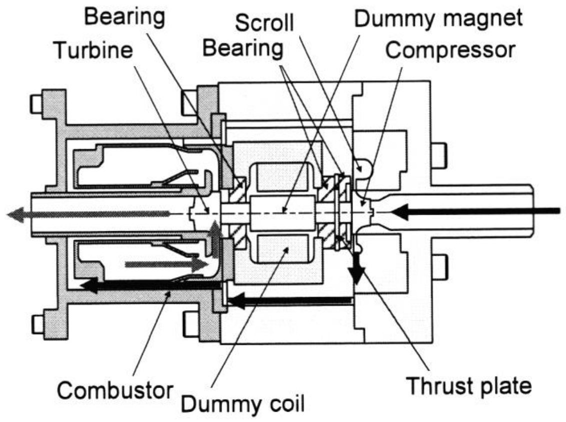
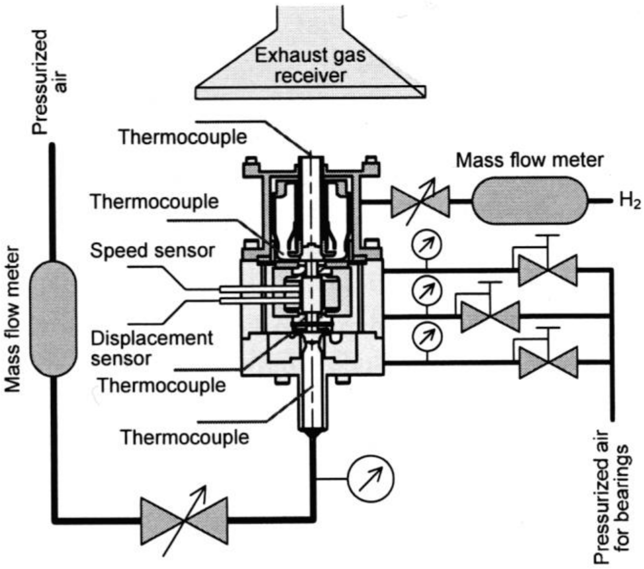
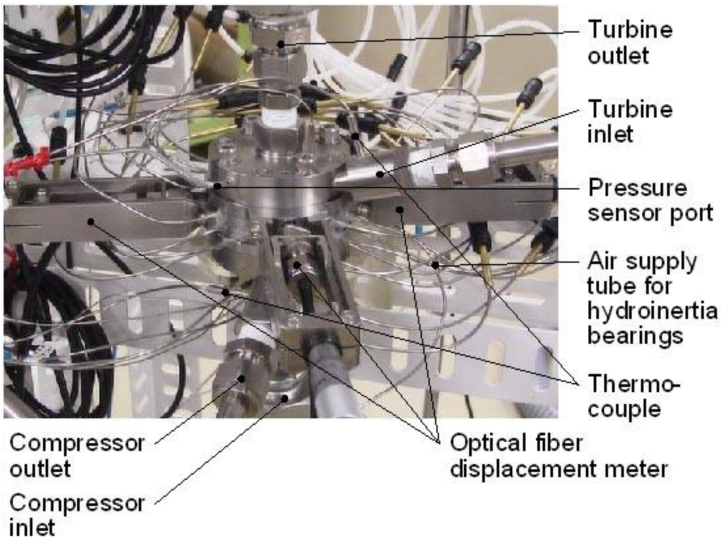
F1 # Small size gas turbine engine dynamo



Gas turbine dynamo developed in IHI

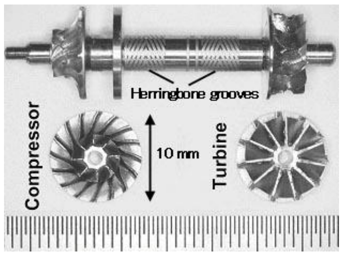


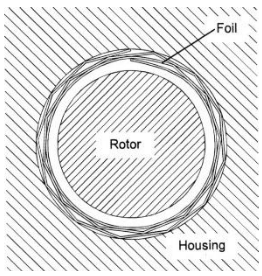


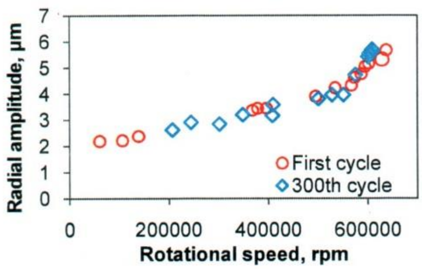
Small gas turbine dynamo (Tohoku Univ. – IHI Corp. – Tohoku-Gakuin Univ. – Tokyo Metroplitan Univ. – The Univ. of Tokyo) (for outdoor robot etc.)

Reference : S.Tanaka, K.Hikichi, S.Togo, M.Murayama, Y.Hirose, T.Sakurai, S.Yuasa, S.Teramoto, T.Niino, T.Mori, M.Esashi and K.Isomura, World's Smallest Gas Turbine Establishing Brayton Cycle, Technical Digest, Power MEMS 2007 (2007) pp.359-362

5 axis stage high speed spindle milling machine used for shaping turbine blade (Toshiba machine F-MACH)



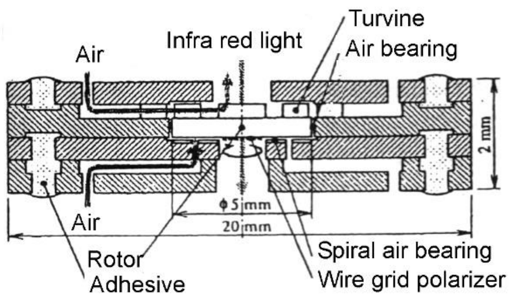


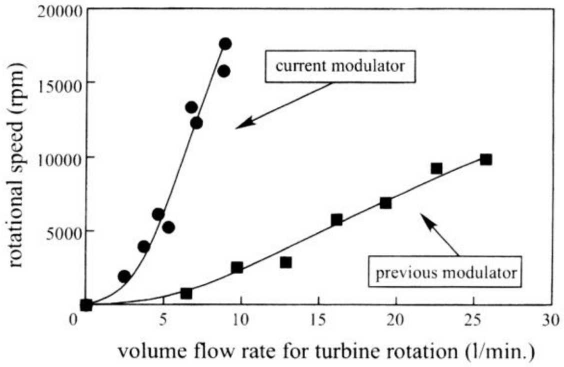


Radial foil bearing (Tohoku Univ. – IHI – Tohoku-Gakuin Univ.)

Reference : K.Hikichi, S.Togo, K.Isomura, N.Saji, M.Esashi and S.Tanaka, Ultra-high-speed Tape-type Radial Foil Bearing for Micro Turbomachinery, Technical Digests Power MEMS 2009 (2009) pp.79-82

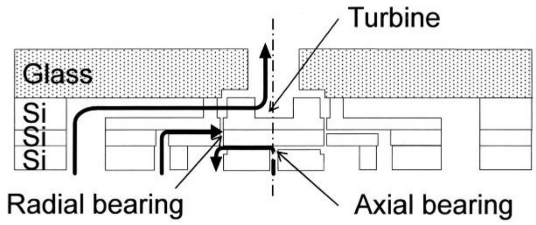
F2 Si micro-turbine and thermoelectric generator

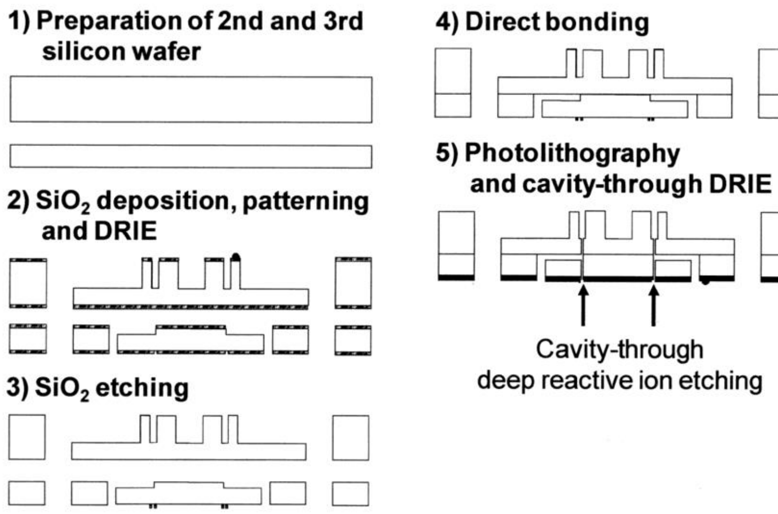




Si air-turbine for high-speed polarization modulator

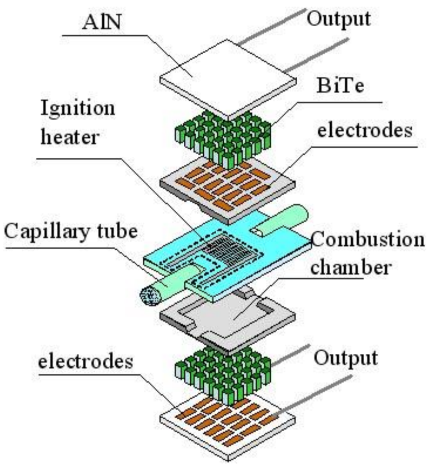
Reference : S.Tanaka, M.Hara and M.Esashi, Mechanical Polarization Modulator Using Micro-turbo Machinery for Fourier Transform Infrared Spectroscopy, Sensors and Actuators, A 96 (2002) pp.215-222

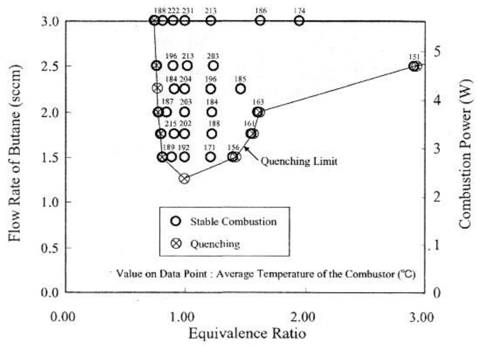


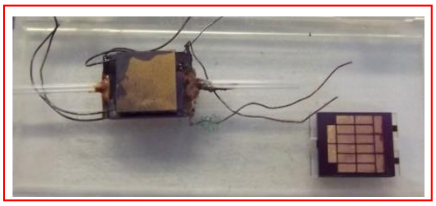


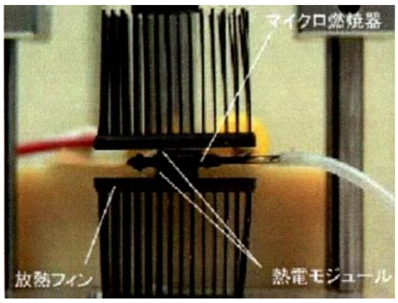
Si air-turbine with radial-inflow type journal bearing

Reference : S.Tanaka, Y.Miura, P.Kang, K.Hikichi and M.Esashi, MEMS-based Air Turbine with Radial-inflow Type Journal Bearing, Trans. on Electrical and Electronic Engng. 3 (2008) pp.297-304





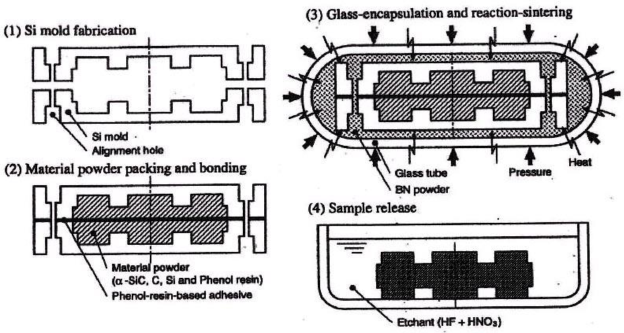




Thermoelectric generator

Reference : K.Yoshida, S.Tanaka, S.Tomonari, D.Satoh and M.Esashi, High-Energy Density Miniature Thermoelectric Generator Using Catalytic Combustion, J. of Microelectromechanical Systems, 15 (2006) pp. 195-203

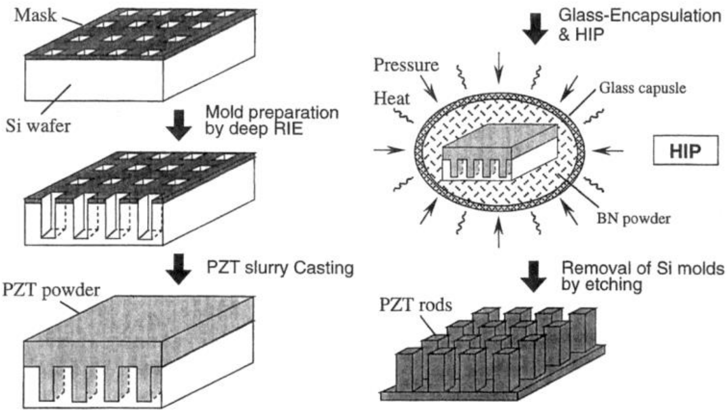
F3 # SiC and PZT by lost-mold process, Si_3N_4 by reaction sintering

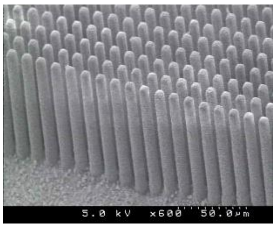


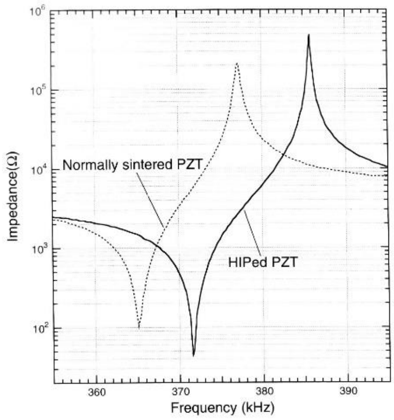
Fabrication Si mold SiC microstructure

SiC microstructure by lost mold process

Reference : S.Tanaka, S.Sugimoto, J.F.Li, R.Watanabe and M.Esashi, Silicon Carbide Micro-Reaction -Sintering Using Micromachined Silicon Molds, J. of Microelectromechanical Systems, 10 (2001) pp.55-61

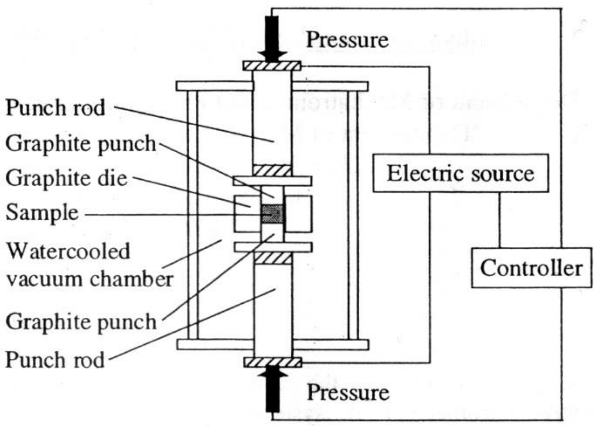


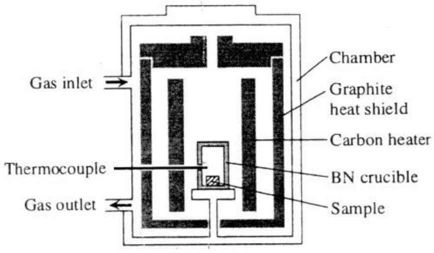




PZT microstructure by lost mold process

Reference : J.-F.Li, S.Wang, K.Wakabayashi, M.Esashi and R.Watanabe, Properties of Modified Lead Zirconate Titanate Ceramics Prepared at Low Temperature (800° C) by Hot Isostatic Pressing, J.American Ceramic Soc., 83 (2000) pp.955-957



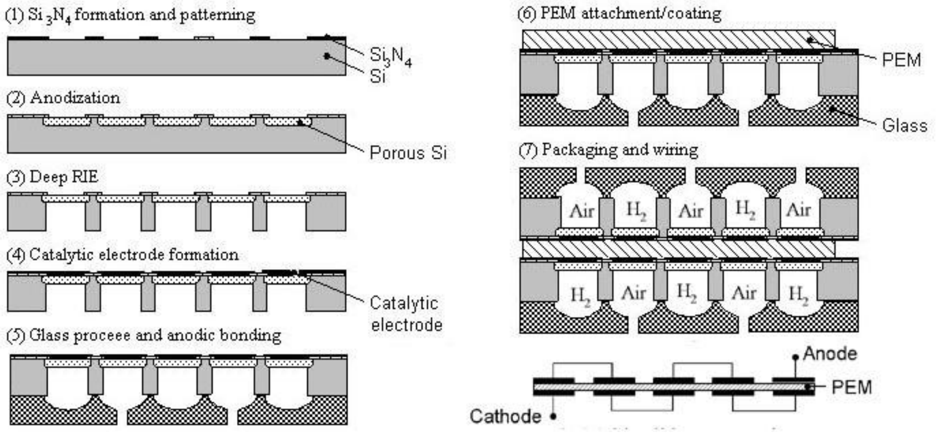


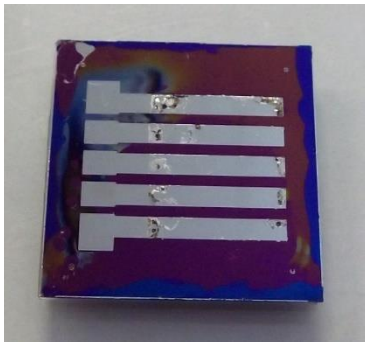
Spark plasma sintering of Si powder Mechanical shaping Sintering at 1400℃ in N_2 to form Si_3N_4

Si_3N_4 structure by sintering in N_2 of porous Si made by spark plasma sintering of Si powder and mechanical shaping

Reference : S.Sugimoto, S.Tanaka, J.-F.Li, T.Yamada, R.Watanabe and M.Esashi, Three-Dimensional Micromachining of Silicon Nitride for Power Microelectromechanical Systems, Technical Digest of the Transducers' 01 (2001) pp.1140-1143

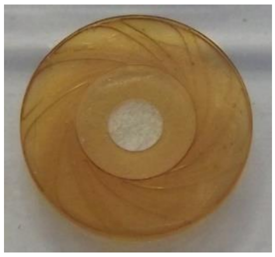
F4 Micro fuel cell

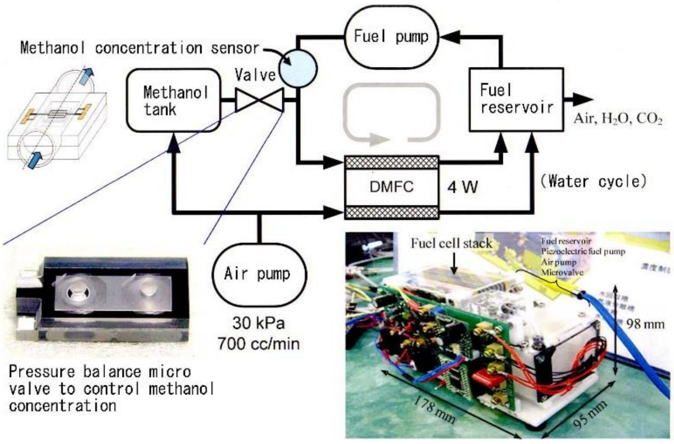




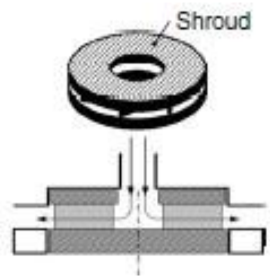
Polymer Electrolyte Membrane (PEM) fuel cell using porous Si as gas permeable membrane

Reference : K.B.Min, S.Tanaka and M.Esashi, MEMS-Based Polymer Electrolyte Fuel Cell, Electrochemistry, 70 (2002) pp.924-927

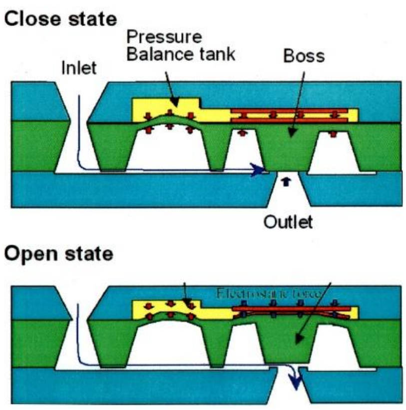


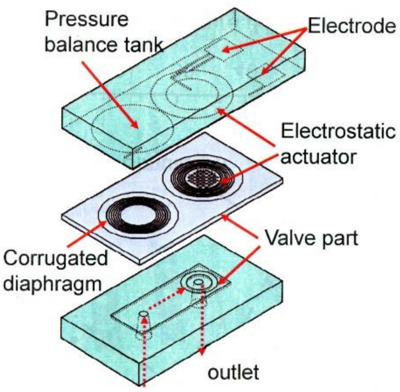


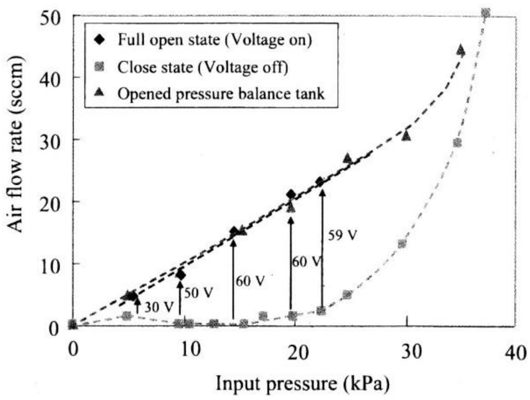
Direct methanol micro fuel cell system (Tohoku Univ. - Matsushita Electric Works)



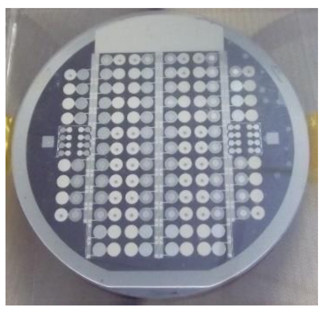
Turbo air pump with SU-8 impeller (Tohoku Univ. - Nippon Kayaku)







Pressure balance type micro valve (Tohoku Univ. - Matsushita Electric Works)



Reference :

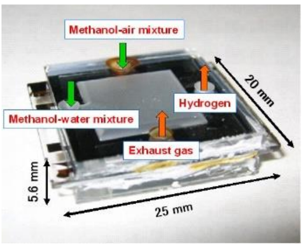
S.Tanaka, K.-S.Chang, K.-B.Min, D.Satoh, K.Yoshida and M.Esashi, MEMS-based Components of a Miniature Fuel Cell/fuel Reformer System, Chemical Eng. J., 101 (2004) pp.143-149

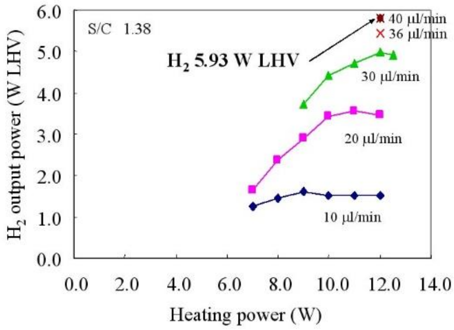
K.Yoshida, S.Tanaka, Y.Hagihara, S.Tomonari and M.Esashi, Normally Closed Electrostatic Microvalve with Pressure Balance Mechanism for Prtable Fuel Cell Application, Sensors and Actuators A, 157 (2010) pp.290-298

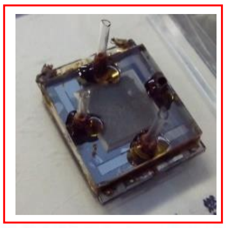
R.Hino, M.Esashi and S.Tanaka, Antisymetric-mode Lamb Wave Methanol Sensor with Edge Reflectors for Fuel Cell Applications, Technical Digest MEMS 2010 (2010) pp.871-874

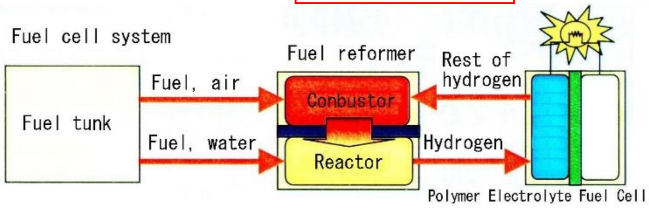
A.Nakajima, P.Kang, N.Honda, K.Hikichi, M.Esashi and S.Tanaka, Fabrication and High-speed Characterization of SU-8 Shrouded Two-dimensional Microimpellers, J.of Micromech. Microeng., 17 (2007) pp.S230-S2

F5 # Micro fuel reformer



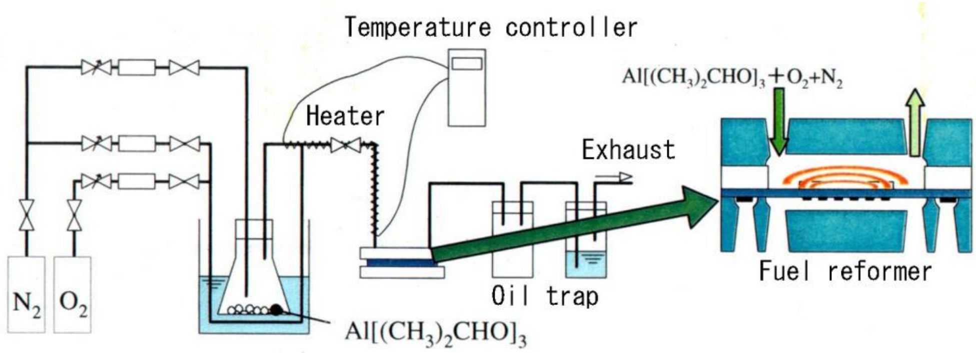


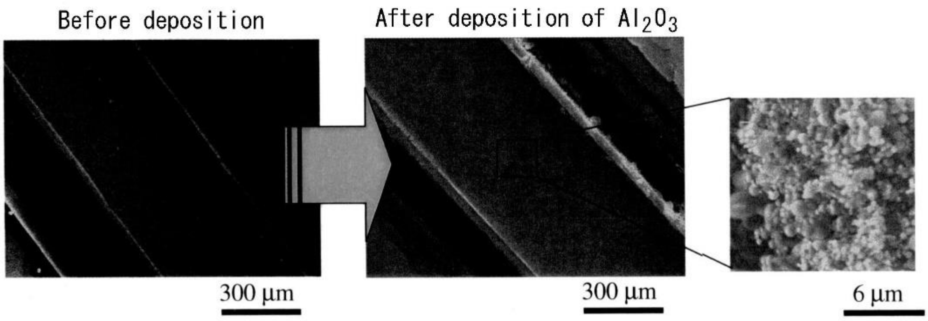


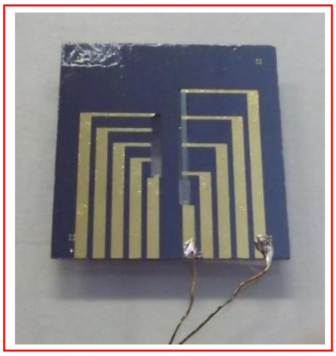


Micro fuel reformer (Tohoku Univ. − Matsushita Electric Works)

Reference : K.Yoshida, S.Tanaka, H.Hiraki and M.Esashi : A Micro Fuel Reformer Integrated with a Combustor and a Microchannel Evaporator, J.of Micromech. Microeng., 16 (2006) pp.S191−S197

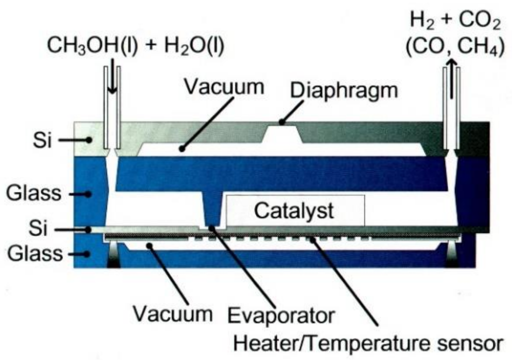


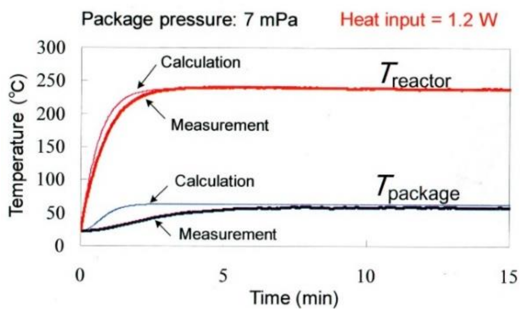


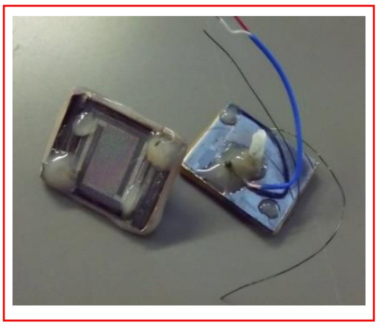


In Situ CVD of catalyst for fuel reformer

Reference : T.Takahashi, S.Tanaka and M.Esashi : Development of an in Situ Chemical Vapor Deposition Method for an Alumina Catalyst Bed in a Suspended Membrane Micro Fuel Reformer, J.of Micromech. Microeng., 16, (2006) pp.S206−S210



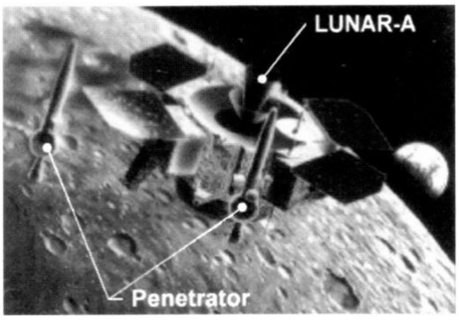




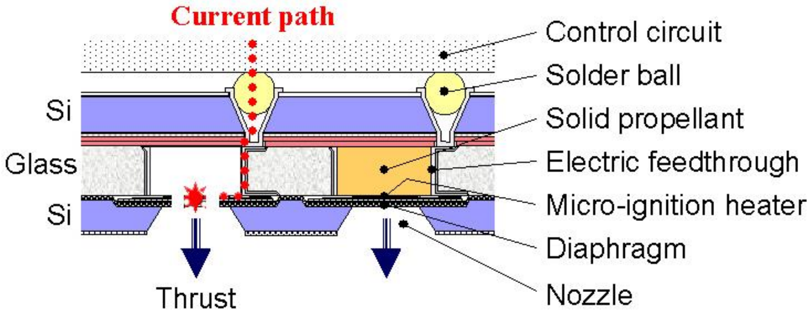
Vacuum−packaged micro fuel reformer

Reference : A.Kasuga, S.Tanaka and M.Esashi, Design and Fabrication of a Vacuum−packaged Micro Fuel Reformer, Technical Digest, Power MEMS 2007 (2007) pp.35−38

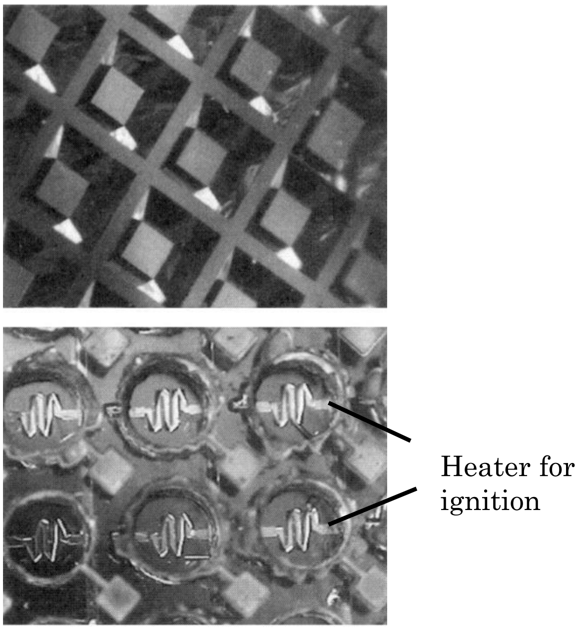
F6 Digital micro thruster (solid rocket engine array)



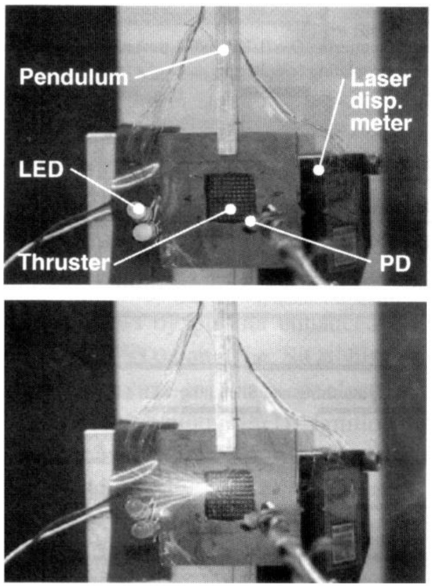
Purpose



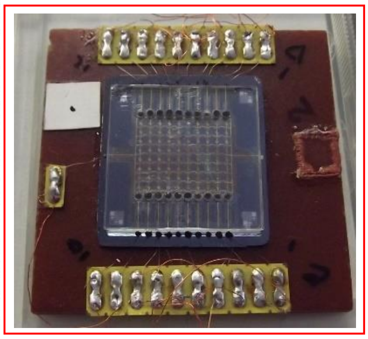
Structure



Top and bottom sides

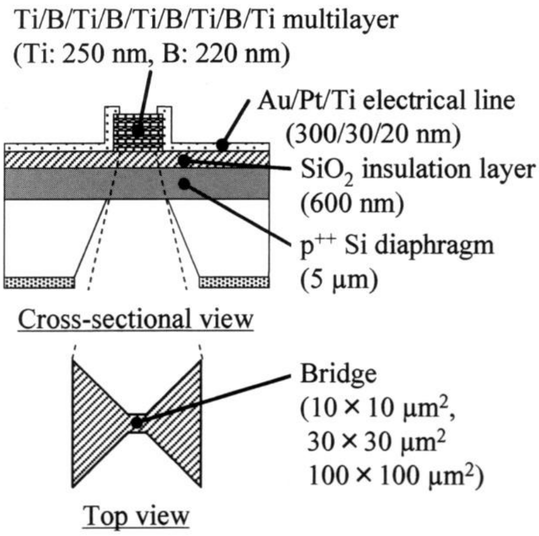


Measurement of thrust force

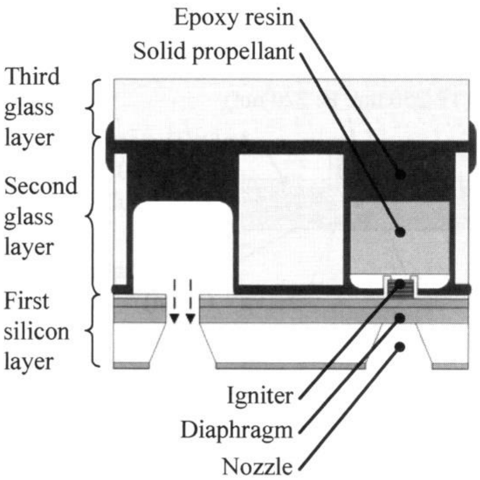


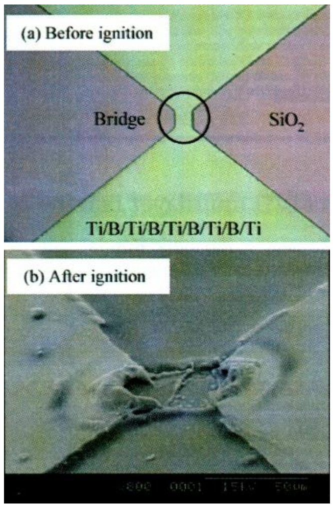
Digital micro thruster (Tohoku Univ. – JAXA)

Reference : S.Tanaka, R.Hosokawa, S.Tokudome, K.Hori, H.Saito, M.Watanabe and M.Esashi, MEMS-Based Solid Propellant Rocket Array Thruster with Electrical Feedthroughs, Trans. Japan Soc. Aero. Space Sci., 46 (2003) pp.47-51



$2B + Ti \rightarrow TiB_2 + 1320$ cal/g.

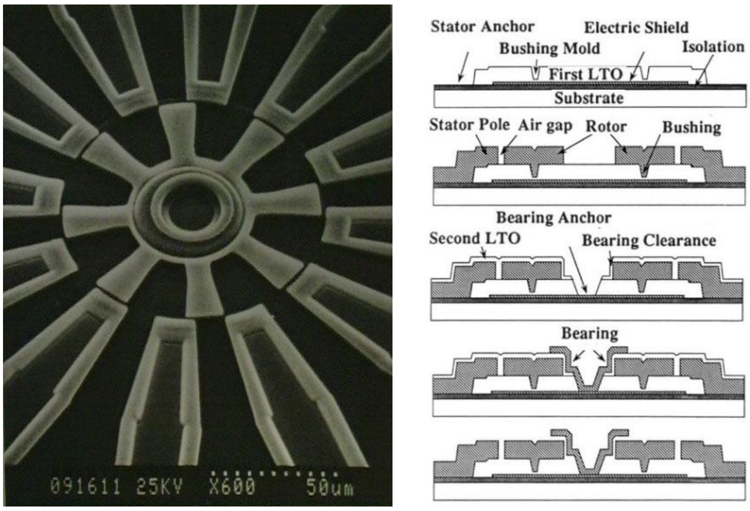


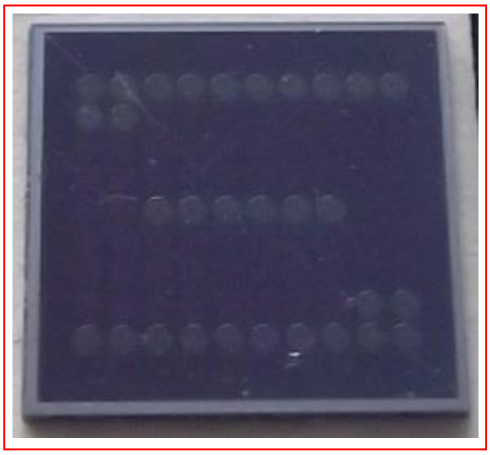


Igniter using a reaction of Bi / Ti (Tohoku Univ. – JAXA)

Reference : S.Tanaka, K.Kondo, H.Habu, A.Itoh, M.Watanabe, K.Hori and M.Esashi, Test of B/Ti Multilayer Reactive Igniters for a Micro Solid Rocket Array Thruster, Sensors and Actuators A, 144 (2008) pp.361-366

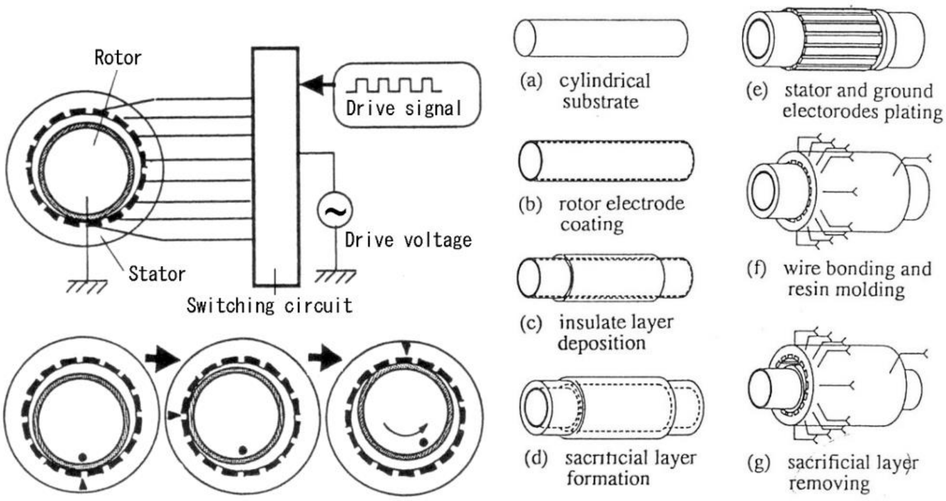
Electrostatic micro motor, actuator

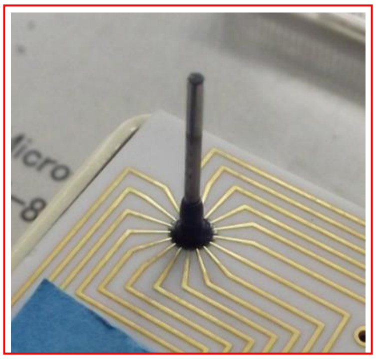


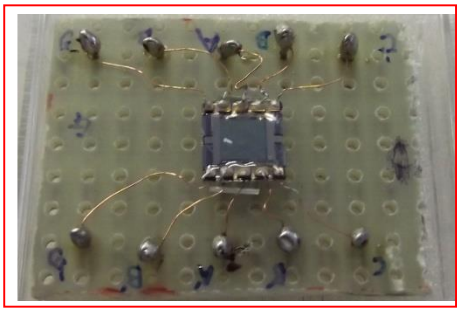


Electrostatic micro motor (MIT USA)

Reference : M.Mehregany, P.Nagarkar, S.D.Senturia and J.H.Lang, Operation of Micro-fabricated Harmonic and Ordinary Side-driven Motors, IEEE MEMS'90 (1990) pp.1-8

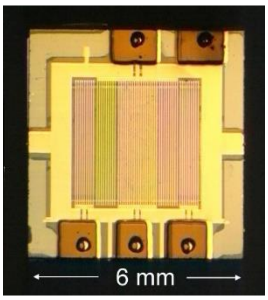


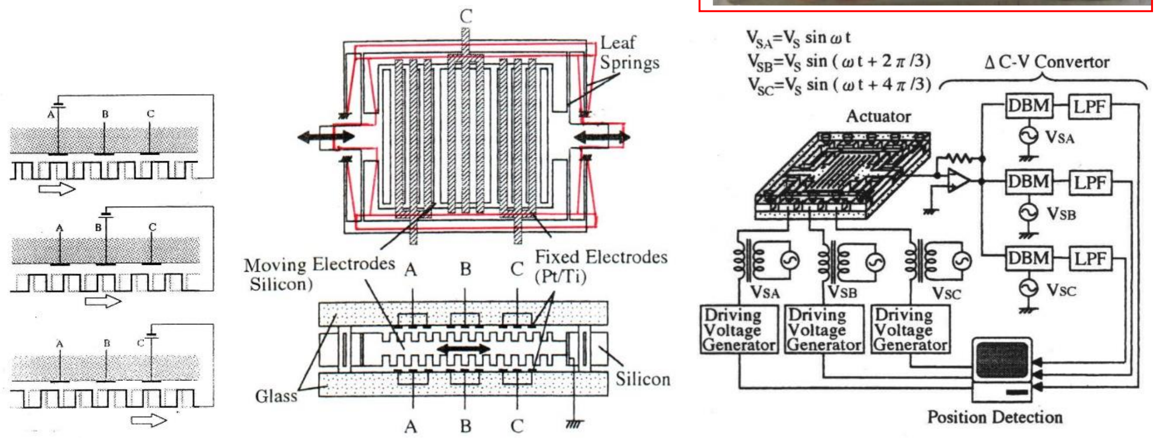




Electrostatic wobble motor (Panasonic Research Institute)

Reference : S.Aoki, H.Ogura, K.Nakamura, A.Ono, A Conventric Build-up Process to Fabricate Practical Wobble Motors, Procedings IEEE MEMS'94 (1994) pp.114-118

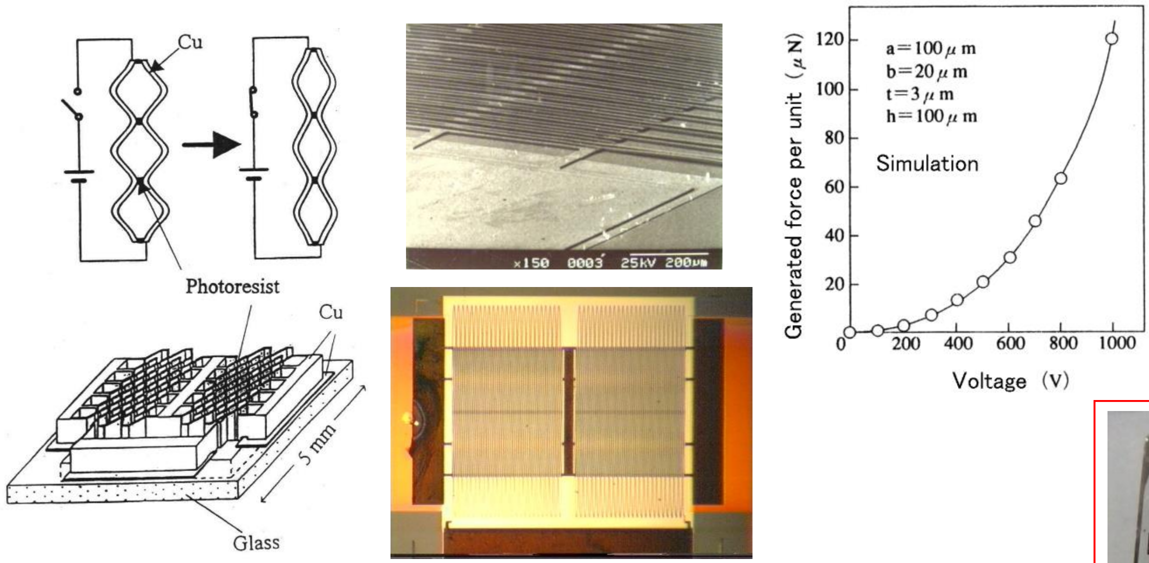




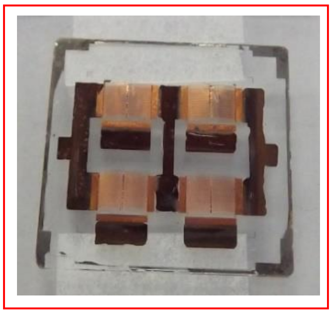
Packaged stepping electrostatic microactuator

Reference : T.Matsubara, M.Yamaguchi, K.Minami and M.Esashi, Stepping Electrostatic Microactuator, Digest of Technical Papers Transducers'93 (1993) pp.50-53

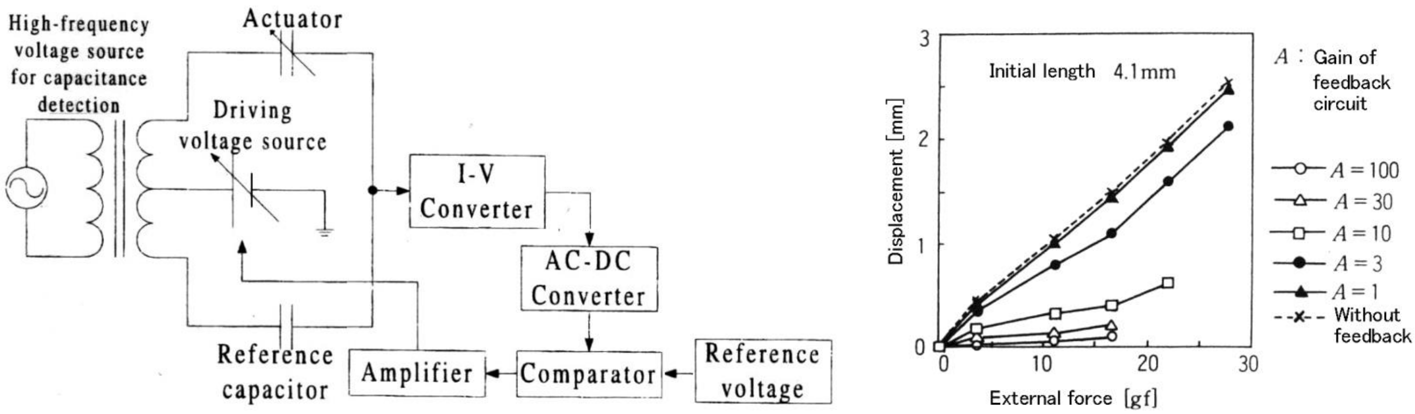
F8 # Distributed electrostatic micro actuator



Distributed electrostatic micro actuator

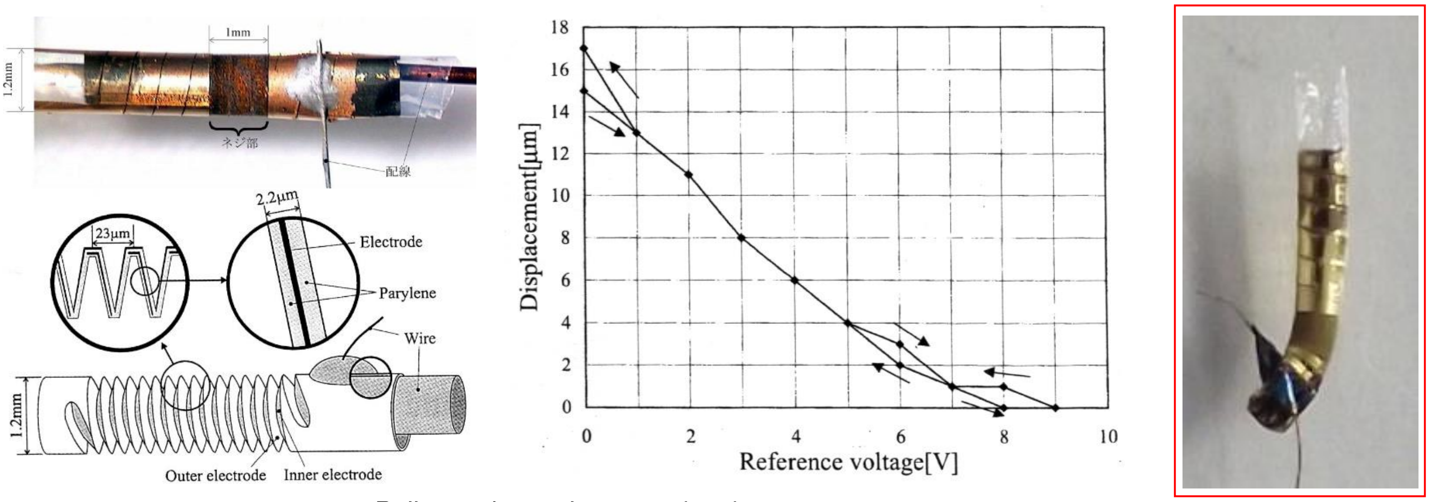


Reference : K.Minami, S.Kawamura and M.Esashi, Fabrication of Distributed Electrostatic Micro Actuator, IEEE Journal of Micromechanical Systems, 2 (1993) pp.121-127



Compliance control of distributed electrostatic microstructure

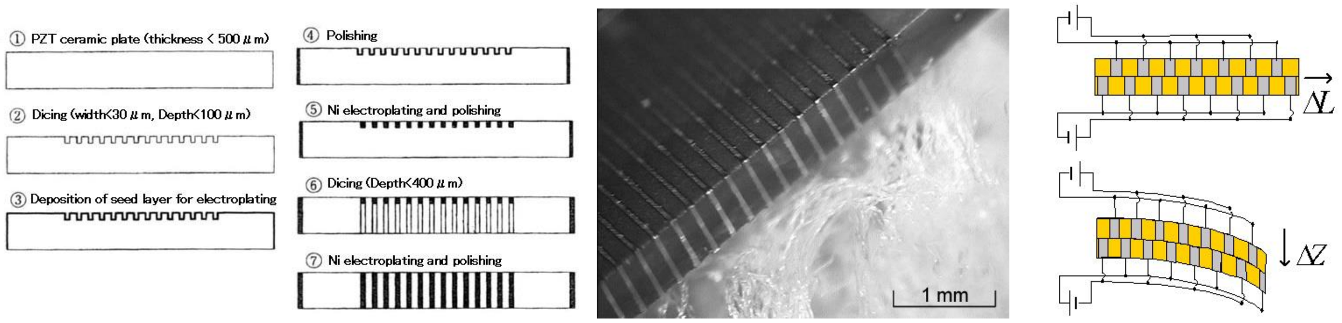
Reference : M.Yamaguchi, S.Kawamura, K.Minami and M.Esashi, Control of Distributed Electrostatic Microstructures, Journal of Micromechanics and Microengineering, 3 (1993) pp.90-95



Bellows-shape electrostatic microactuator

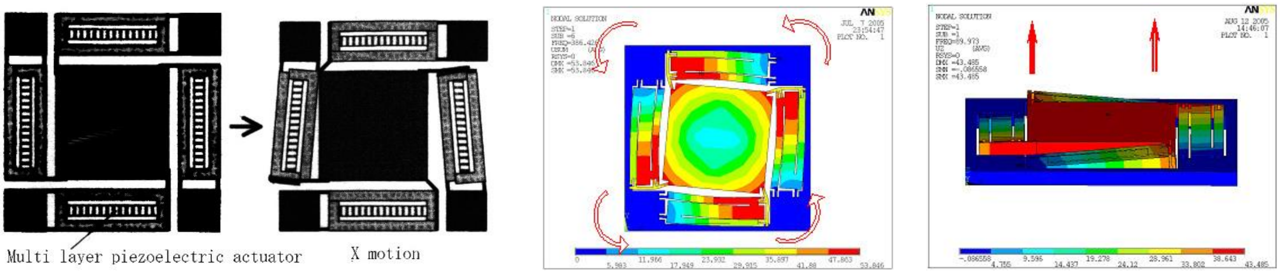
Reference : K.Minami, H.Morishita and M.Esashi, A Bellows-shape Electrostatic Microactuator, Sensors and Actuators, 72 (1999) pp.269-276

F9 Piezoelectric micro stage



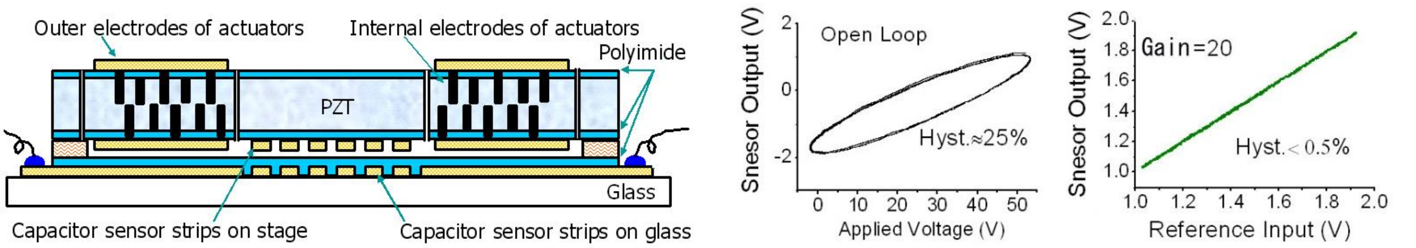
Multi-layer actuator by dicing PZT ceramic plate and filling the groove with electroplated metal

Reference : G.Suzuki and M.Esashi, Planer Fabrication of Multilayer Piezoelectric Actuator by Groove Cutting and Electroplating, Proc. of the Micro Electro Mechanical Systems'2000 (2000) pp.46-51



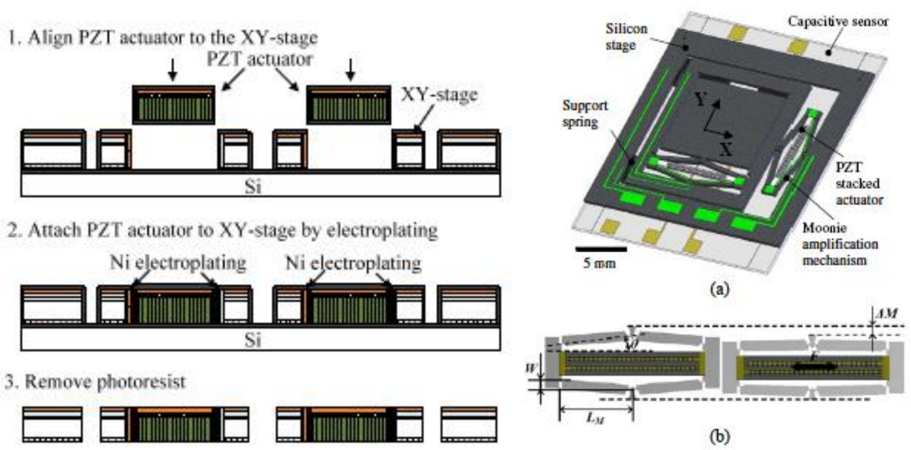
XYZ θ stage made of PZT ceramic plate

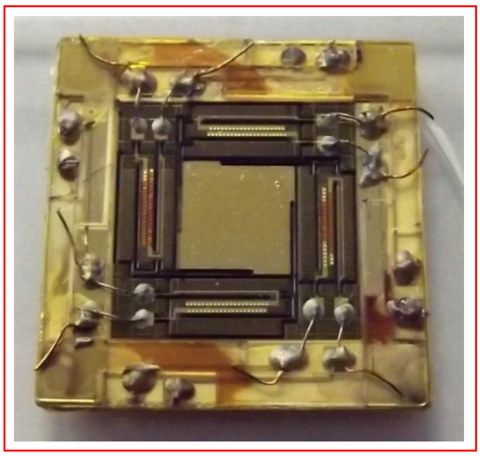
Reference : D.Zhang, C.Chang, T.Ono and M.Esashi, A Piezodriven XY-microstage for Multiprobe Nanorecording, Sensors and Actuators, A 108 (2003) pp.230-233



Feedback position control using capacitive position sensor

Reference : H.G.Xu, T.Ono and M.Esashi, Precise Motion Control of a Nanopositioning PZT Microstage Using Integrated Capacitive Displacement Sensors, J.of Micromech. Microeng., 16 (2006) pp.2747-2754

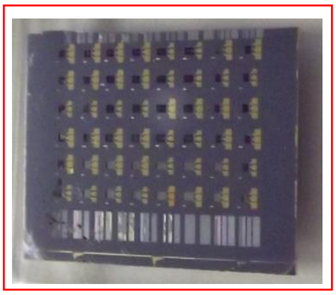


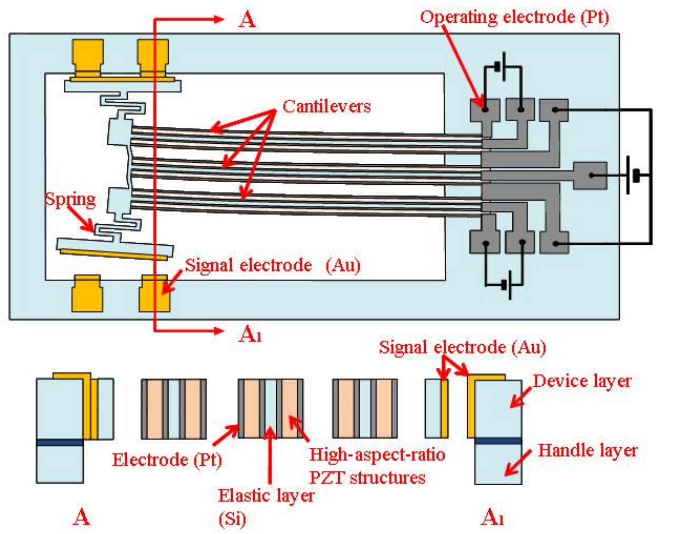


Si stage with multi-layer PZT actuators

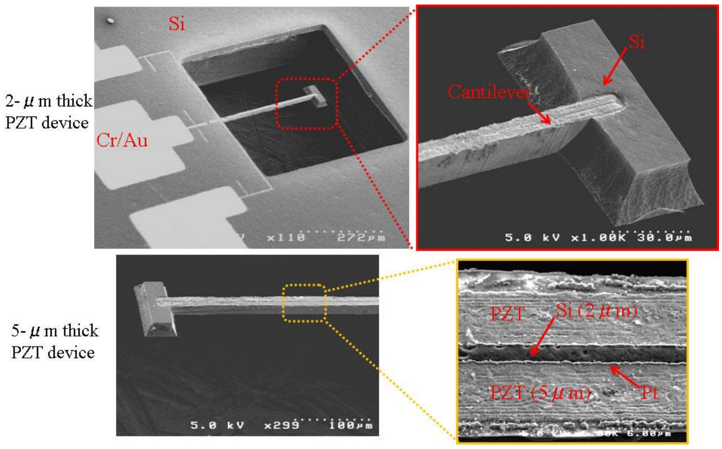
Reference : M.Faizul M.Sabri, T.Ono and M.Esashi, Modeling and Experimental Validation of the Performance of a Silicon XY-microstage Driver by PZT Actuators, J.of Micromech. Microeng., 19 (2009) 095004(9pp)

F10 # Lateral motion piezoelectric microactuator

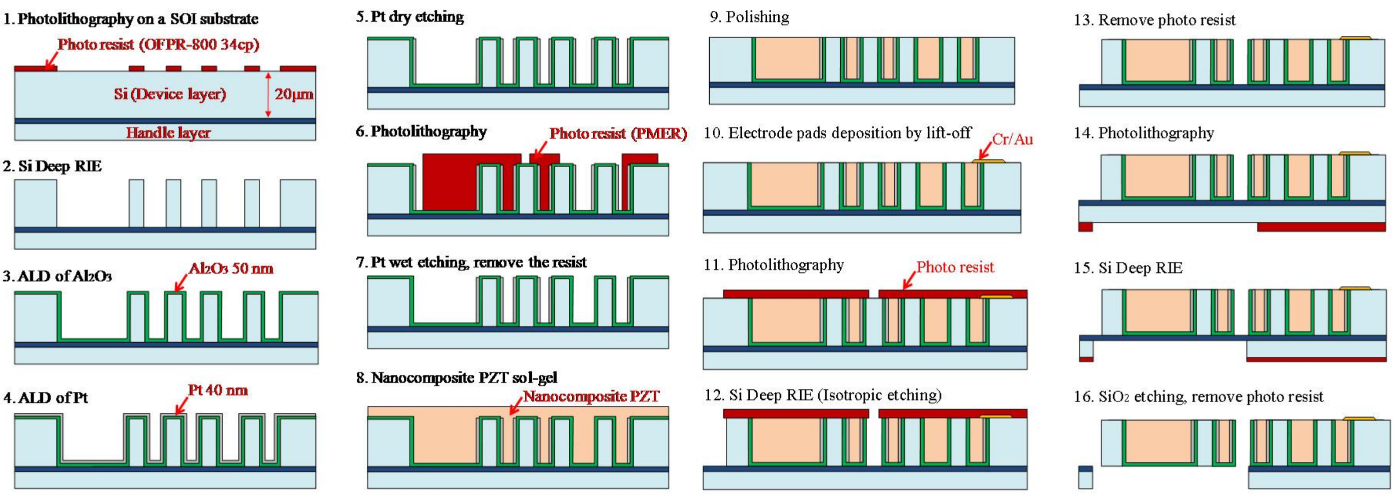




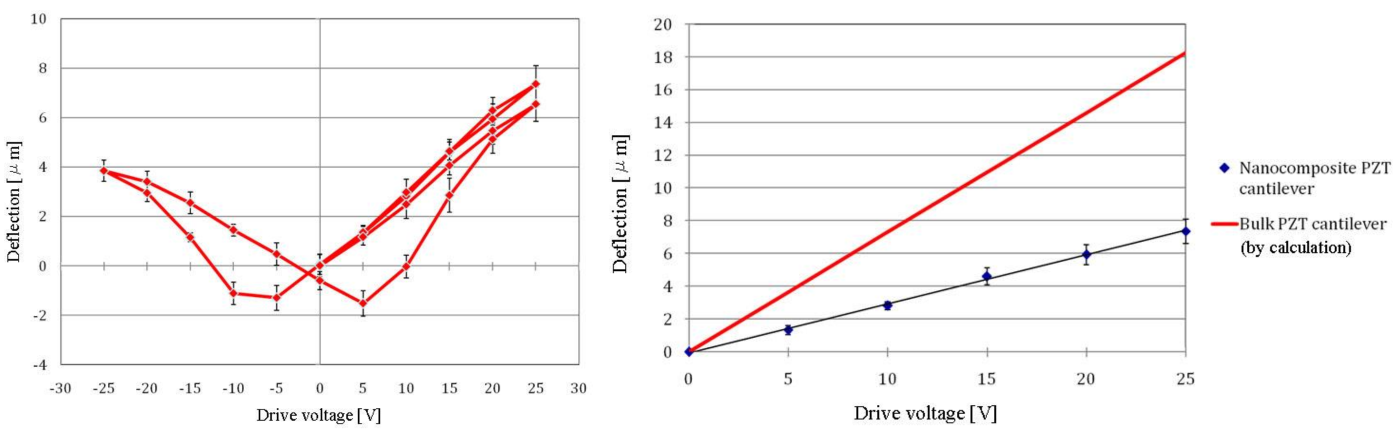
Structure



Photograph



Fabrication

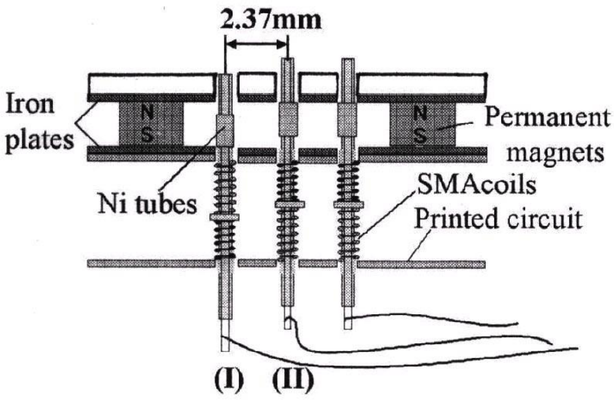


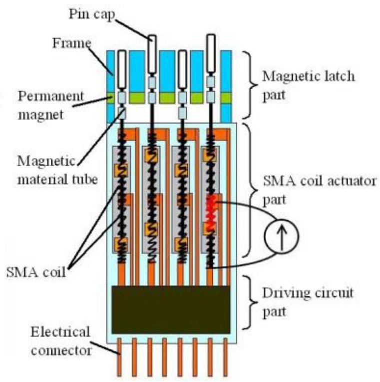
Displacement versus voltage

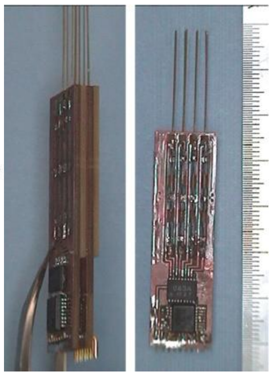
Lateral motion piezoelectric microactuator

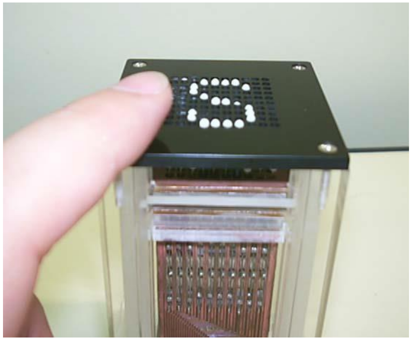
Reference : N.Wang, S.Yoshida, M.Kumano, Y.Kawai and M.Esashi, Fabrication of High-aspect-ratio PZT Structure by Nanocomposite S0l-gel Method for Laterally-driven Piezoelectric MEMS Switch, 2012 7th IEEE Intnl. Conf. on Nano/Micro Engineered and Molecular Systems (IEEE NEMS 2012) (2012) pp.321-326

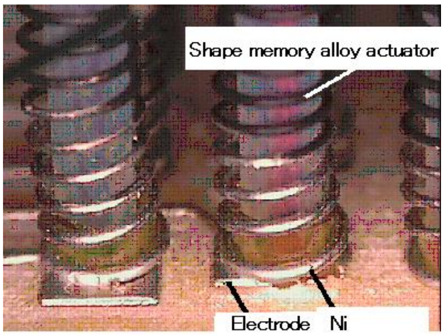
F11 Tactile display and tactile imager

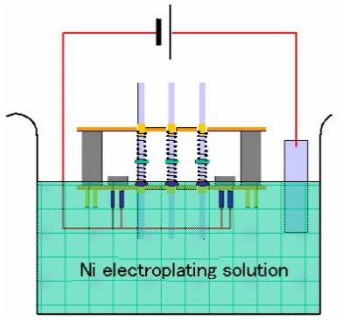






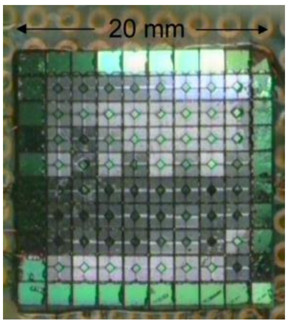


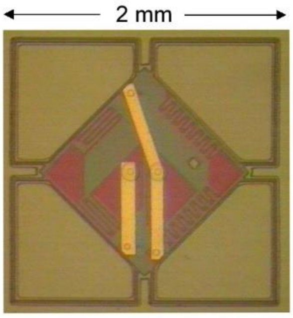


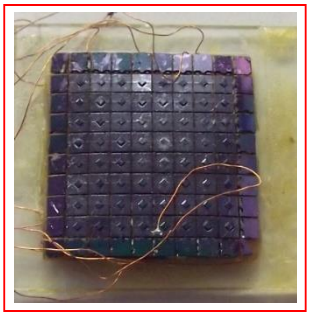


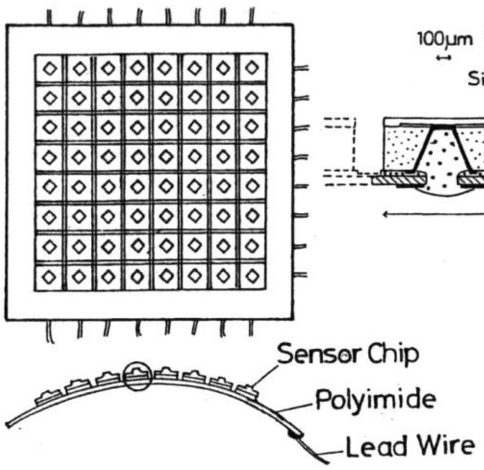
Tactile display

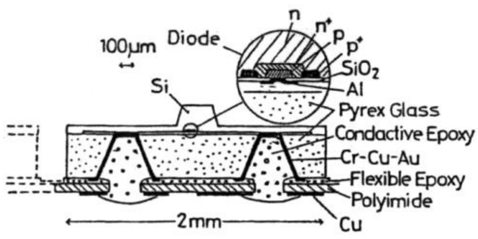
Reference : Y.Haga, W.Makishi, K.Iwami, K.Totsu, K.Nakamura and M.Esashi : Dynamic Braille Display Using SMA Coil Actuator and Magnetic Latch, Sensors & Actuators A, 119 (2005) pp.316-322

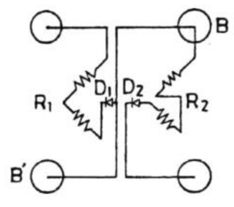


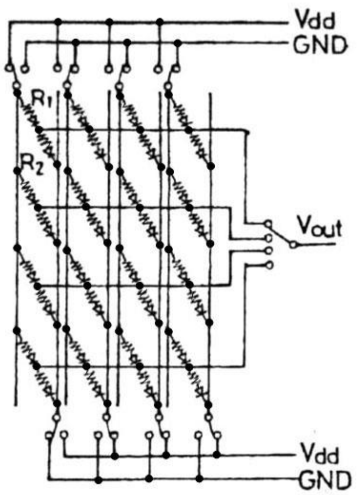








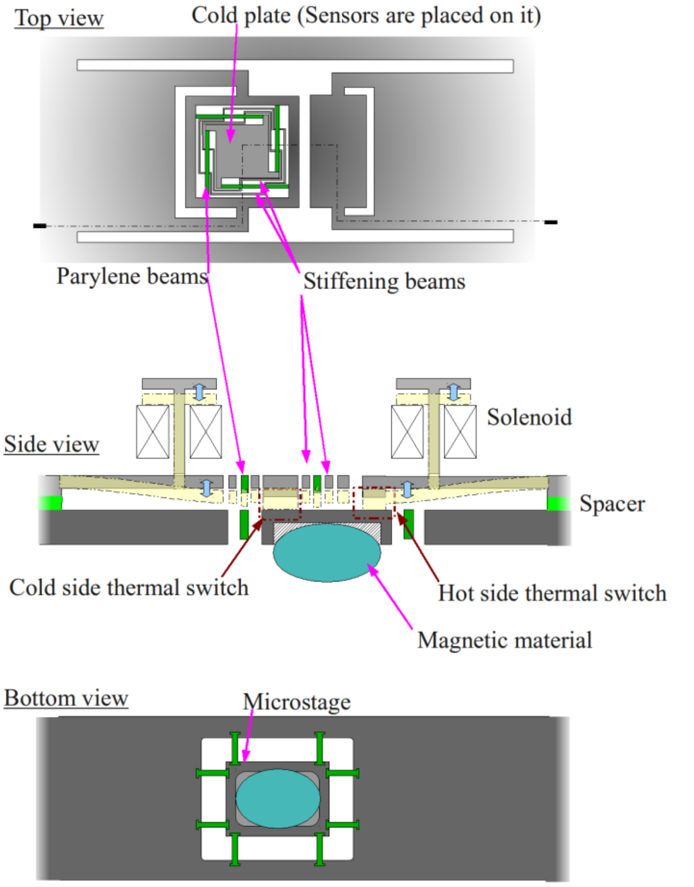




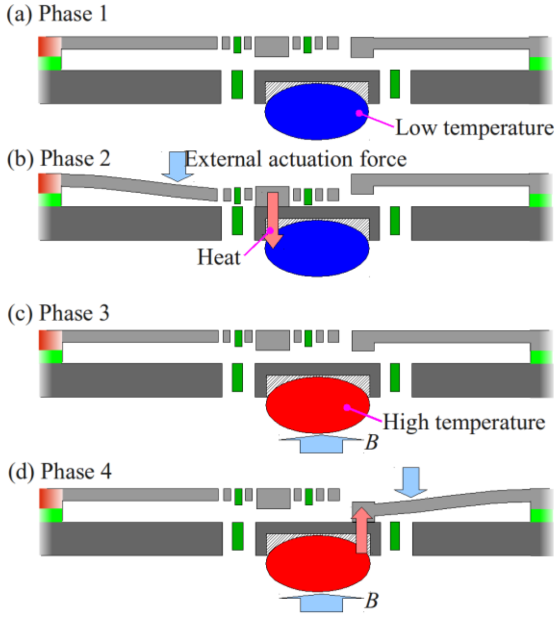
Tactile imager

Reference : M.Esashi, S.Shoji, A,Yamamoto, and K.Nakamura, Fabrication of Semiconductor Tactile Imager, Electronics and Communications in Japan, Part 2, 73 (1990) pp.97-104

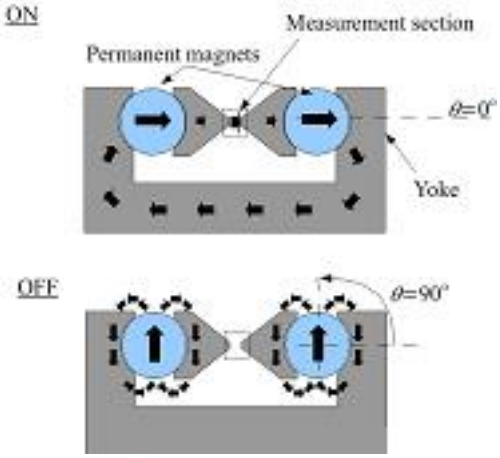
F12 Micro refrigeration system

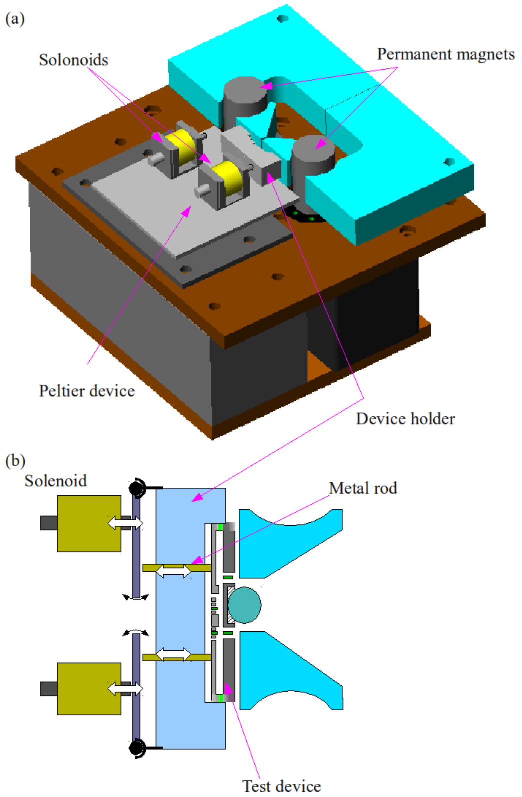


Micro magnetic refrigerator for cooling of micro devices

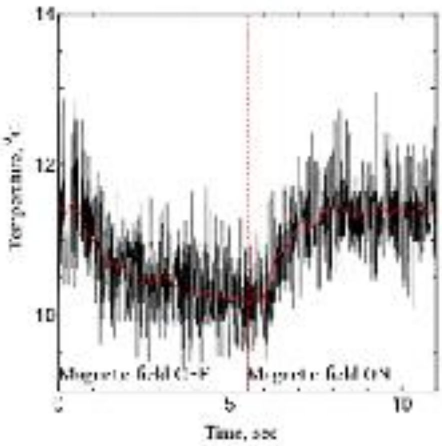


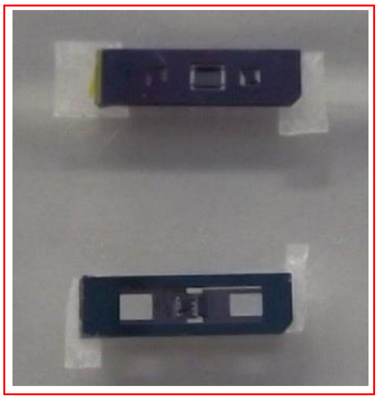
Refrigeration cycle (a)Adiabatic demagnetization (b)Heat dissipation from cold plate (c)Adiabatic magnetization (d)Heat dissipation to ambient.





Refrigeration system



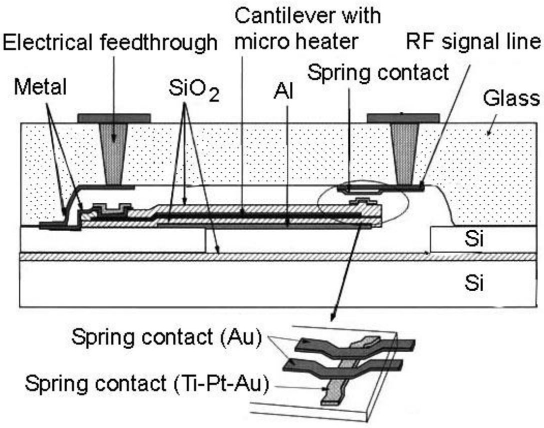


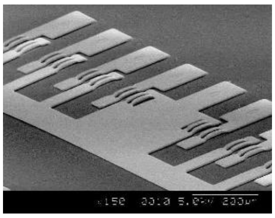
Rotating permanent magnets generate modulated magnetic field

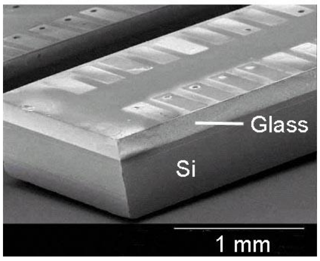
Magnetic field induced temperature change of the magnetic material

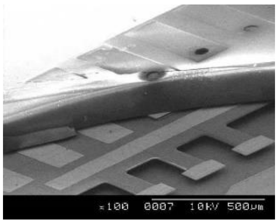
Reference : T.Tsukamoto, M.Esashi and S.Tanaka, A Micro Thermal Switch with a Stiffness-enhanced Thermal Isolation Structure, J.of Micromech. Microeng., 21 (2011) 104008(6pp)

F13 # Thermal MEMS switch



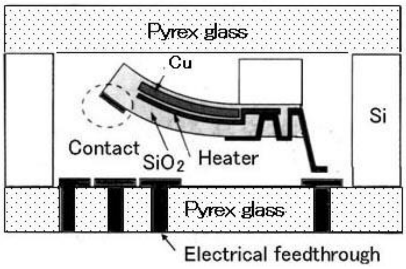


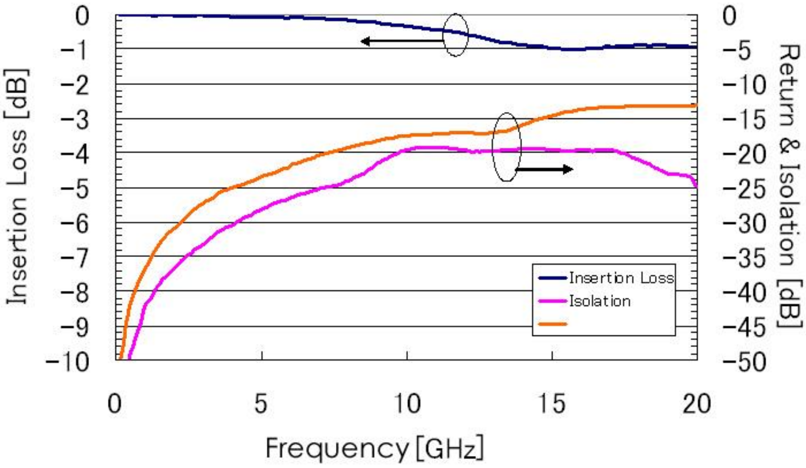




Thermal MEMS switch

Reference : Y.Liu, X.Li, T.Abe, Y.Haga and M.Esashi, A Thermomechanical Relay with Microspring Contact Array, Technical Digest IEEE Micro Electro Mechanical Systems'2001 (2001) pp.220-223





Advantages of conventional mechanical switch

・Imune to high voltage

・Excellent isolation at high frequency

Advantages of small size and integration

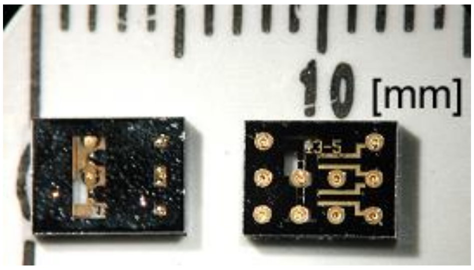
・Wide frequency range

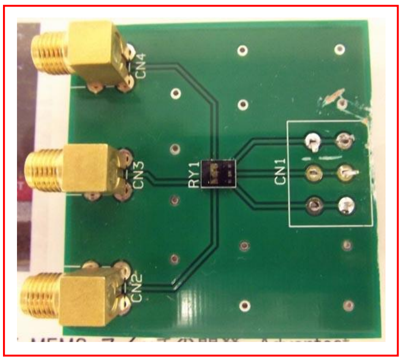
RF MEMS switch

・Imunity to electrostatic discharge : 1000V

・Frequency range : DC – 10GHz

Drive power	<160mW (6V)
On resistance	<0.3 Ω (initial)
Switching speed	<3ms
Cotact life	8000 times (3V-15mA dry)



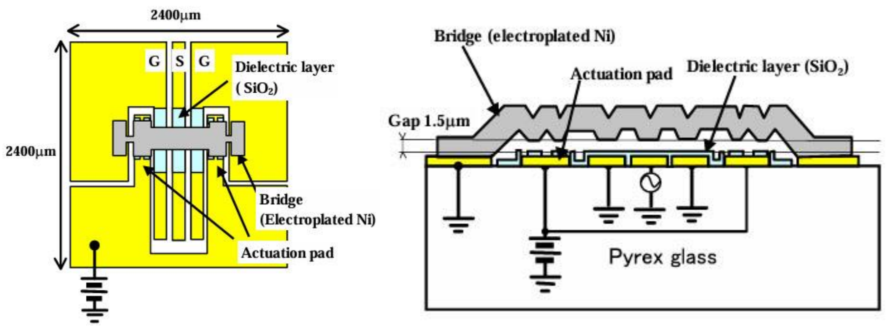


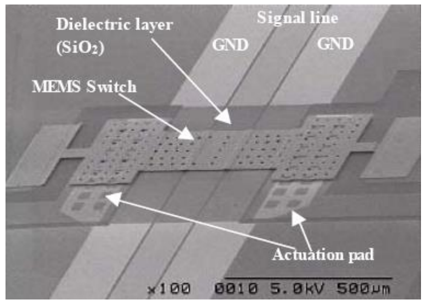
SoI test system T2000

LSI tester using the thermal MEMS switch and Advantest component producing the MEMS switch in Sendai

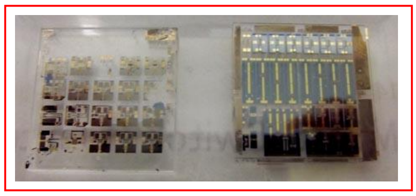
Reference : K.Nakamura, F.Takayanagi, Y.Moro, H.Sanpeo, M.Onozawa and M.Esashi : Development of RF MEMS switch, Advantest Technical Report, 22 (2004) pp.9-16

F14 Electrostatic and piezoelectric MEMS switch

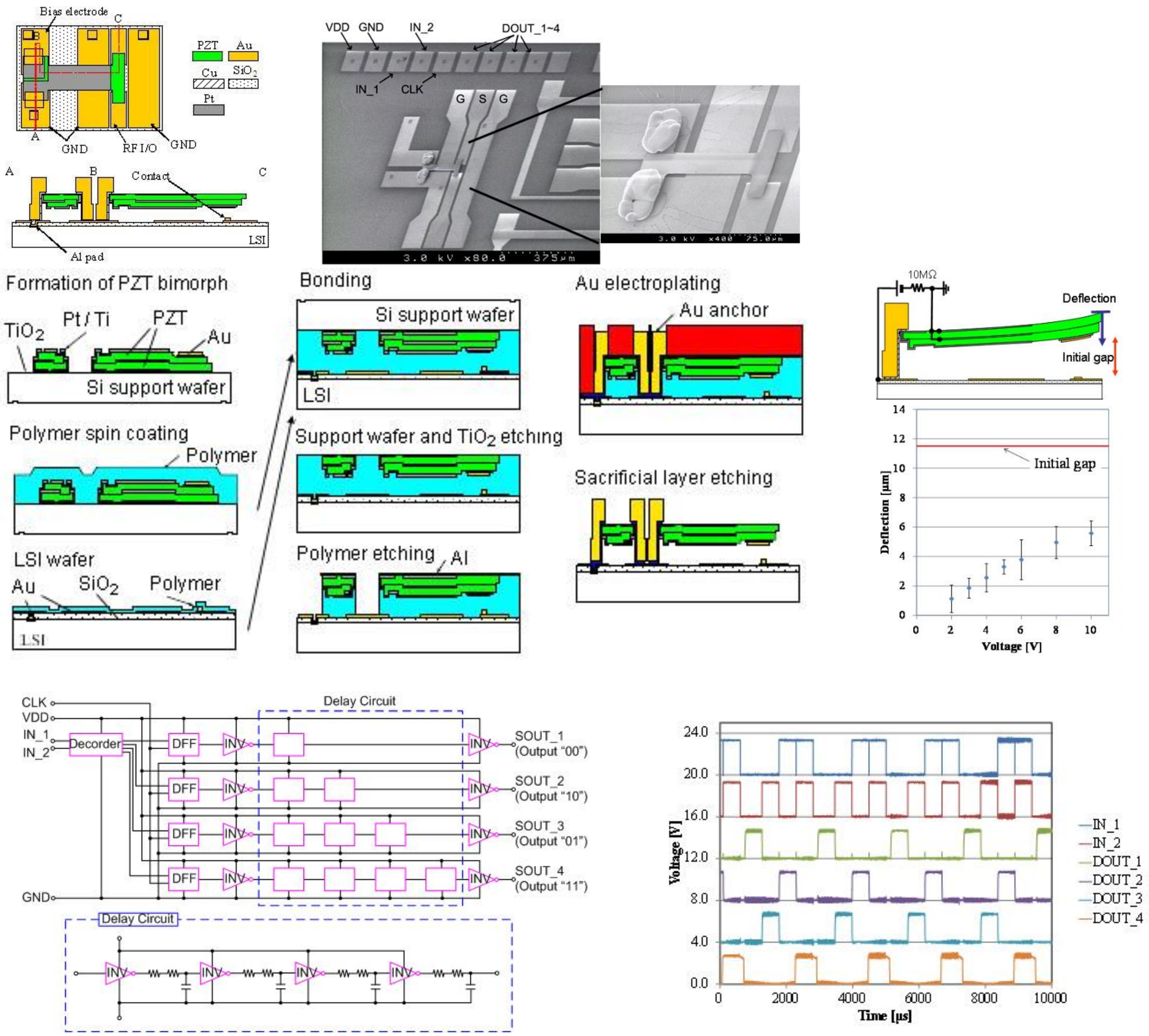




Electrostatically actuated capacitive switch



Reference : T.Yuki, J.H.Kuypers, S.Tanaka and M.Esashi, Capacitive RF Switch Fabricated by Low-temperature Surface Process and Packaged Using Dry Film Resist, Proc. of the 24th Sensor Symp. (2007) pp.37-40



MEMS switch using piezoelectric thin film

Reference : K.Matsuo, M.Moriyama, M.Esashi and S.Tanaka, Low-voltage PZT-actuated MEMS Switch Monolithically Integrated with CMOS Circuit, Technical Digest IEEE MEMS 2012 (2012) pp.1153-1156