1.2 Historical Background

- **Microelectronics**

  + 1947 - first transistor invented at Bell Lab

  + 1959 - first IC invented by Kilby

  + 1961 - first commercial IC fabricated by Fairchild and Texas Instruments

  + 1969 - LSI, 1000 ~ 10000 components/chip

  + 1975 - VLSI, more than 10000 components/chip

  + Present – ULSI
    0.35μm to 0.25μm to 0.18μm to …
    5in to 6in to 8in to 12in

MDL
NTHU

Planar Technology

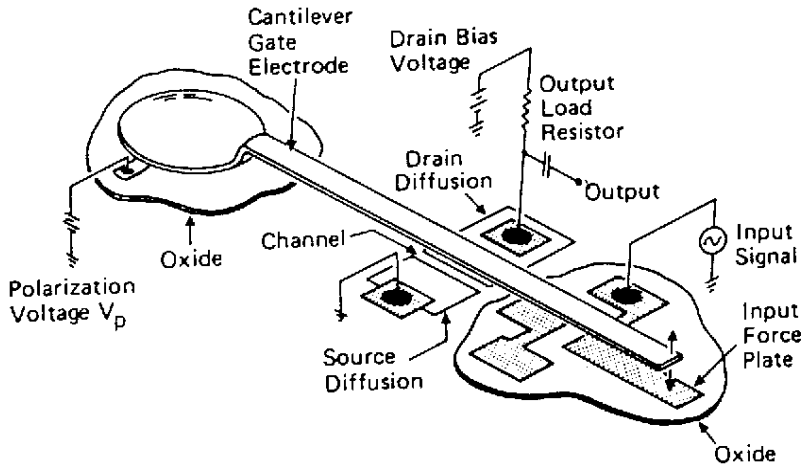
MDL
NTHU

- IC : TSMC, UMC, VIS, ...
- Magnetic recording head : HP, WD, ...
- LED/VCSEL/Diode laser : Opto tech, EPISTAR
- TFT-LCD : AU Optronics, INNOLUX, ...
- MEMS : TSMC, UMC, APM, ...

MDL
NTHU

- **Micromachining**

+ 1965 - concept of (surface) micromachining from resonant gate transistor



H.C. Nathason and R.A. Wickstorm, Applied Physics Letter, 1965.

+ 1966 - silicon membrane fabricated by back side etch

R.J. Jaccodine and W.A. Schlegel, J. of Applied Physics, 1966.

+ 1967 - anisotropic etching

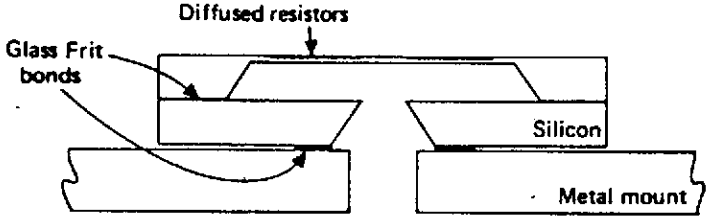
R.M. Finne and D.L. Klein, J. of Electrochemical Society, 1967.

MDL
NTHU

+ 1972 - silicon micromachined beams

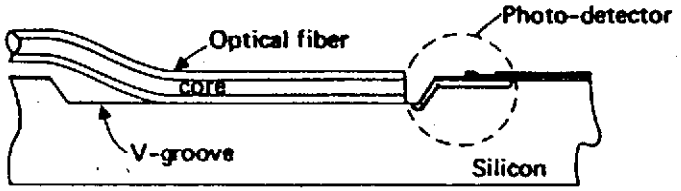
S.C.H. Lin and I. Pugacz-Muraszkiewicz, J. of Applied Physics, 1972.

+ 1974 - pressure transducer



A.C.M. Gieles and G.H.J. Somers, Philips Tech. Rev., 1973.
Figure source: K.E. Petersen, Proceeding of the IEEE, 1982.

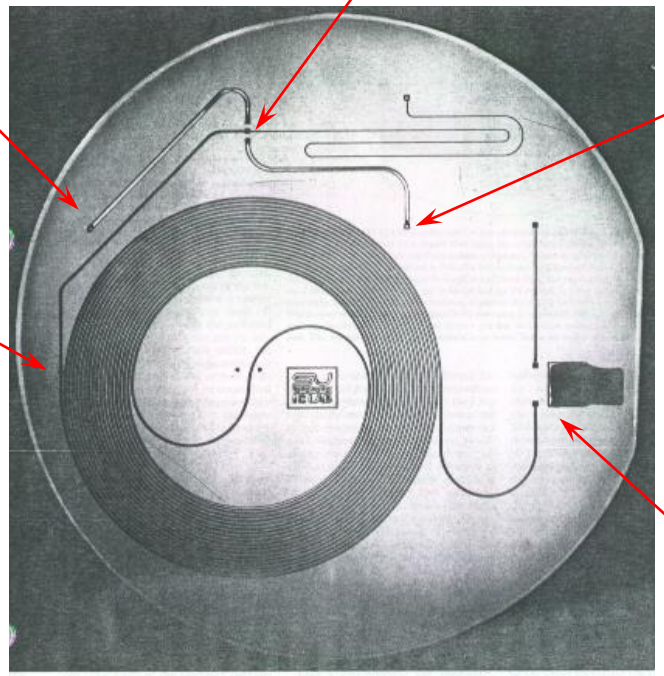
+ 1974 - optical fiber alignment (groove)



L.P. Boivin, Applied Optics, 1974.

MDL
NTHU

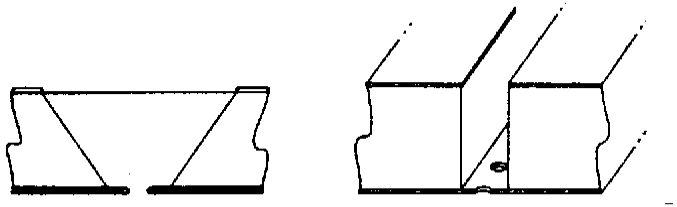
+ 1975 - gas chromatograph (groove, hole, bonding)



S.C. Terry, Ph.D. thesis, 1975.
S.C. Terry, J.H. Jerman and J.B. Angell, IEEE Transaction on ED, 1979.

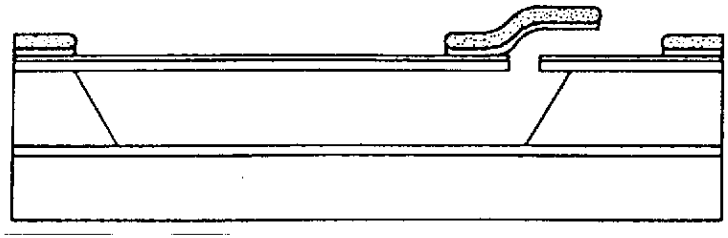
MDL NTHU

+ 1977 - ink jet nozzles (nozzle)



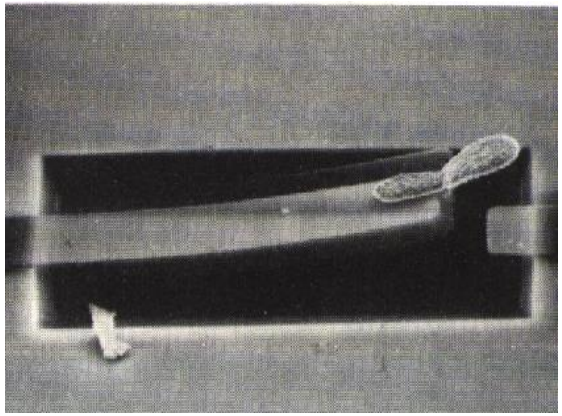
E. Bassous, L. Kuhn, A. Reisman, and H.H. Taub, U.S. Patent 4 007 464, 1977.

+ 1978 - electrical switch (cantilever beam)

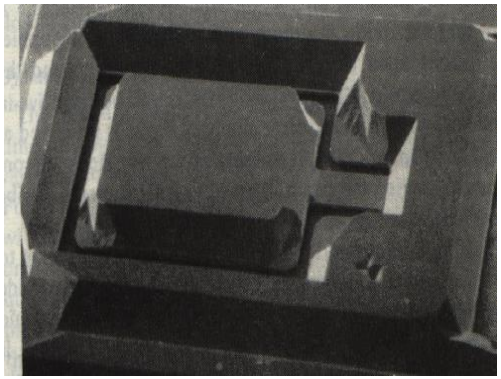


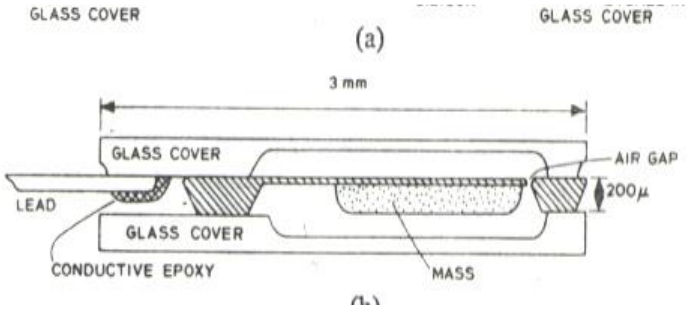
K.E. Petersen, IEEE Transaction on ED, 1978.

MDL
NTHU



K.E. Petersen, IEEE Transaction on ED, 1978.

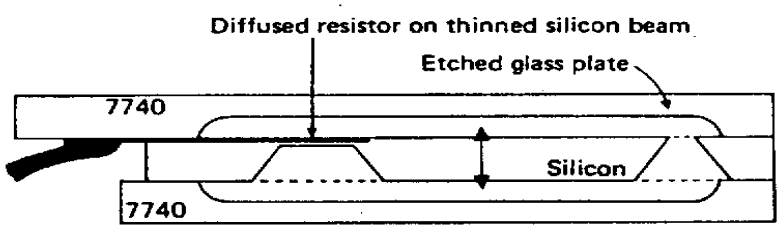




L.M. Roylance and J.B. Angell, IEEE Transaction on ED, 1979.

MDL
NTHU

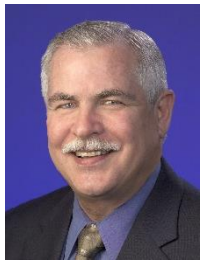
+ 1979 - accelerometer (cantilever beam)



L.M. Roylance and J.B. Angell, IEEE Transaction on ED, 1979.

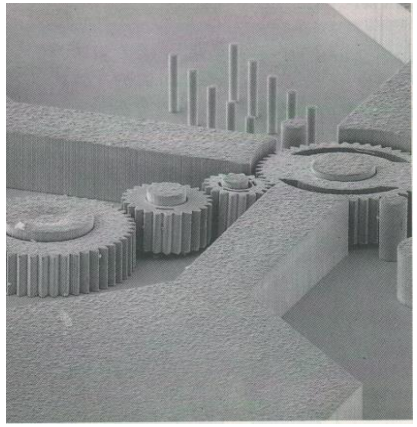
+ 1982 - silicon micromachining named by Petersen

K.E. Petersen, Proceeding of the IEEE, 1982.



IEEE Medal of Honor, 2019

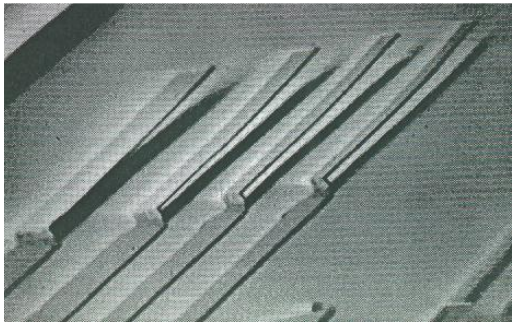
+ 1982 - LIGA process developed by Becker et. al.



E.W. Becker, et al., Naturwissenschaften, 1982.
Figure source: J. Bryzek, K. Petersen, and W. McCulley, IEEE Spectrum, 1994.

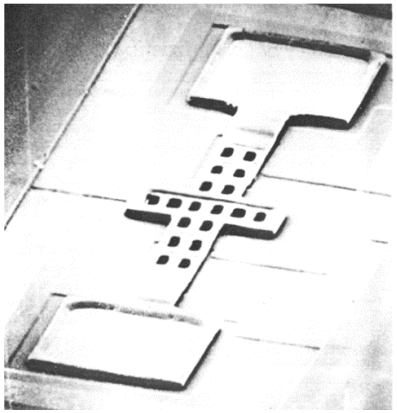
MDL
NTHU

+ 1983 - surface micromachining re-developed by Howe



R.T. Howe and R.S. Muller, J. of Electrochemical Society, 1983.

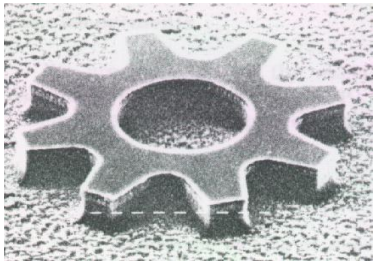
+ 1986 - surface micromachined resonant microbridge

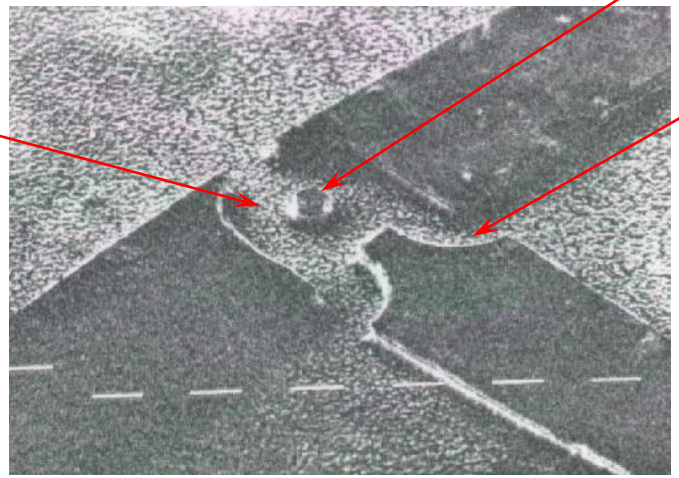


R.T. Howe, and R.S. Muller, *IEEE Trans. on Electronic Devices*, ED-33, pp. 499-506, 1986

MDL
NTHU

+ 1987 - concept of movable micromachined structures (turbines) through assembly





M. Mehregany, K.J. Gabriel, and W.S.N. Trimmer, Sensors and Actuators, 1987

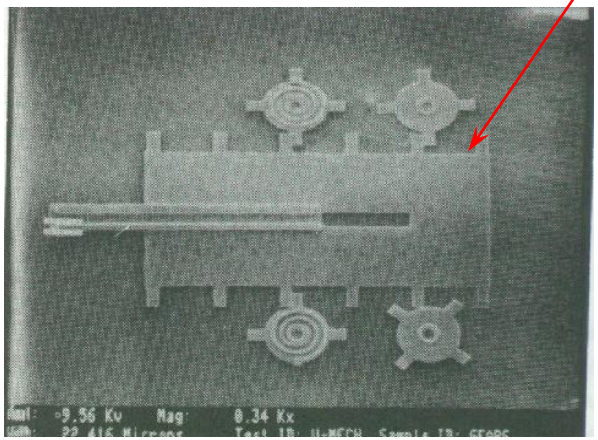
+ 1987 - MEMS (Microelectromechanical System) named after three workshops

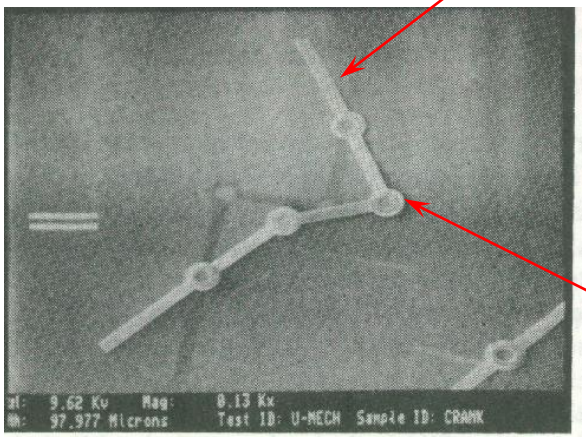
MDL
NTHU

+ 1988 - first movable and integrated micromachined structures including sliders, hinges and cranks

slider

crank



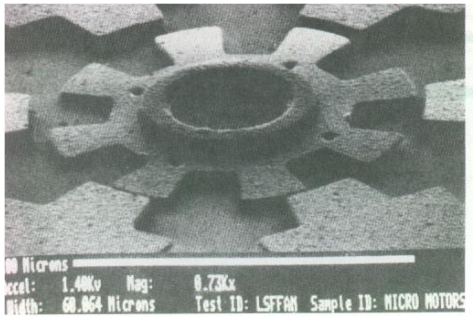


hinge

L.-S. Fan, Y.-C. Tai, and R.S. Muller, IEEE Trans. on ED, 1988.

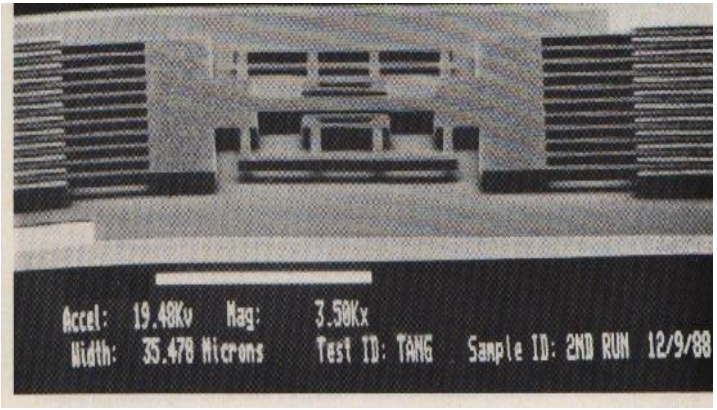
MDL
NTHU

+ 1988 - first micromachined motor



L.-S. Fan, Y.-C. Tai, and R.S. Muller, Int. Electron Devices meeting, 1988.

+ 1989 - first micromachined linear actuator

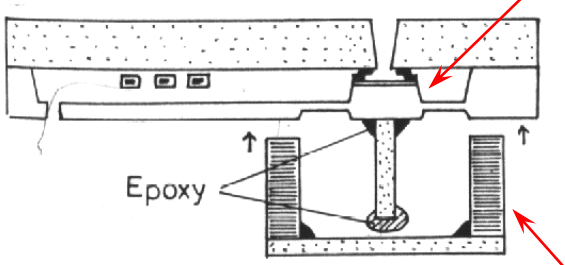


W.C. Tang, T.-C.H. Nguyen, and R.T. Howe, IEEE MEMS Conf., 1989.

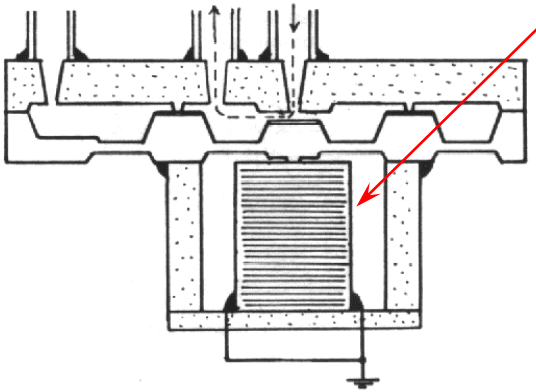
MDL
NTHU

+ 1990 - microfluidic system attract attention

valve



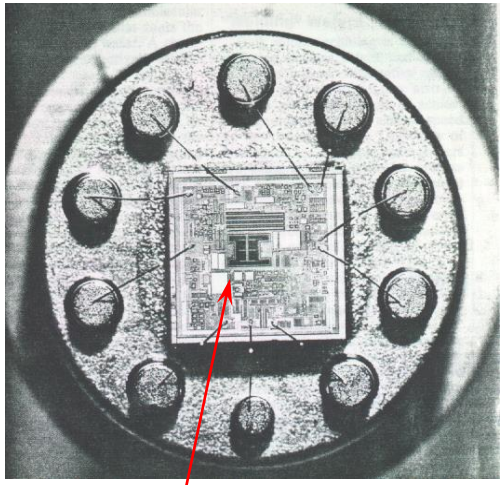
Piezo actuator

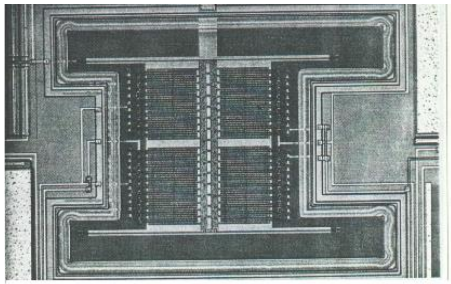


M. Esashi, Sensors and Actuators, 1990

MDL
NTHU

+ 1991 - first commercialized surface micromachined accelerometer introduced by Analog Devices



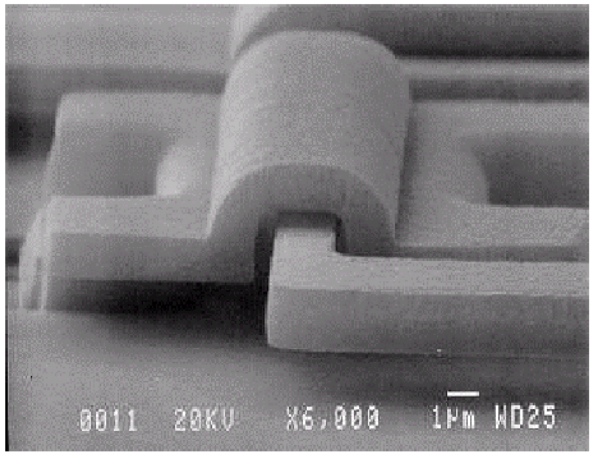


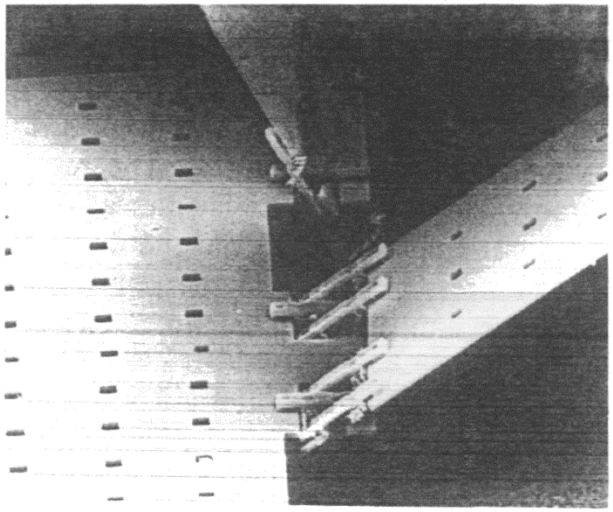
mechanical component

Figure source: L. O'Connor, Mechanical Engineering, 1992.

MDL NTHU

+ 1992 - micromachined hinge

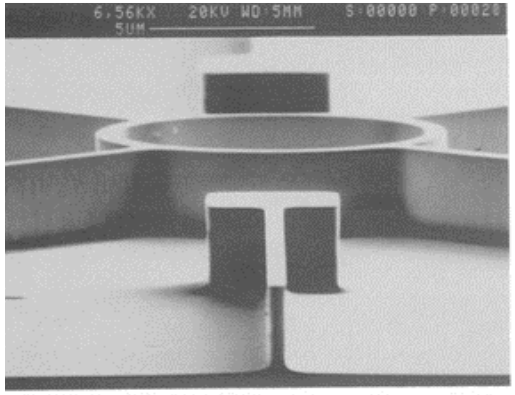




K. S. J. Pister, Sensors and Actuators A, 1992

MDL
NTHU

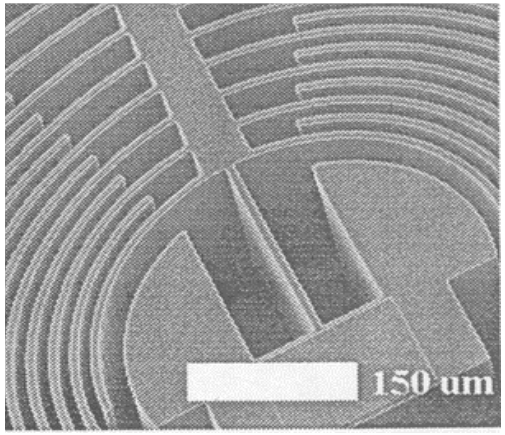
+ 1993 - thick micromachined structures (SCREAM)



4 μm

Z.L. Zhang and N.C. MacDonald, J. of MEMS, 1993

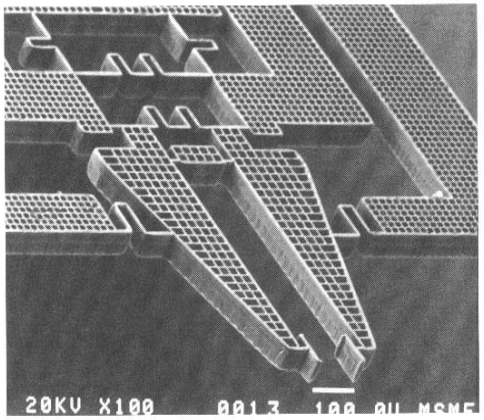
+ 1995 - thick micromachined structures (DRIE)



E.H. Klaassen, et.al., Transducers'95, 1995

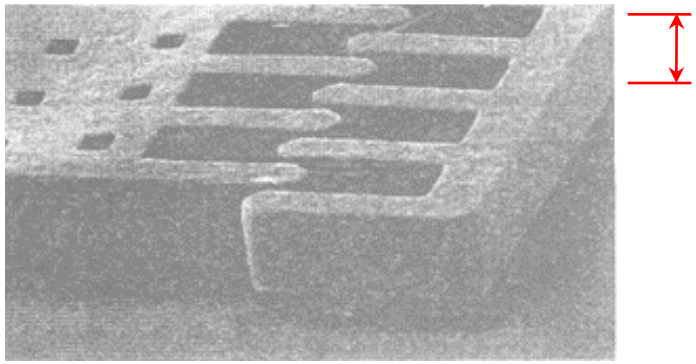
MDL
NTHU

+ 1995 - thick micromachined structures (Hexsil)



R.T. Howe, J. of MEMS, 1995

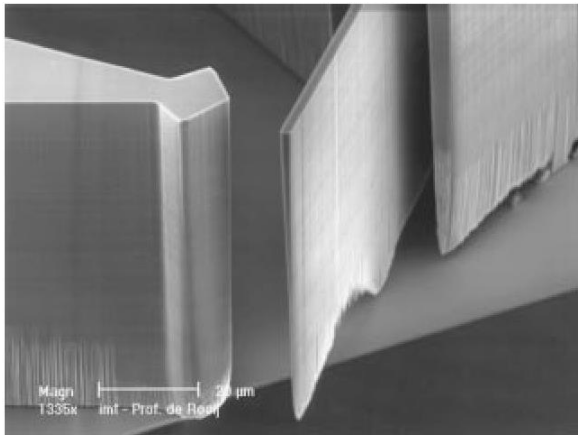
+ 1996 - thick micromachined structures (by etch-diffusion processes)

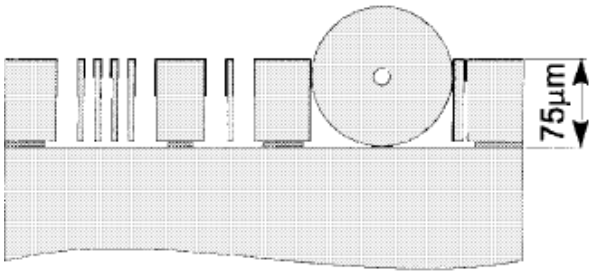


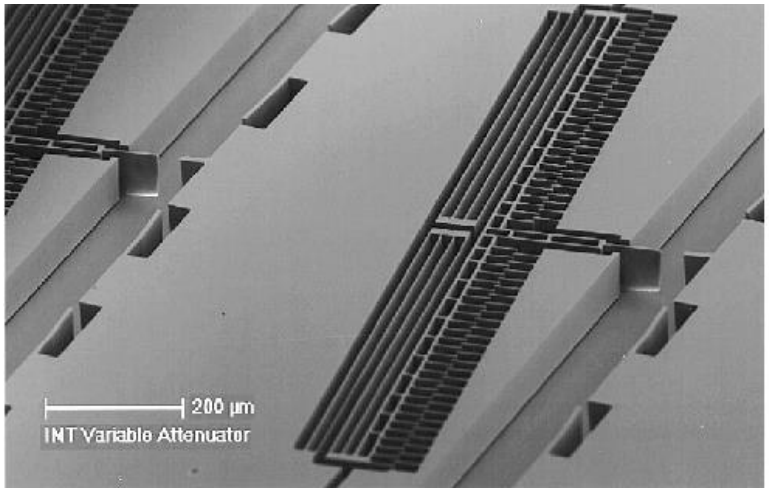
W.-H. Juan and S.W. Pang, J. of MEMS, 1996

MDL
NTHU

+ 1995? - SOI







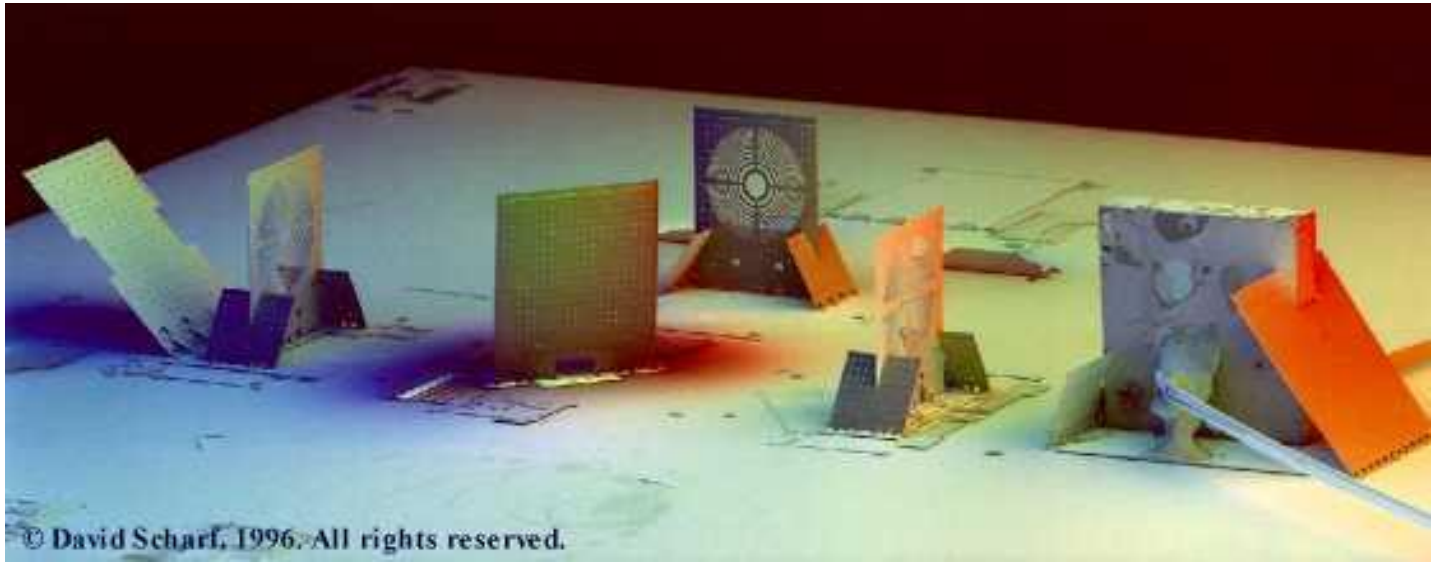
Optical Switch

C. Marxer, N. F. de Rooij, J. MEMS 97

MDL
NTHU

+ 1996 - Optical bench (original idea: M.C. Wu et al. , *Sensors and Actuators A*, 1995)

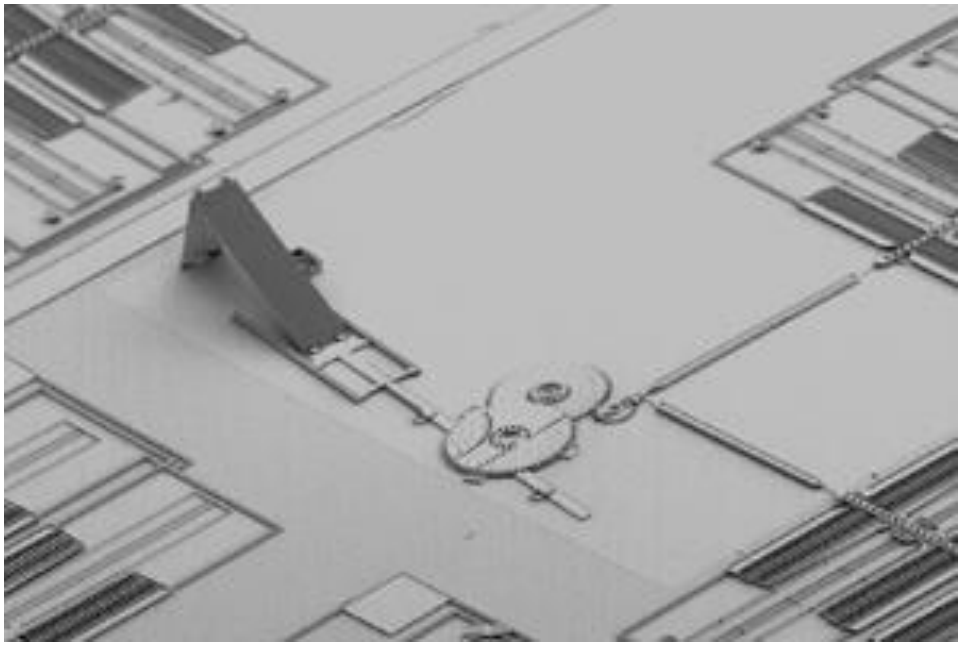
Optical-disk pickup head realized by FSMOB technology :

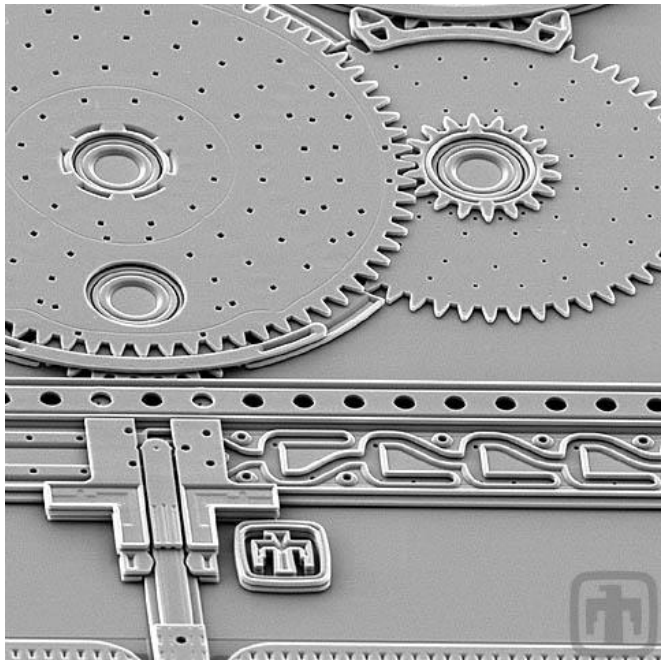


L. Y. Lin et al. , Opt. Lett. , 1996

MDL
NTHU

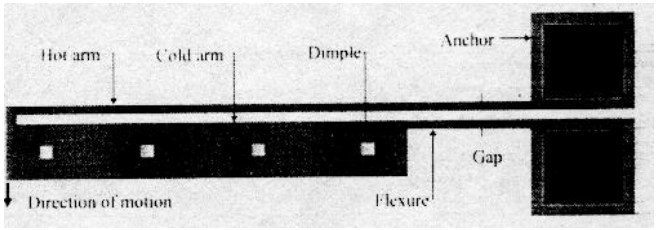
+ 1996? – SUMMIT processes by Sandia National Lab, three layers micromachined structures

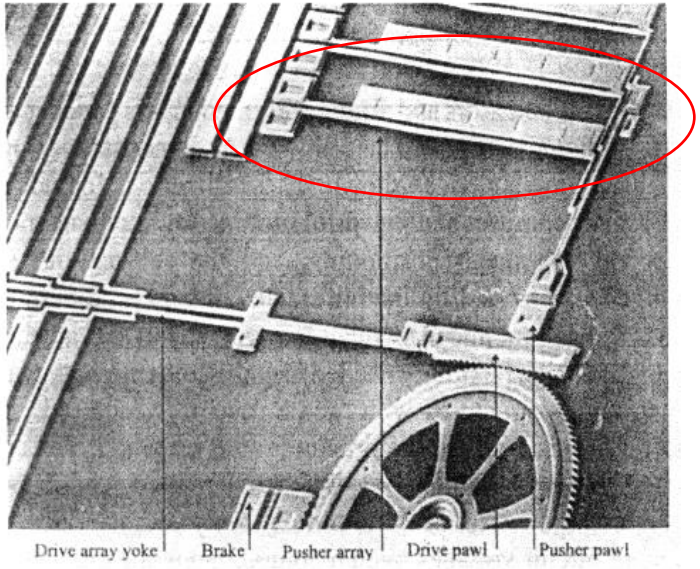




MDL
NTHU

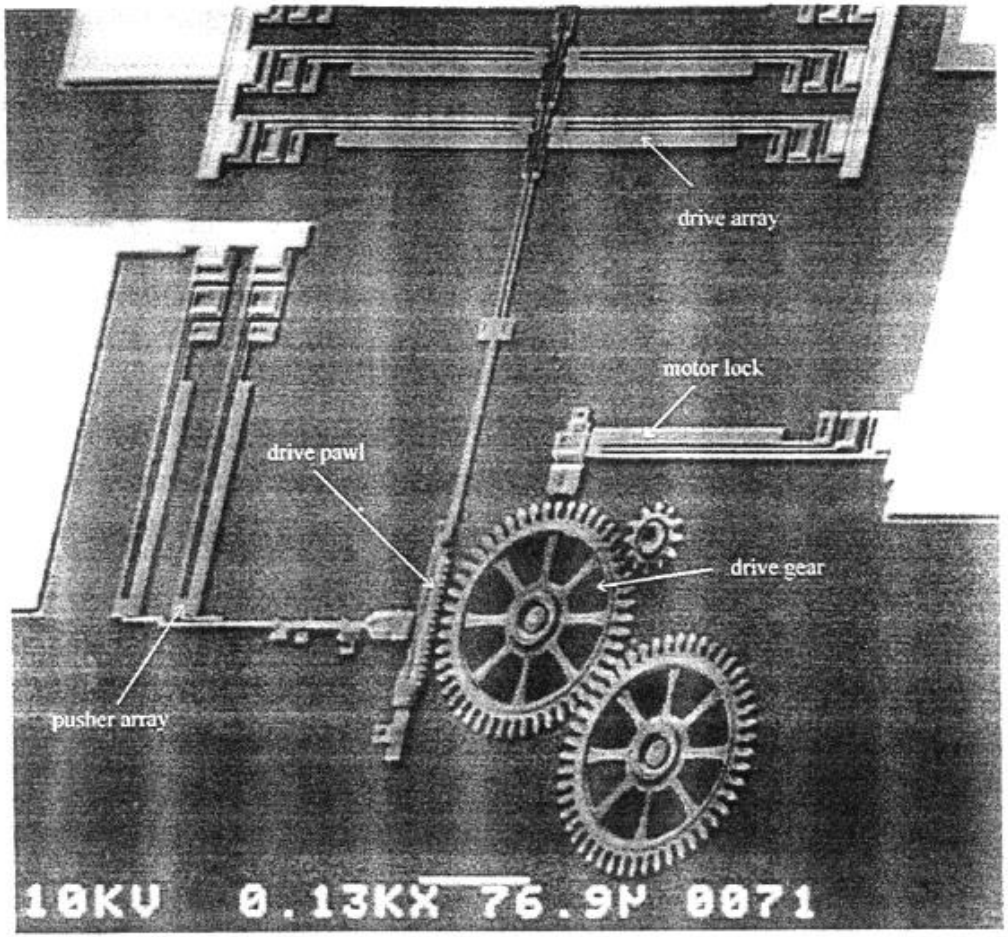
+ 1997 - complicated mechanism driven by electro-thermal actuators





J.H. Comtois and V.M. Bright, Sensors and Actuators A, 1997

MDL
NTHU



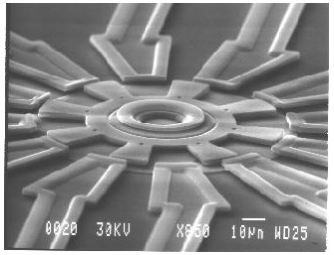
D.M. Burns and V.M. Bright, 1997

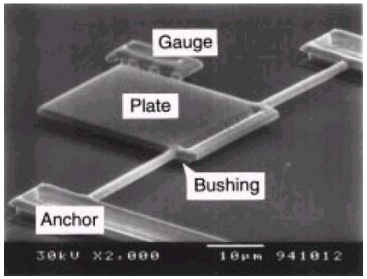
MDL
NTHU

+ 1999? – SUMMIT V processes by Sandia National Lab, five layers micromachined structures

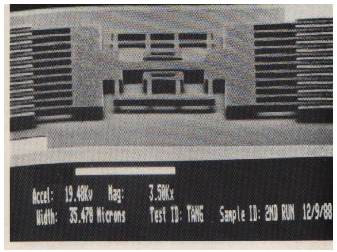
MDL
NTHU

Motor
L.S.Fan, Y.C. Tai, R.S.Muller
(1988)





Comb-drive
Tang, Nguyen, Howe
(1989)

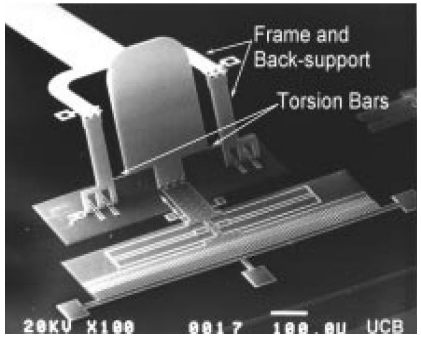


Hinge
K.S.J. Pister
(1992)

SDA
Japan
(1992)

MUMPs *(1993)*

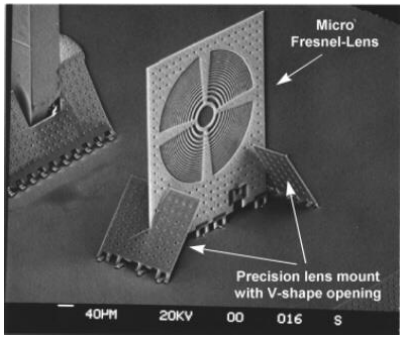
Free-Space Micro-Optical Bench
UCLA, M.C. Wu,(1995)



Summit
Summit V

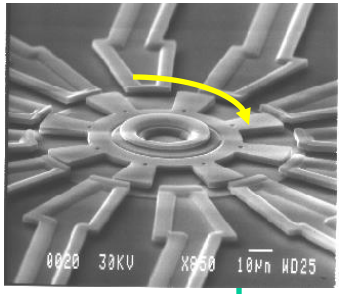
?
(2001~)

Dynamic Application
M.H.Kiang, R.S.Muller
(1996)

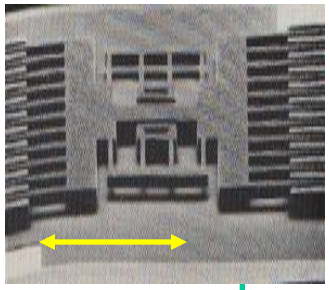


MDL
NTHU

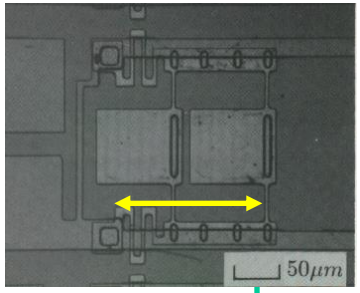
Motor



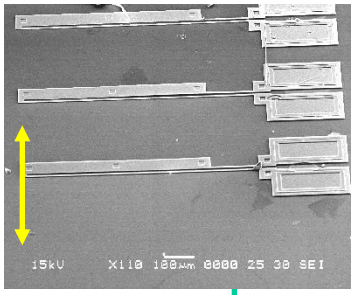
Comb actuator



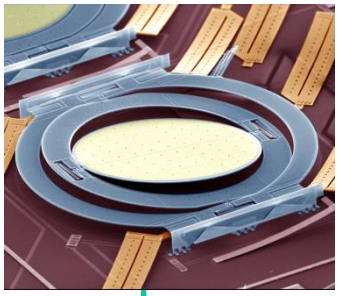
SDA



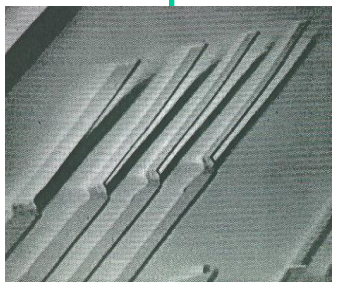
Thermal actuator



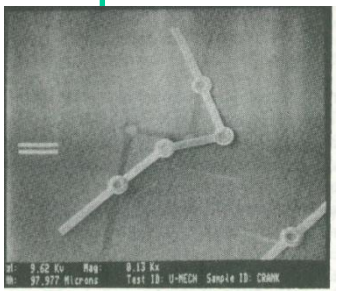
Optical scanner



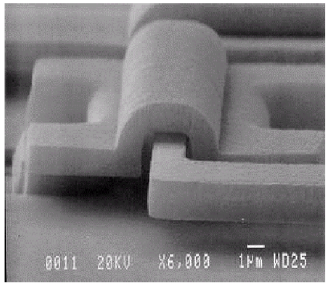
1984 1988 1989 1992 1993 1995 1997 1998 2000



Beam & plate

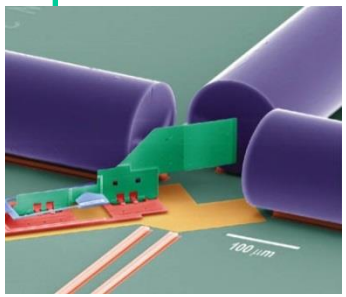


Crank & spindle



Hinge

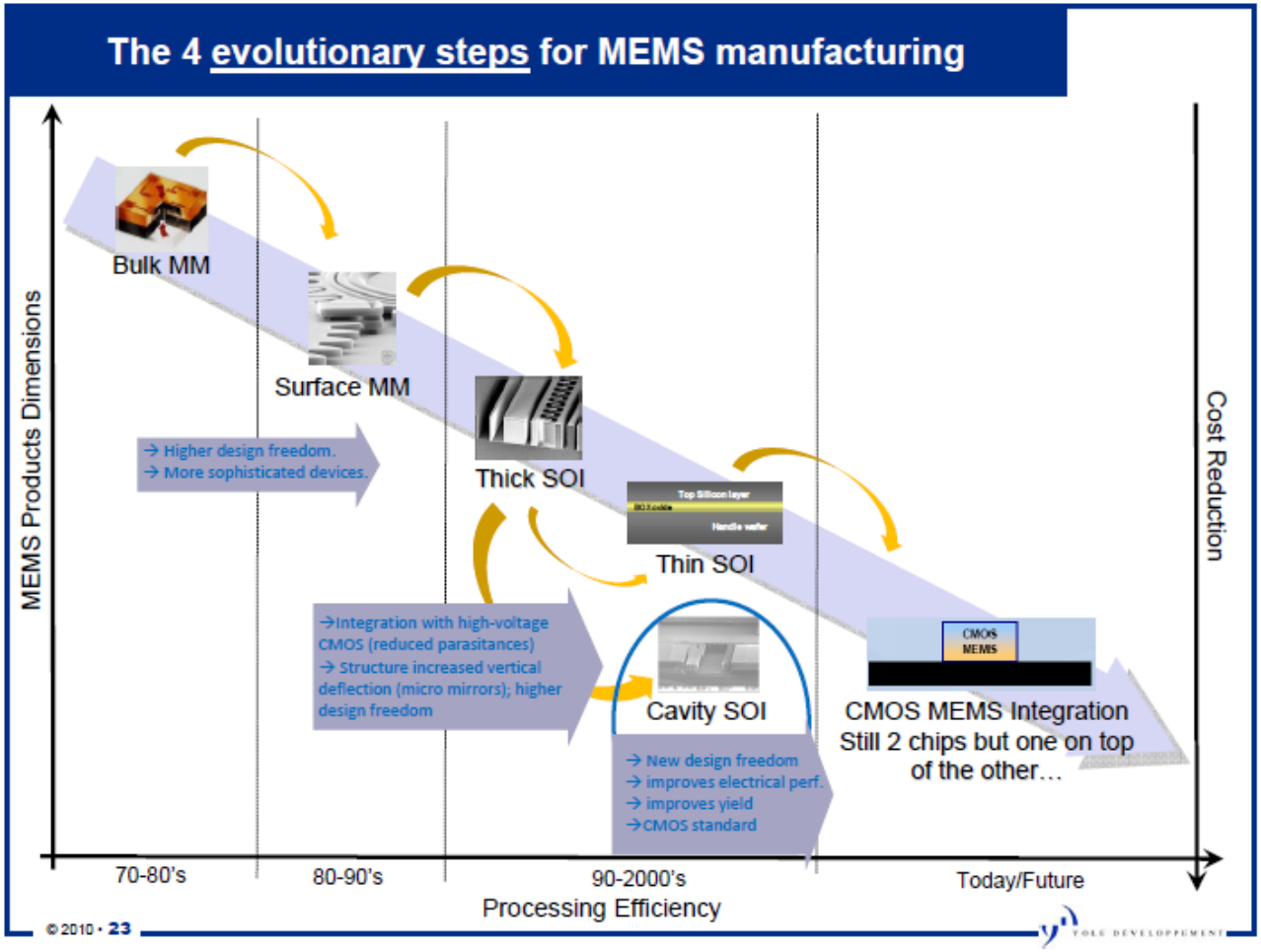
Optical bench



Optical switch

BSAC, Sophia U., U. Colorado, UCLA, Agilent

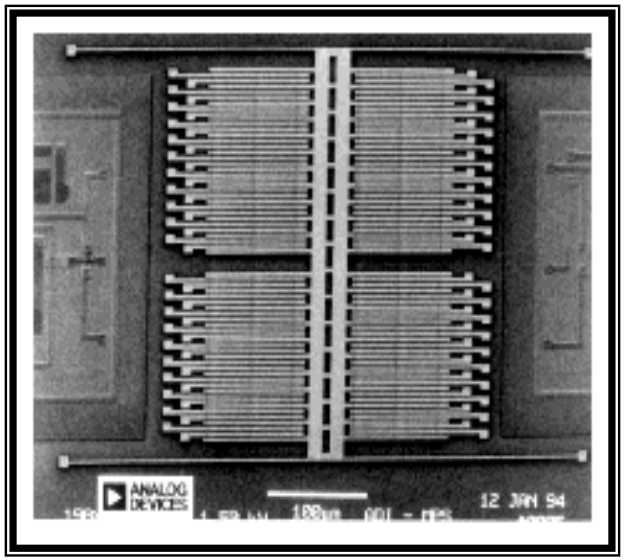
MDL
NTHU



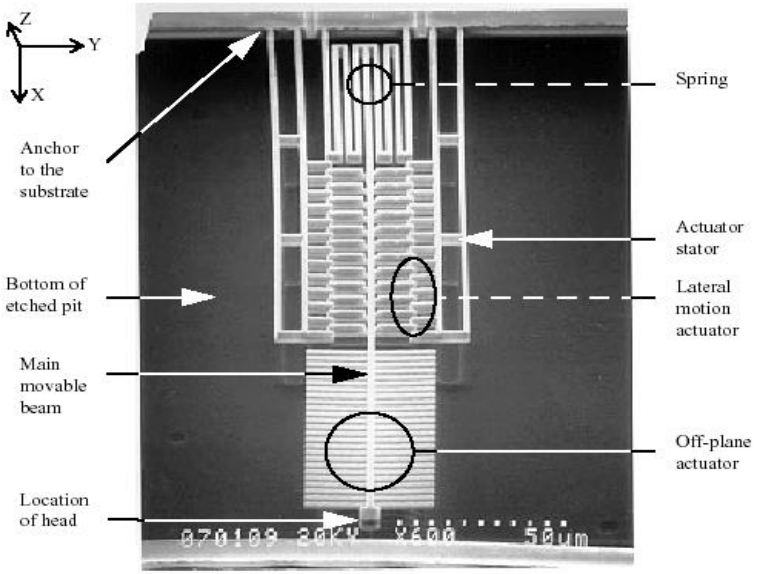
Yole's report, 2010

MDL
NTHU

+ 1995 – CMOS MEMS



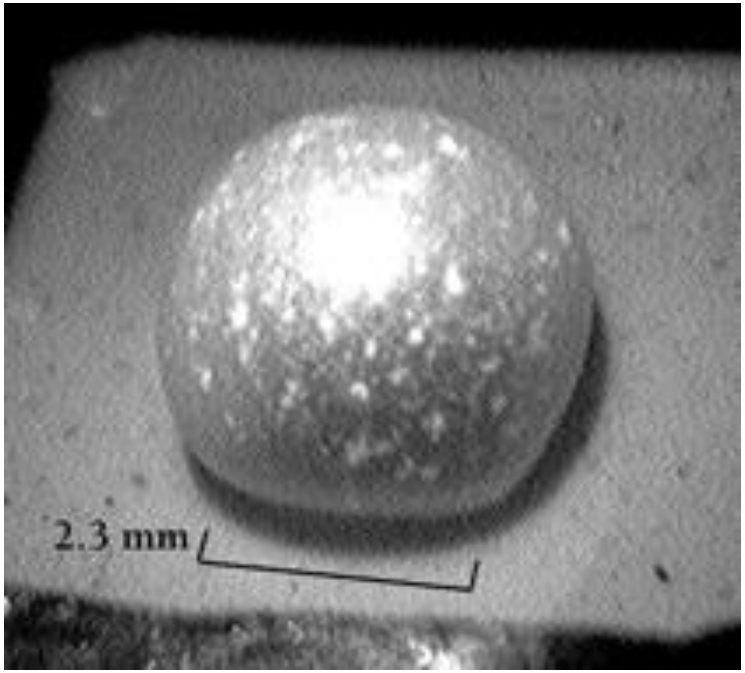
CMOS Based MEMS Accelerometer



Optical data storage by CMOS MEMS, Japan

MDL
NTHU

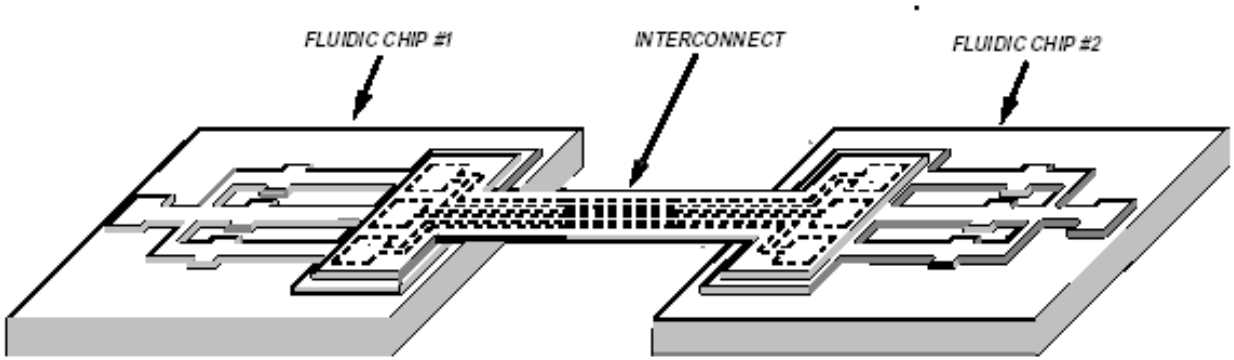
+ ? - Polymer MEMS

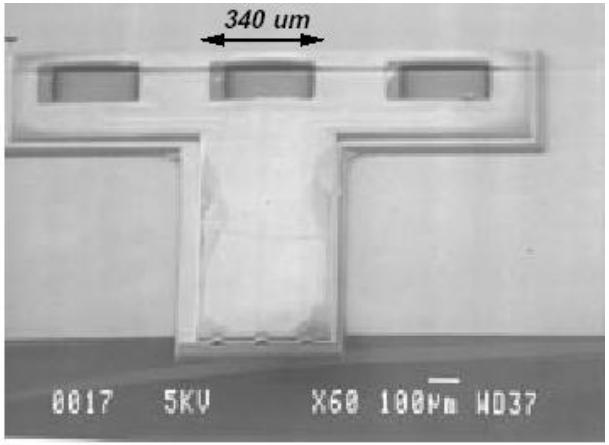


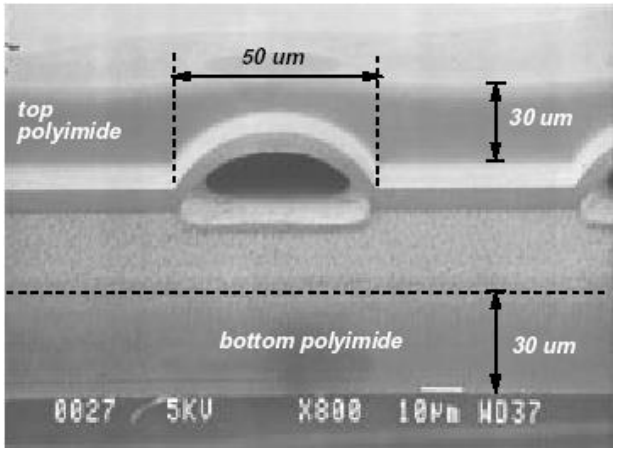
Thermal pneumatic Silicone Membrane Valve, X. Yang et. al., Caltech, 1997

MDL
NTHU

+ ? - Polymer MEMS



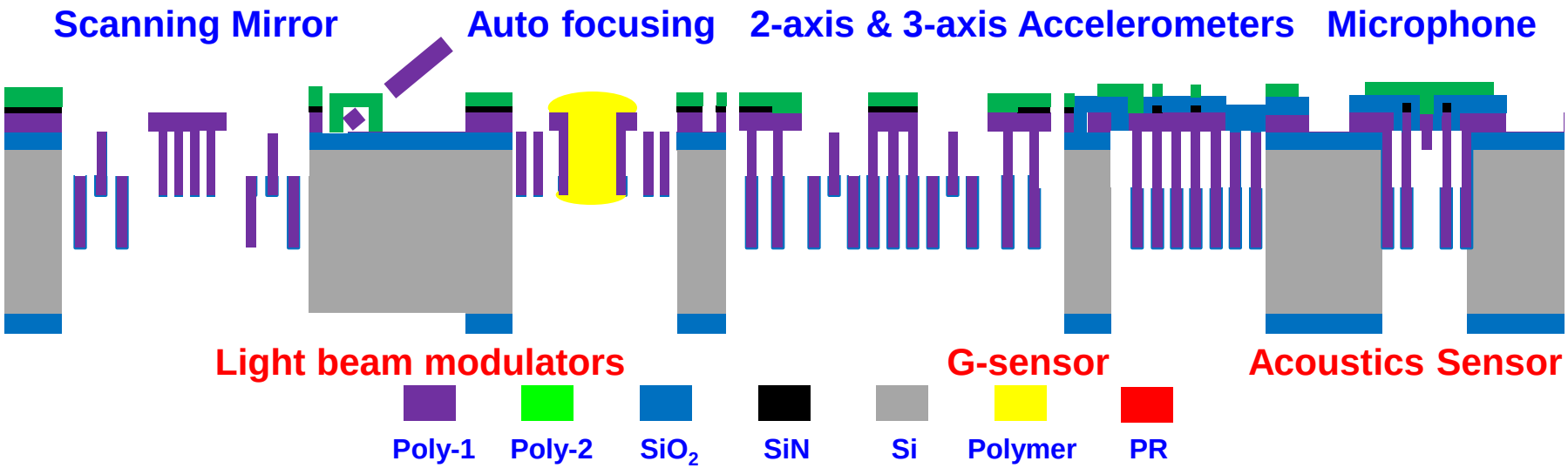


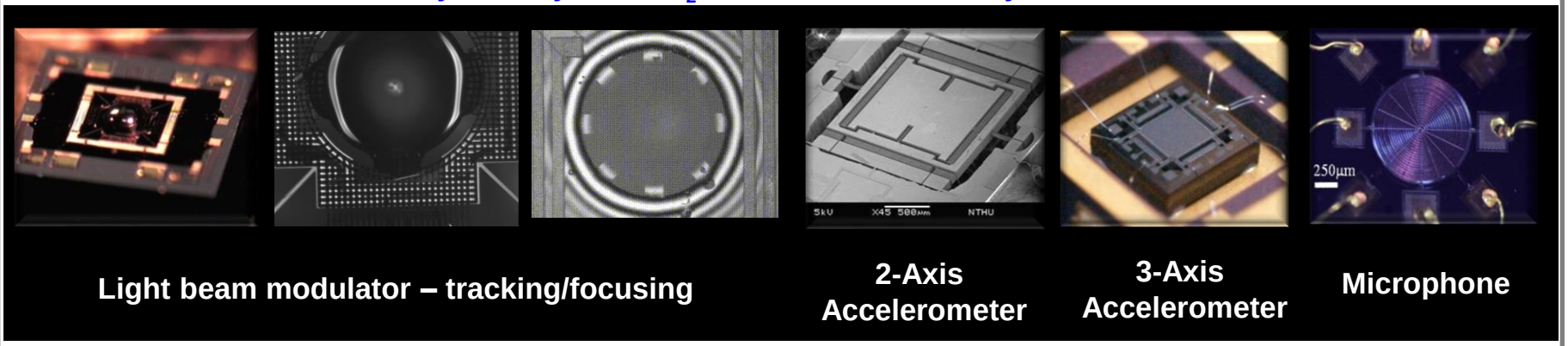


Biochip fluidic interconnect, Michigan, USA

MDL NTHU

Poly-Silicon Platform



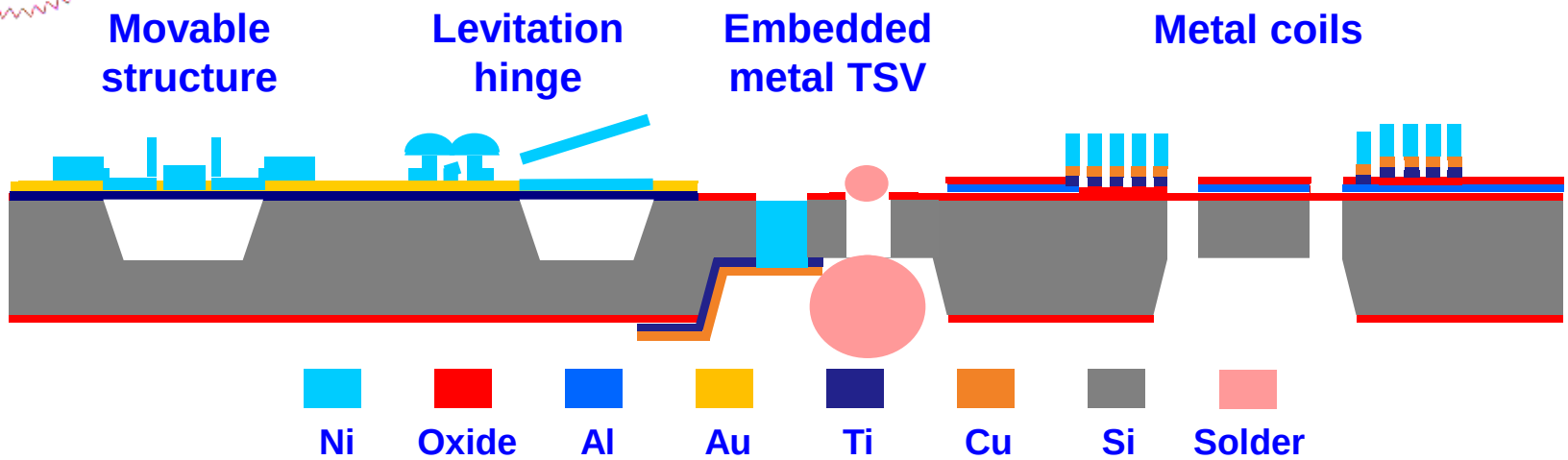


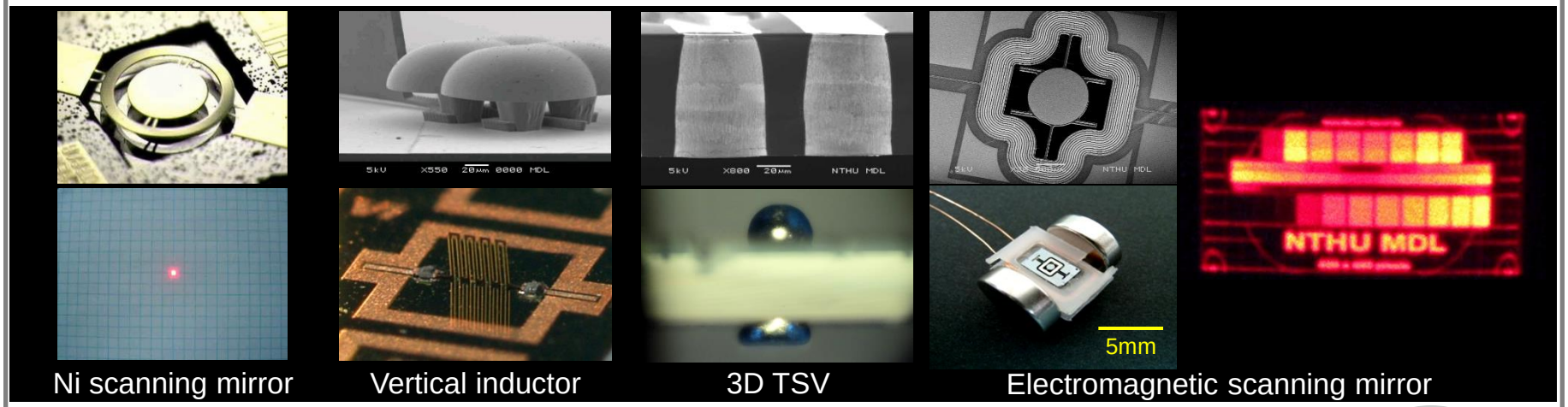
Light beam modulator – tracking/focusing | 2-Axis Accelerometer | 3-Axis Accelerometer | Microphone

Wu, and Fang, *J. Micromech. Microeng., 2005*
Wu, and Fang, *J. Micromech. Microeng., 2006*
Wu, and Fang, *J. Opt. A.*, 2006
Wu, and Fang, *IEEE Photonics Technol. Lett.*, 2006
Wu, and Fang, *IEEE Photo. Tech. Lett.*, 2007
Chan, and Fang, *Transducers*, Denver, 2009
Chan, and Fang, *MEMS*, Hong Kong, 2010
Chan, and Fang, *IEEE Sens. J.*, 2011

MDL
NTHU

Metal-MEMS Platform



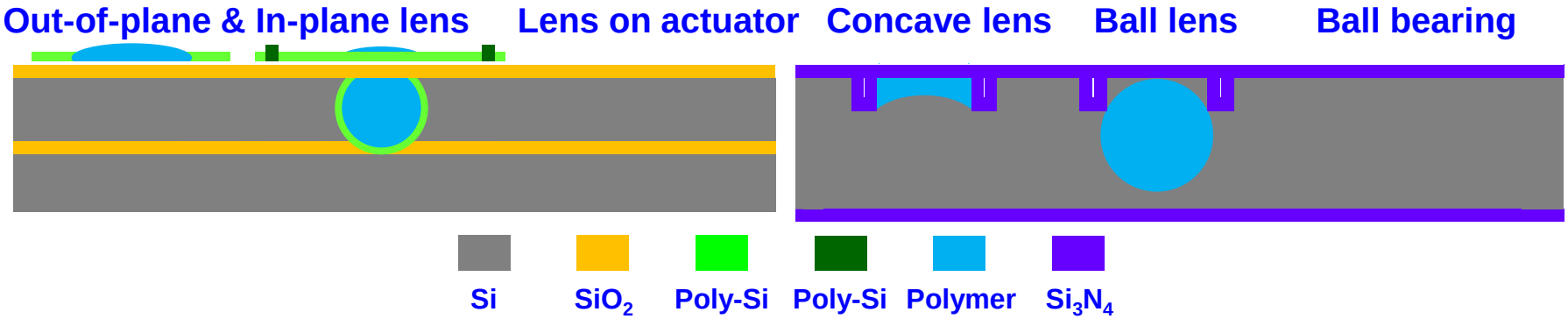


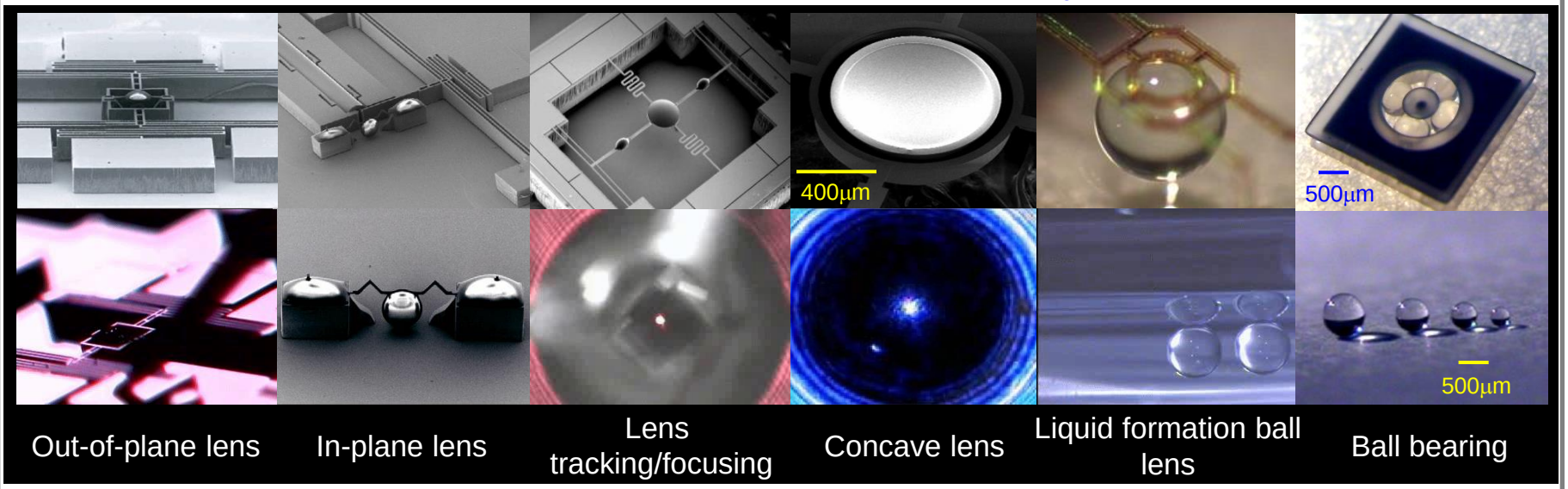
Ni scanning mirror | Vertical inductor | 3D TSV | Electromagnetic scanning mirror

Yang, and Fang, *IEEE MEMS*, Istanbul, 2005
Yang, and Fang, *JMM*, 2006
Yang, and Fang, *JMEMS* , 2007
Su, and Fang, *IEEE MEMS*, Sorrento, 2009
Huang, and W. Fang, *JMMM,* 2010
Tang, and Fang, *JMM*, 2010
Tang, and Fang, *IEEE MEMS*, Cancun, 2011
Tang, and Fang, *JMM*, 2011

MDL
NTHU

Polymer-MEMS Platform



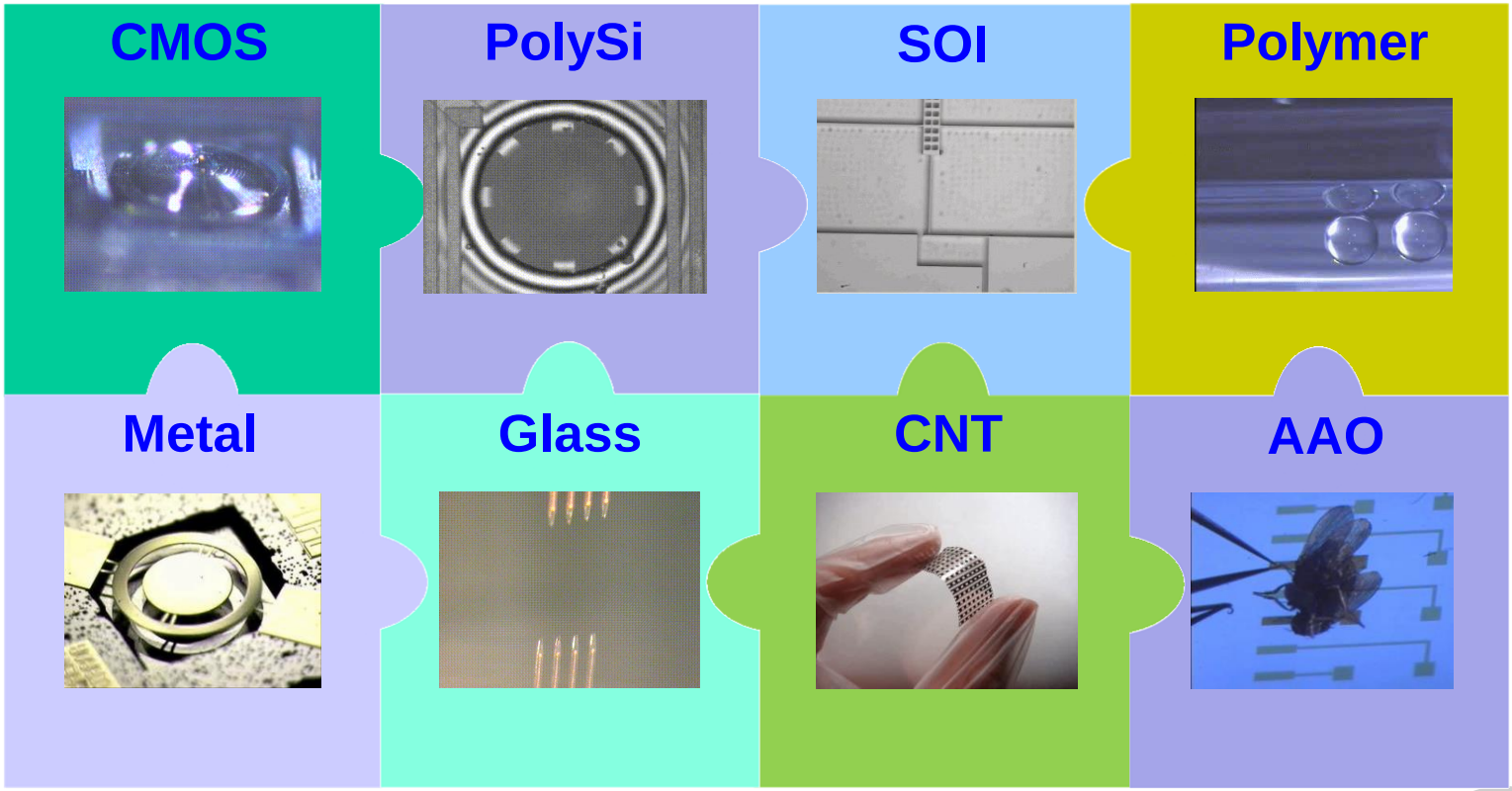


Hsieh, and Fang, *JMM*, 2007
Tung, and Fang, *IEEE MEMS*, Kobe, Japan, 2007
Lee, and Fang, *Transducers*, Leon, France, 2007
Hsiao, and Fang, *IEEE MEMS*, Tucson, USA, 2008
Lee, and Fang, *IEEE MEMS*, Sorrento, Italy, 2009
Lee, and Fang, *Transducers*, Denver, USA, 2009
Lee, and Fang, *IEEE MEMS*, Hong Kong, 2010
Lee, and Fang, *IEEE MEMS*, Cancun, Mexico, 2011

MDL
NTHU

Building Blocks for Microsystem

- Process platforms as building blocks for microsystem



MDL
NTHU

Summary

MDL
NTHU

- **Evolution of the devices**

  + Miniaturization

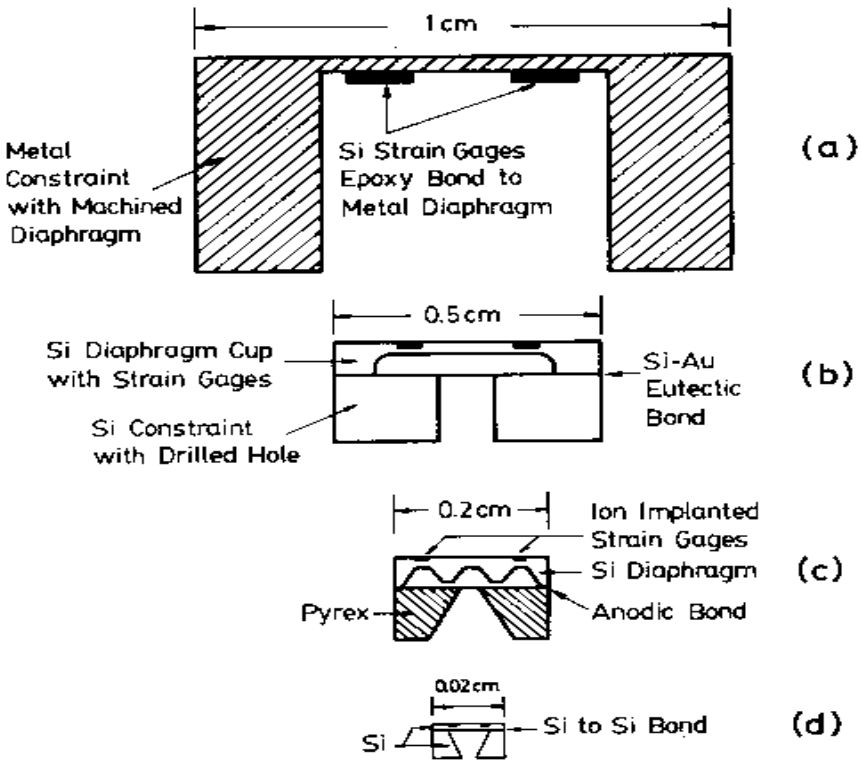
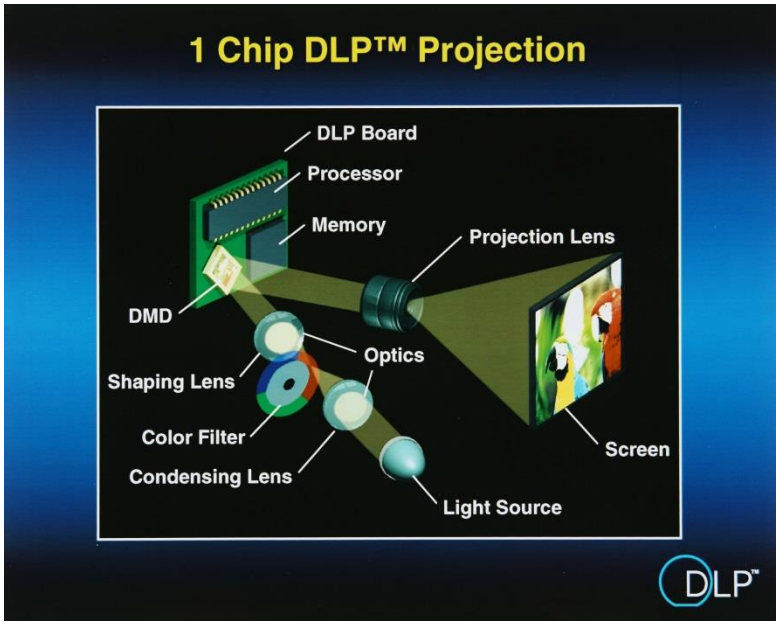


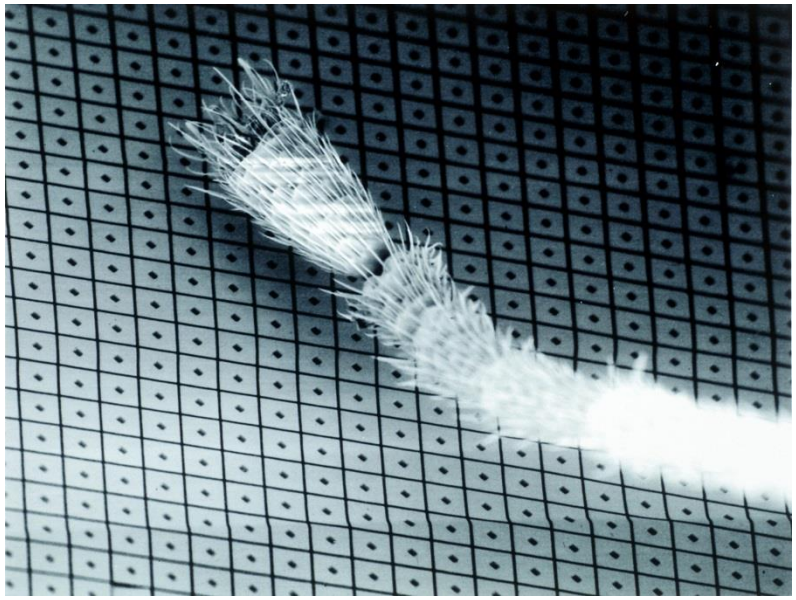
Fig. 5 Evolution of diaphragm pressure sensors. (After Ref. 11)

Semiconductor Sensors, edited by S.M. Sze, 1994.

MDL NTHU

+ Microsystems – TI DMD (DLP)





Digital mirror device by TI

MDL
NTHU

- **Miniaturization - length scale**
- **Distribution - array, multi function**
- **Integration - mechanical and electrical**
- **Motion - moving parts and media**

MDL
NTHU