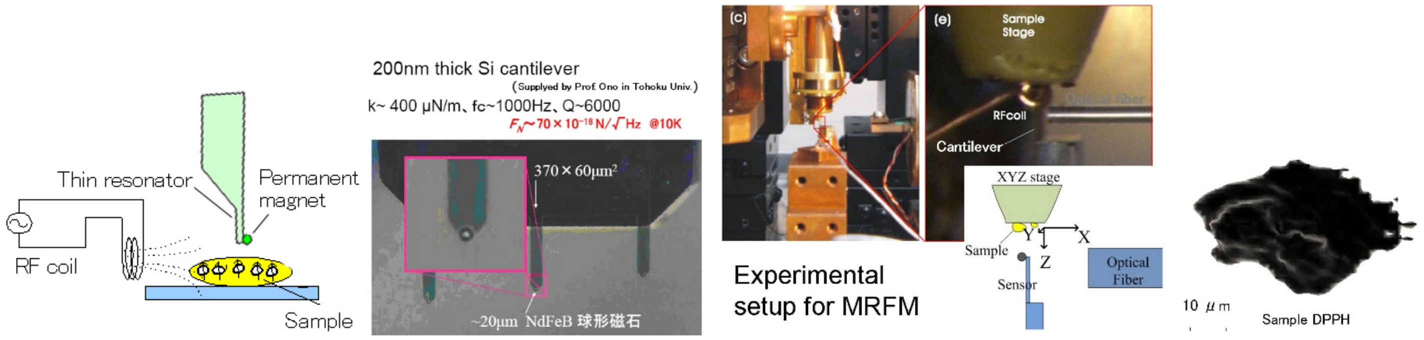




Bow-tie antenna

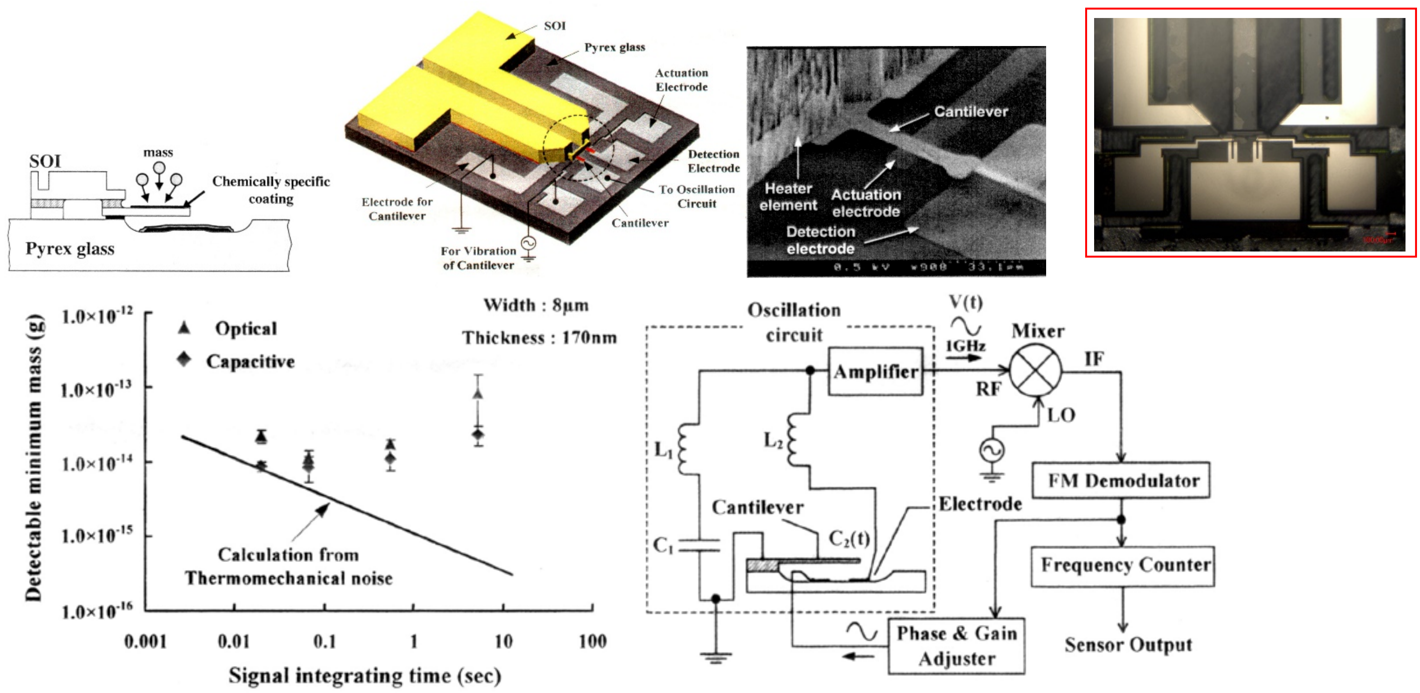
Reference : K.Iwami, T.Ono and M.Esashi, Optical Near-Field Probe Integrated with Self-Aligned Bow-Tie Antenna and Electrostatic Actuator for Local Field Enhancement, J. of Microelectromechanical Systems, 15 (2006) pp.1201-1208

Highly sensitive sensors using thin resonator



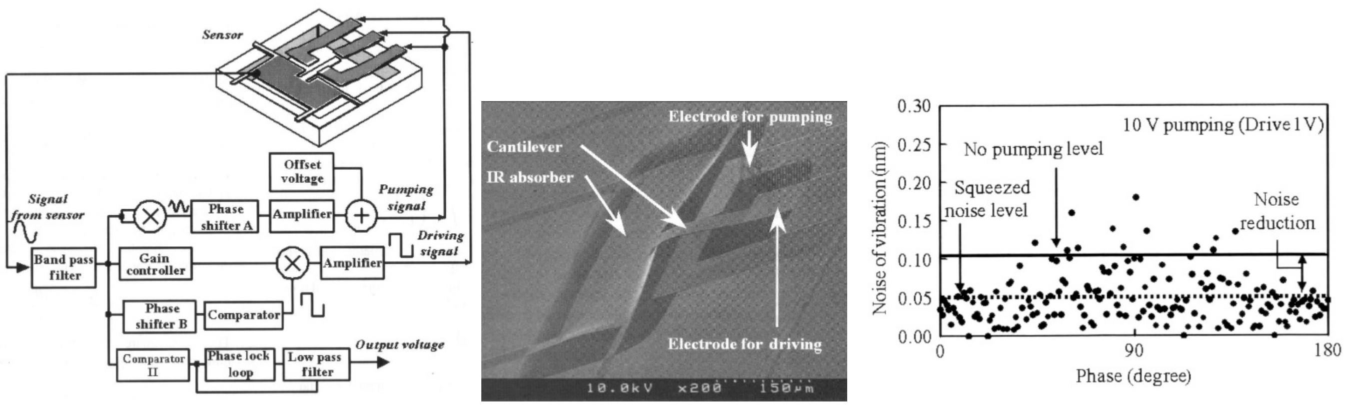
ESR (Electron Spin Resonance) imaging by MRFM (Magnetic Resonance Force Microscope) (JEOL – Tohoku Univ.)

Reference : S.Tsuji, Y.Yoshinari, E.Kawai, K.Nakajima, H.S.Park and D.Shindo, Magnetic resonance force microscopy combined with surface topography, J. of Magnetic Resonance, 188 (2007) pp.380-396



Capacitive detection of resonating cantilever mass sensor

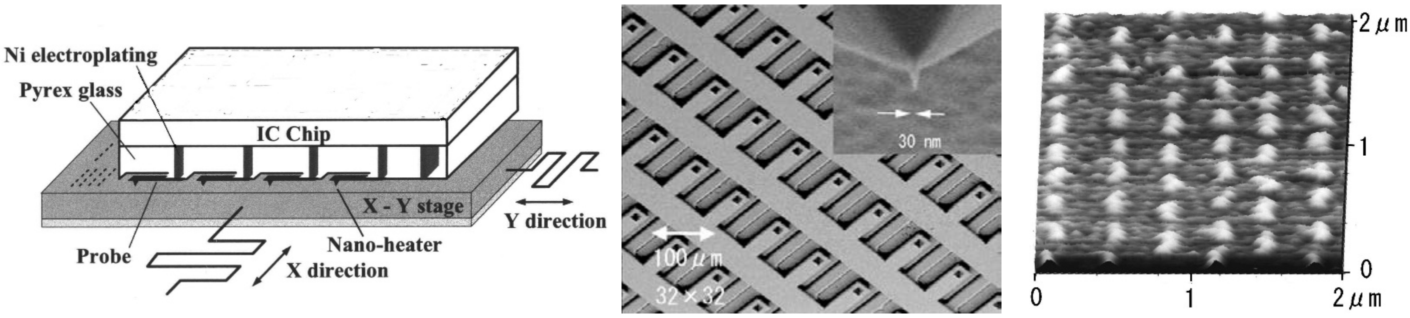
Reference : S.-J.Kim, T.Ono and M.Esashi, Mass Detection Using Capacitive Resonant Silicon Resonator Employing LC Resonant Circuit Technique, Rev. of Sci. Instru., 78 (2007) 085103(6)



Reduction of thermal fluctuation of resonant frequency by parametric noise squeezing

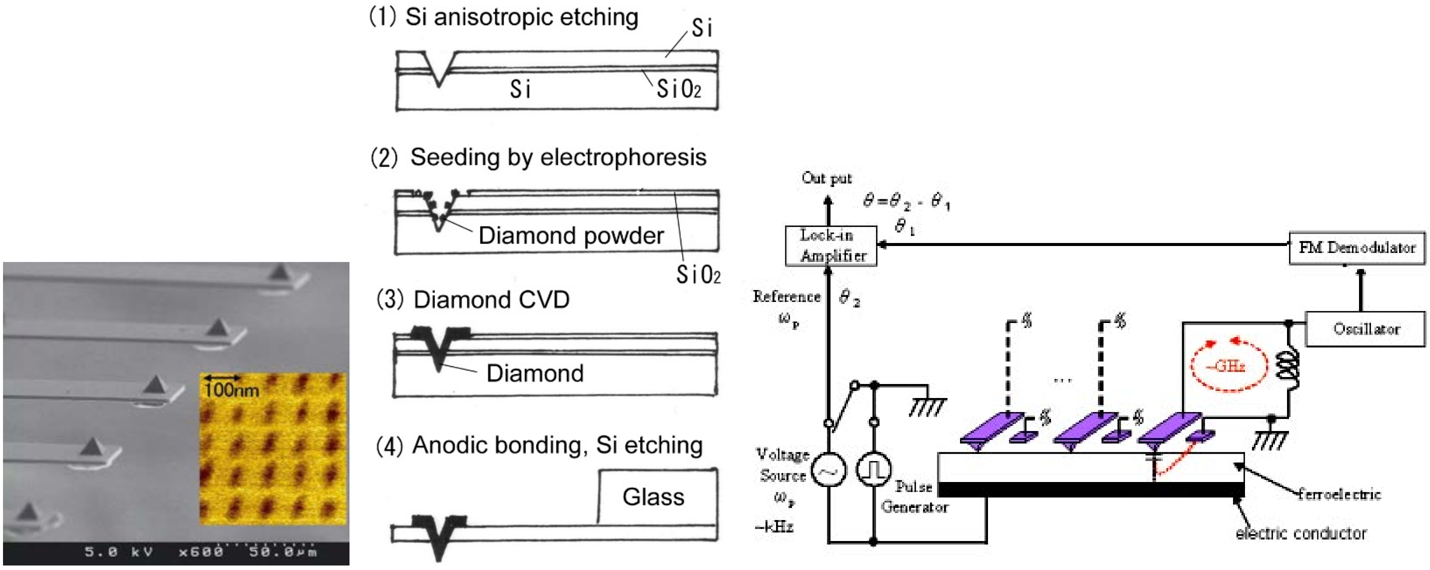
Reference : T.Ono, H.Wakamatsu and M.Esashi, Parametrically Amplified Thermal Resonant Sensor with Pseudo-Cooling Effect, J.of Micromech. Microeng., 15 (2005) pp.2282-2288

C13 # Multi-probe data storage



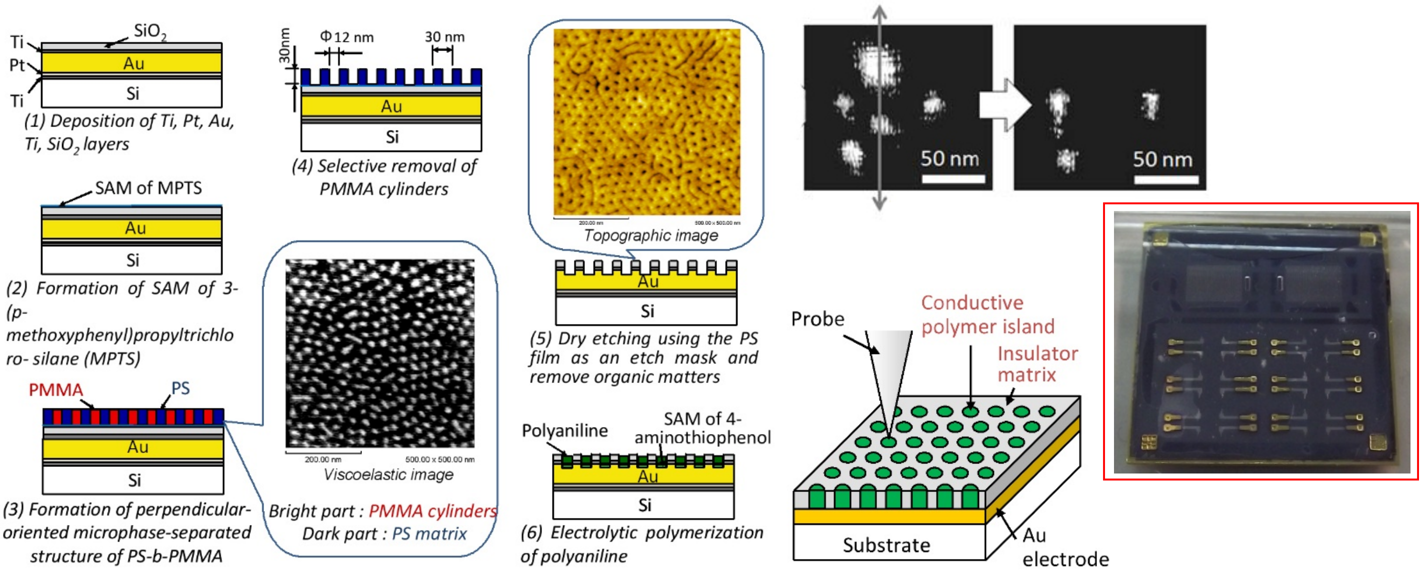
Thermal recoding to phase change recording media

Reference : D.W.Lee, T.Ono, T.Abe and M.Esashi, Microprobe Array with Electrical Interconnection for Thermal Imaging and Data Storage, J. of Microelectromechanical Systems, 11 (2002) pp.215–219



Electrical recoding and reading using diamond probe (Tohoku Univ. – Pioneer)

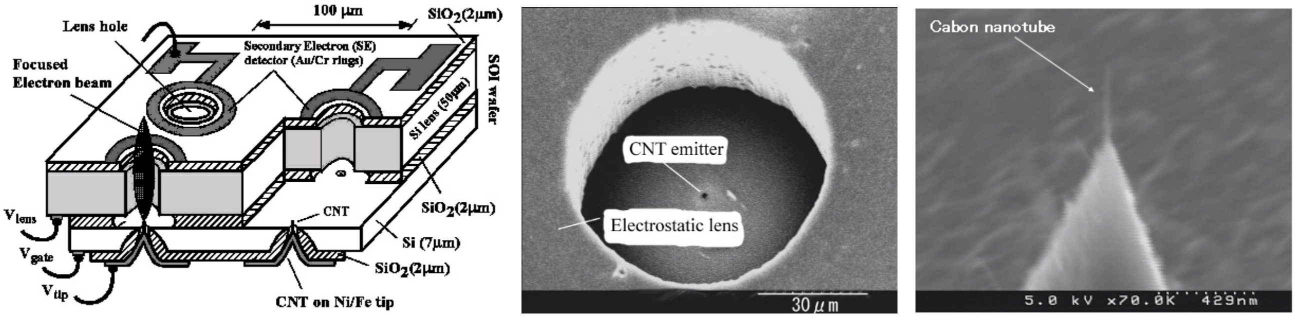
Reference : H.Takahashi, A.Onoe, T.Ono, Y.Cho and M.Esashi, High-Density Ferroelectric Recording Using Diamond Probe by Scanning Nonlinear Dielectric Microscopy, Jap. J. of Applied Physics. 45 (2006) pp.1530–1533



Patterned recording media using micro-phase separation of diblock copolymer

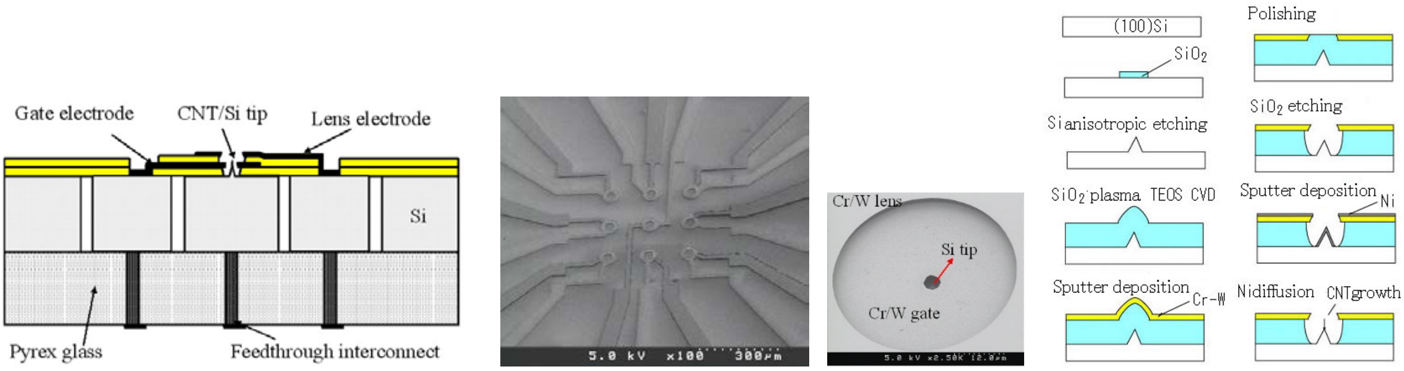
Reference : S.Yoshida, T.Ono and M.Esashi, Conductive Polymer Patterned Media for Scanning Multiprobe Data Storage, Nanotechnology, 18 (2007) 505302(5pp)

C14 Electron source



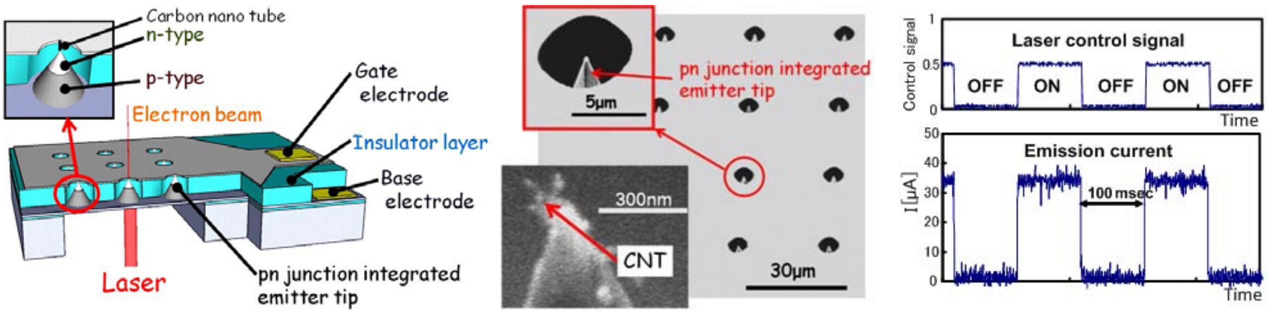
Cabon nanotube electron source

Reference : P.N.Minh, L.T.T.Tuyen, T.Ono, H.Mimura, K.Yokoo and M.Esashi, Carbon Nanotube on a Si Tip for Electron Field Emitter, Jpn. J. Appl. Phys., 41 Part2 (2002) pp.L1409-L1411



Carbon nanotube electron source with electrostatic lens

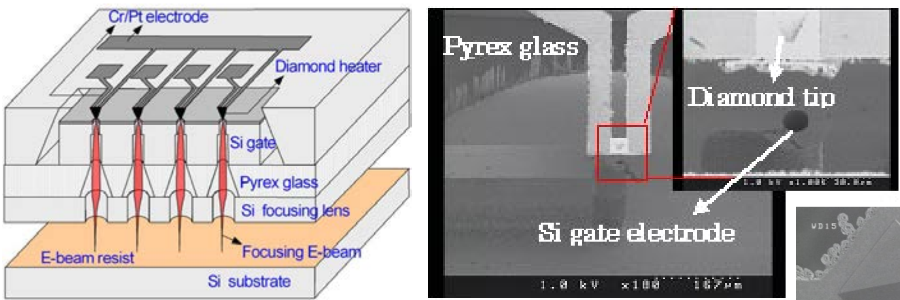
Reference : J.Ho, T.Ono, C.-H Tsai and M.Esashi, Photolithographic Fabrication of Gated Self-aligned Parallel Electron Beam Emitters with a Single-stranded Carbon Nanotube, Nanotechnology, 19 (2008) 365601(5pp)

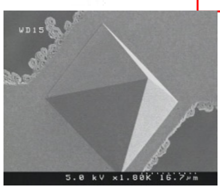


Optically-controlled multi electron source

Reference : E.Tomono, H.Miyashita, T.Ono and M.Esashi, Optically-Controlled Multi Electron Source, The 5th Asia-Pacific Conference on Transducers and Micro-Nano Technology (APCOT 2010) (2010) pp.78-79

Optically-controlled multi electron source





Diamond Schottky emitter

Reference : C.-H.Tsai, T.Ono and M.Esashi, Fabrication of Diamond Schottky Emitter Array by Using Electrophoresis Pre-treatment and Hot-filament Chemical Vapor Deposition, Diamond and Related Materials, 16 (2007) pp.1398-1402