1.2 Historical Background

- **Microelectronics**

  + 1947 - first transistor invented at Bell Lab

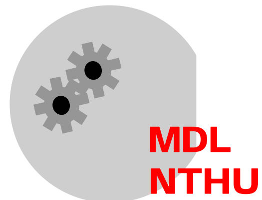
  + 1959 - first IC invented by Kilby

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

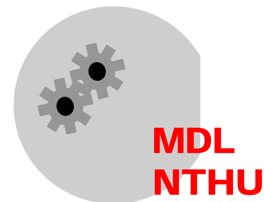
  + 1969 - LSI, 1000 ~ 10000 components/chip

  + 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



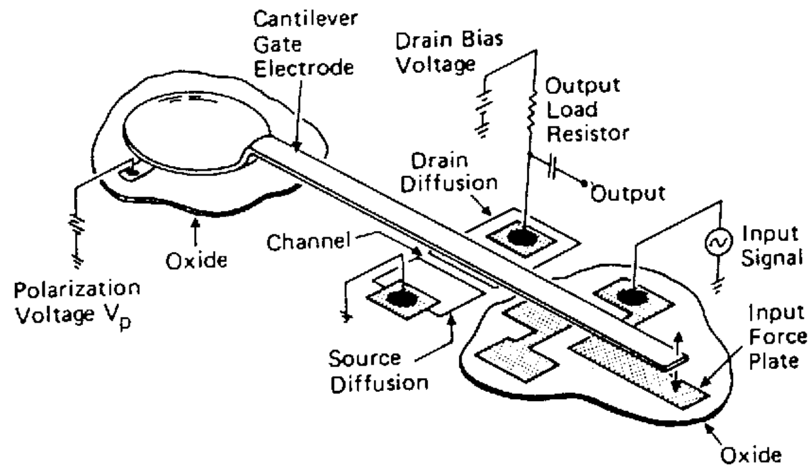
Planar Technology



- IC : TSMC, UMC, Winbond, ...
- Magnetic recording head : Seagate, Quantum, ...
- LED/VCSEL/Diode laser : Opto tech, Metrodyne
- TFT-LCD : AU Optronics, Quanta Display, ...
- MEMS : Walsin Lihwa, APM, Neostone, ...

- # Micromachining

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



H.C. Nathanson 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.

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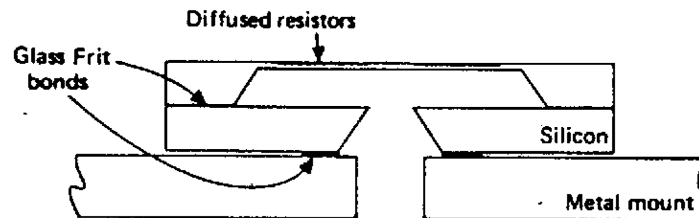
+ 1972 - silicon micromachined beams

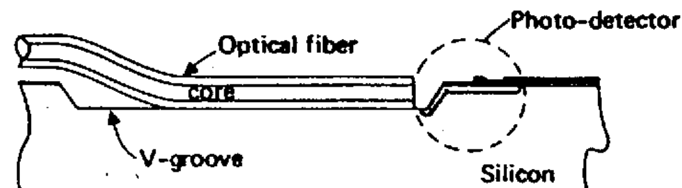
S.C.H. Lin and I. Pugacz-Muraszkiewicz, J. of Applied Physics, 1972.

+ 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.

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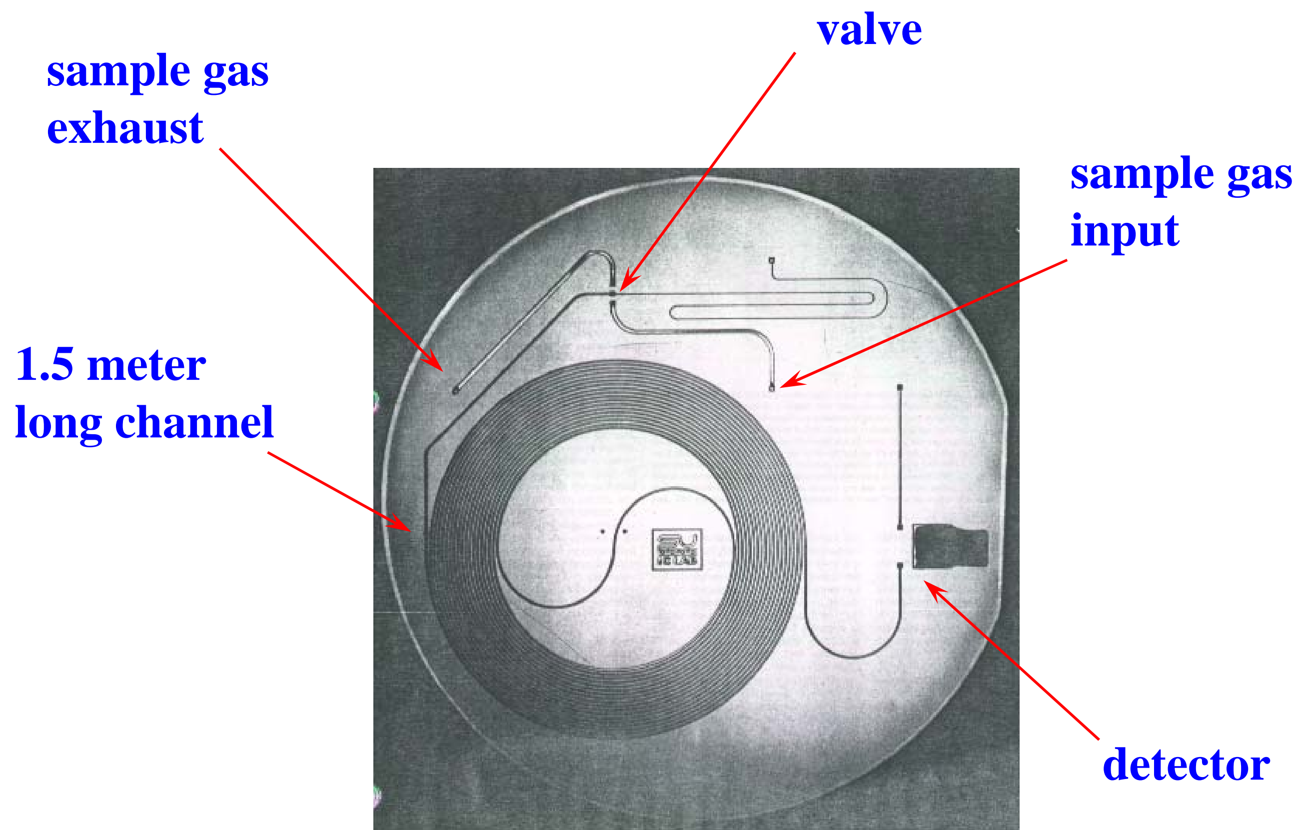
+ 1975 - gas chromatograph (groove, hole, bonding)



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

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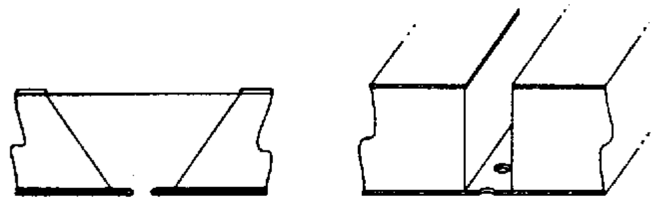
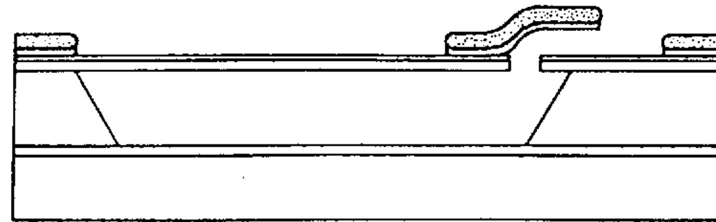
+ 1977 - ink jet nozzles (nozzle)

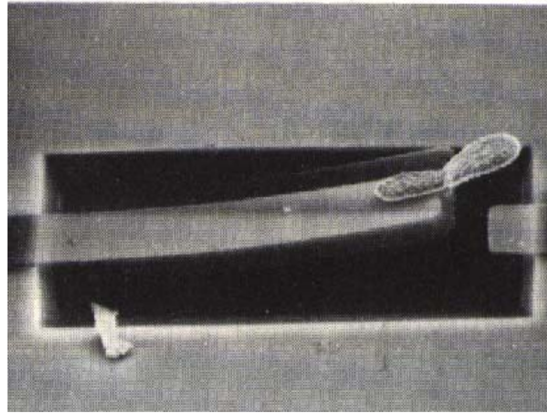


E. Bassous, L. Kuhn, A. Reisman, and H.H. Taub, U.S. Patent 4 007 464, 1977.

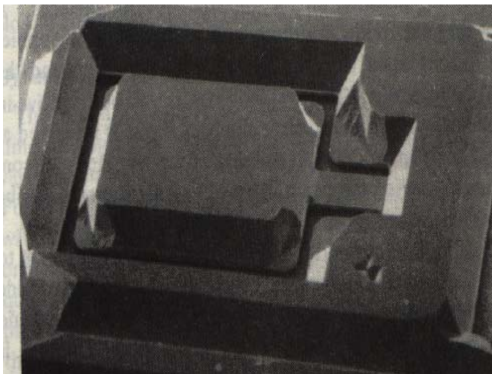
+ 1978 - electrical switch (cantilever beam)

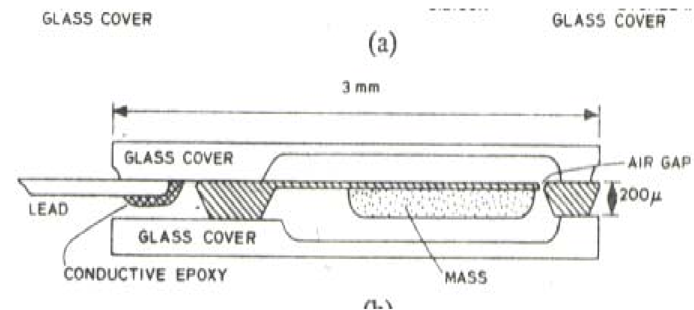


K.E. Petersen, IEEE Transaction on ED, 1978.



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





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

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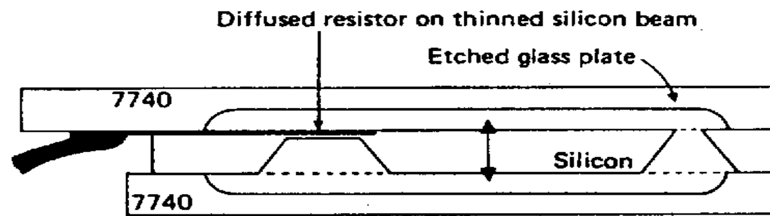
+ 1979 - accelerometer (cantilever beam)

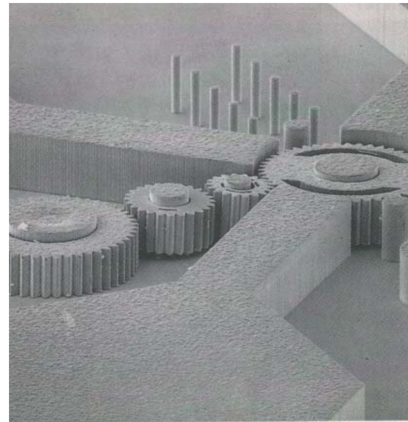


L.M. Roylance and J.B. Angell, IEEE Transaction on ED, 1979.

+ 1982 - silicon micromachining named by Petersen

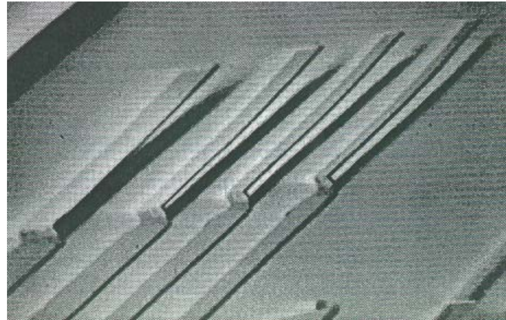
K.E. Petersen, Proceeding of the IEEE, 1982.

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



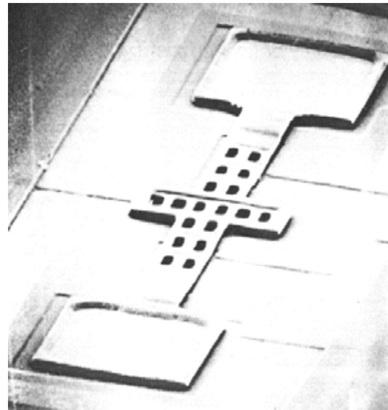
E.W. Becker, et al., Naturwissenschaften, 1982.
Figure source: J. Bryzek, K. Petersen, and W. McCulley IEEE Spectrum, 1994.

+ **1983 - surface micromachining re-developed by Howe**



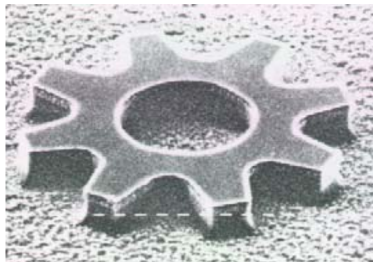
R.T. Howe and R.S. Muller, J. of Electrochemical Society, 1983.

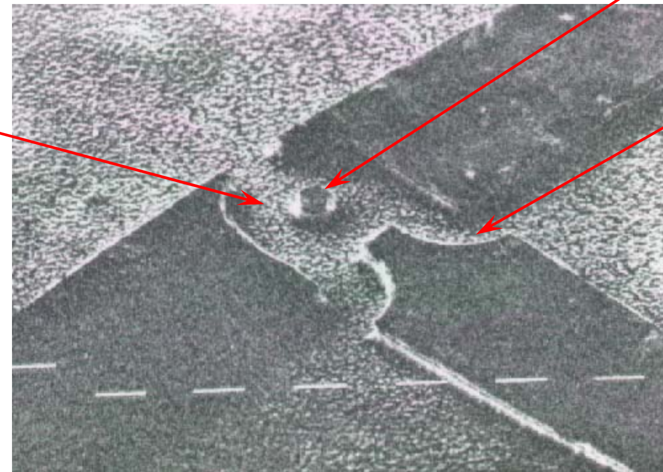
+ **1986 - surface micromachined resonant microbridge**



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

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

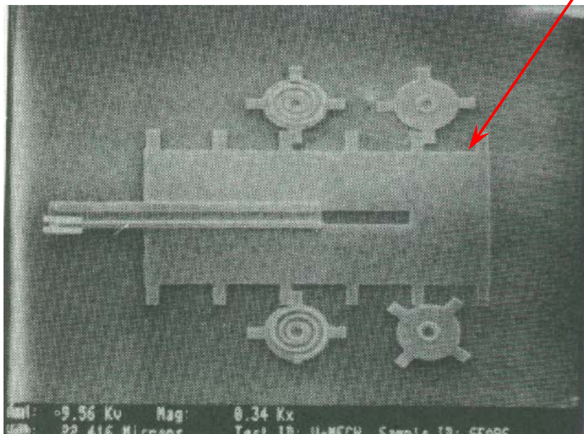


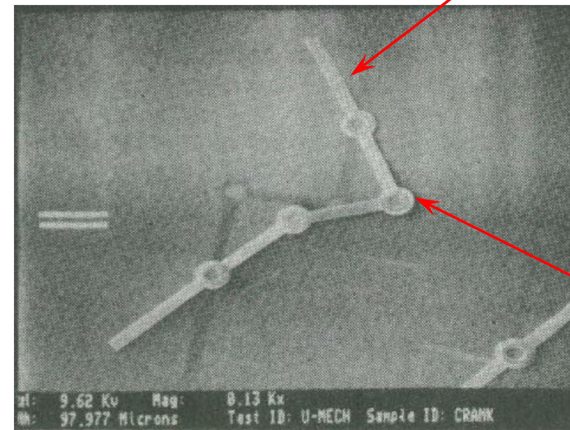


M. Mehregany, K.J. Gabriel, and W.S.N. Trimmer, Sensors and Actuators, 1987

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

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





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

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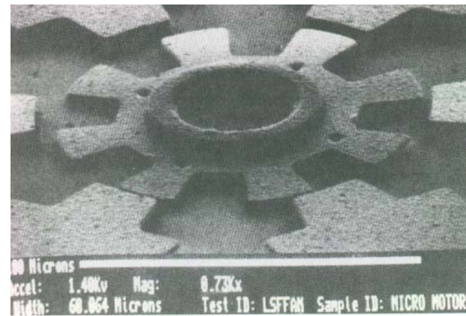
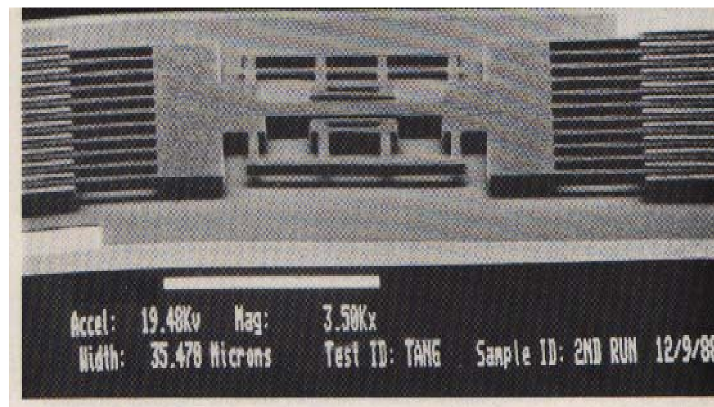
+ 1988 - first micromachined motor



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 Conference, 1989.

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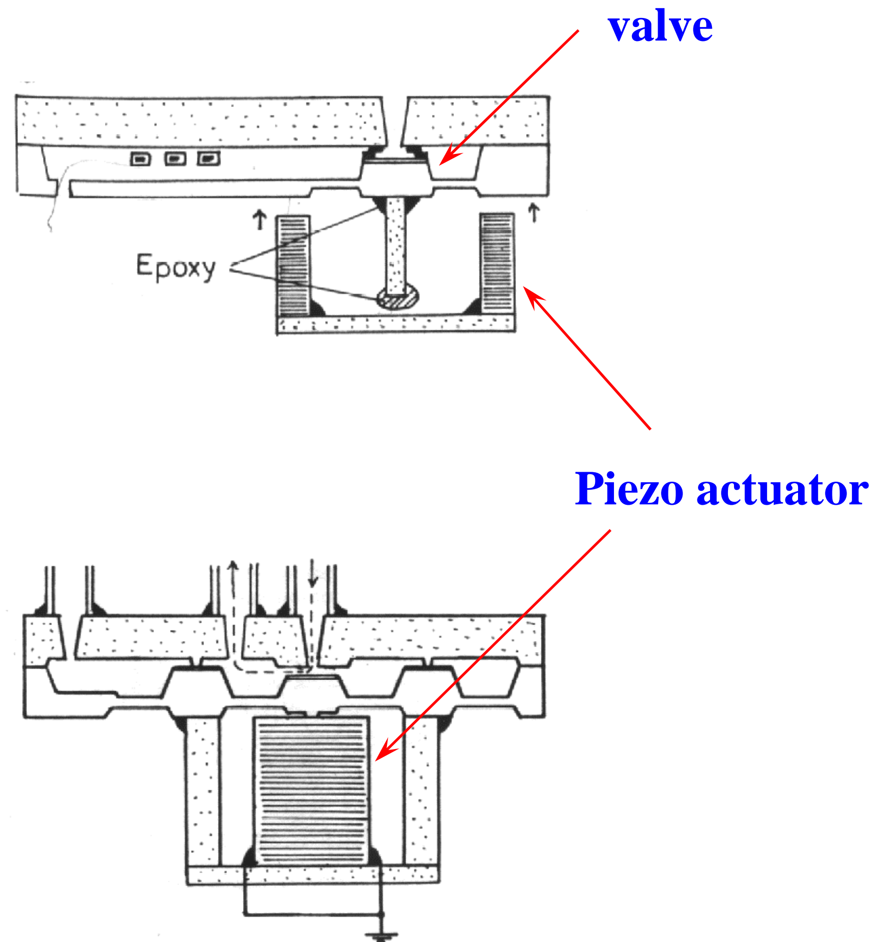
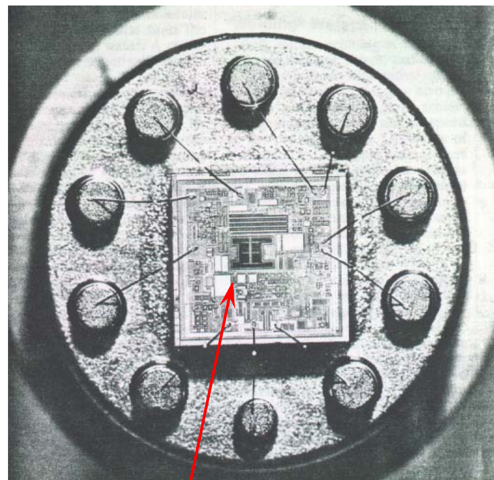
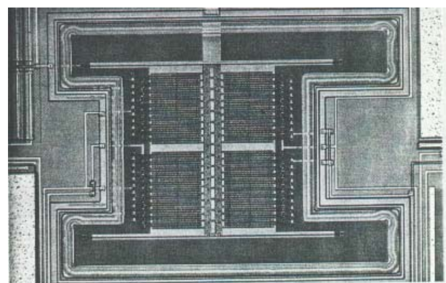
+ 1990 - microfluid system attract attention



M. Esashi, Sensors and Actuators, 1990

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





mechanical component

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

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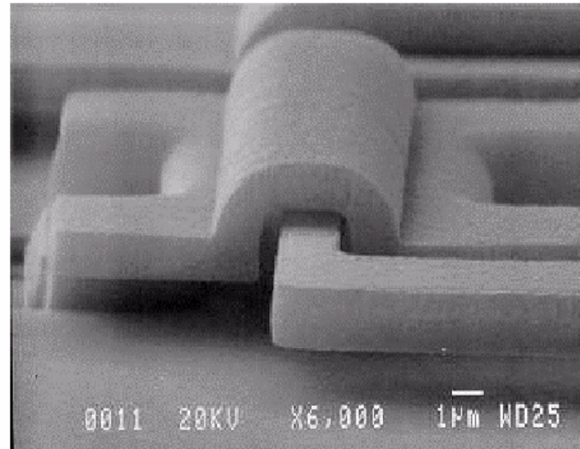
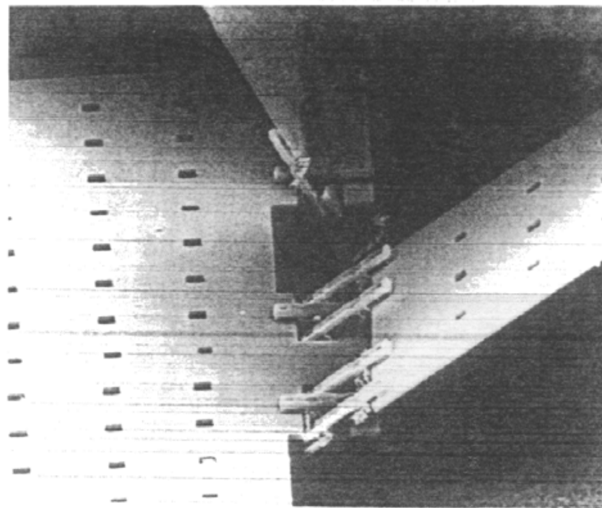
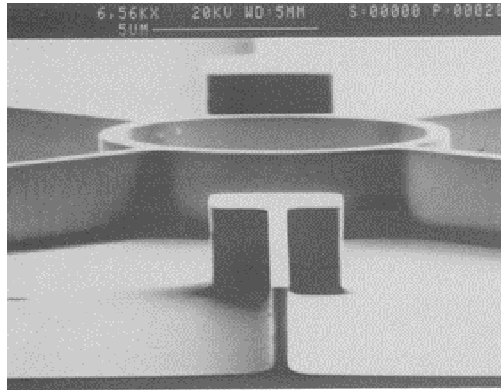
+ 1992 - micromachined hinge





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

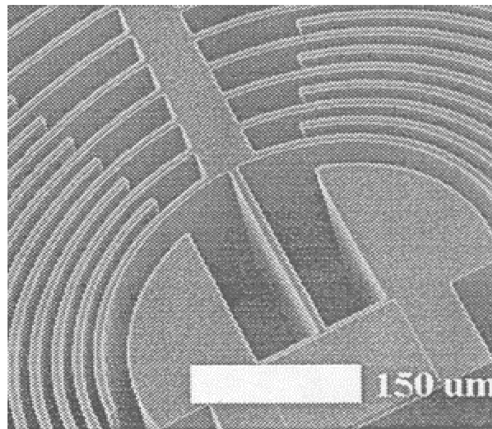
+ 1993 - thick micromachined structures (SCREAM)



4 μm

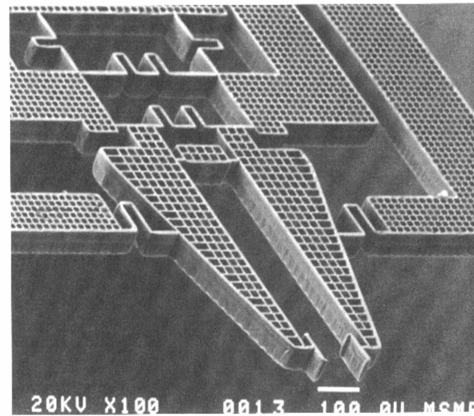
Z.L. Zhang and N.C. MacDonald, J. of MEMS, 1993

+ 1995 - thick micromachined structures (DRIE)



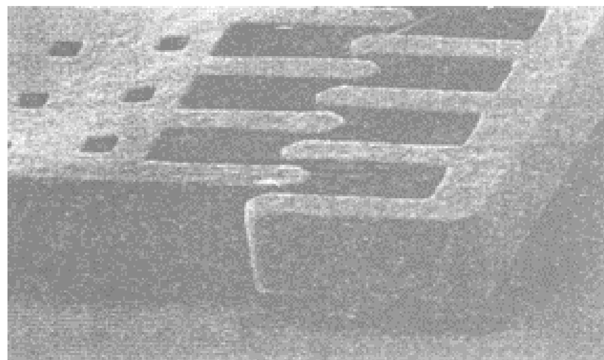
E.H. Klaassen, et.al., Transducers'95, 1995

+ 1995 - thick micromachined structures (Hexsil)



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

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



12 µm

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

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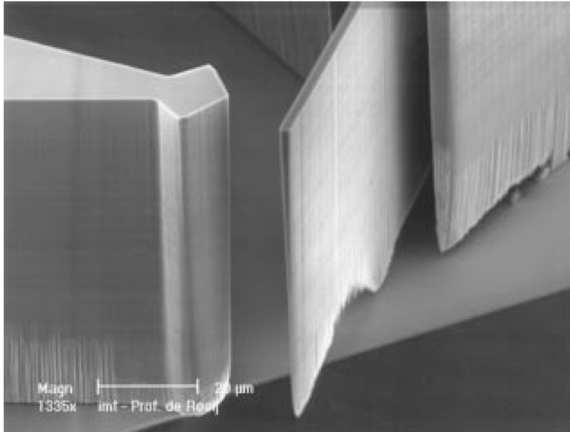
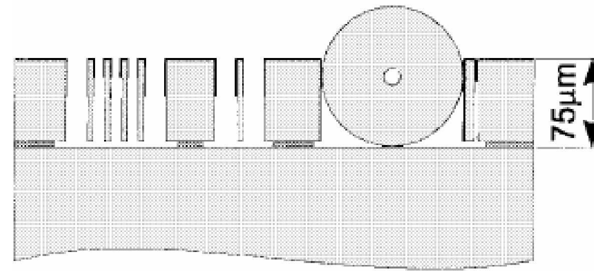
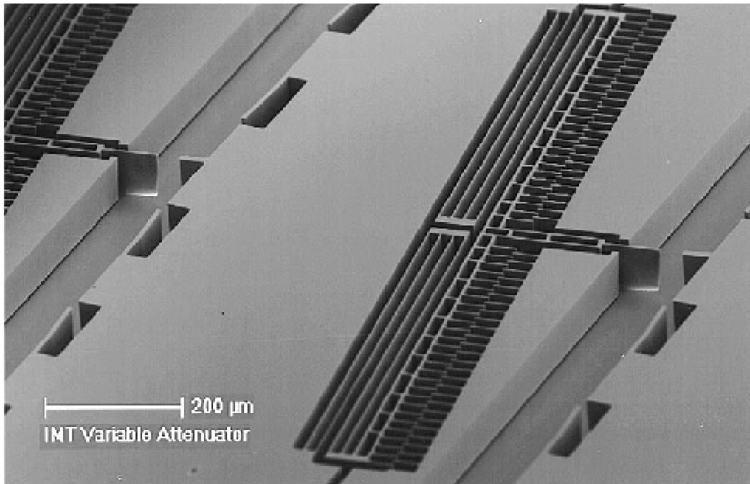
+ 1995? - SOI







Optical Switch

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

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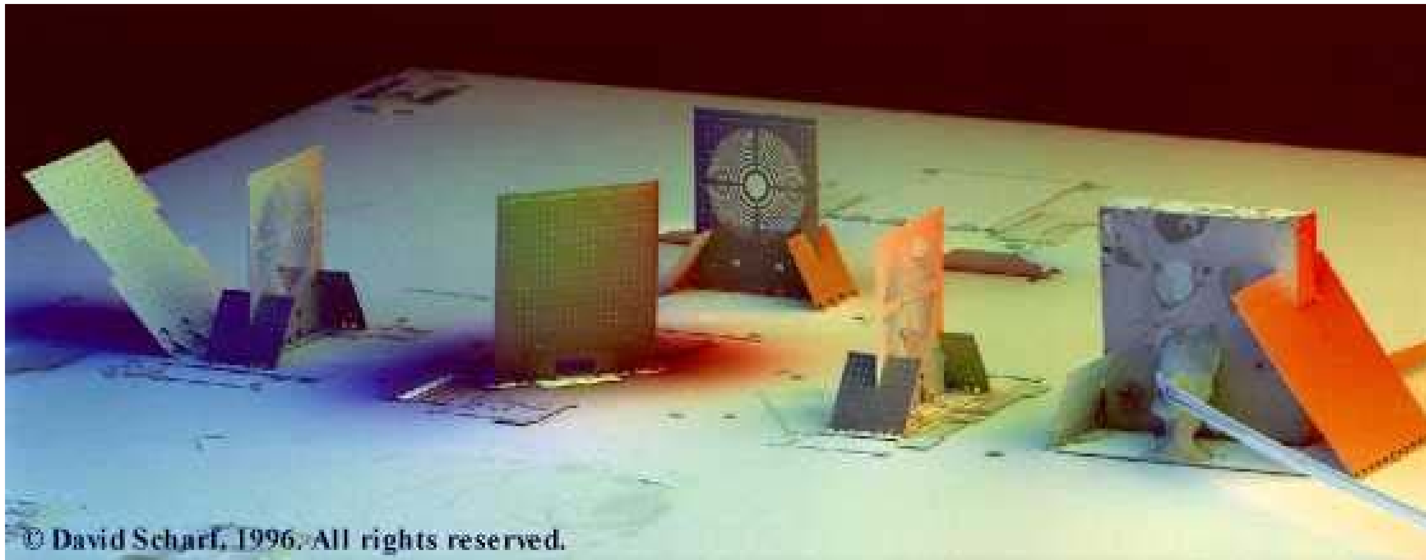
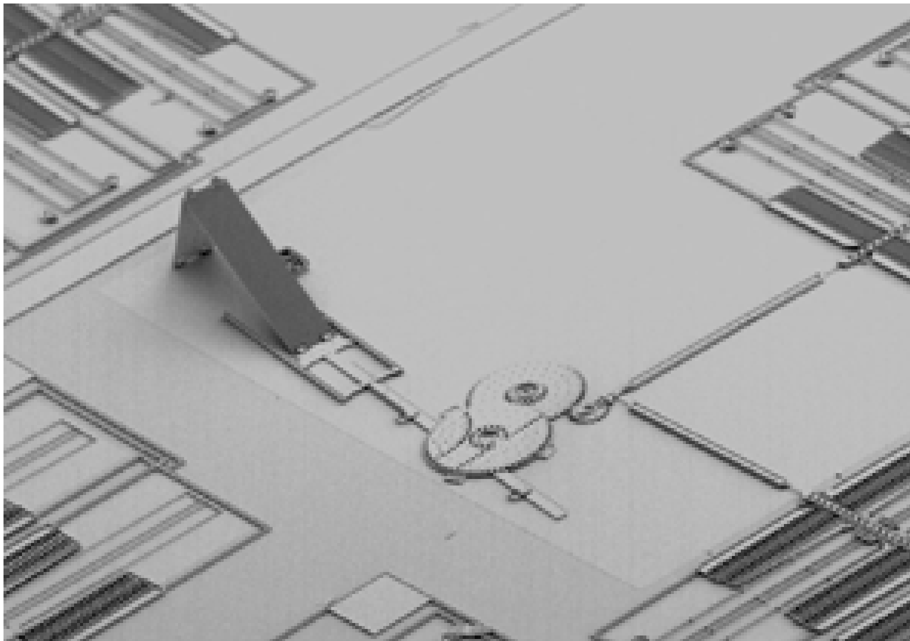
+ 1996 - Optical bench (original idea: M. C. Wu et al. , *Sensors and Actuators A*, 1995)

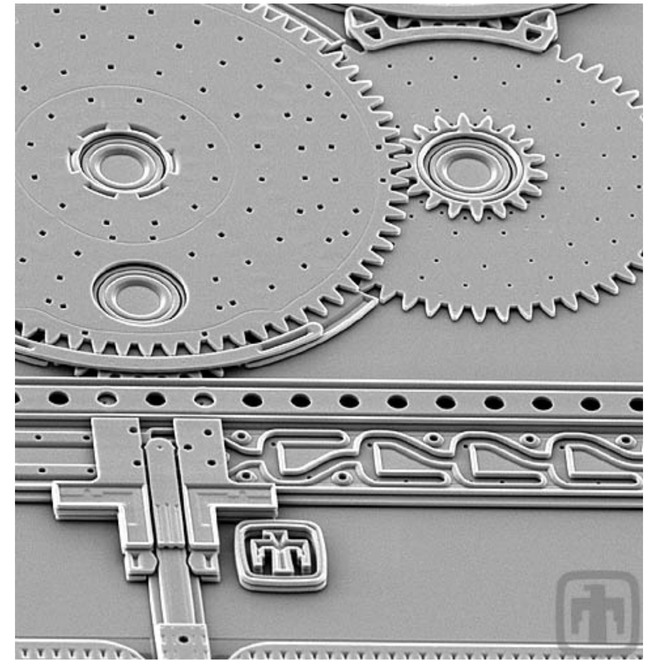
Optical-disk pickup head realized by FSMOB technology :



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

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





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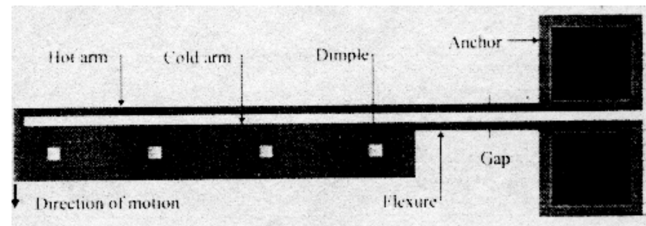
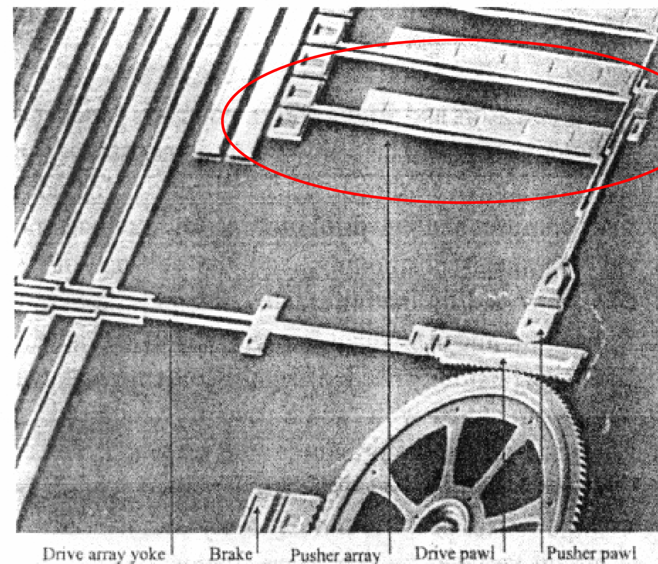
+ 1997 - complicated mechanism driven by electro-thermal actuators





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

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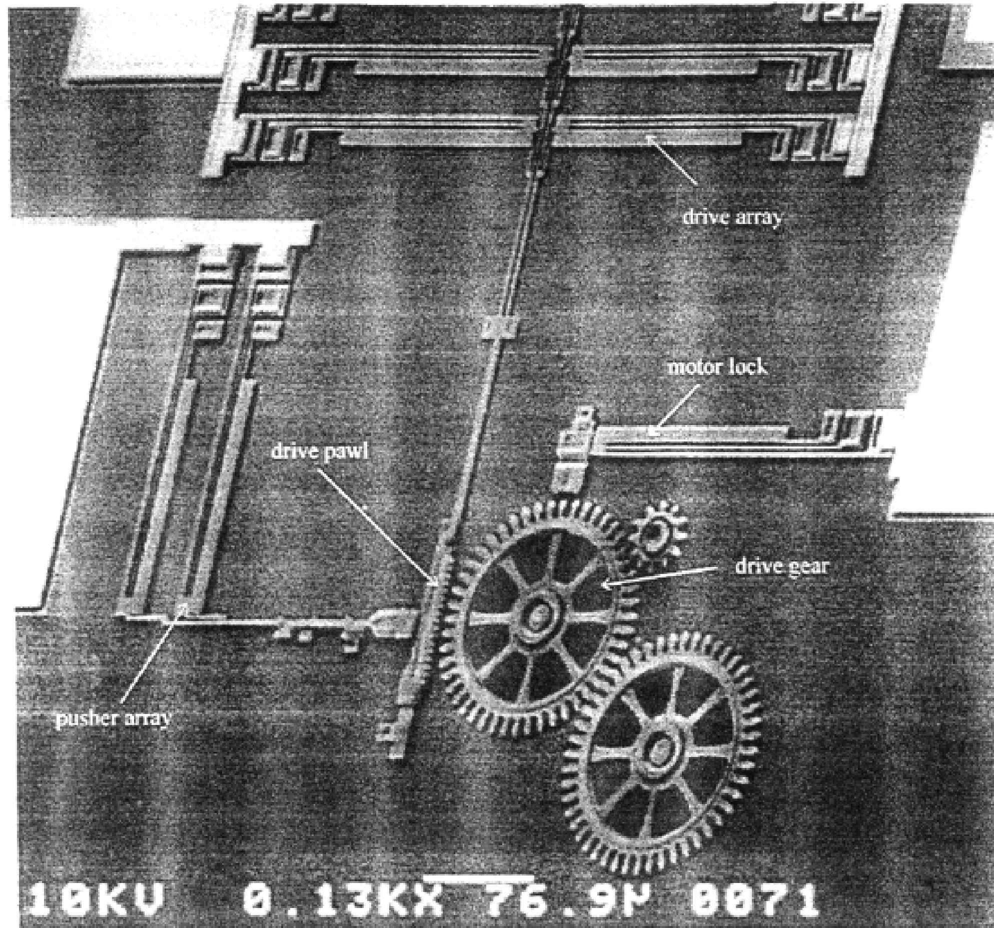

D.M. Burns and V.M. Bright, 1997

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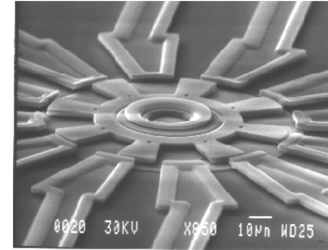
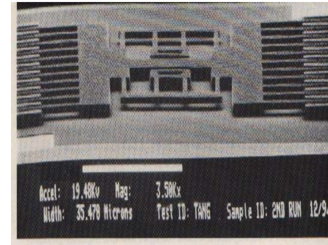
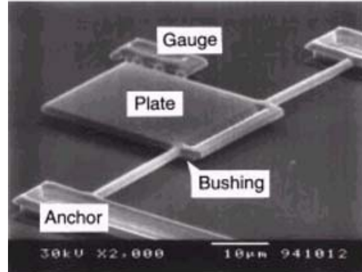
Motor
L.S.Fan, Y.C. Tai, R.S.Muller
(1988)



Comb-drive
Tang, Nguyen, Howe
(1989)



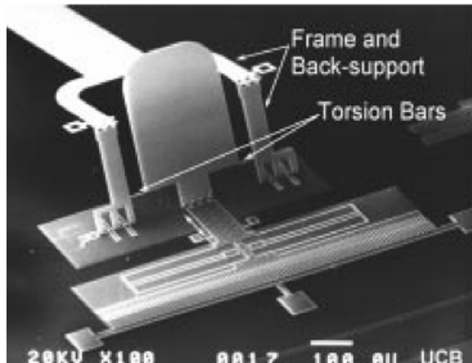


Hinge
K.S.J. Pister
(1992)

SDA
Japan
(1992)

MUMPs *(1993)*

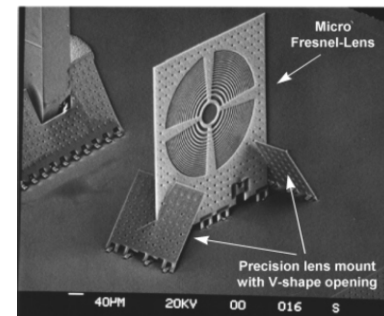
Free-Space Micro-Optical Bench
UCLA, M.C. Wu,(1995)



Summit
Summit V

?
(2001~)

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



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

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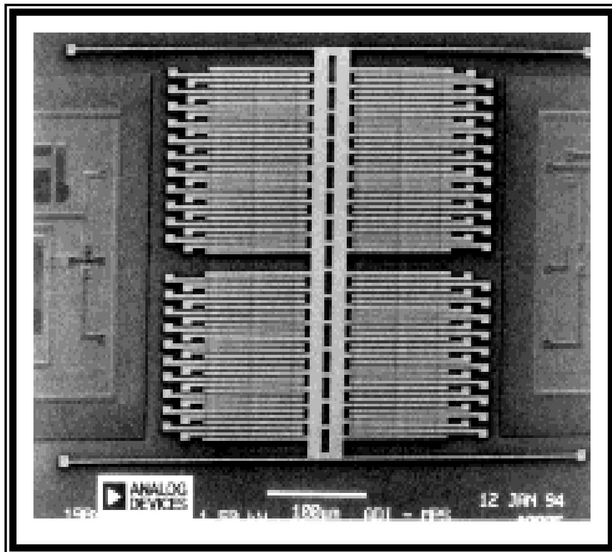
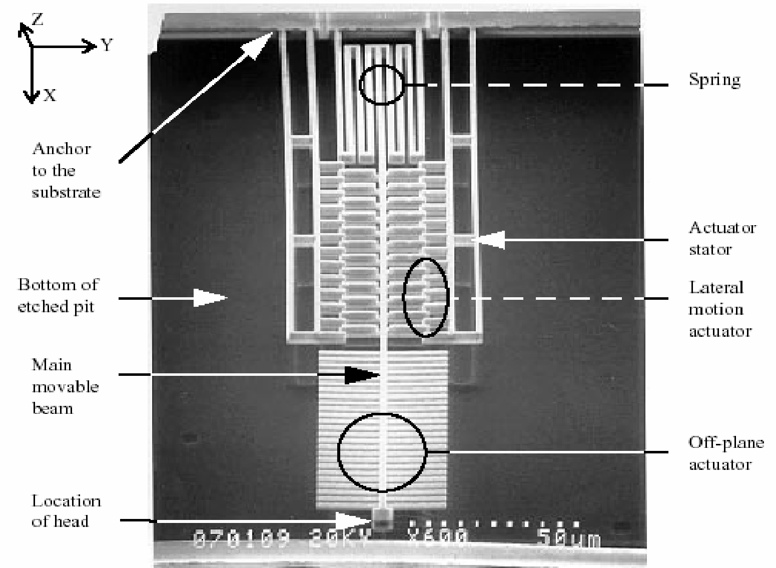
+ ? – CMOS MEMS



CMOS Based MEMS Accelerometer



MEMS optical data storage in CMOS process, Japan

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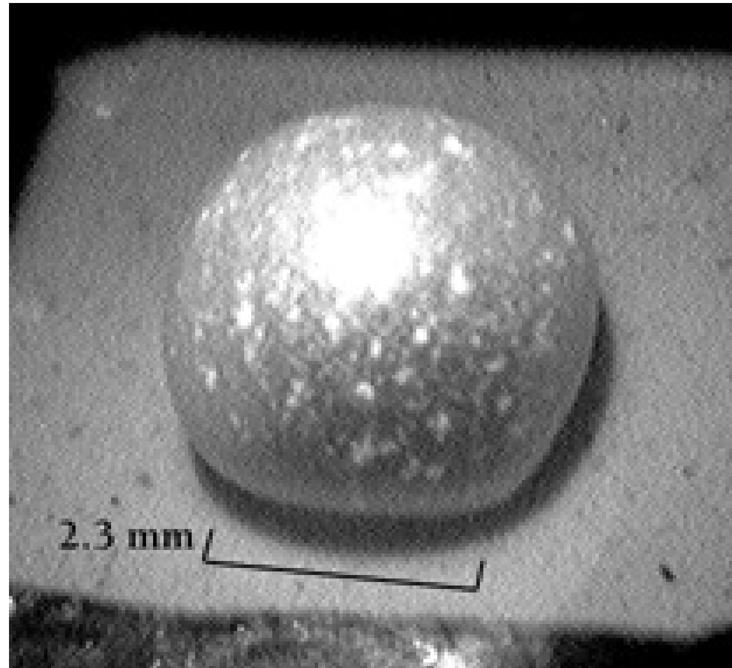
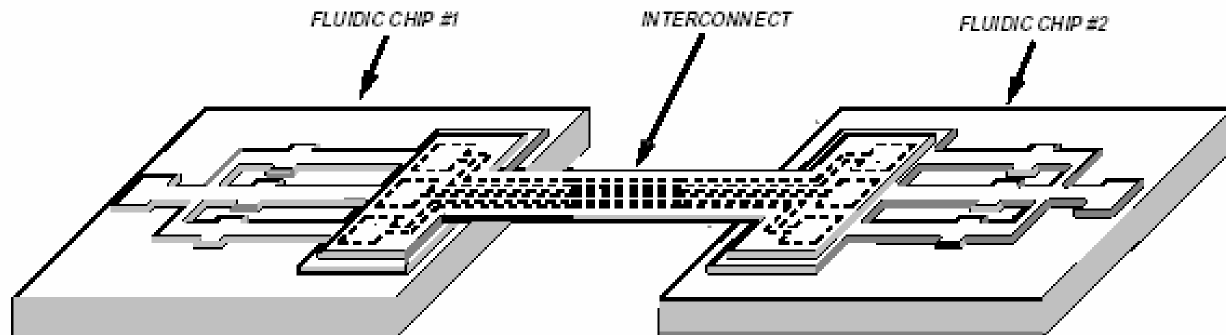
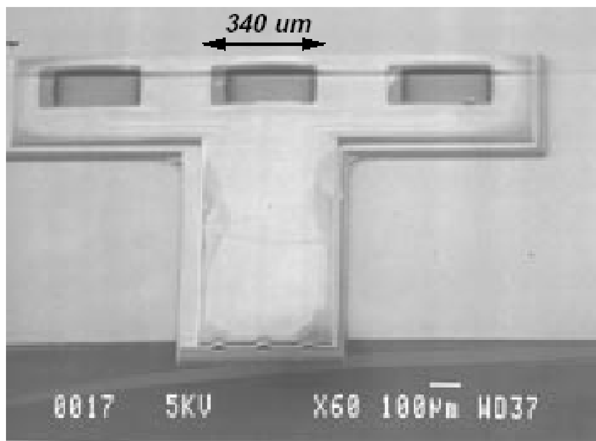
+ ? - Polymer MEMS

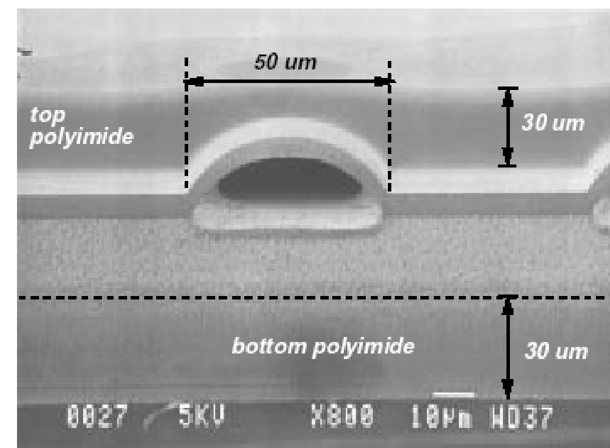


Thermal pneumatic Silicone Membrane Valve, X. Yang et. al., Caltech, 1997

+ ? - Polymer MEMS







Biochip fluidic interconnect, Michigan, USA

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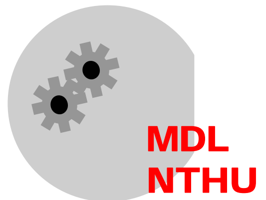
MEMS is an enabling technology



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

- **Evolution of the devices**

  + Miniaturization

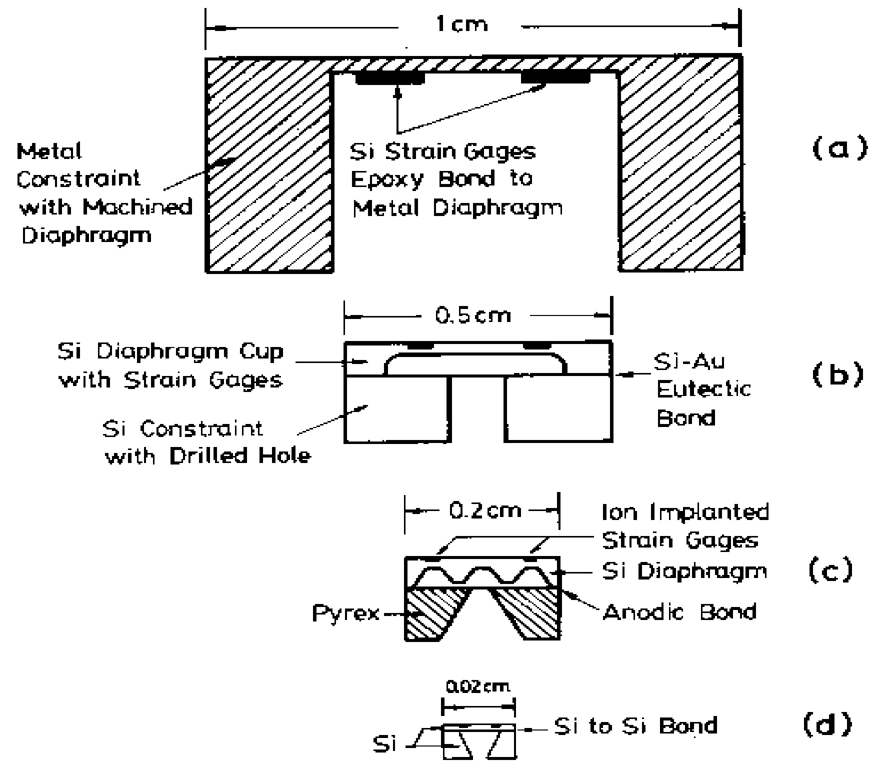


Fig. 5 Evolution of diaphragm pressure sensors. (After Ref. 11)

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

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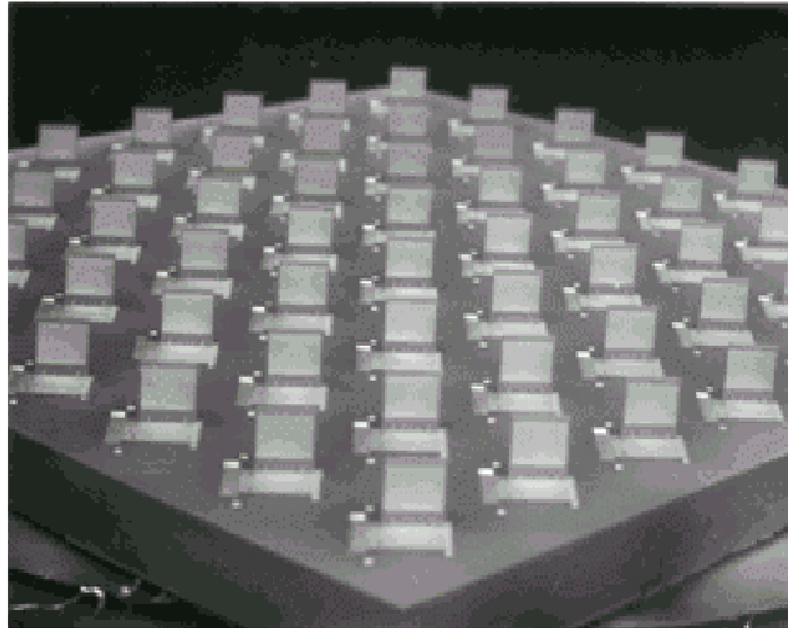
+ Distribution – integrated machines



Optical switch array by OMM Inc.

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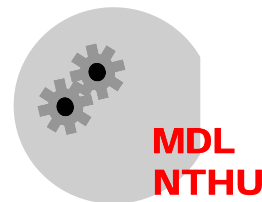
酷・驚喜・耶誕 到寶島

"美玲！妳的呼叫器呢？"

"親愛的！我把呼叫器藏在手錶裡"

080-231528

12/18/1997 中國時報



EPSON

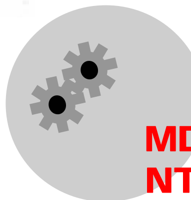
3/30/1998

毫釐之差 天壤之別
EPSON彩色噴墨印表機技高一籌

微針點壓電噴墨技術 列印品質的新基準

PerfectPicture Imaging System

3/30/1998 中國時報



- **Applications**

  + Optical MEMS

  1. Optical communication

  2. Display

  + RF MEMS

  1. Wireless communication

  + Bio MEMS

  1. Bio physics – hearing aid, manipulator, etc.

  2. Bio chemistry – lab on chip

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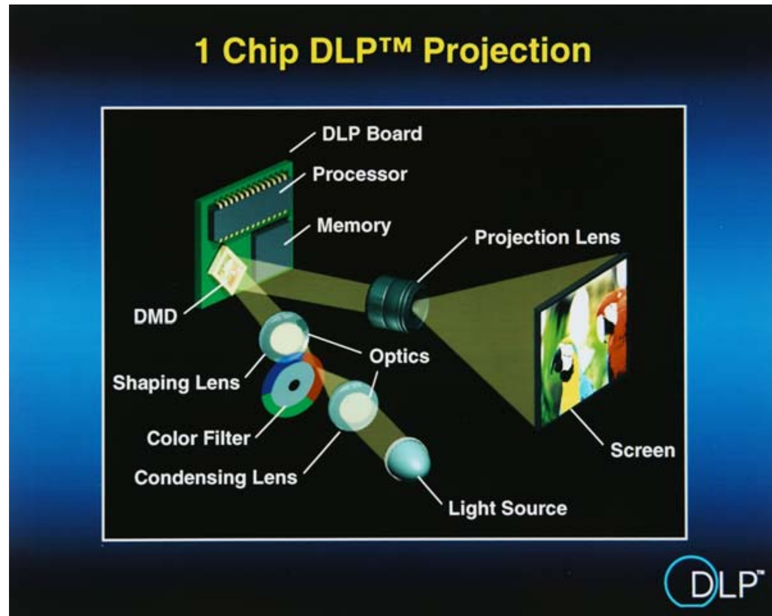
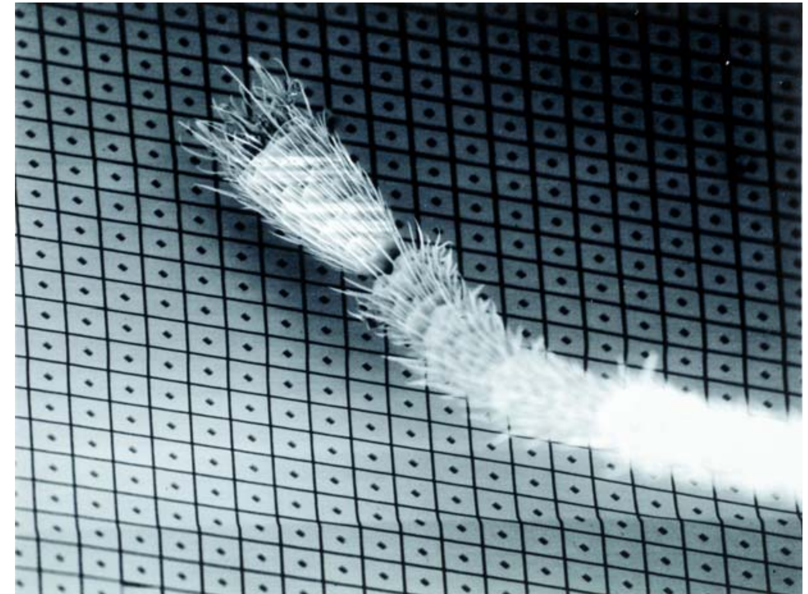
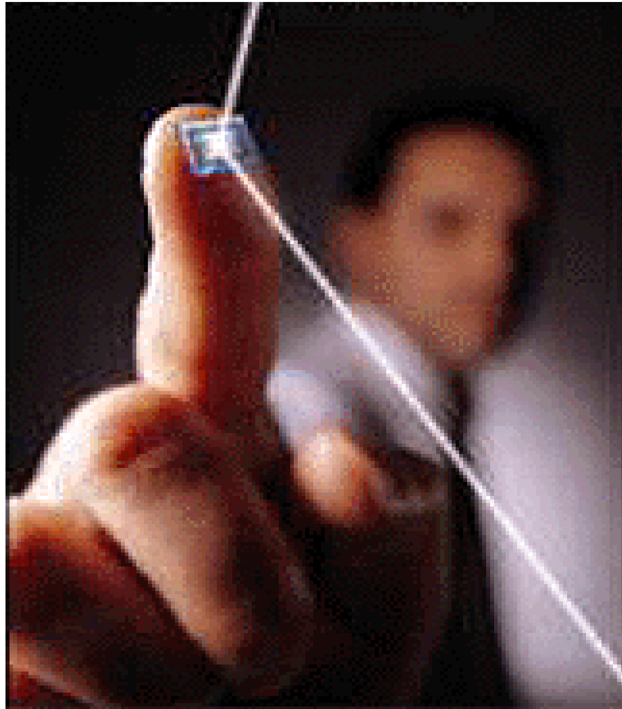
+ Optical MEMS - modulator (scanner, switch)

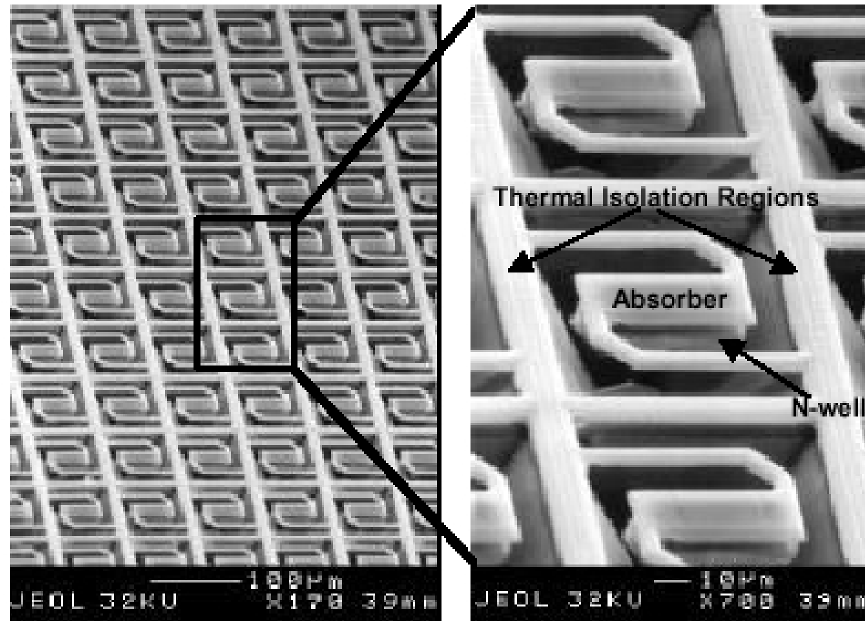




Digital mirror device by TI



Optical scanner for headmount display by Microvision Inc.



IR imager by Honeywell

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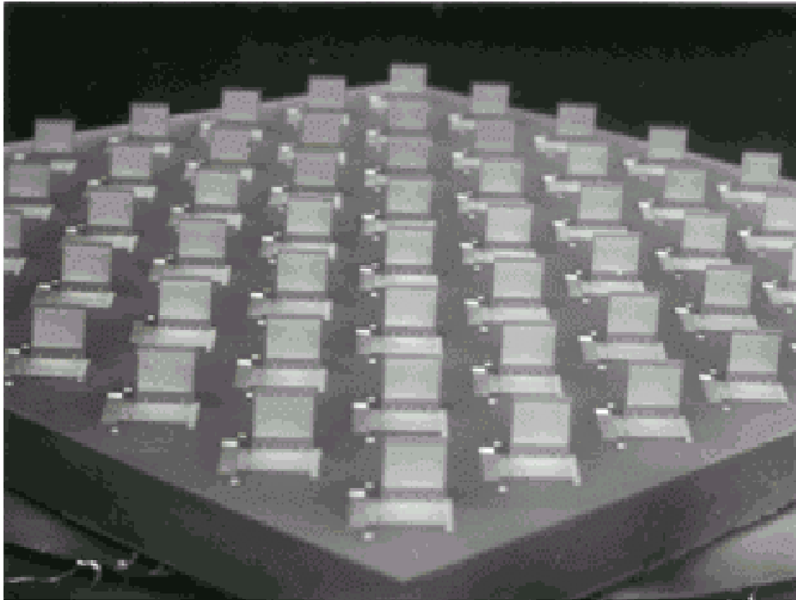
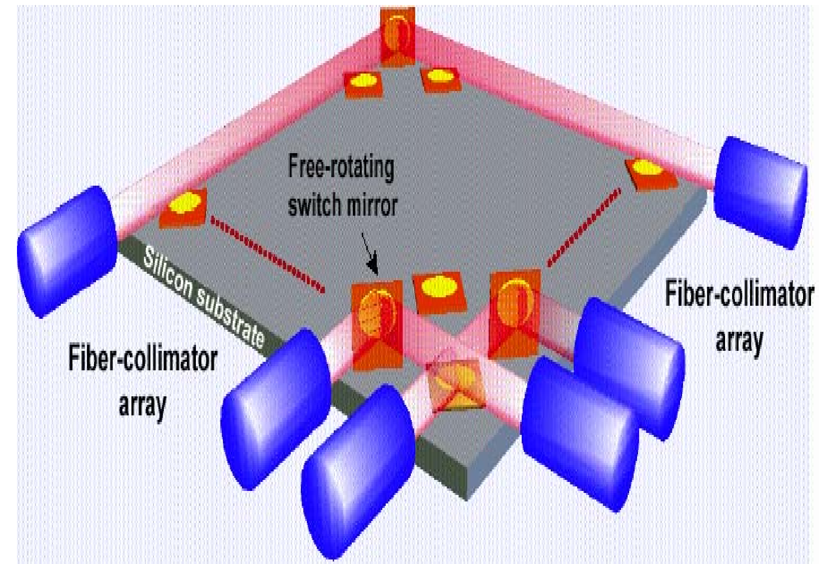
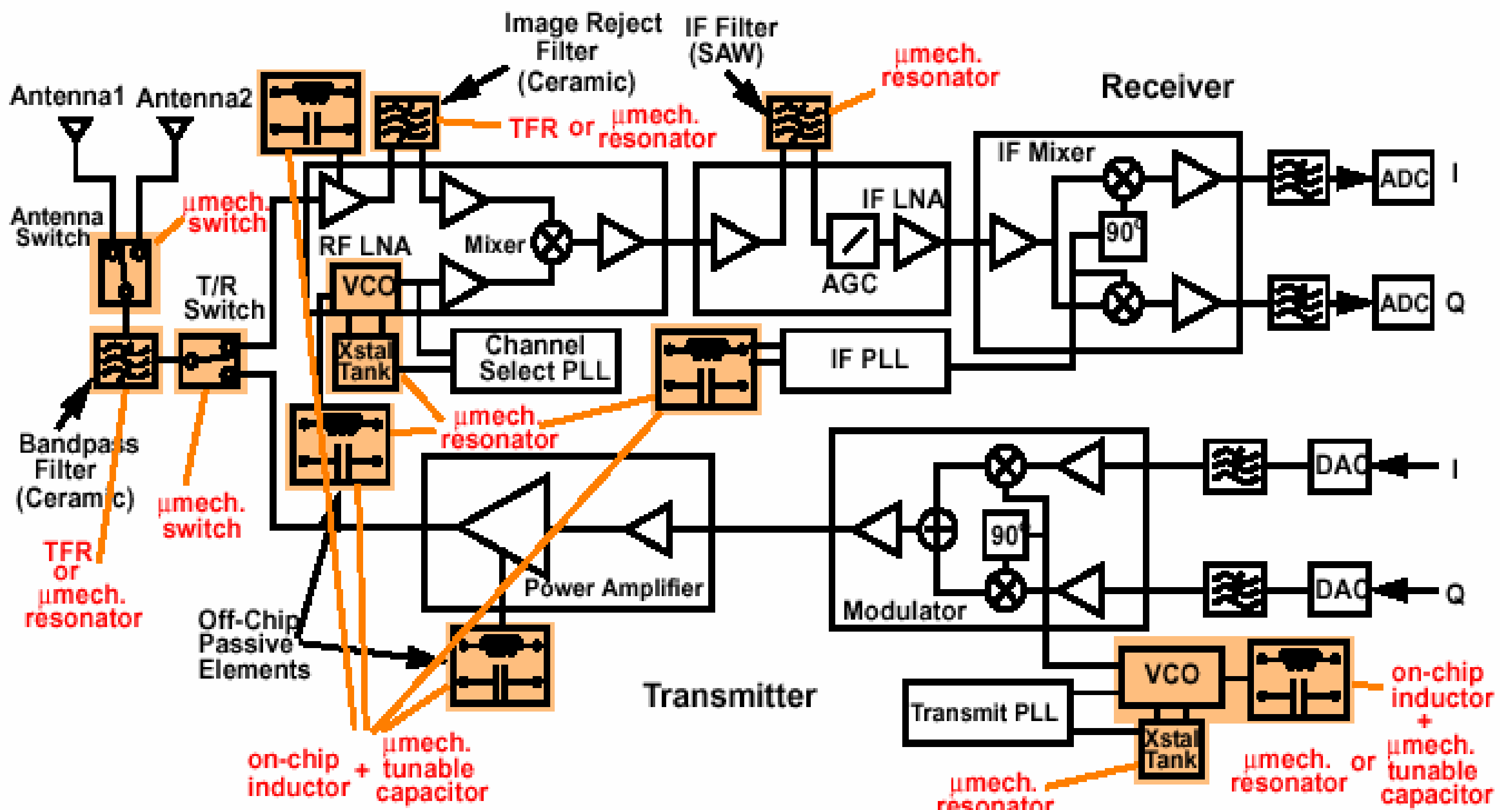




2D optical switch by OMM

+ RF MEMS - switch, filter, oscillator



Nguyen, 1999

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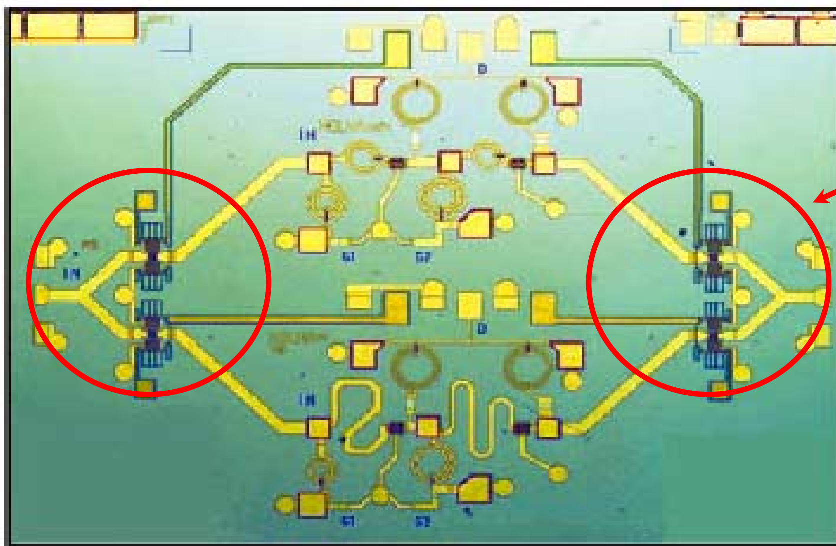
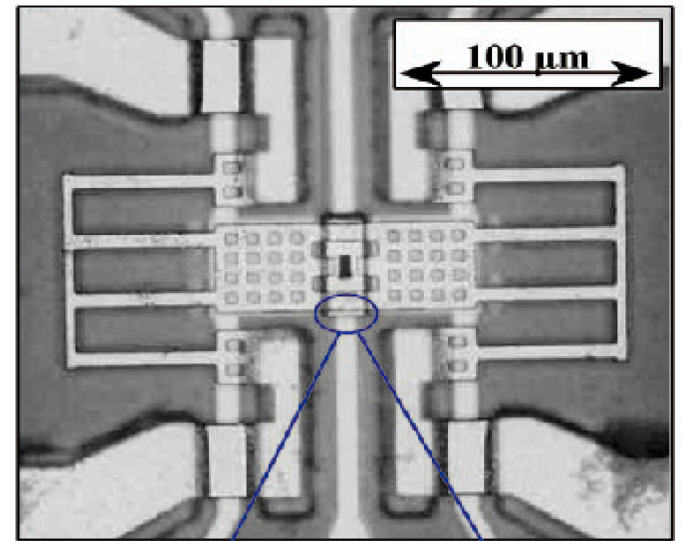
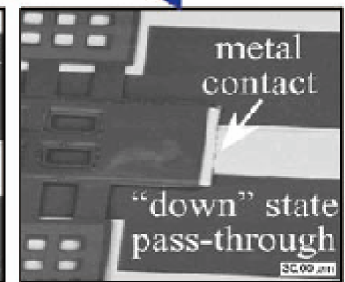




(a)



Micro switch by Rockwell Science Center

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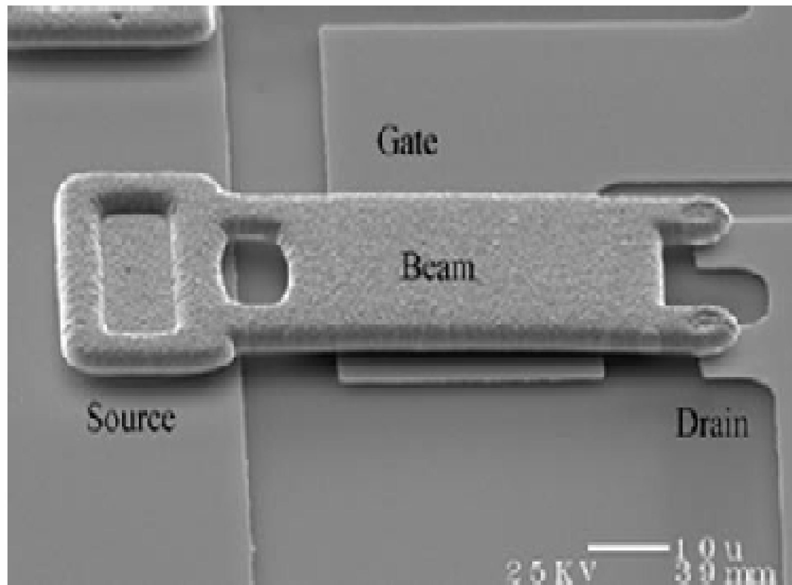
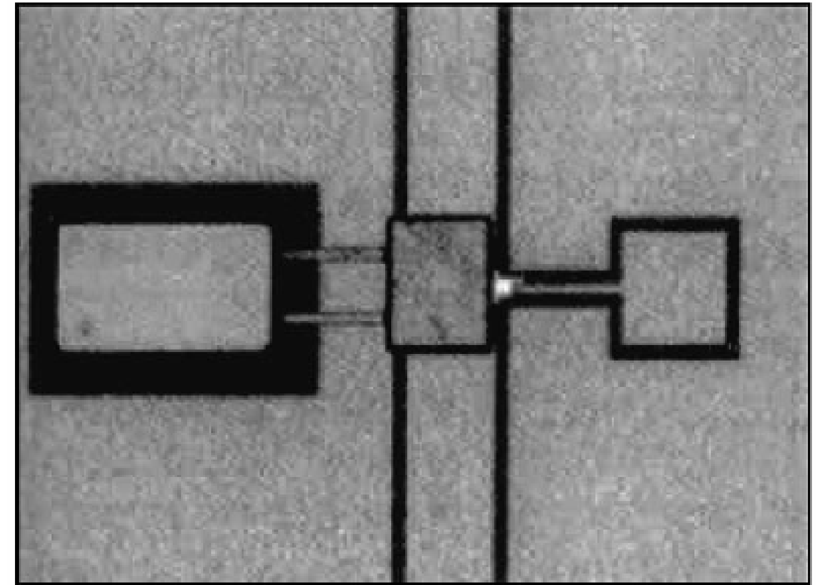


Micro switch by Northeastern U.



Micro switch by NEC

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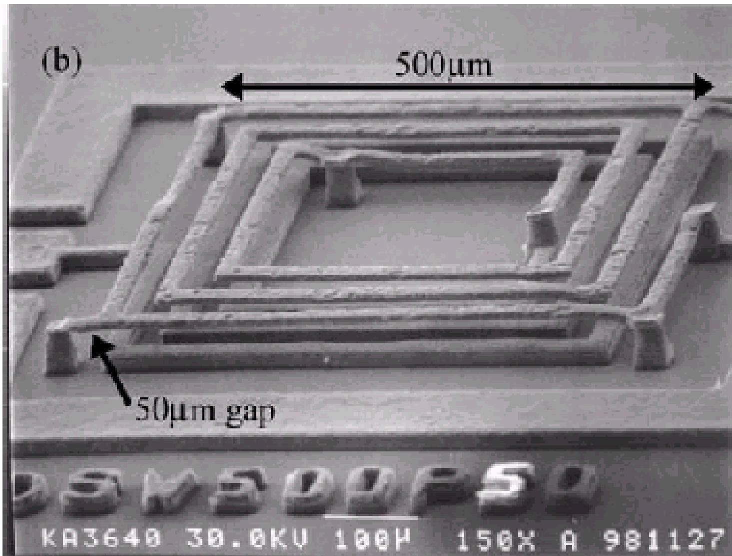
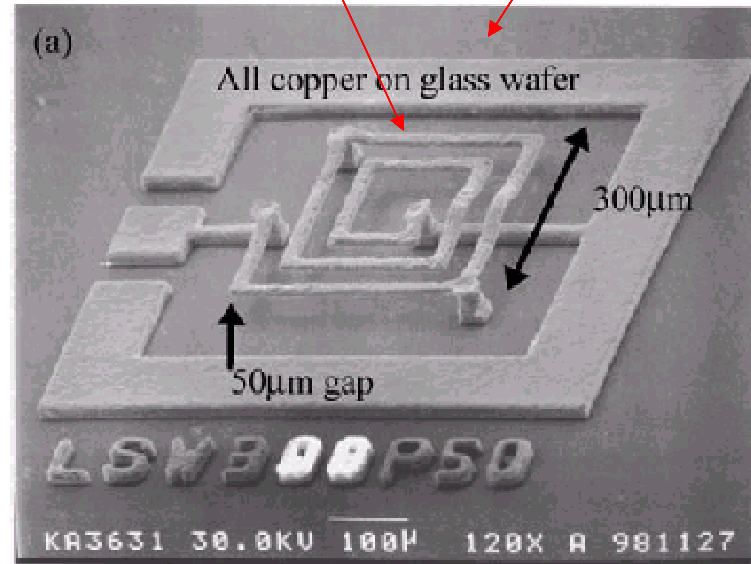


Cu spiral

Glass substrate



High-Q inductor by KAIST

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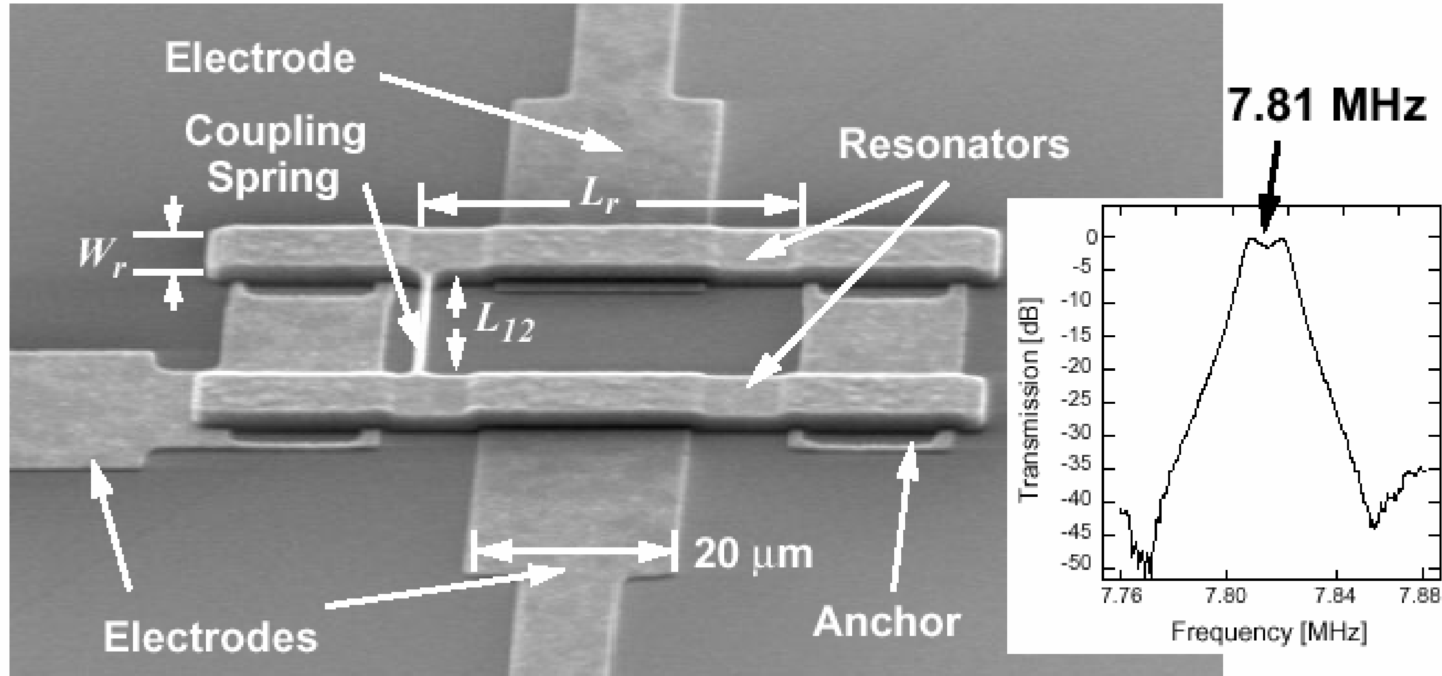
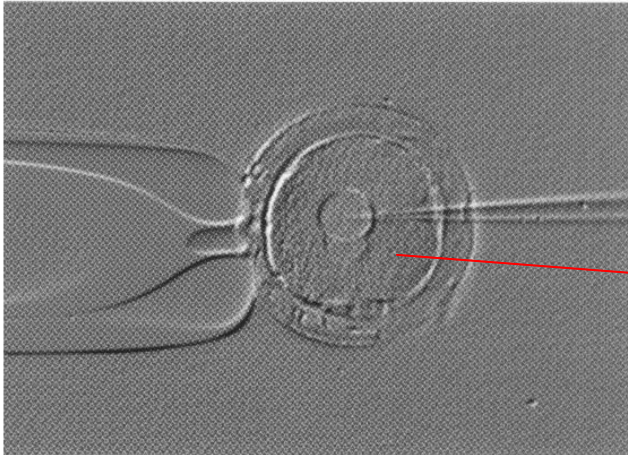
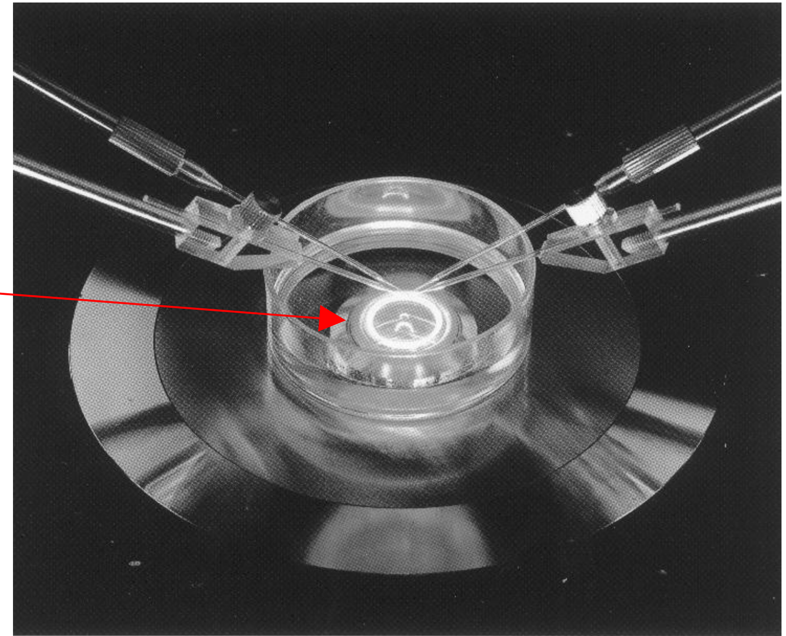


High frequency mechanical filter by U. of Michigan

+ Bio MEMS - DNA, lab on chip, μTAS

DNA test by Caliper Tech





Bio-manipulator

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Hearing aid

- **Applications**

+ Automobile

1. pressure sensor - fuel system, hydraulic and air-flow systems
2. accelerometer - air bag, suspension system
3. gyroscope sensor - navigation system

+ Medical

1. pressure sensor - blood pressure, intrauterine pressure
2. microfluid system - drug dosage system, blood cell counting system

+ Data storage

1. accelerometer - impact detector
2. actuator - track positioning
3. suspension - recording head