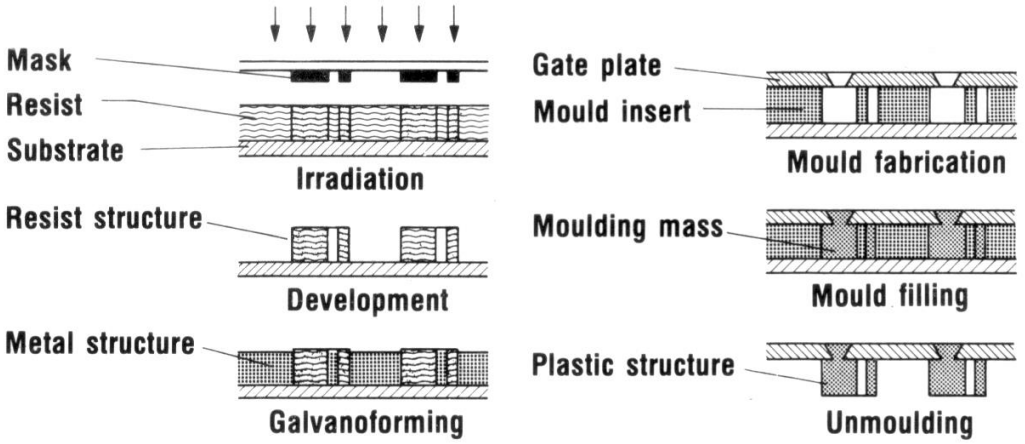
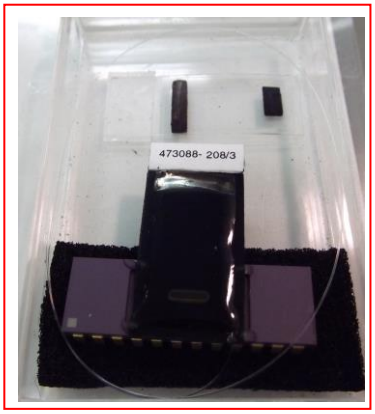
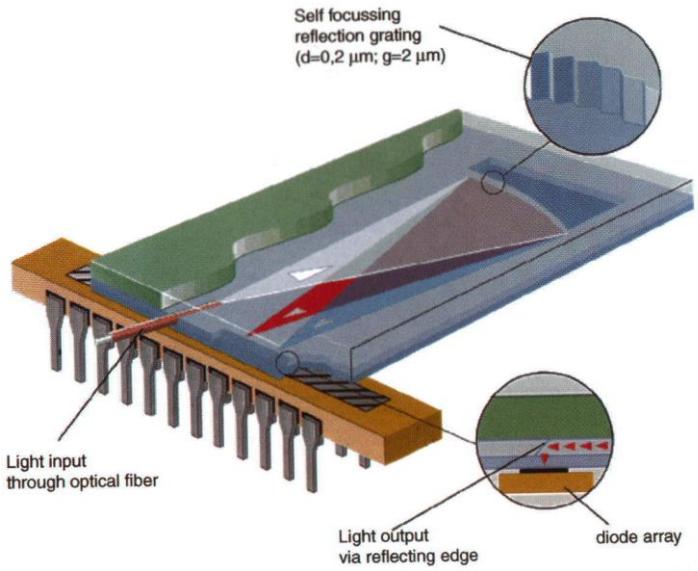
E1 LIGA process

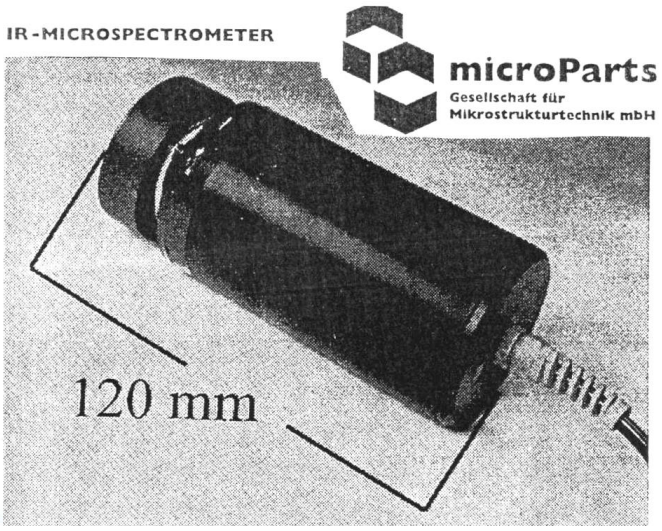




LIGA process by X ray exposure, electroplating and plastic molding (Germany)

Reference : E.W.Becker, W.Ehrfeld, P.Hagmann, A.Maner and D.Munchmeyer, Fabrication of Microstructures with High Aspect Ratios and Great Structural Heights by Synchrotron Radiation Lithography, Galvanoforming, and Plastic Moulding (LIGA Process), Microelectronic Engineering, 4 (1986) pp.35-56

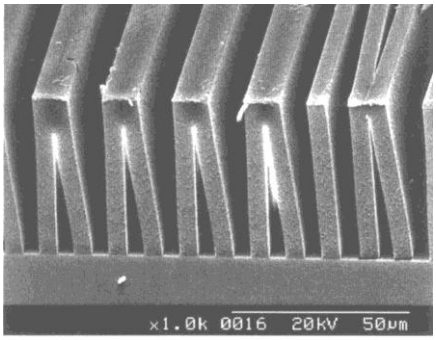




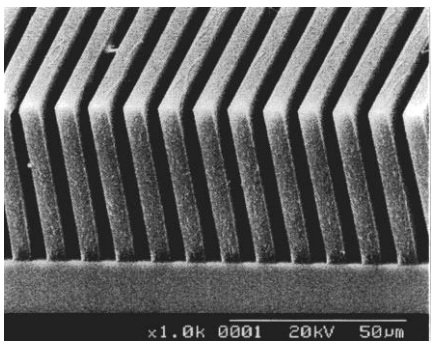
Micro spectrometer fabricated with LIGAprocess (Micro Parts, Germany)

Reference : Microspectrometer Fabricated by the LIGA Process, Interdisciplinary Science Review, 18 (1993) pp.273-279

Synchrotron orbital radiation facility (SORTEC)



Adhesion during drying

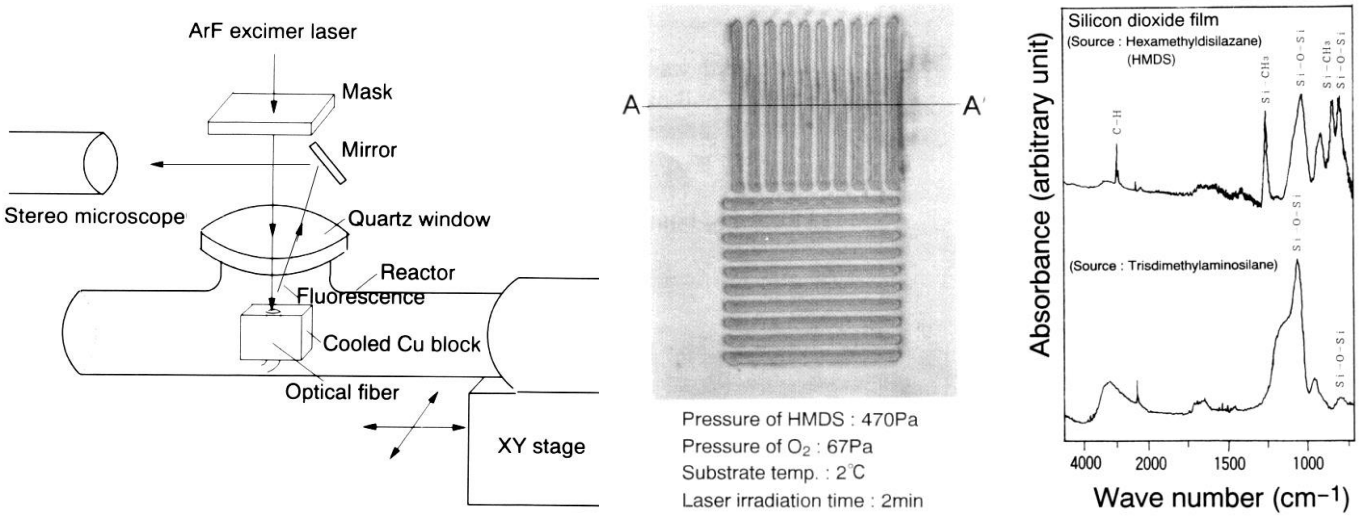


Drying using low surface tension liquid

LIGA process using negative resist (THB-N1 (JSR) Ltd.) (Tohoku Univ. – SORTEC)

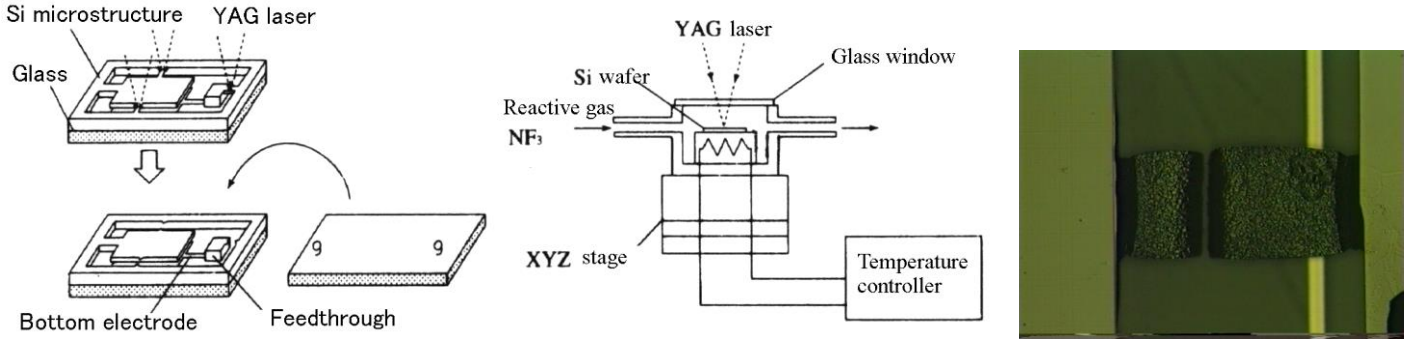
Reference : S.Watanabe, M.Esashi and Y.Yamashita, Fabrication Methods for High Aspect Ratio Microstructures, J.of Intelligent Material Systems and Structures, 8 (1997) pp.173-176

E2 Laser processes and stealth dicing



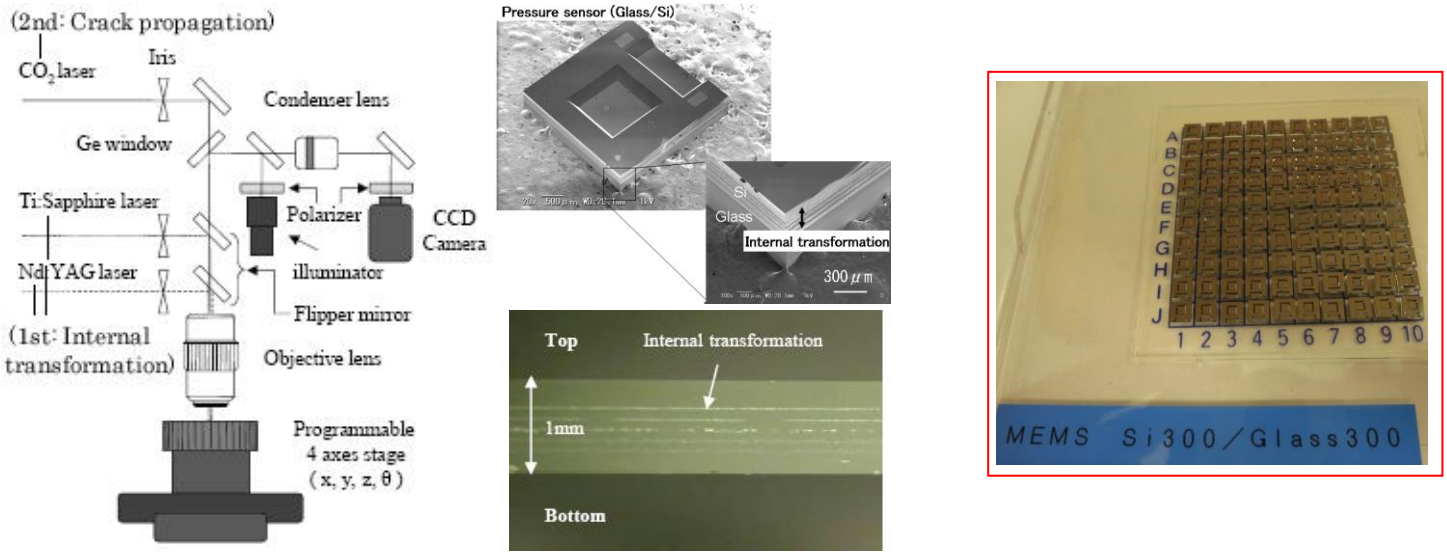
Laser projection CVD

Reference : K.Takashima, K.Minami, M.Esashi and J.Nishizawa, Laser Projection CVD Using the Low Temperature Condensation Method, Applied Surface Science, 79/80 (1994) pp.366-374



Laser assisted Si etching

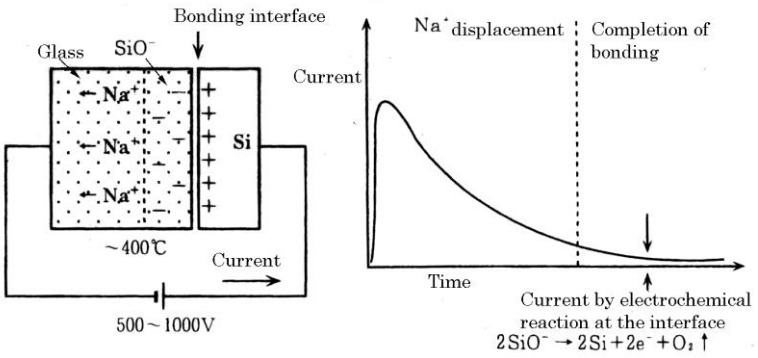
Reference : K.Minami, Y.Wakabayashi, M.Yoshida, K.Watanabe and M.Esashi, YAG Laser-Assisted Etching of Silicon for Fabricating Sensors and Actuators, J. of Micromechanics and Microengineering, 3 (1993) pp.81-86



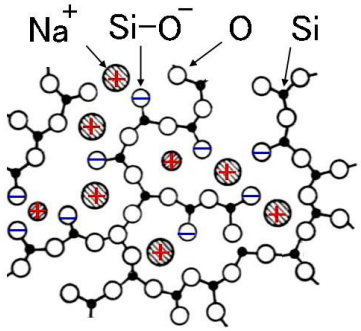
Laser (stealth) dicing of Si-glass structure (Tohoku Univ. - Inst. For Laser Tech.)

Reference : M.Fujita, Y.Izawa, Y.Tsurumi, S.Tanaka, H.Fukushi, K.Sueda, Y.Nakata, M.Esashi and N.Miyanaga , Debris-free Low-stress High-speed Laser Assisted Dicing for Multi-layered MEMS, Trans. IEE of Japan, 130-E (2010) pp.118-123

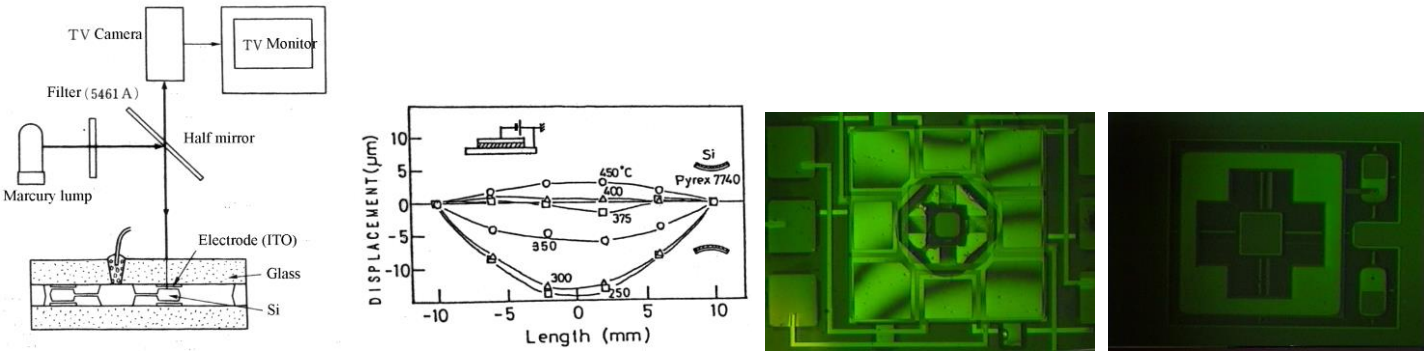
E3 Anodic bonding



Principle of anodic bonding

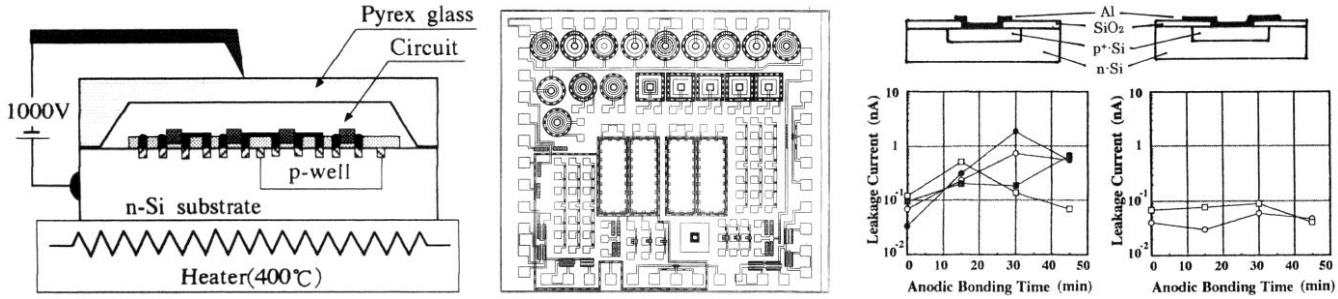


Molecular structure of glass



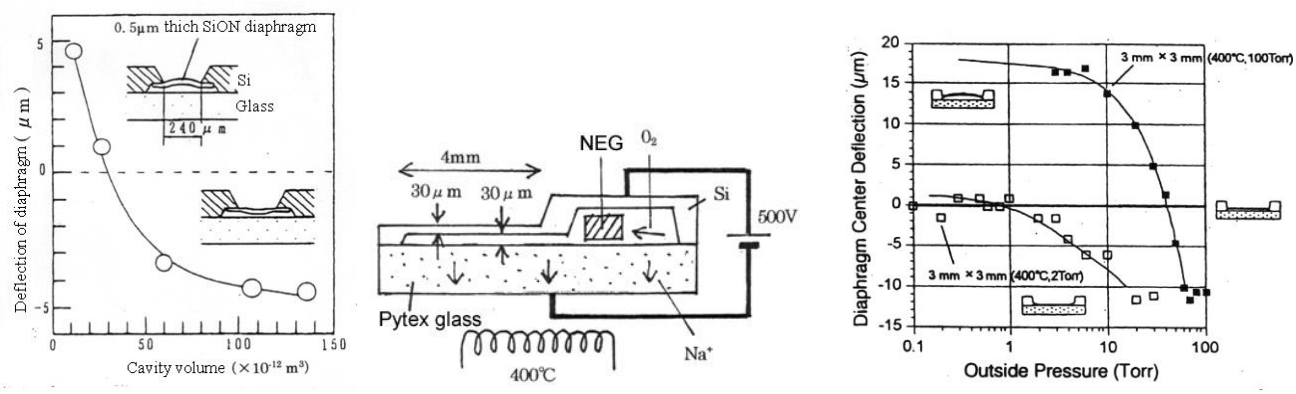
Distortion after anodic bonding

Reference : Y.Shoji, K.Minami, M.Esashi, Glass-silicon Anodic Bonding for the Reduction of Structural Distortion, Trans. IEE of Japan, 115-A (1995) pp.1208-1213



Influences of anodic bonding to CMOS circuit

Reference : M.Shirai, M.Esashi, Circuit Damage by Anodic Bonding, Technical Report IEE of Japan, ST-92-7 (1992) pp.9-17

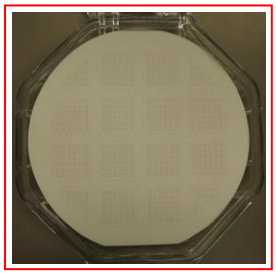


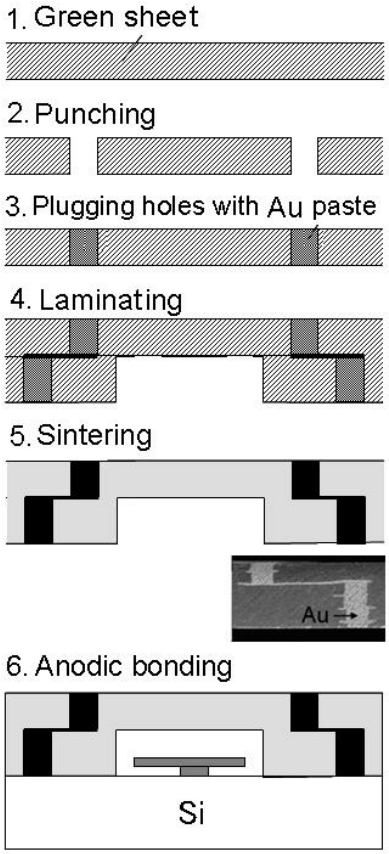
Vacuum packaging and pressure controlled packaging (right) by anodic bonding

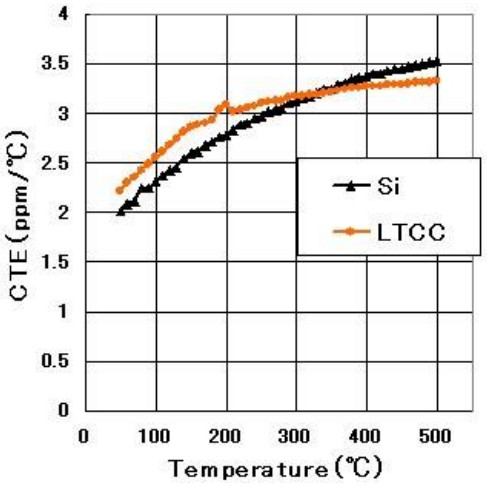
Reference : N.Ura, K.Nakaichi, K.Minami, M.Esashi, Vacuum Packaging by Anodic Bonding, The 11th Sensor Symposium (1992) p.63

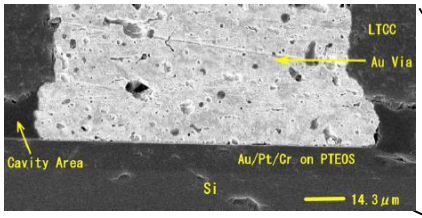
M.Esashi, Vacuum Packaging Technology for Microsensors, Trans. IEE of Japan, 120-E (2000) pp.310-314

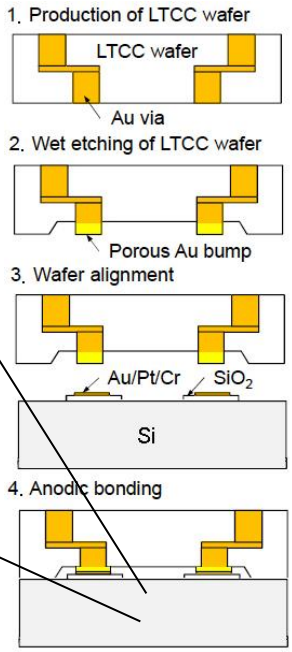
E4 Anodically bondable LTCC with electrical feedthrough (Nikko)



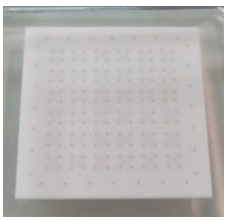




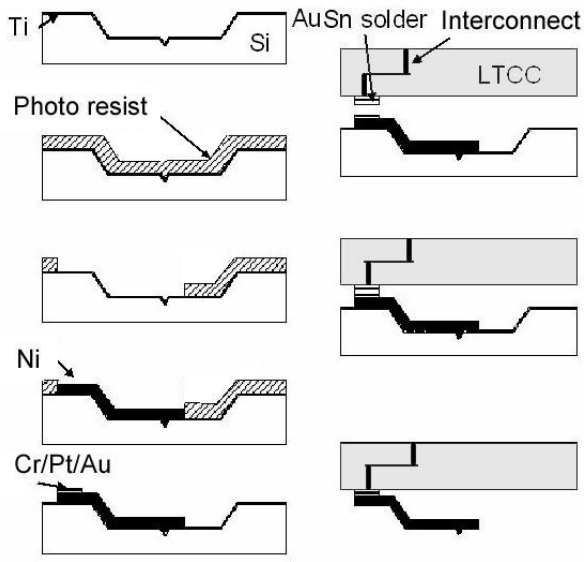


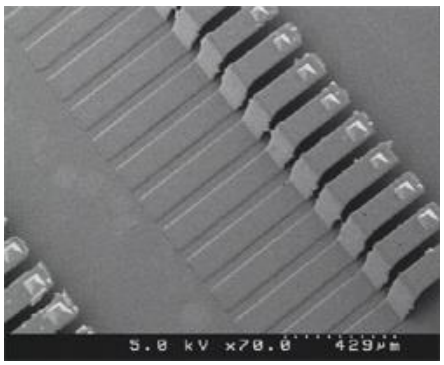


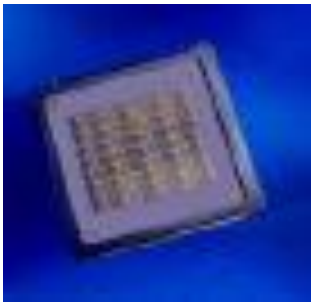
Anodically bondable LTCC (Low Temperature Co-fired Ceramics) with electrical feedthrough and electrical interconnection using porous gold (Nikko – Tohoku Univ.)



Reference : M.Mohri, A.Okada, H.Fukushi, M.Esashi and S.Tanaka, Packaging Technology for Hermetic Sealing with Electrical Connection Using Anodically-Bondable LTCC Substrate with Etched Cavities, The 28th Sensor Symposium on Sensors, Micromachines and Applied Systems (2011) p.62



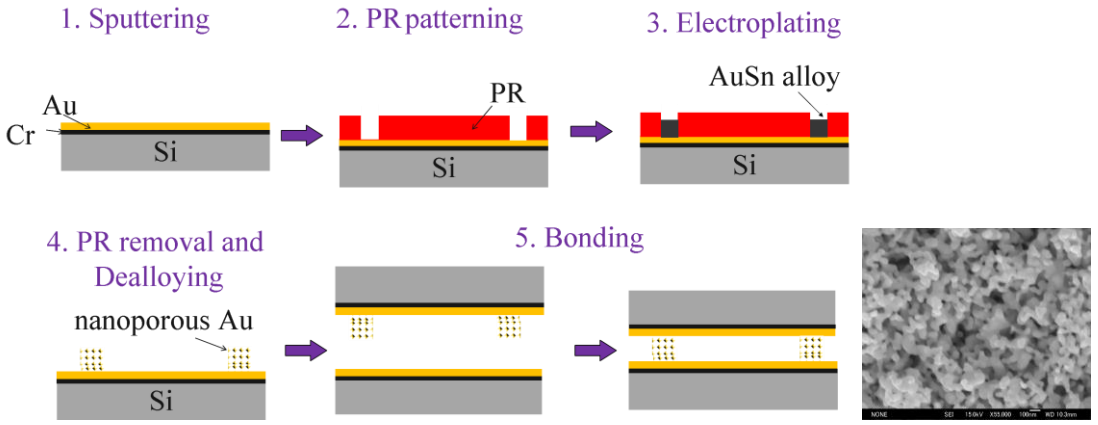


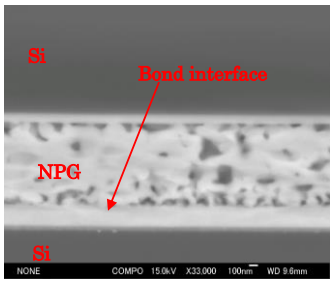


Probe card using LTCC for wafer-level burn-in test

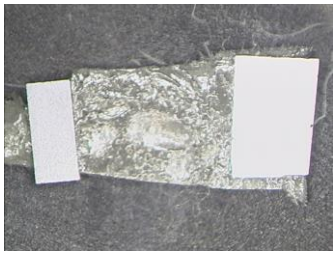
Reference : S.-H.Choe, S.Tanaka and M.Esashi, A Matched Expansion MEMS Probe Card with Low CTE LTCC Substrate, IEEE International Test Conference 2007 (2007) Paper 20.2

E5 Bonding materials (WPI-AIMR, Fraunhofer ENAS – Tohoku University)

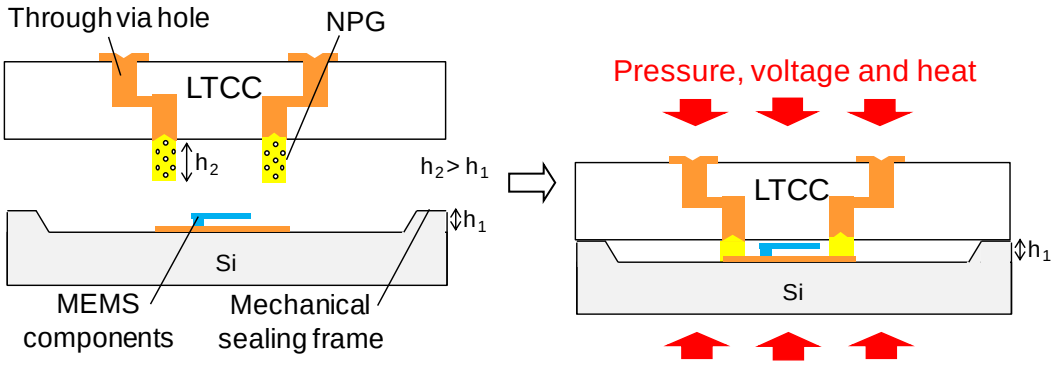


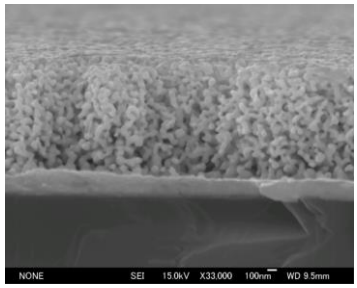


Nanoporous gold (NPG) for low temperature substrate bonding



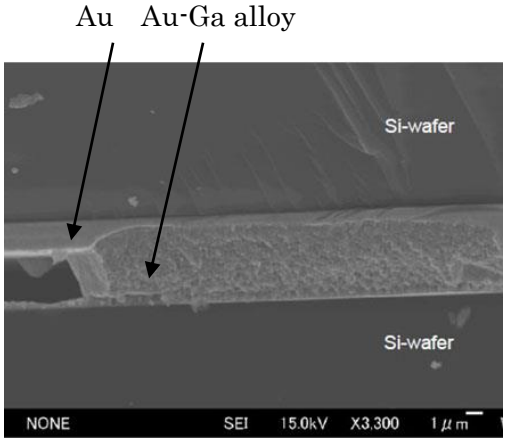
Reference : W. -S. Wang, Y. -C. Lin, L. Y. Chen, M. W. Chen, T. Gessner and M. Esashi, Demonstration of Substrate Bonding utilizing Au Film and Nanoporous Gold Structures, Proceedings of the International Conference on Wafer Bond '11, Dec. 7-8 (2011)

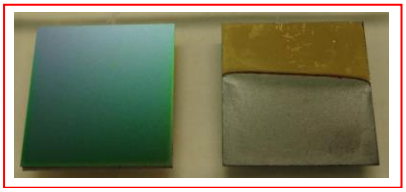




Electrical interconnection by using nano-sponge for MEMS packaging

Reference : Y. -C. Lin, W. -S. Wang, L. Y. Chen, M. W. Chen, T. Gessner and M. Esashi, Anodically-bondable LTCC substrates with Novel nano-structured electrical Interconnection for mems packaging, Proceedings of the international conference on solid-state sensors and actuators (Transducers '11), June 5-9 (2011) pp. 2351-2354





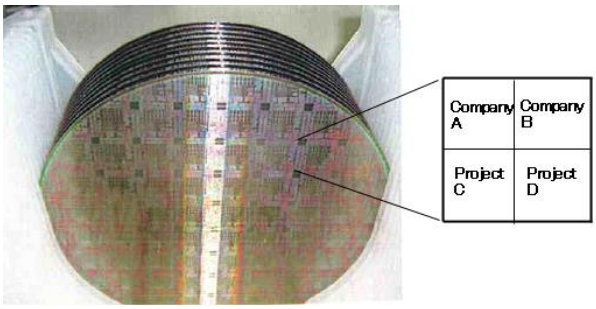
Left : Bonded wafer
Right : Ga is electroplated on the lower part

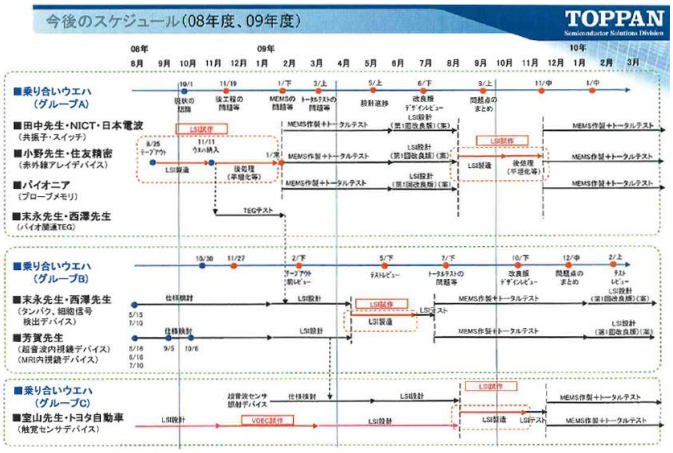
$GaCl_3$	gallium cloride
$C_6H_{15}NO_3$	triethanolamine
NaCl	sodium chloride
KOH	potassium hydroxide

Room temperature Ga SLID (Solid-Liquid Inter-Diffusion bonding) (left:bonding interface, right:electroplating)

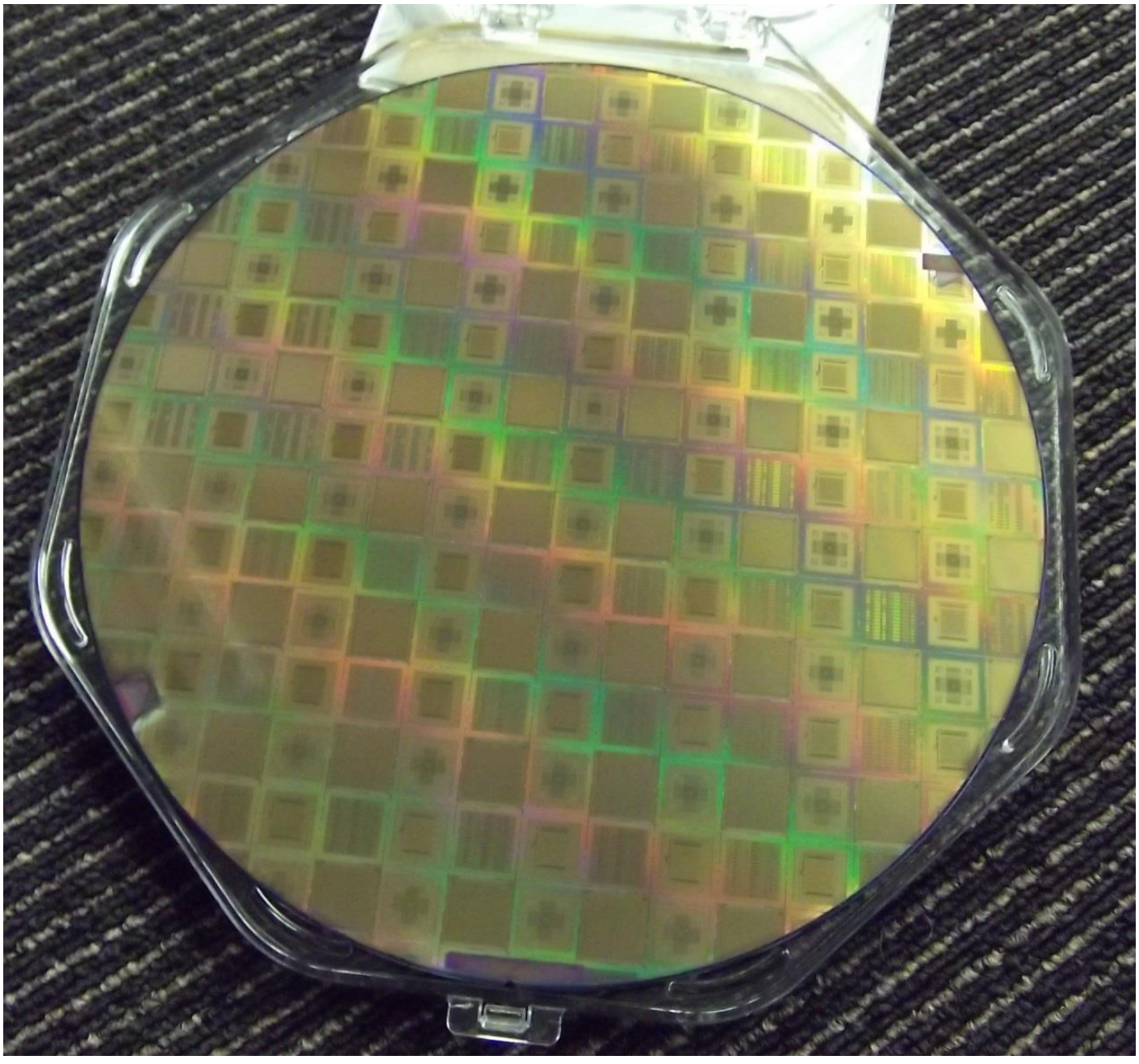
Reference : J.Frömel, Y.-C.Lin, M.Wiemer, T.Gessner and M.Esashi, Low Temperature Metal Interdiffusion Bonding for Micro Devices, 2012 3rd IEEE International Workshop on Low Temperature Bonding for 3D Integration (LTB-3D), Tokyo (2012, 22-23 May) 163)

E6 Shared CMOS LSI wafer (Special Coordination Funds for Promoting Science and Technology, Formation of Innovation Center for Fusion of Advanced Technologies)

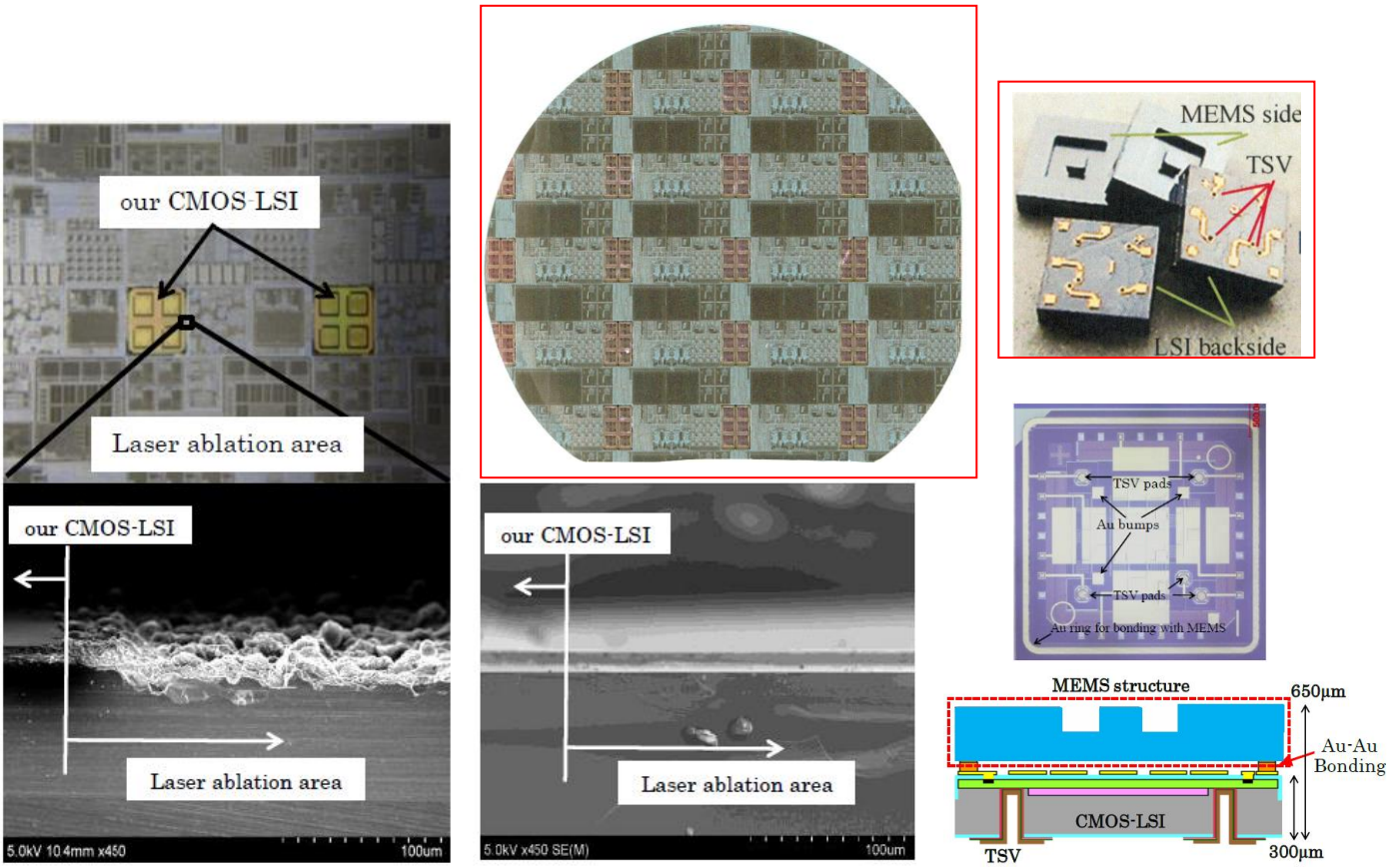




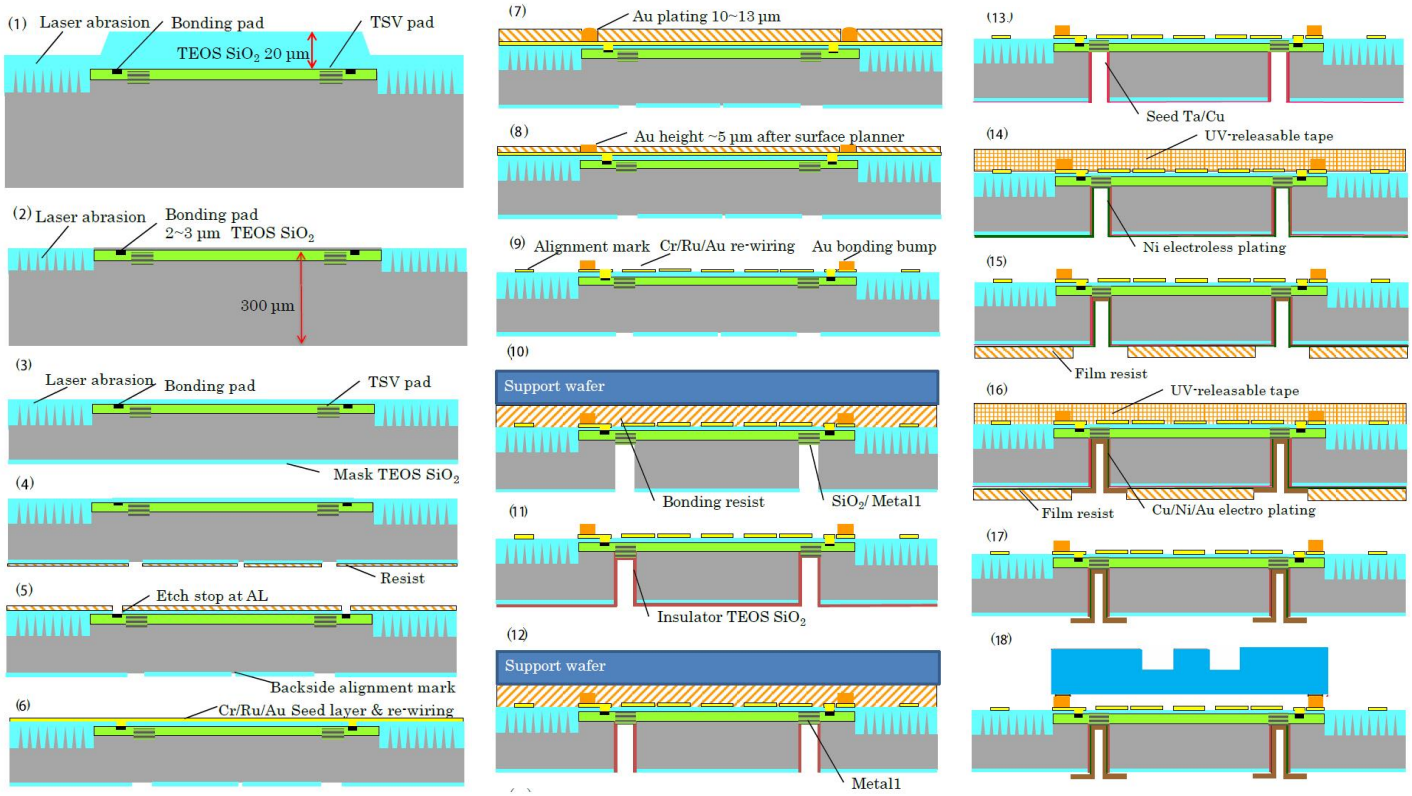
Shared CMOS wafer



E7 Laser-erased wafer process



Multi project wafer in which other chips are erased by laser and process Application to tactile sensor network chip for making MEMS and TSV on the CMOSLSI wafer

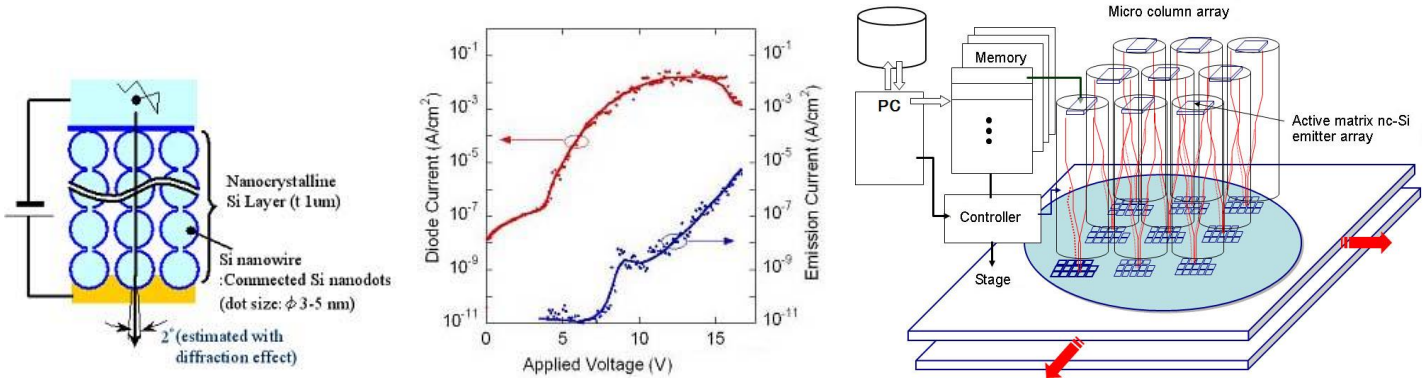


Fabrication process

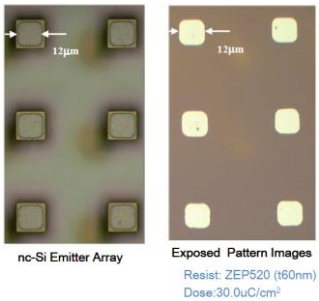
(Y.Suzuki, S.Tanaka et.al, Fabrication of Deep TSV in Laser-Erased CMOS-LSI Multi-project WAFER for Surface MountableIntegrated MEMS, Sensor Symp. 2016, 24pm2-B-6)

E8 Massive parallel electron beam write (MPEBW)

(Funding Program for World-Leading Innovative R&D on Science and Technology (FIRST))

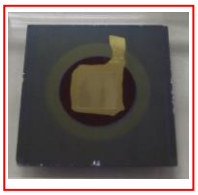


Principle of nano-crystalline (nc) Si emitter and concept of the electron beam exposure system using the nc-Si emitter

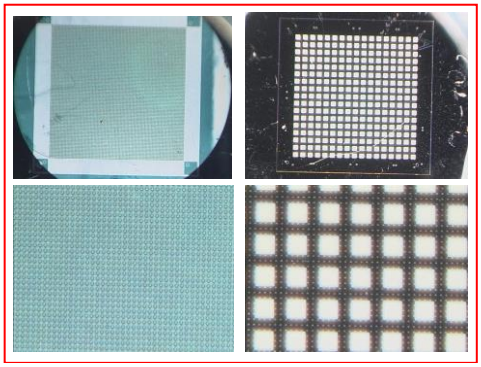


Planer type nc-Si emitter with through Si via and result of exposure

CMOS LSI for driving active matrix electron emitter

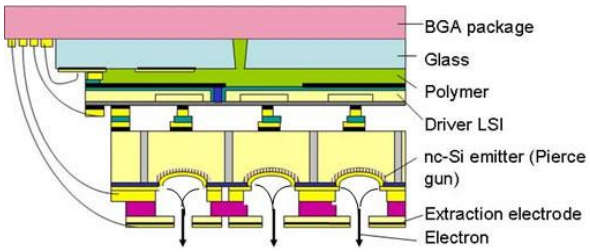


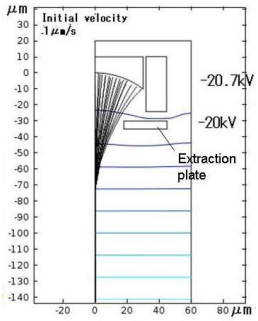
Nc-Si electron emitter



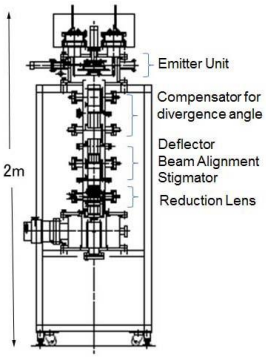
Electron emitter array
(left : front side、right : back side)
(top : chip、bottom : magnified)

N.Ikegami, T.Yoshida, A.Kojima, H.Ohyi, N.Koshida and M.Esashi.,
Active-Matrix nc-Si Electron Emitter Array for Massively Parallel Direct-Write Electron-Beam System, J. Micro/Nanolith. MEMS MOEMS 11, 3 (2012) 031406

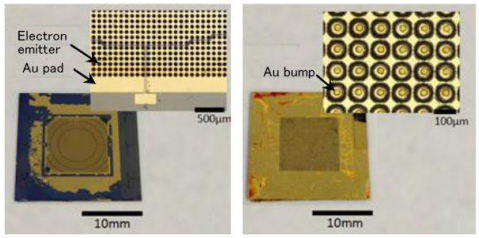




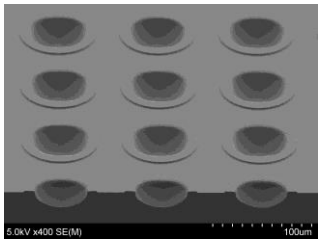
Experiment of electron emission driven by CMOS LSI



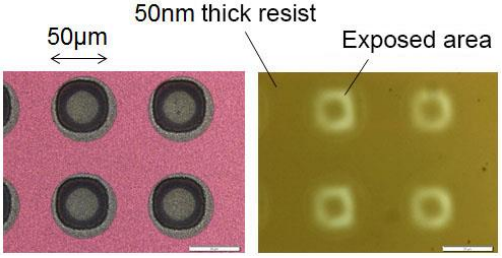
Fabrication of nc-Si emitter on CMOS LSI (under development)



nc-Si Pierce-gun emitter, emitter side (left), bump side (right)



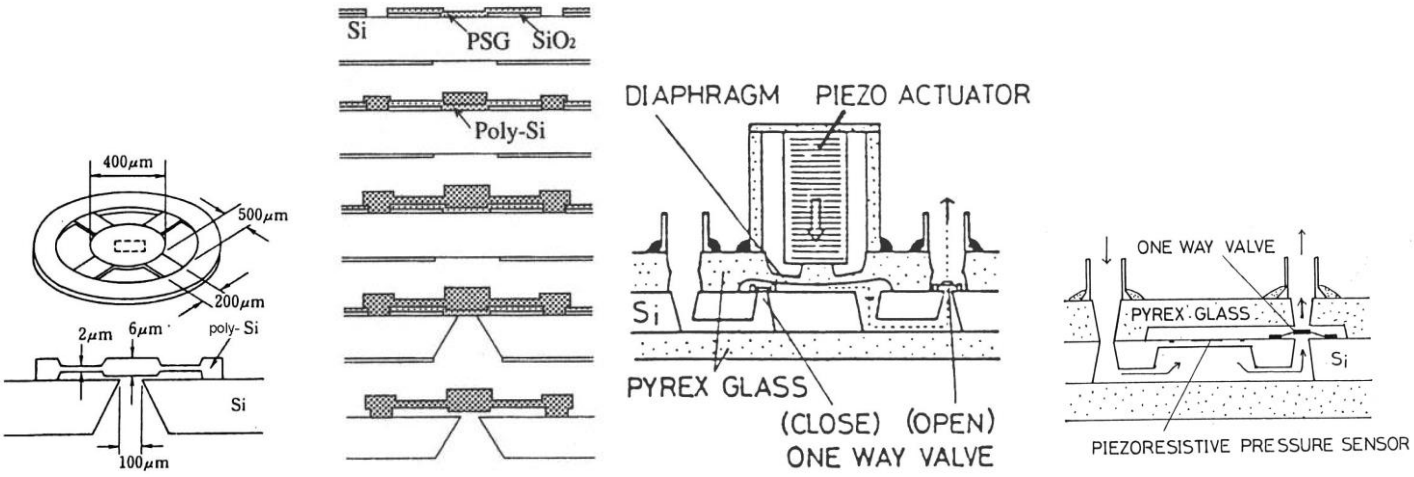
nc-Si Pierce-gun emitter



Exposure using nc-Si emitter

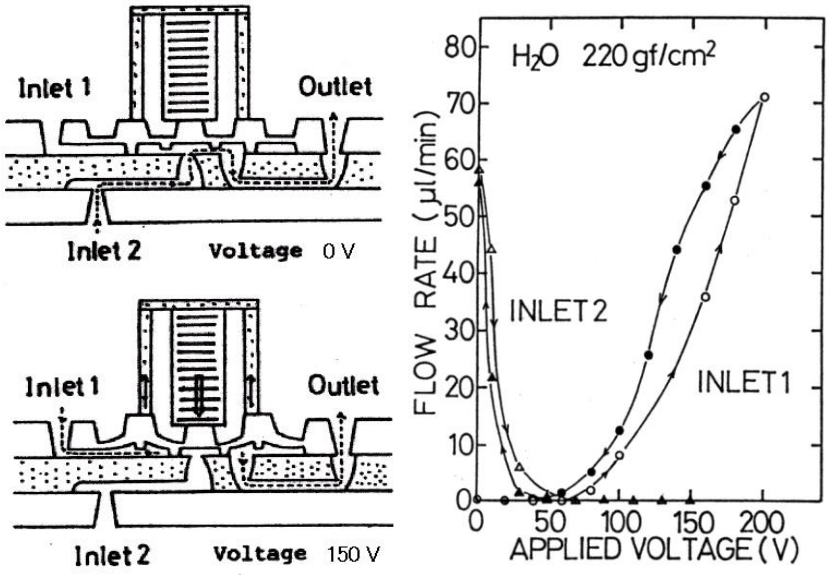
H.Nishino, S.Yoshino, S.Tanaka, M.Esashi, A.Kogima, N.Ikegami, N.Koshida, Basic study for fabrication of integrated Pierce-gun type area electron emitter for massive parallel electron beam exposure system, 2013 IEEJ convention, (2013/3/20 Nagoya) 3-127 (in Japanese)

E9 Micro pump, micro valve and chemical analysis system for liquid

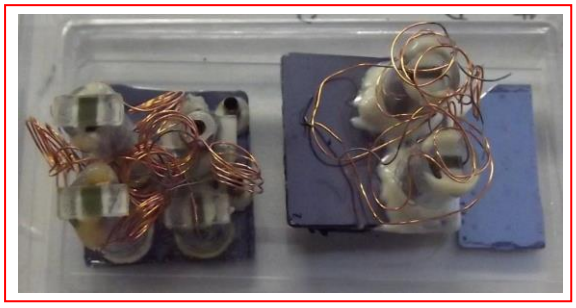


One-way valve, micro pump and flow sensor

Reference : S.Shoji, M.Esashi, Fabrication of a Micro-pump for Integrated Chemical Analysing Systems, Trans. ICIEC, J71-C (1988) pp.1705-1711

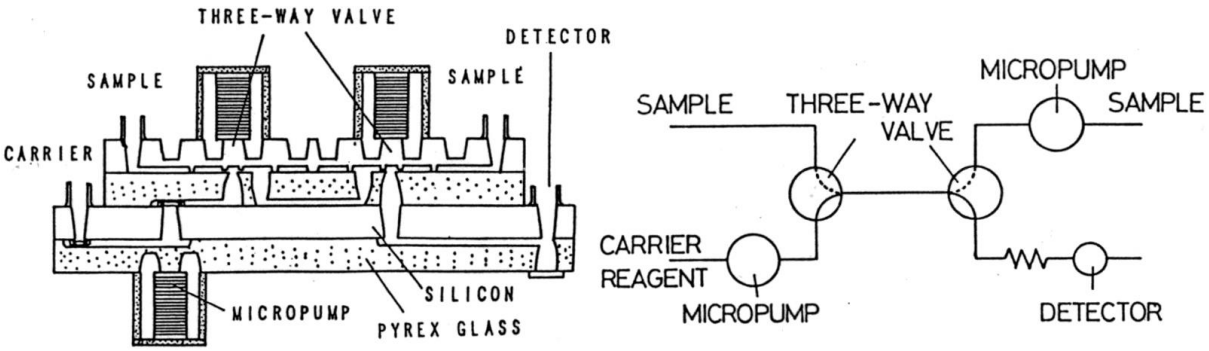


Tree-way valve



On-chip Flow-injection analysis system and micro pump

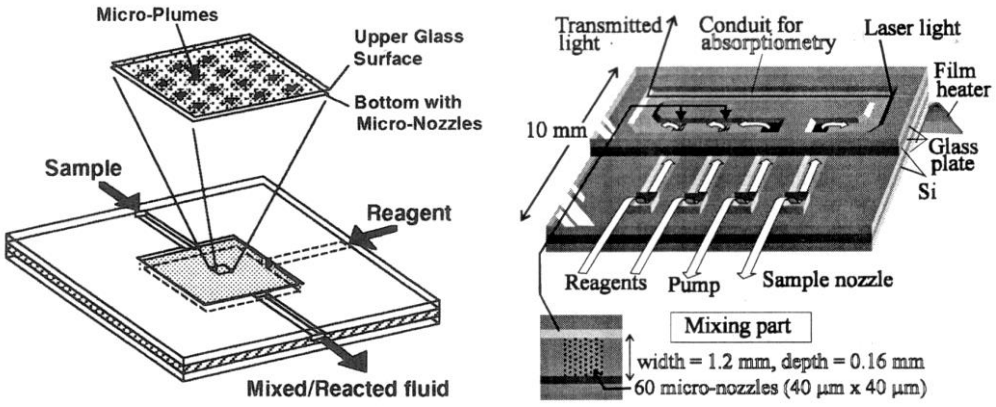
Reference : S.Shoji, S.Nakagawa and M.Esashi, Micropump and Sample-injector for Integrated Chemical Analyzing Systems, Sensors and Actuators, A21-A23 (1990) pp.189-192



Flow injection analysis system integrated on a chip

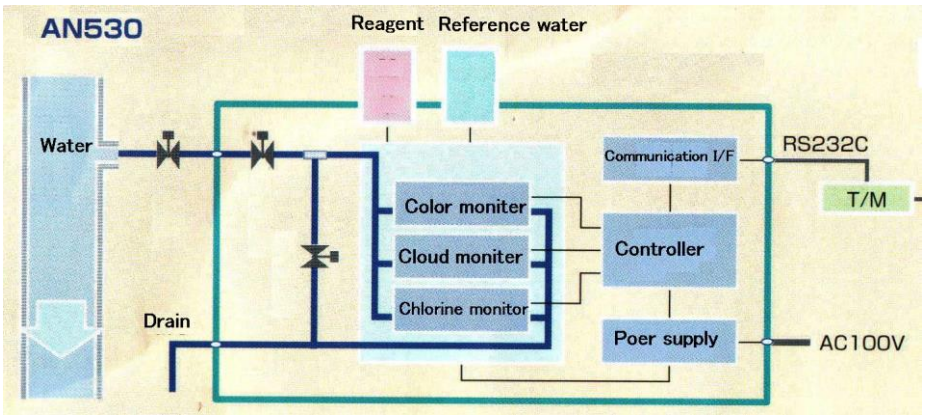
Reference : S.Nakagawa, S.Shoji and M.Esashi, A Micro Chemical Analyzing System Integrated on a Silicon Wafer, Proc. of the Micro Electro Mechanical Systems'90 (1990) pp.89-94

E10 Micro mixer and particle analysis (Hitachi)



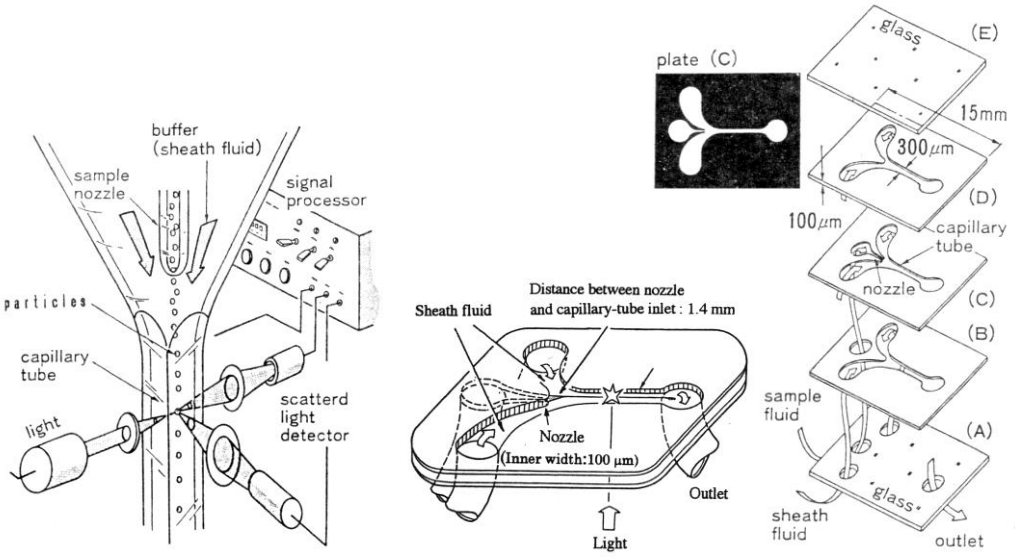
Absorptionmetric Micro-flowcellusing micro mixer

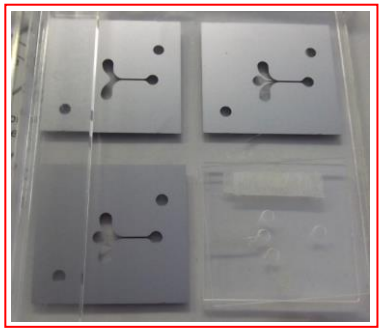
Reference : R.Miyake, K.Tsuzuki, T.Takagi, K.Imai, A Highly Sensitive and Small Flow-type Chemical Analysis System with Integrated Absorptionmetric Micro-flowcell, Trans. IEE of Japan, 117-E (1997) pp.147-154



Water-analysis system

Reference : R.Miyake, H.Enoki, S.Mori, T.Ishihara, A Small Water-Analysis System with Micro-machined Flowcells, Technical Report IEE of Japan, CHS-00-7 (2000) pp.33-37

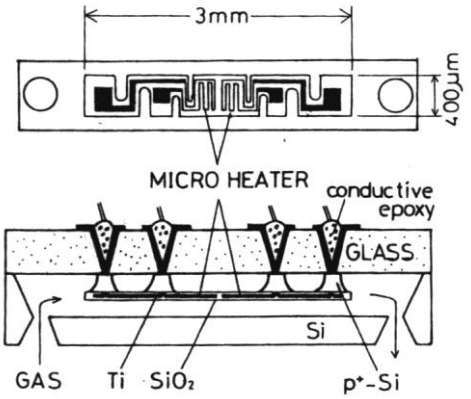


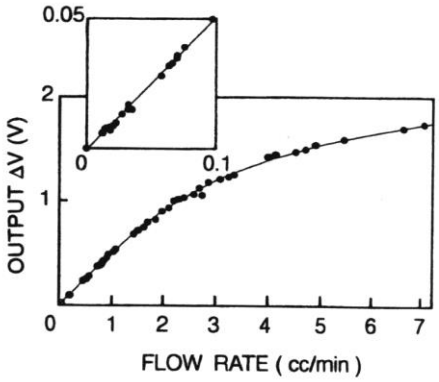


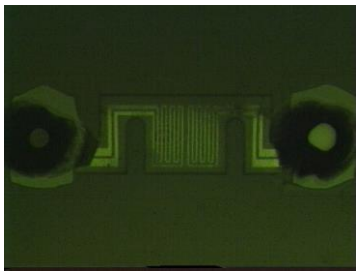
Micro sheath flow chamber for flow cytometer

Reference : R.Miyake, H.Ohki and I.Yamazaki, A Development of Micro Sheath Flow Chamber, Proc. of IEEE MEMS'91 (1991) pp.265-270

E11 Flow sensor and mass-flow controller for gas

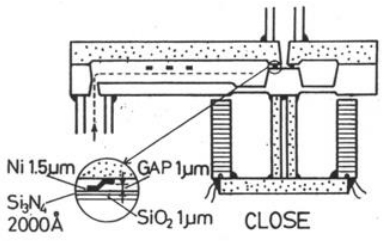


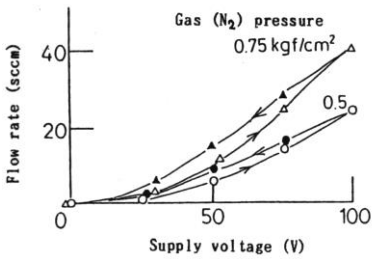


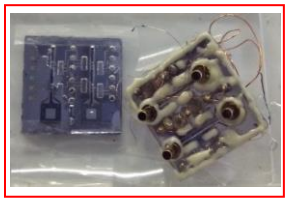


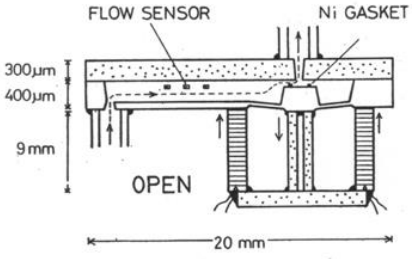
Thermal mass-flow sensor

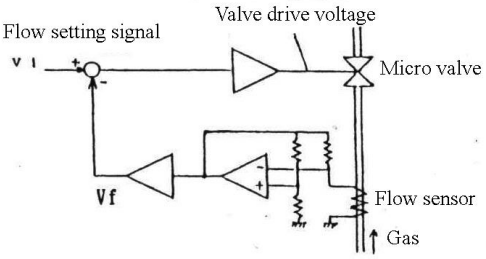
Reference : M.Esashi, H.Kawai, K.Yoshimi, Differential Output Type Micro Flow Sensor, Trans. ICIEC, J75-C-II (1992) pp.738-742

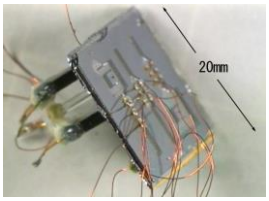


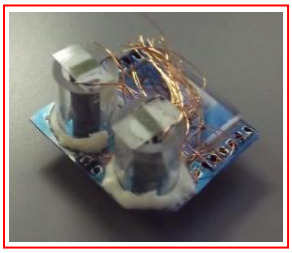


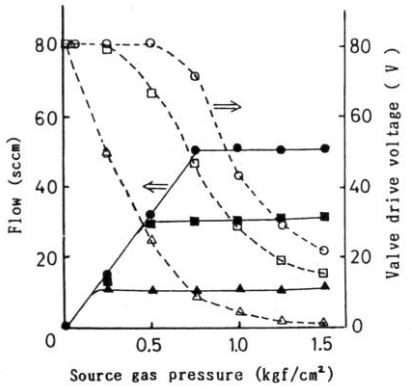


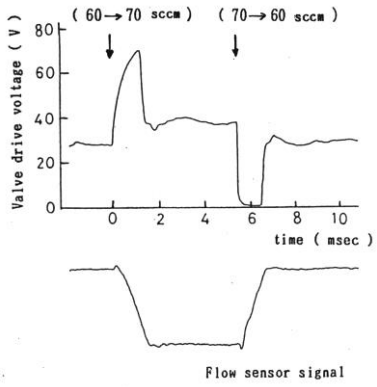




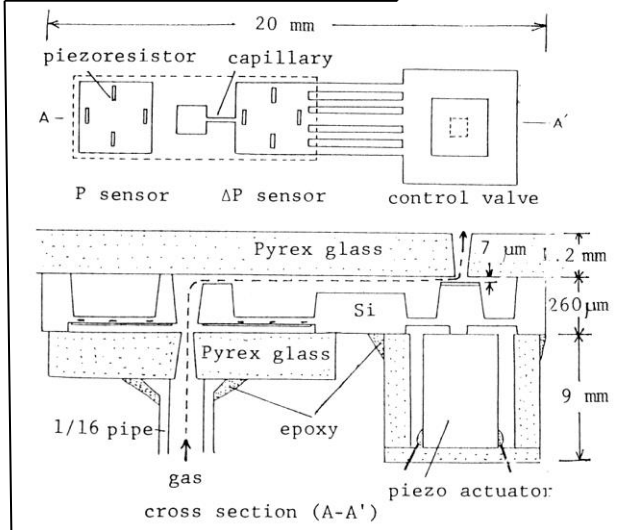








Thermal mass-flow sensor + micro valve

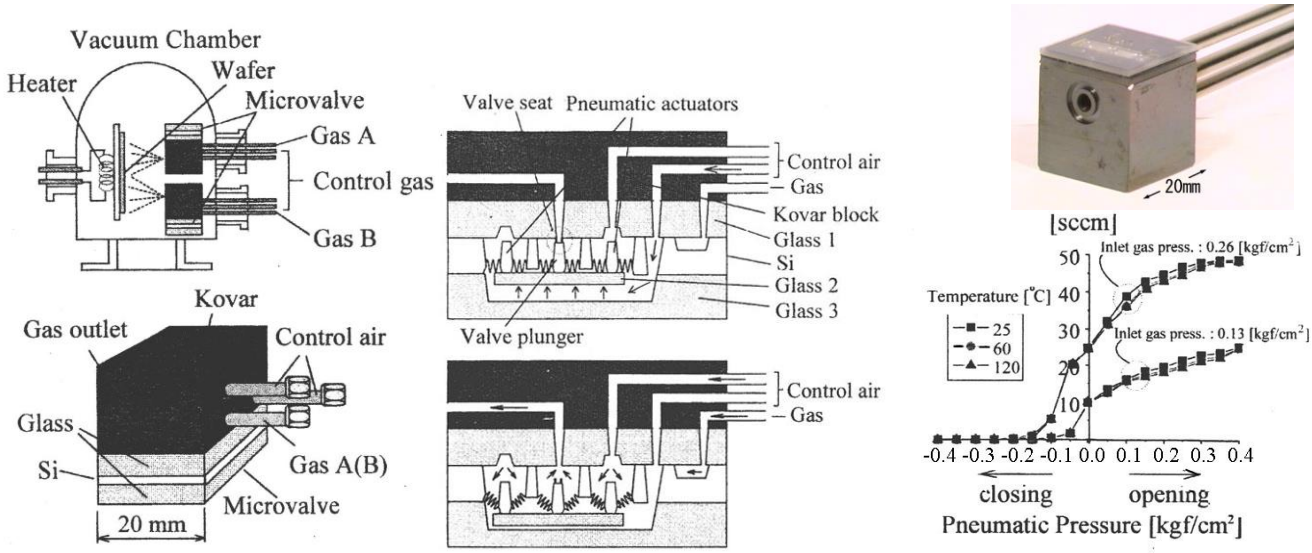


Differential pressure mass-flow sensor+micro valve

Integrated mass-flow controller

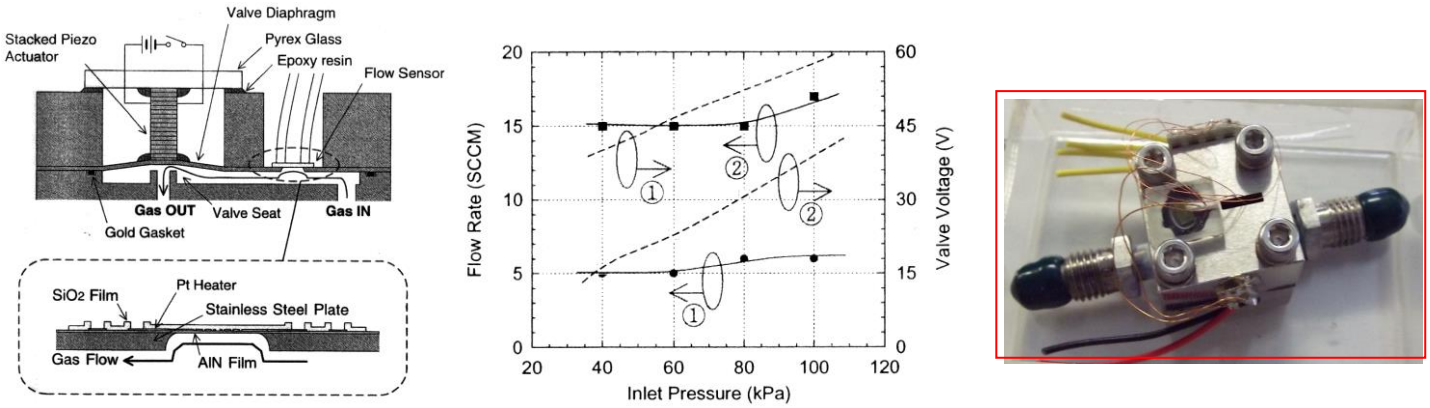
Reference : M.Esashi, S.Eoh, T.Matsuo and S.Choi, The Fabrication of Integrated Mass Flow Controller, Digest of Technical Papers, The 4th Int.Conf.on Solid State Sensors and Actuators (1987) pp.830-833

E12 Bakable micro valve and anticorrosive mass-flow controller



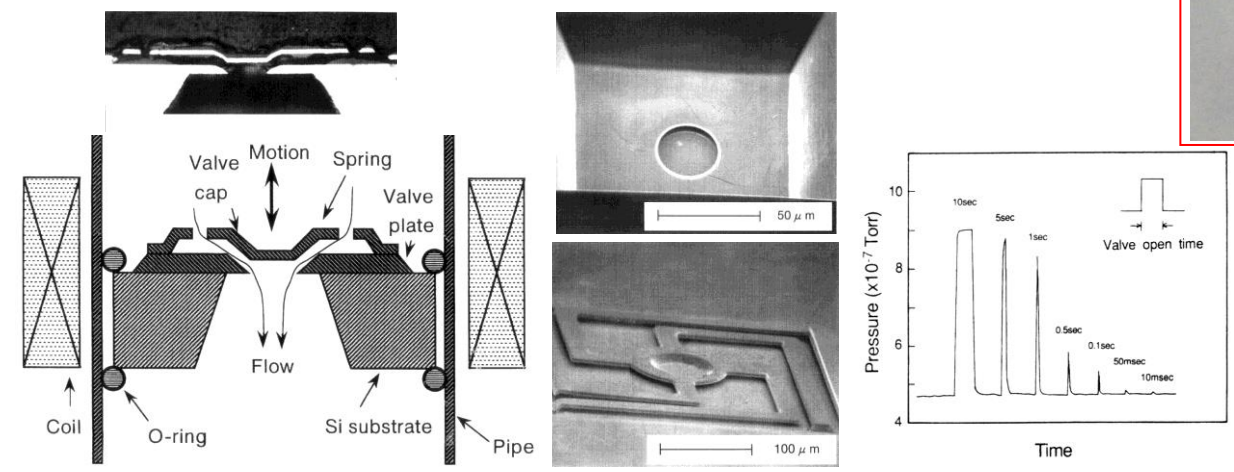
Bakable micro valve

Reference : D.Y.Sim, T.Kurabayashi and M.Esashi, A Bakable Microvalve with a Kovar-Glass-Silicon-Glass Structure, J. of Micromechanics and Microengineering, 6 (1996) pp.266-271



Anticorrosive mass-flow controller

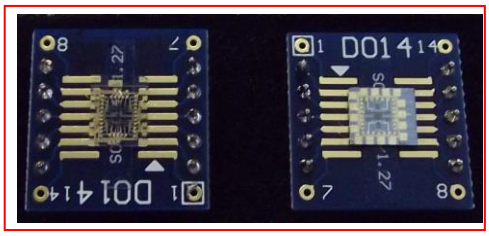
Reference : K.Hirata, D.Y.Sim and M.Esashi, Stainless Steel-Based Integrated Mass-Flow Controller for Reactive and Corrosive Gases, Technical Digest of the Transducers'01 (2001) pp.962-965

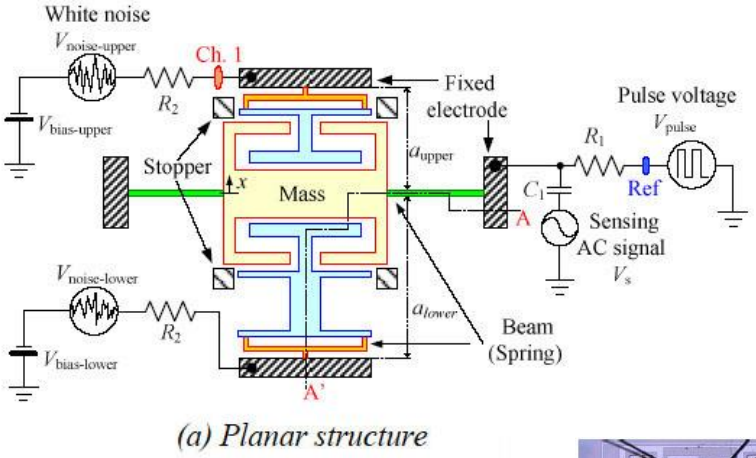


Electromagnetically driven microvalve (NTT)

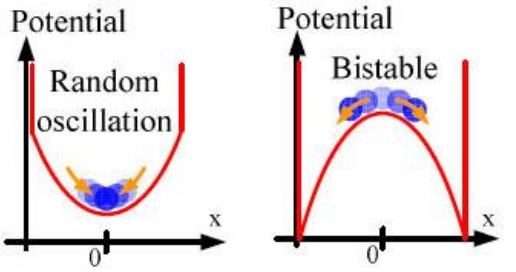
Reference : K..Yanagisawa, H.Kuwano and A.Tago, An Electromagnetically Driven Microvalve, Digest of Technical Papers, Transducers'93 (1993) pp.102-105

E13 Sensing in harsh environment

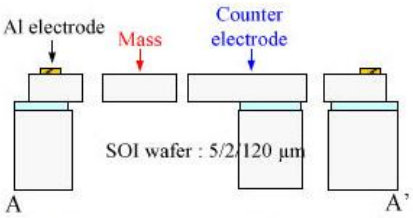




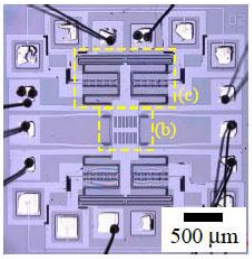
(a) Planar structure



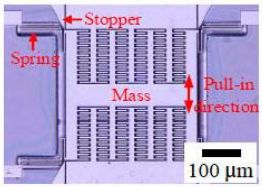
(a) V_{pulse} is zero or low. (b) V_{pulse} is high.



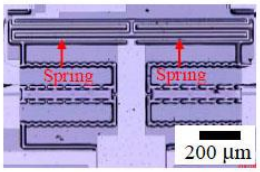
(b) Cross-sectional structure



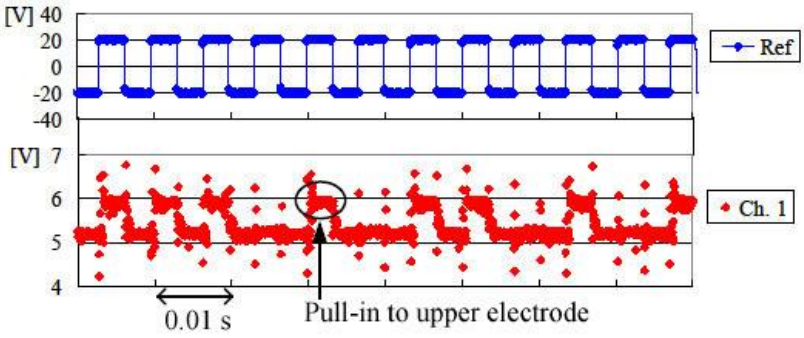
(a) Overall top view

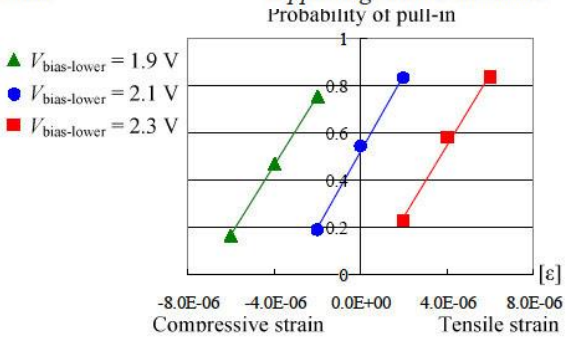


(b) Magnified view of the mass



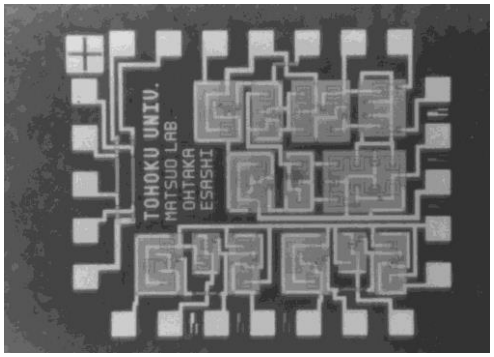
(c) Magnified view of springs supporting counter electrode

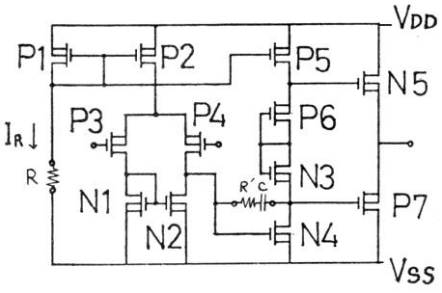


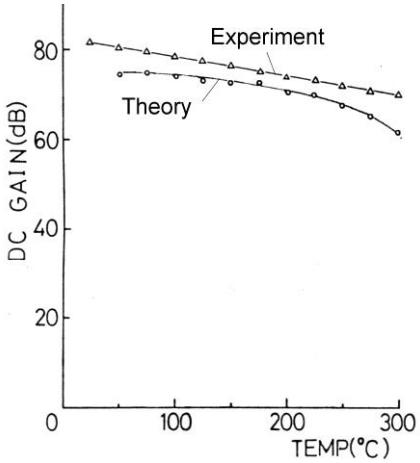


Stochastic sensor

Reference : Y.Hatakeyama, M.Esashi and S.Tanaka, Stochastic Gravity Sensor with Robust Output Using White-Noise-Applied Vi-Stable State for Low S/N Environments, Tech. Digest IEEE MEMS 2012 (2012) pp.132-135

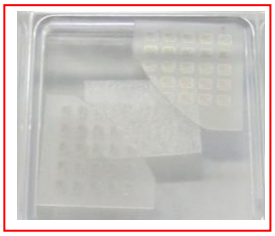




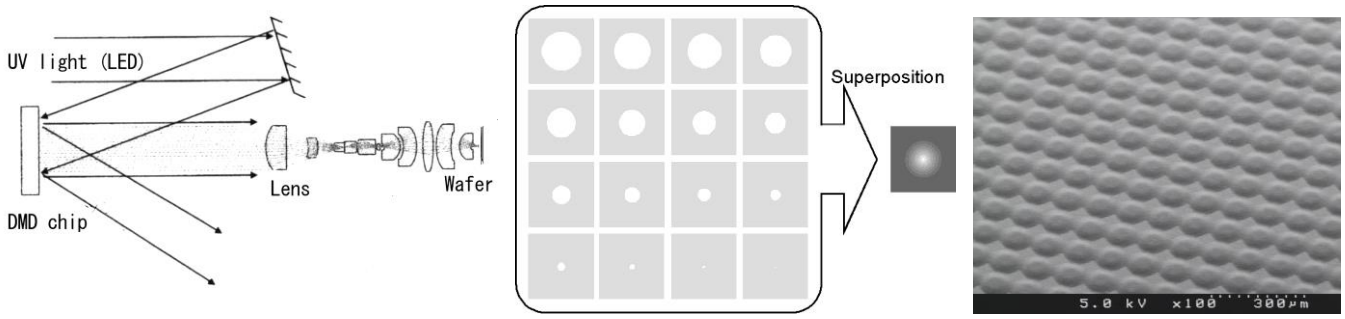


Operational amplifier for high temperature SOS (Silicon On Sapphire) OMOS

Reference : M.Esashi, S.Ohtaka, T.Matsuo, Fabrication of High Temperature Integrated Circuit and High Temperature Pressure Sensor, Technical Report, IEICE of Japan, SSD86-57 (1986) pp.67-74

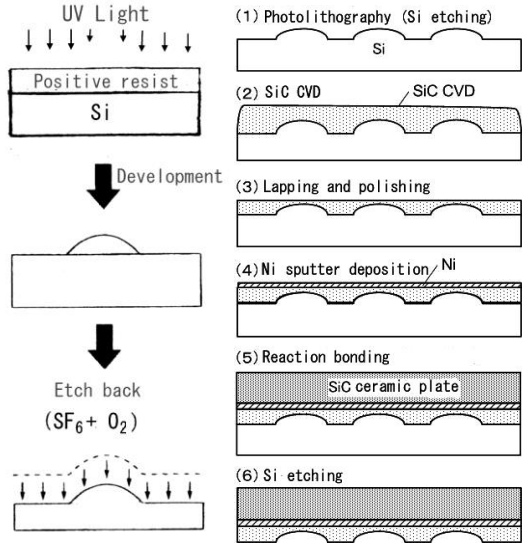


E14 Silicon carbide (SiC) mold for glass press-molding

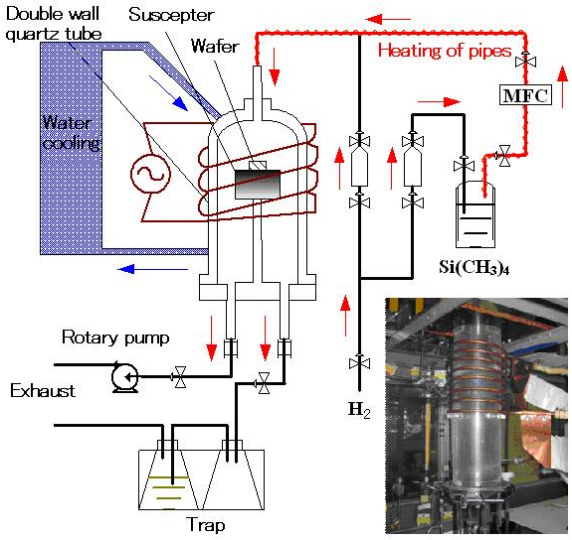


Forming of non-spherical lens shape by multiple maskless exposure using DMD

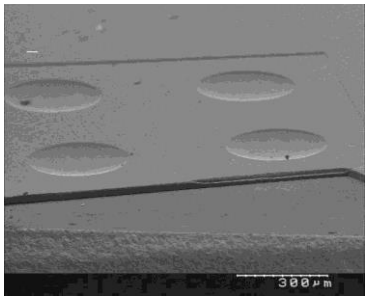
Reference : K.Totsu, K.Fujishiro, S.Tanaka and M.Esashi, Fabrication of Three-dimensional Microstructure Using Maskless Gray-scale Lithography, Sensors and Actuators A, 131 (2006) pp.387-392



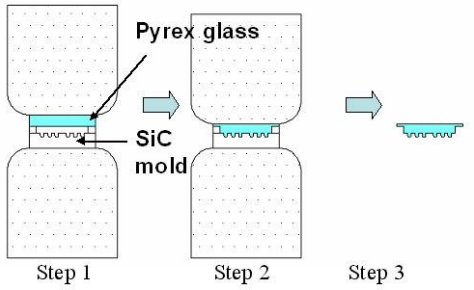
Fabrication of SiC mold

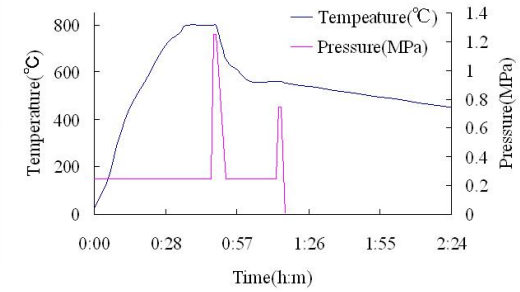


SiC CVD system

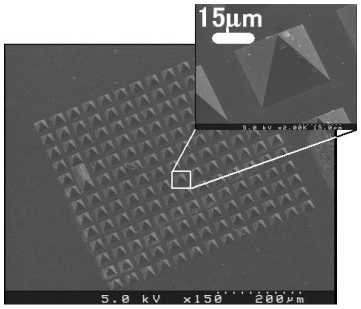


SiC mold

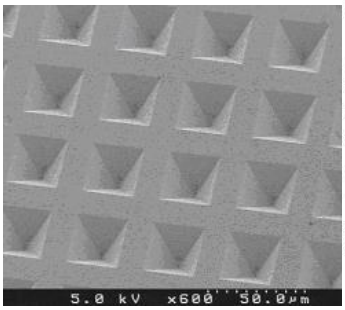




Glass press-molding

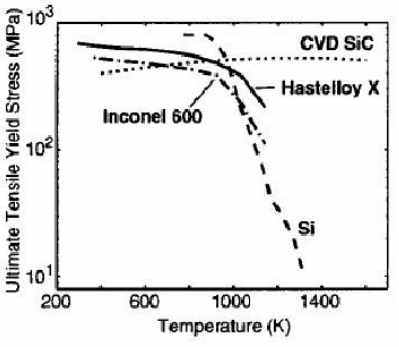


SiC mold (after 4 time use)

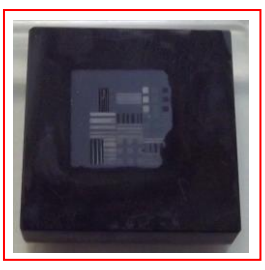


Pyrex glass formed by molding

Glass press-molding using SiC mold



Mechanical property of SiC at high temperature
(A.H.Epstein, J. of Eng.. for Gas Turbines and Power, 126, (2004) 205)



Reference : K.-O. Min, S.Tanaka and M.Esashi, Glass Press Mold Fabricated by SiC APCVD, SiC-SiC Bonding and Silicon Lost Molding, Proceedings of the 21th Sensor Symposium (2004) pp.473-478