Outline

1 Introduction

2 Basic IC fabrication processes

3 Fabrication techniques for MEMS

4 Applications

5 Mechanics issues on MEMS

3. Fabrication Techniques for MEMS

3.1 Bulk micromachining

3.2 Surface micromachining

3.3 LIGA process

3.4 Hybrid micromachining

3.5 Thick micromachined structures

3.1 Bulk Micromachining

- Bulk micromachining - the technique to fabricate 3-D micromechanical devices by etching the silicon substrate

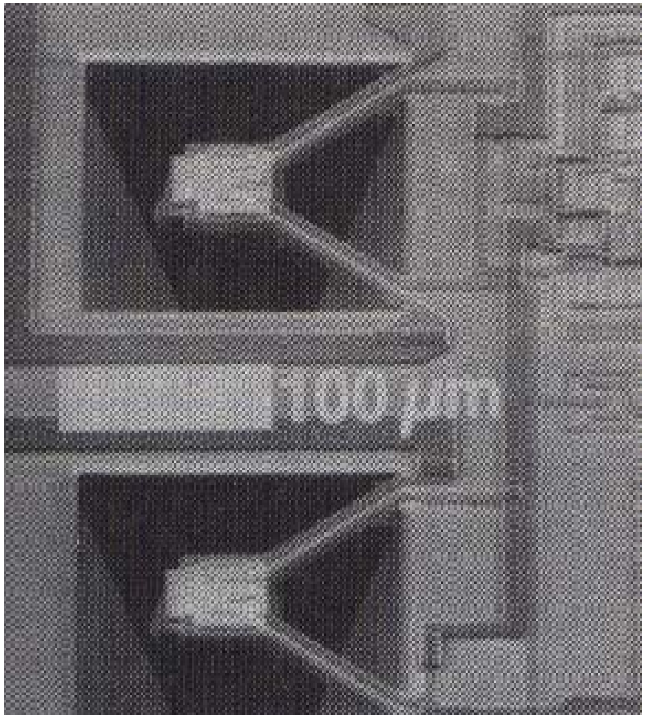
- Basically the difficulty of the process depends on the number of mask

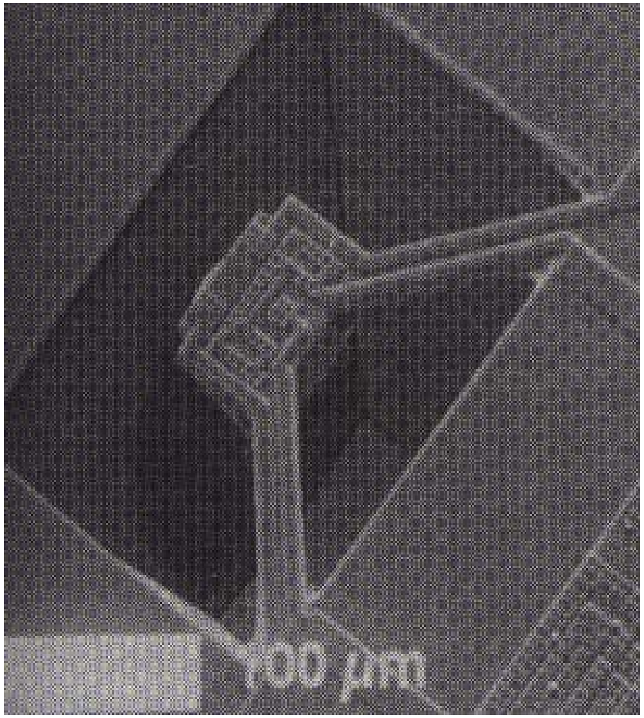
- Complicated structures can be fabricated by multiple masks or bonding

Fundamental Structures

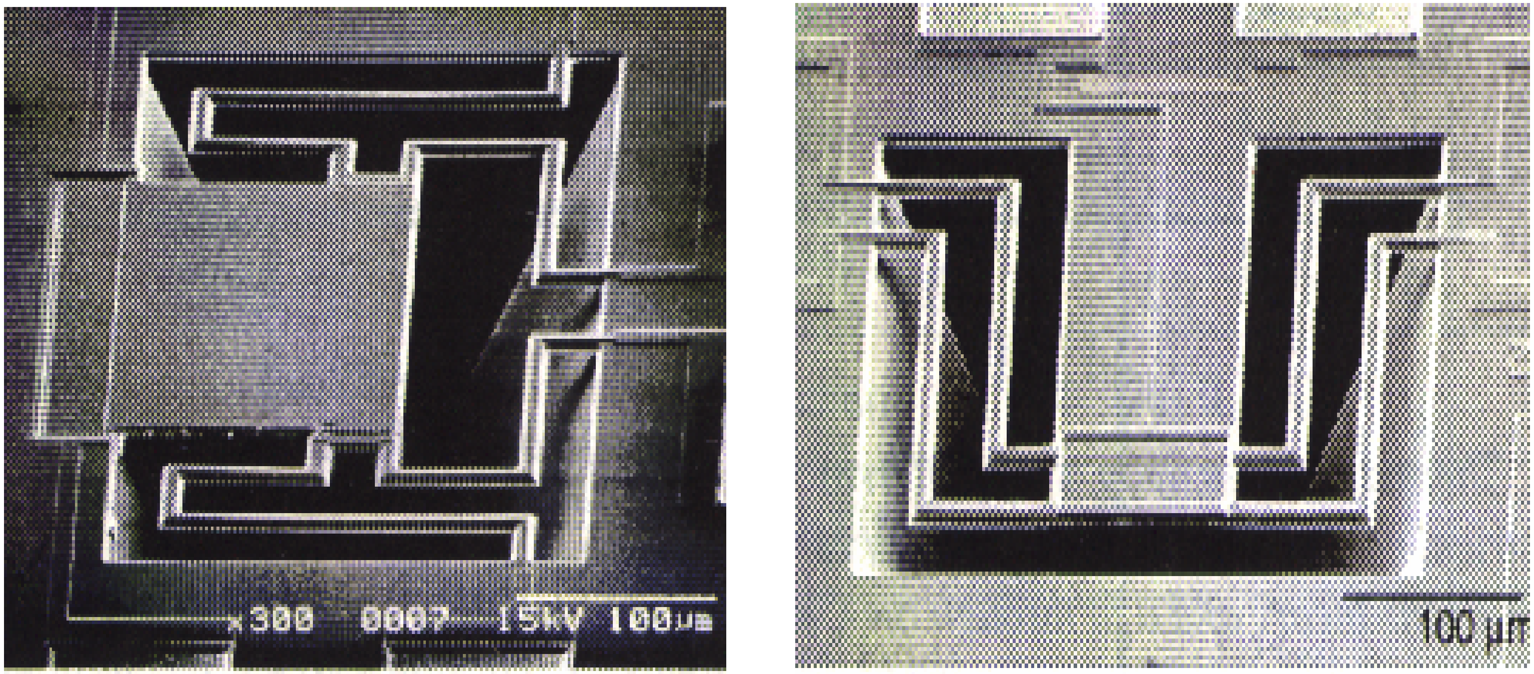
- The following structures can be fabricated by a single mask process
  - \+ Beams and suspensions
  - \+ Membrane
  - \+ Cavity
  - \+ Nozzle
  - \+ Mesa

Suspensions and Beams

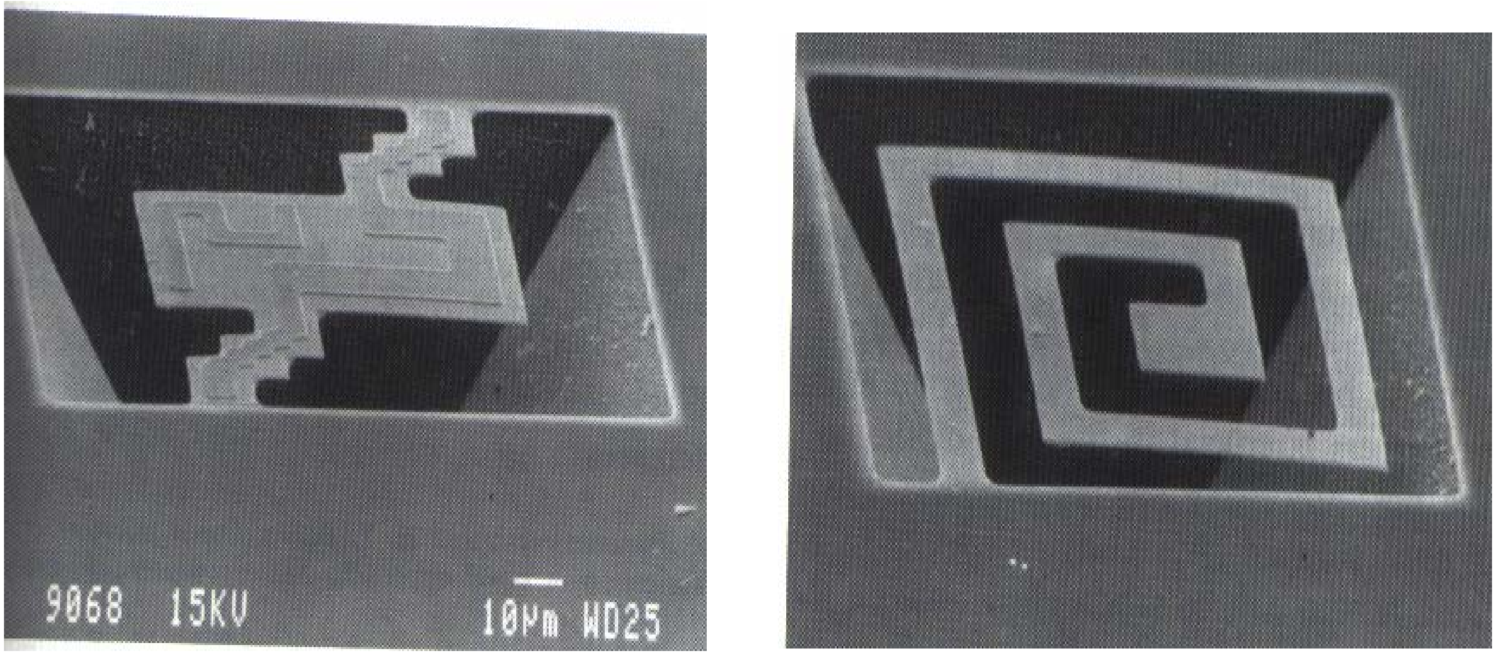




E.H. Klaassen, R.J. Reay, and G.T.A. Kovacs, Eurosensors IX, 1995.

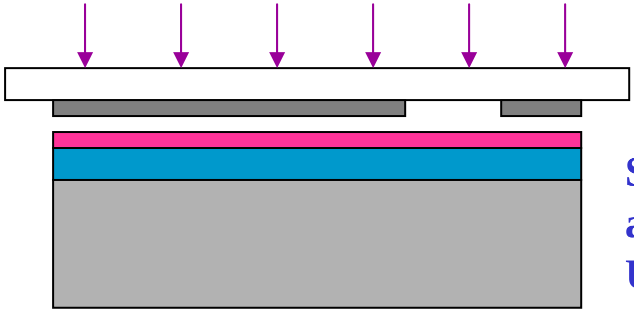


O. Paul, M. von Arx, and H. Baltes, Eurosensors IX, 1995.



D. Moser, M. Parameswaran, and H. Baltes, Sensors and Actuators, 1990

- **SiO2 cantilever beam**



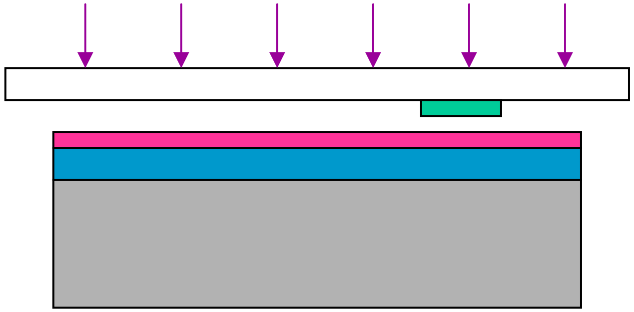
Spin coat PR and expose to UV light

PR is patterned after develop

Pattern SiO_2 by HF and remove PR

Si bulk etching to free suspend the cantilever

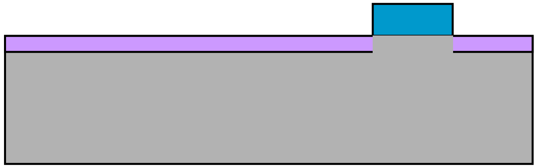
- **Doped Si beam**



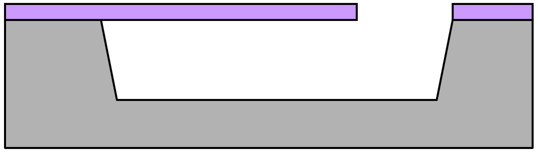
Spin coat PR and expose to UV light

PR is patterned after develop

Pattern SiO_2 by HF and remove PR



Use SiO_2 as the mask and doped boron to Si wafer



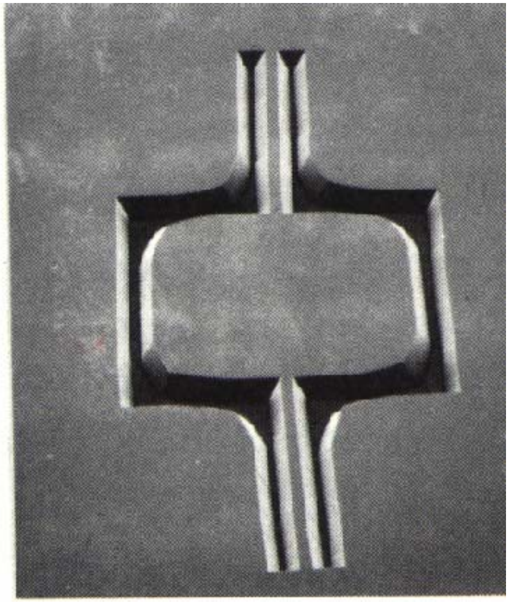
Remove SiO_2 mask and then etch Si to obtain beam

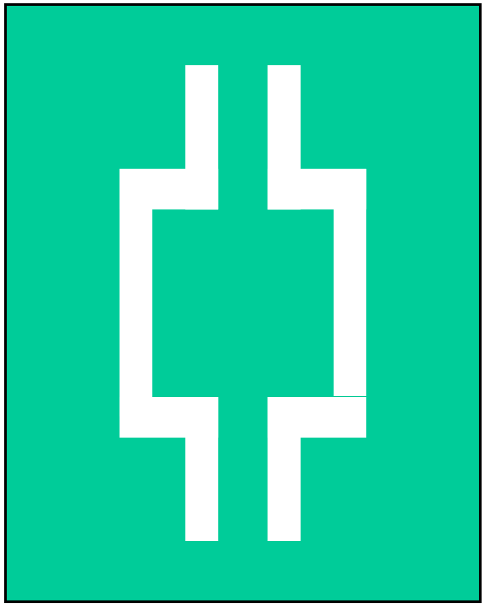
- **Torsional mirror (very thick suspension)**

  + same material as the wafer

  + etching through the wafer

+ mask pattern

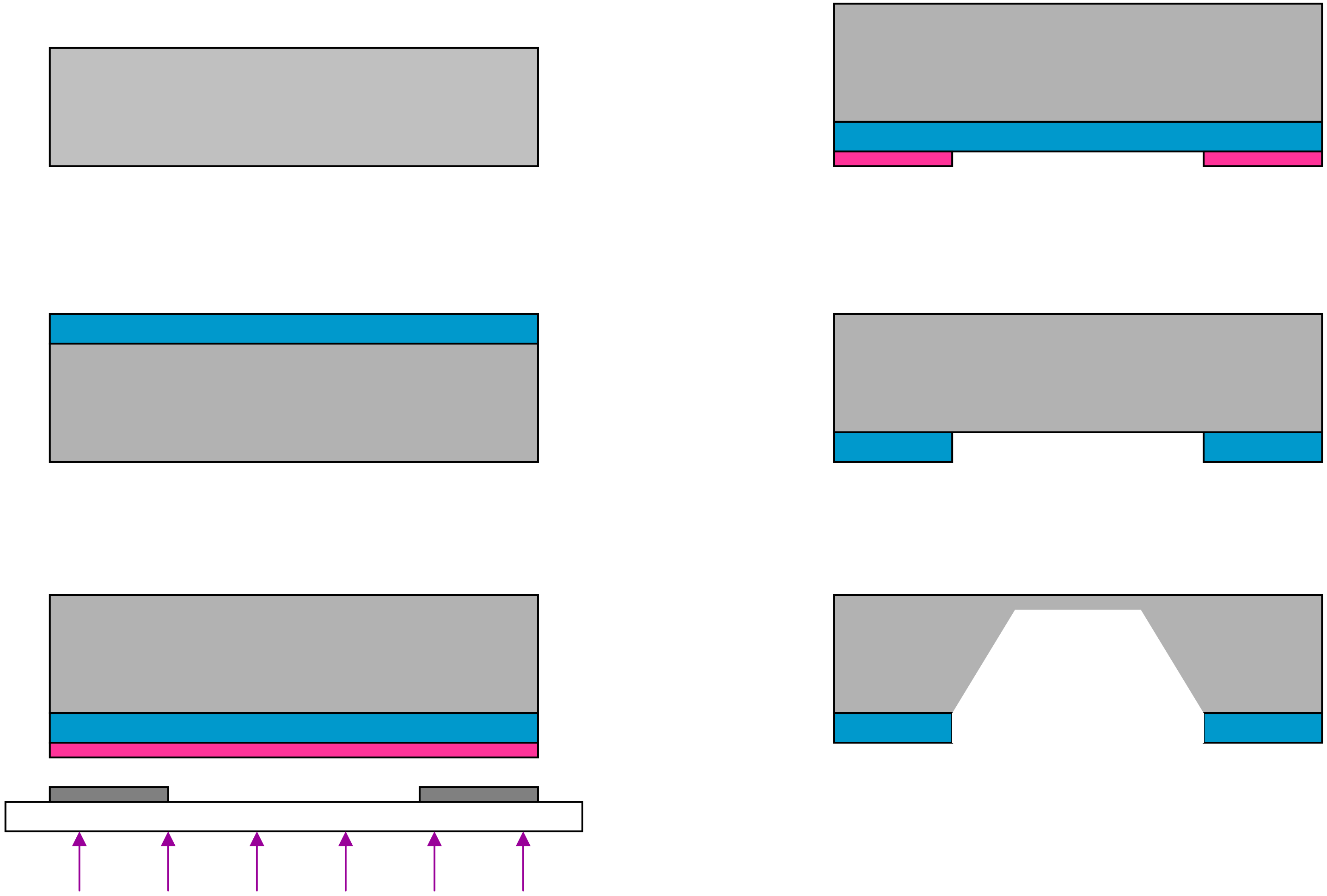




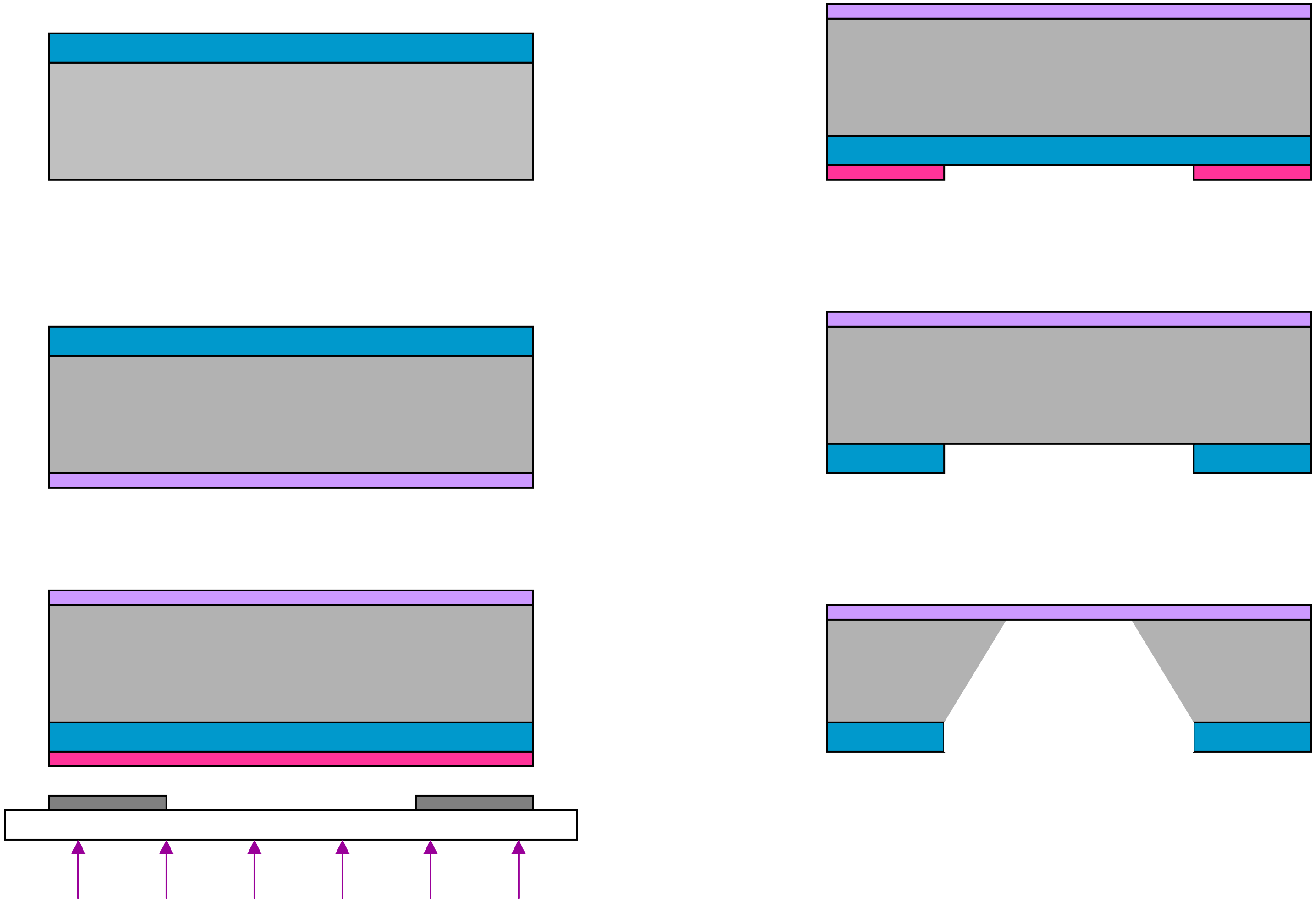
K.E. Petersen, IBM J. of Research and Development, 1980.

Membrane

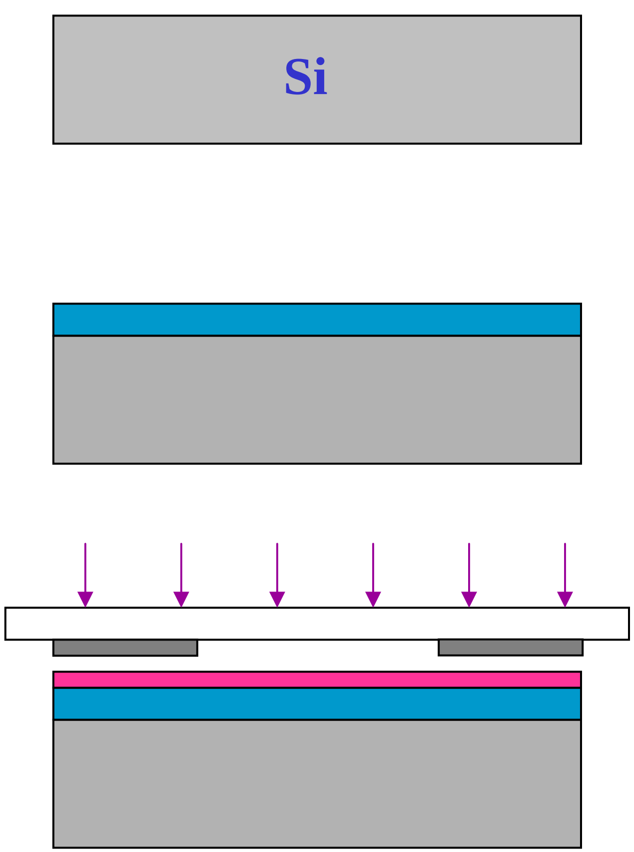
- **Si membrane**



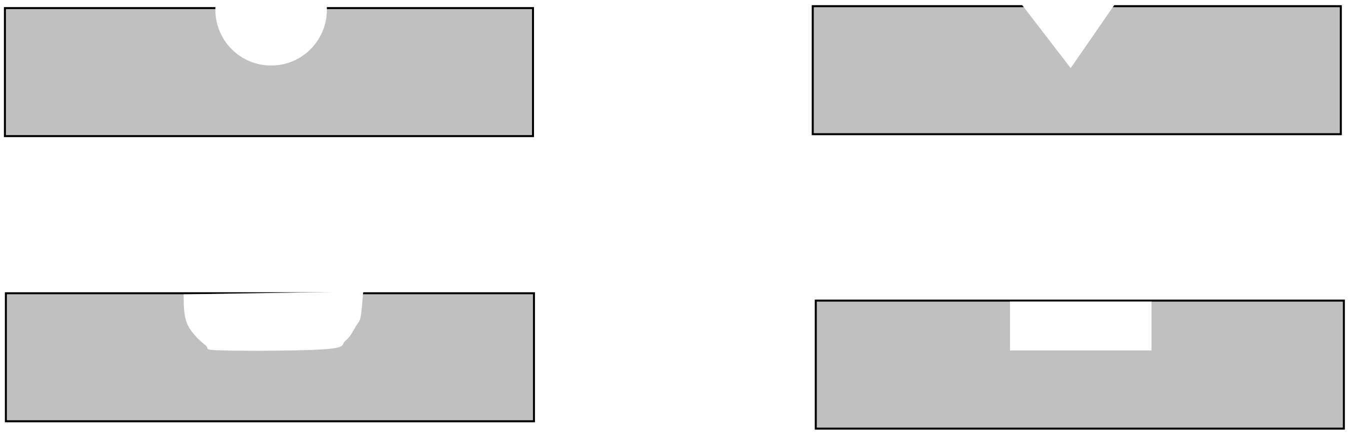
- **Membrane formed by deposited (doped) films**



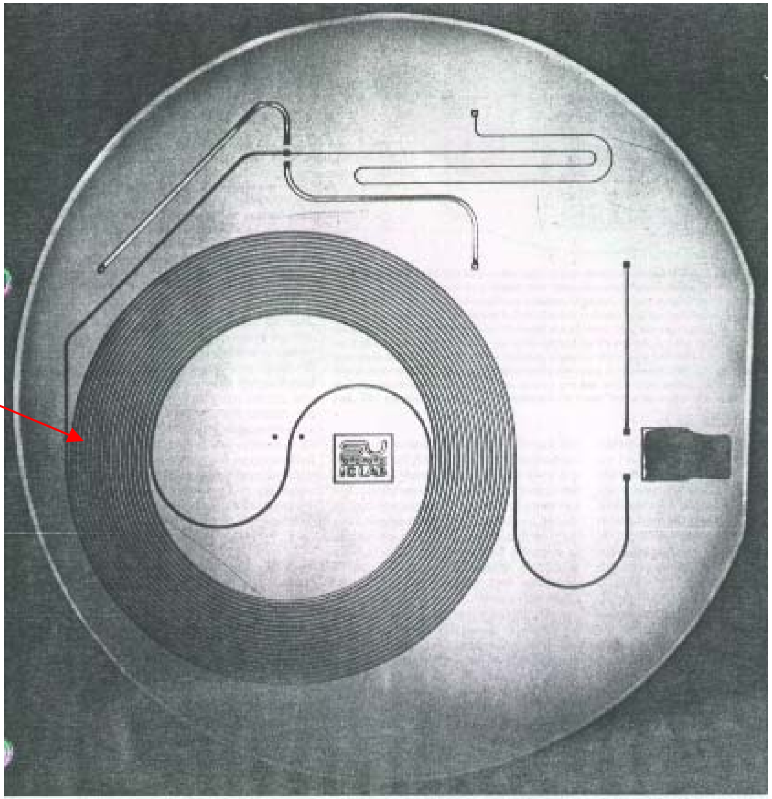
Cavity



- **Other possible shapes for cavity**



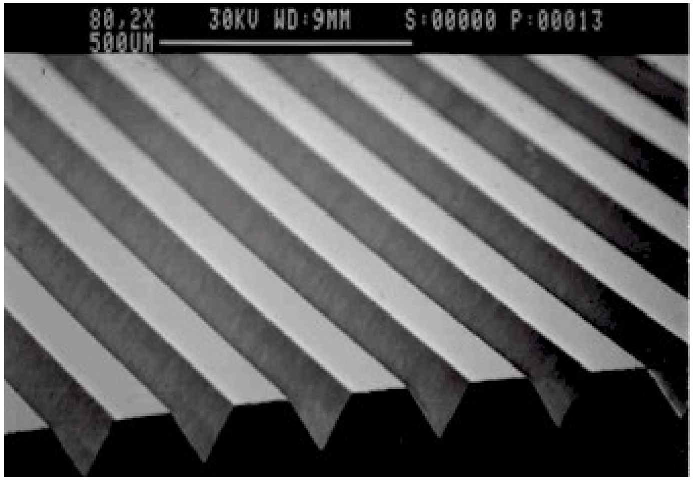
- **Gas Chromatograph**

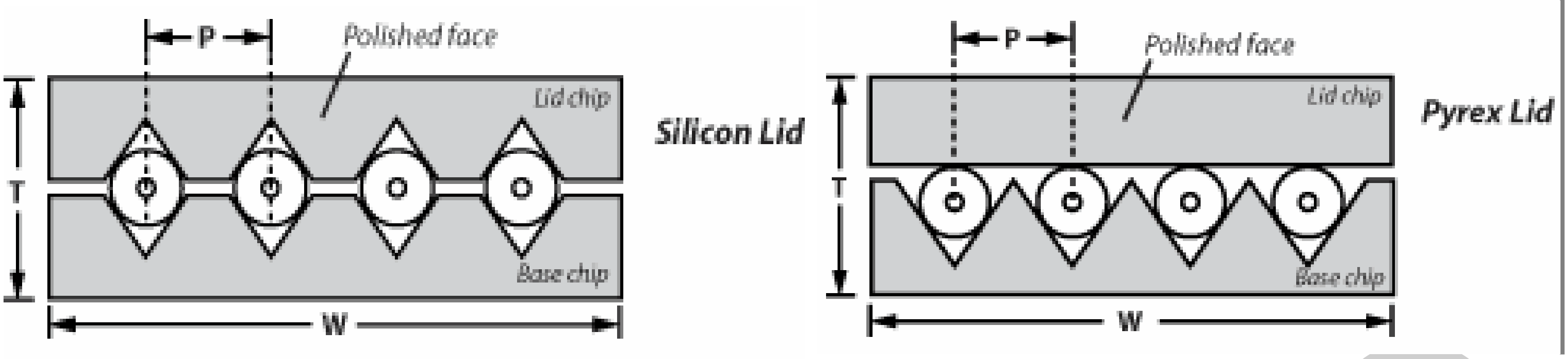


Channel for micro fluidics

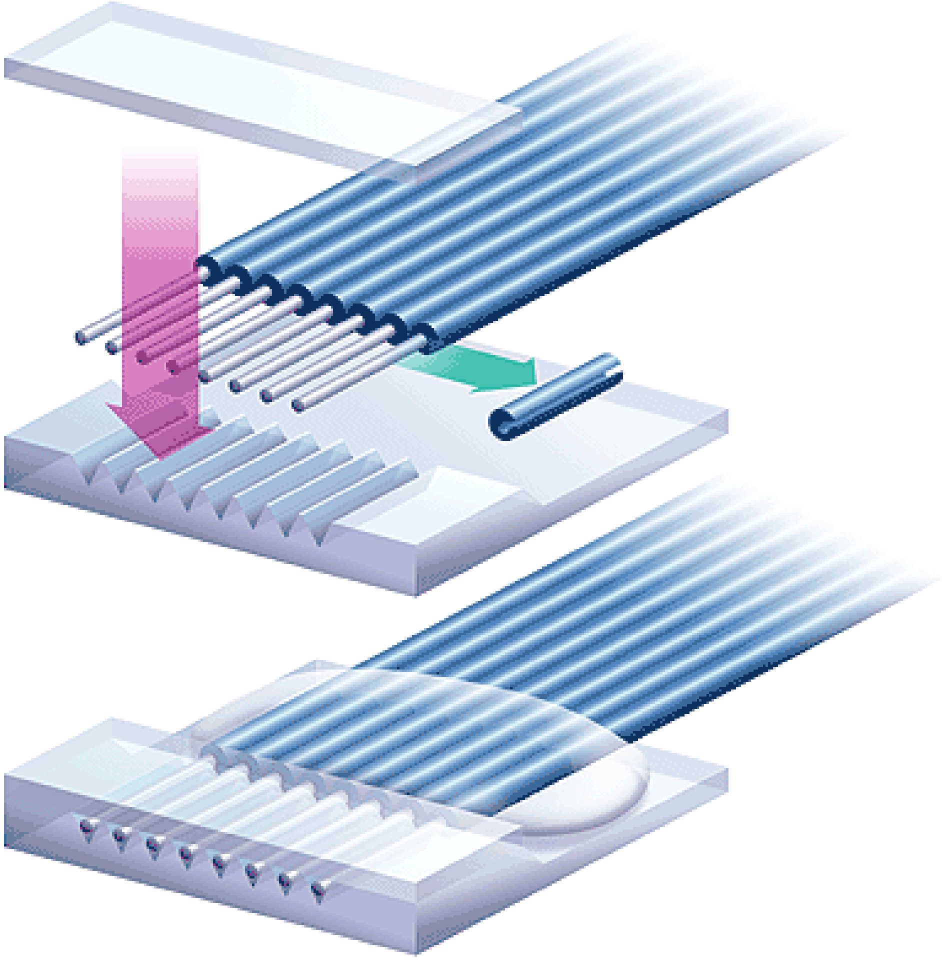
S.C. Terry, Ph.D. thesis, 1975.
S.C. Terry, J.H. Jerman and J.B. Angell, IEEE Transaction on ED, 1979.

- **Fiber alignment (V-groove)**

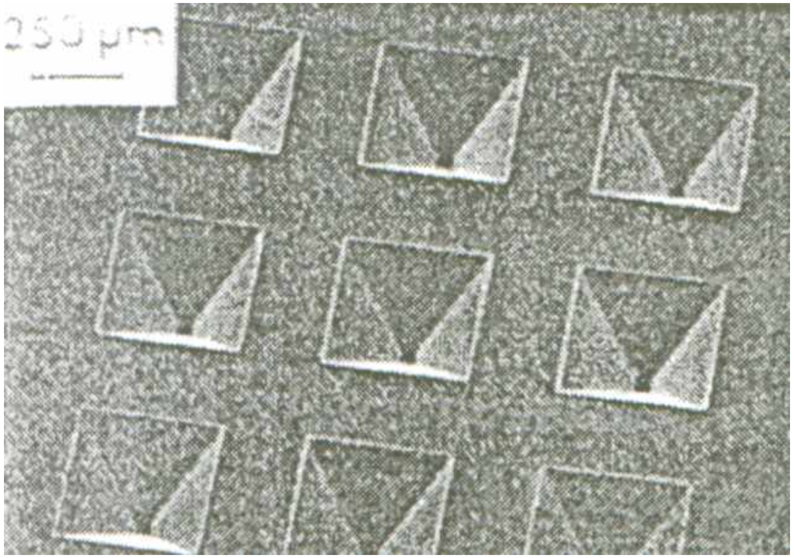




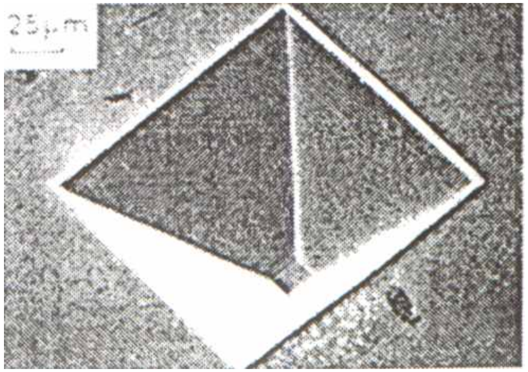
Kyocera Inc.

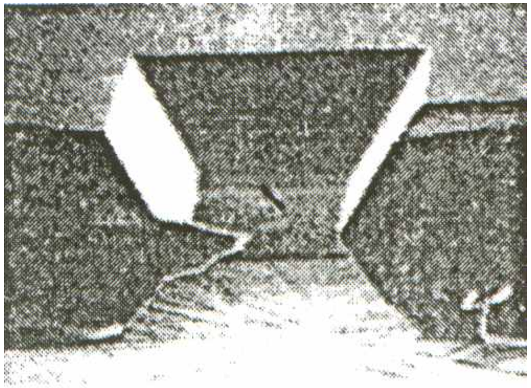


Nozzle



Nozzle array

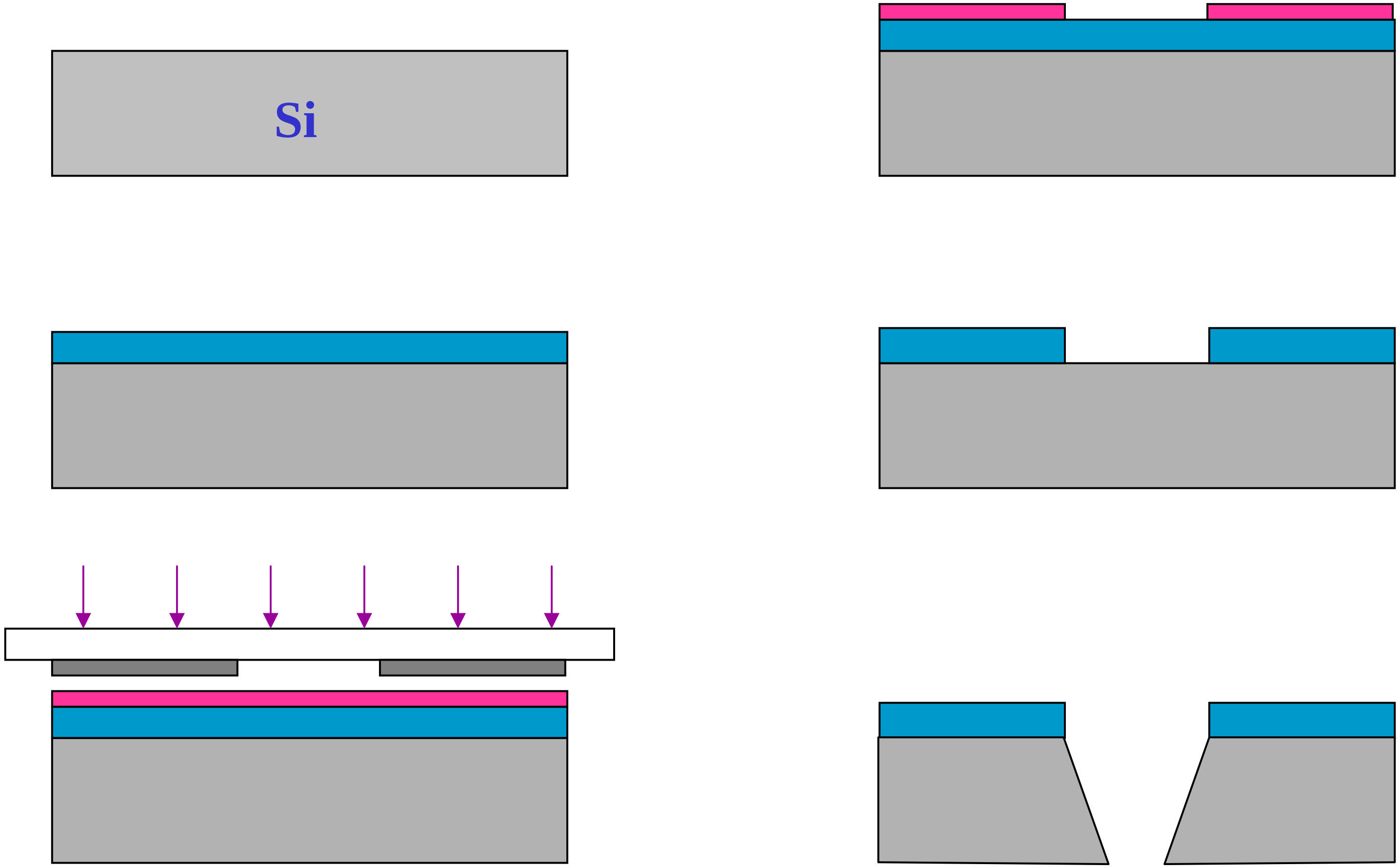




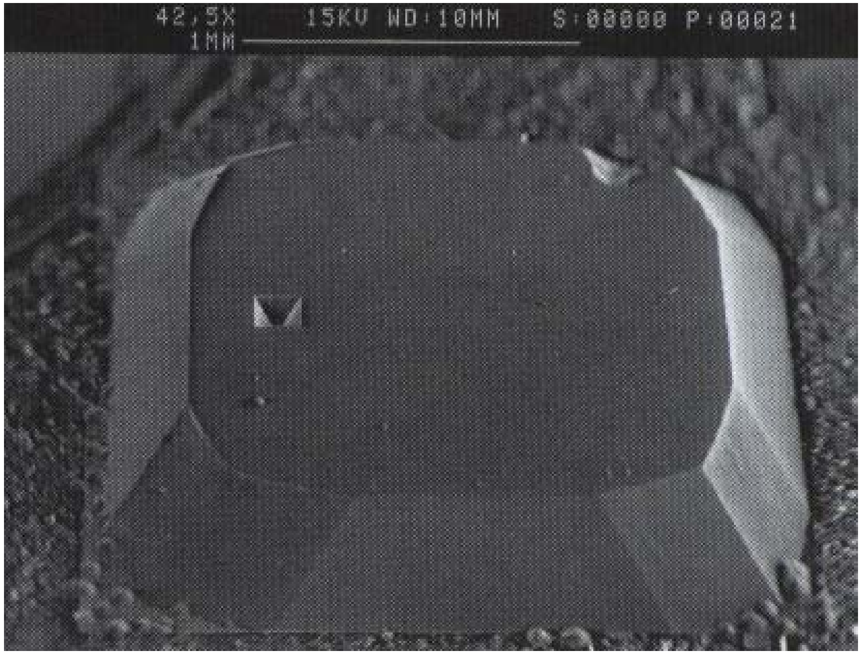
Nozzle after bonding

B. Petit, et.al., J. Electrochem. Soc., 1985

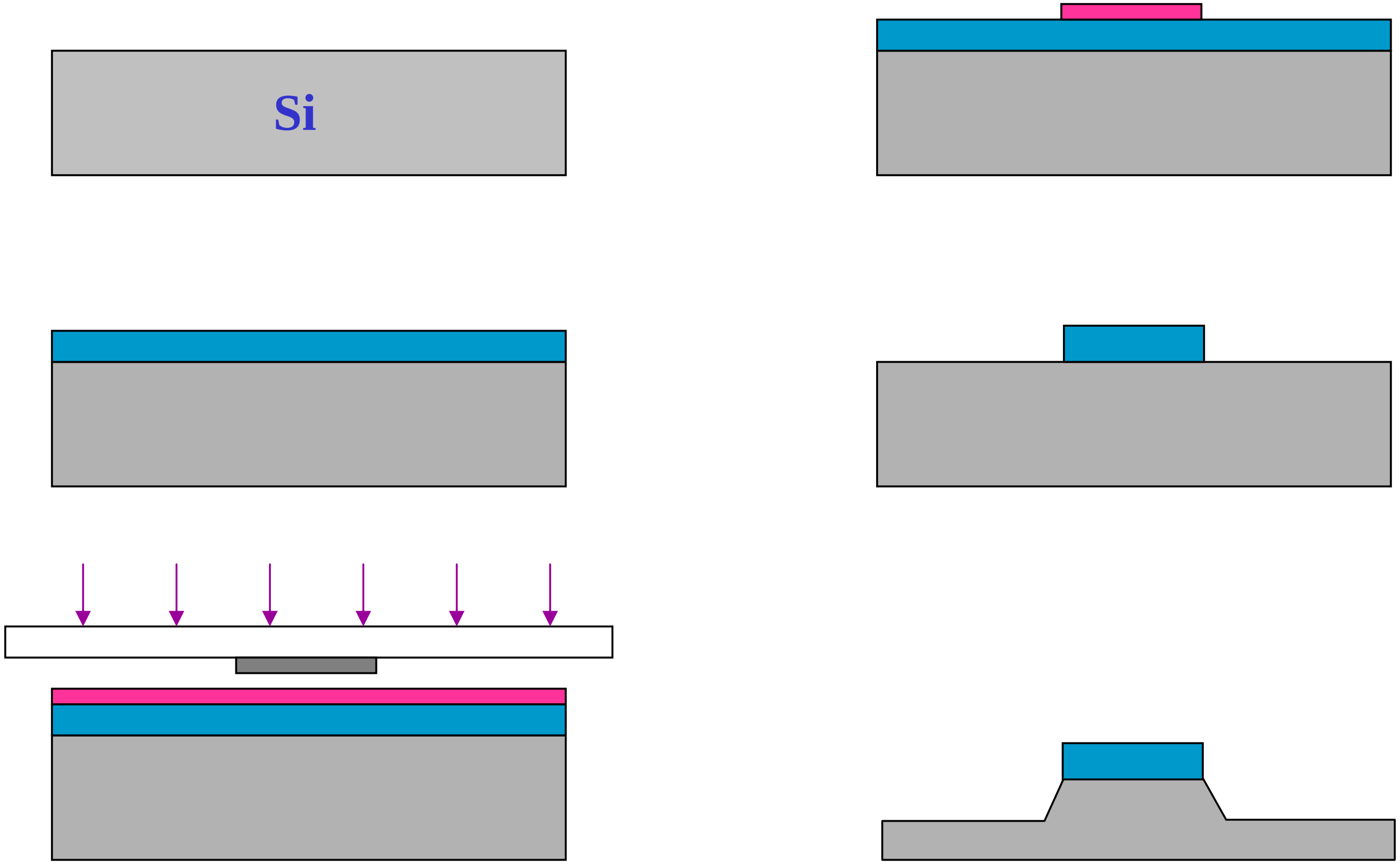
Nozzle



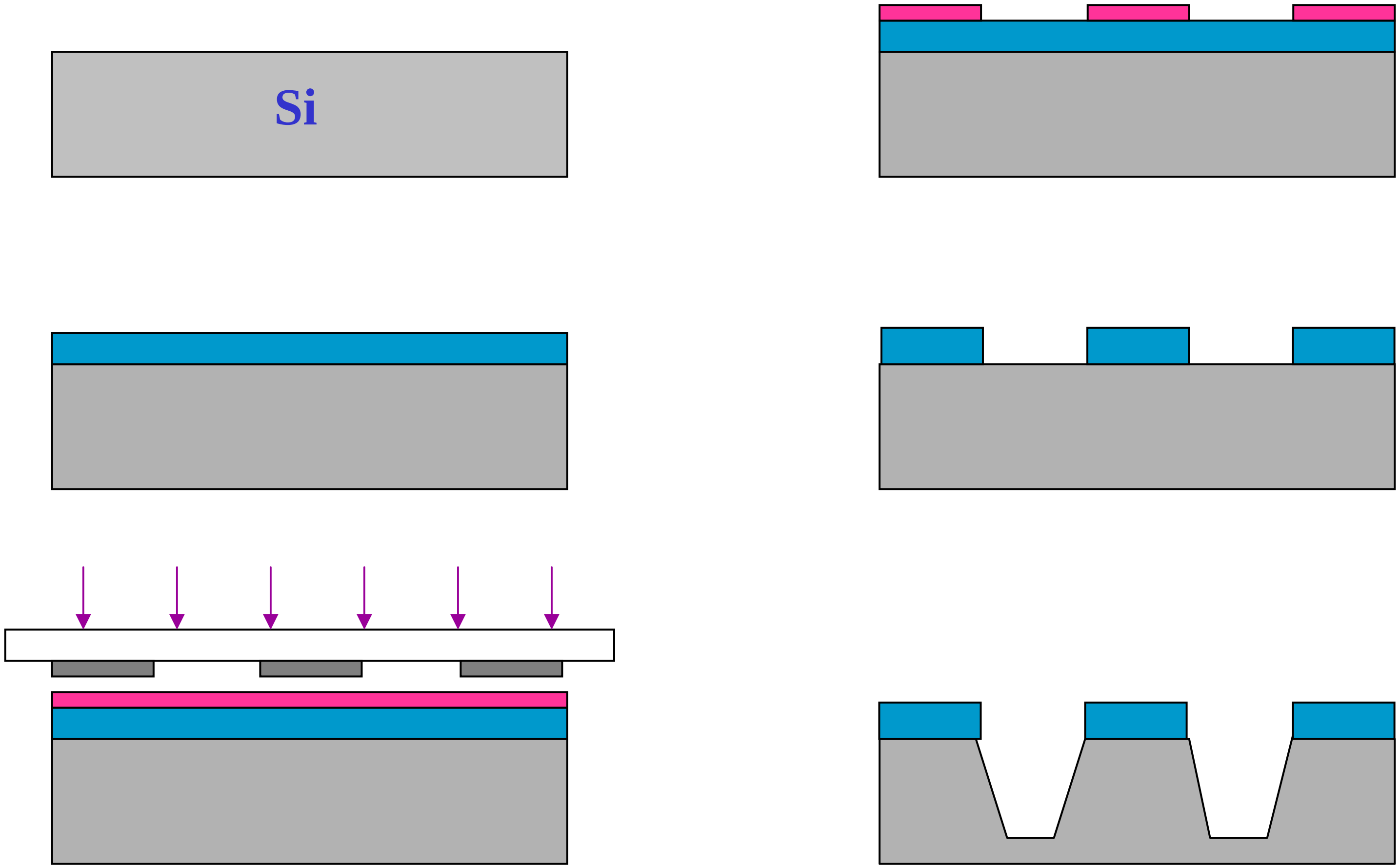
Mesa



B. Puers and W. Sansen, Sensors and Actuators, 1990.

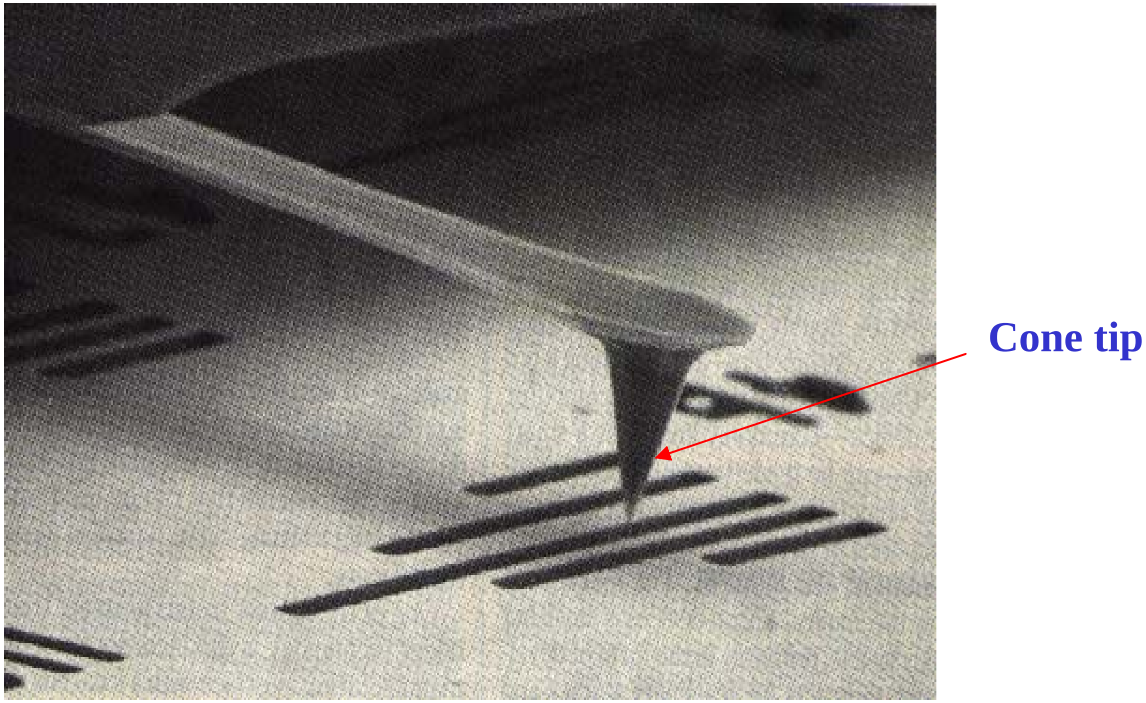

Si

Mesa on suspension

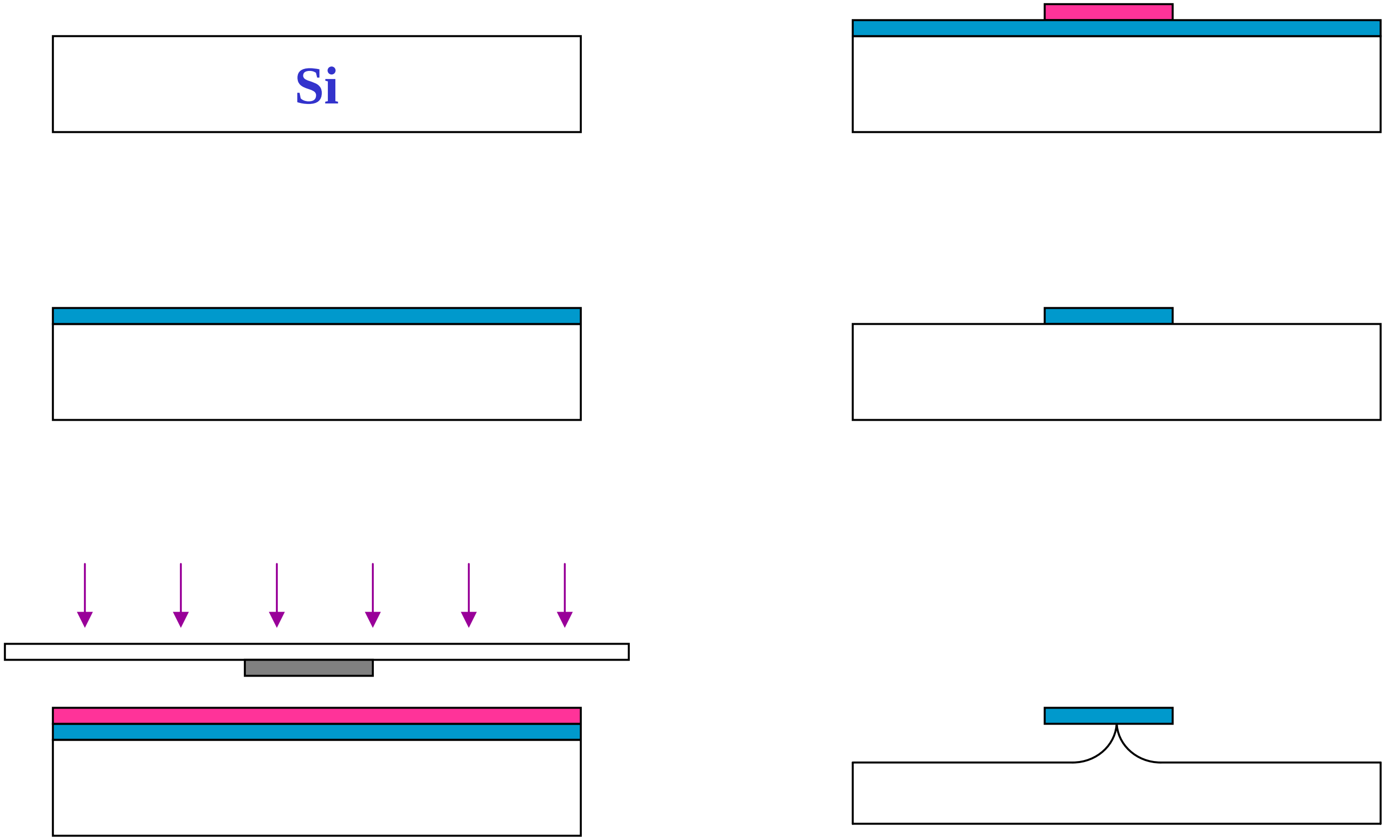


Cone

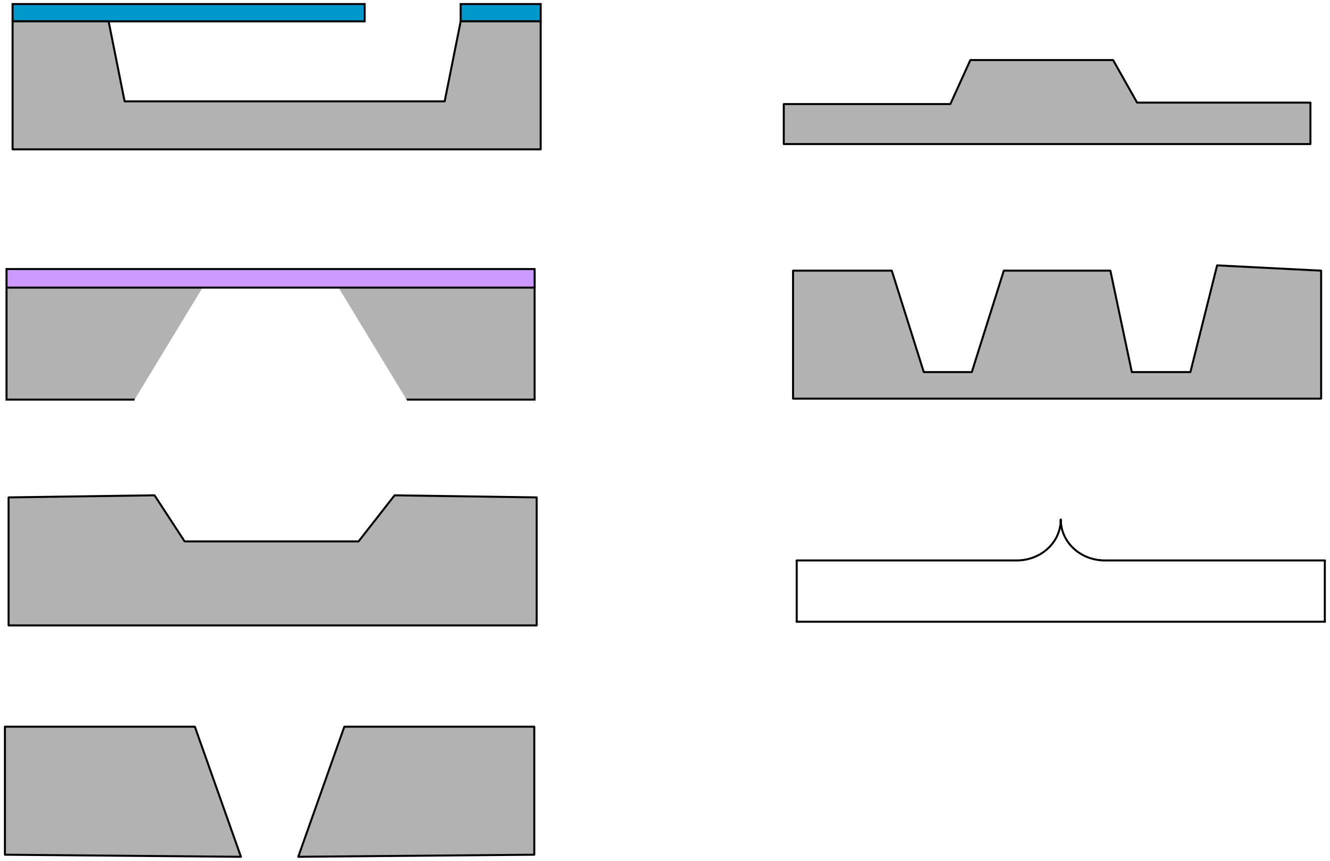
- **Atomic force microscope**



Cone



MDL
NTHU

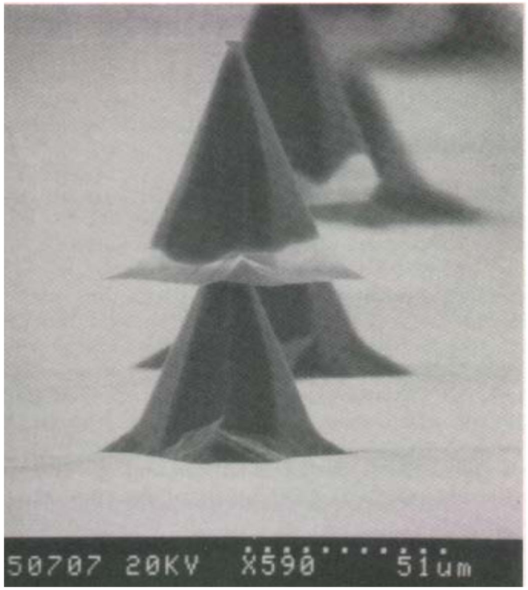


3.1.2 More Complicated Structures

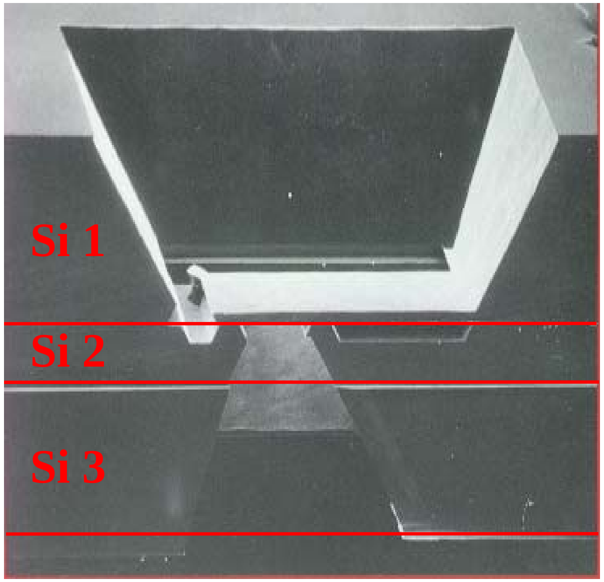
- The following structures can not be fabricated by only single mask, they have to be experienced mutiple mask processes or single mask together with bonding process

+ Multiple mask process

+ Etching and bonding



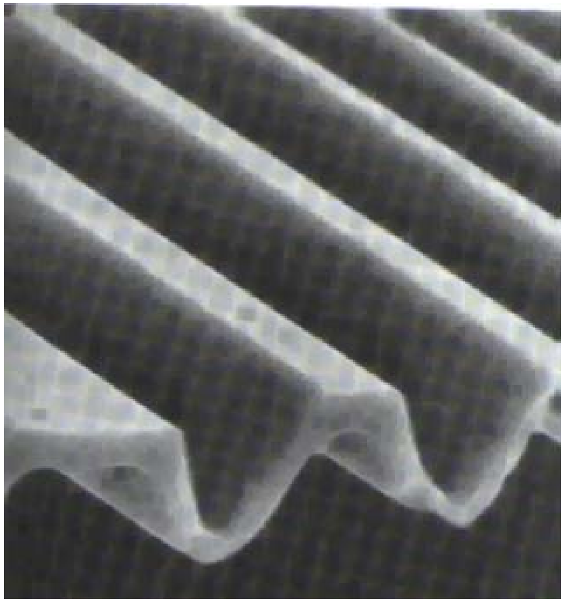
R. Dizon, et.al., J. of MEMS, 1992



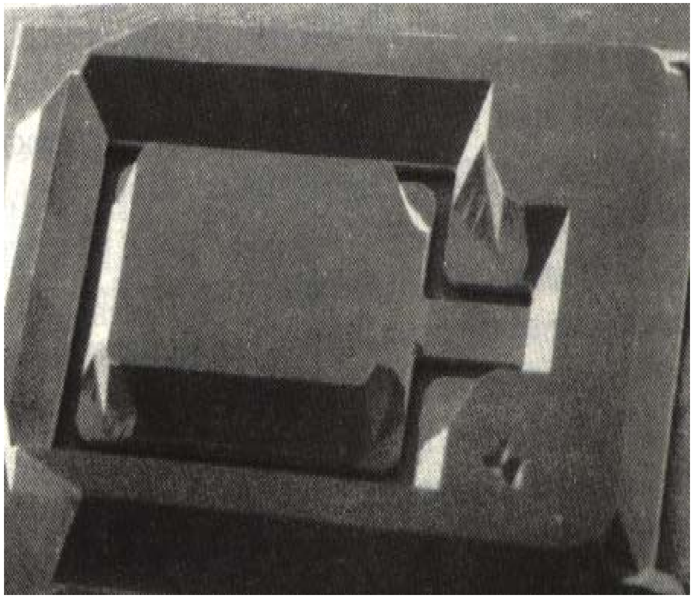
R. Zengerle, Physik unserer Zeit, 1993

Plate

- Corrugated plates
- Membrane with lump mass (mesa)

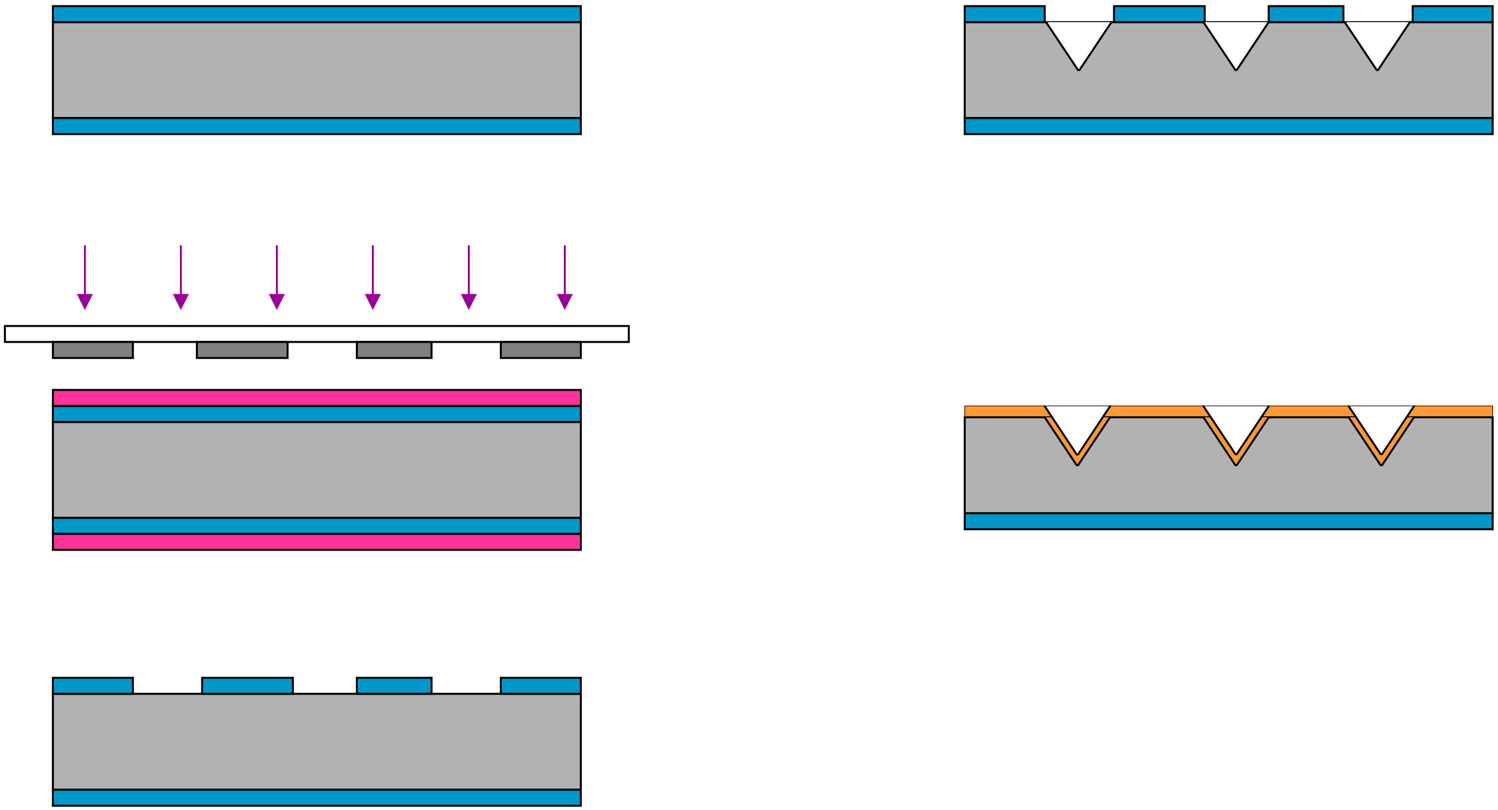


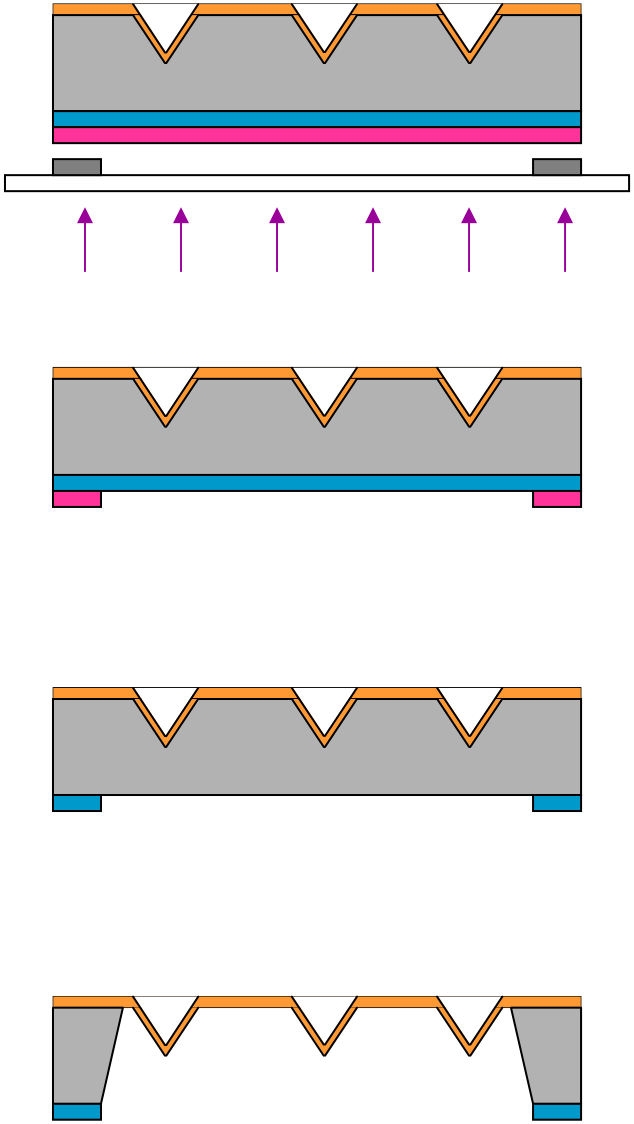
G. Delapierre, Sensors and Actuators, 1989



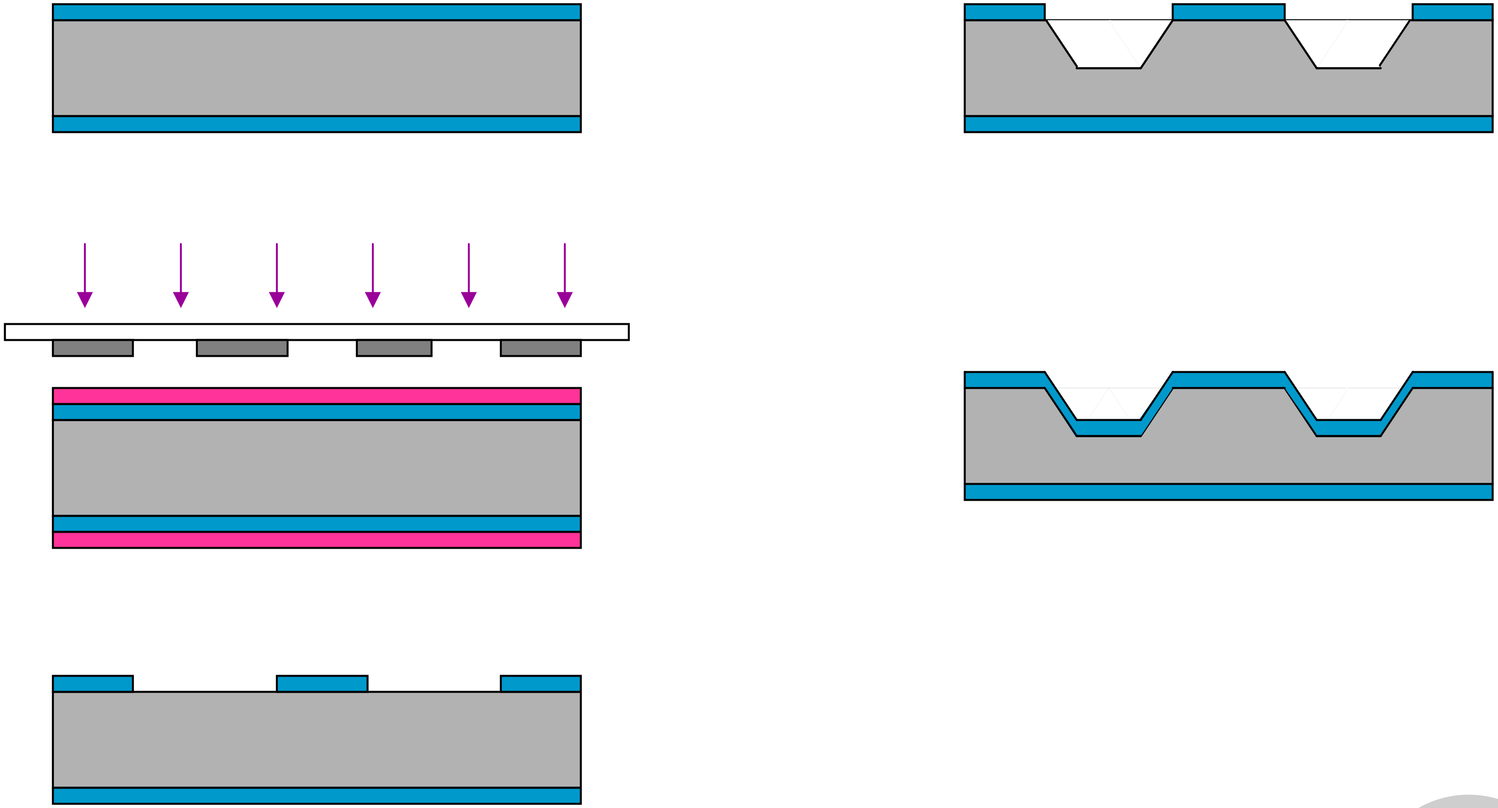
L.M. Roylance and J.B. Angell,
IEEE Trans. on ED, 1979

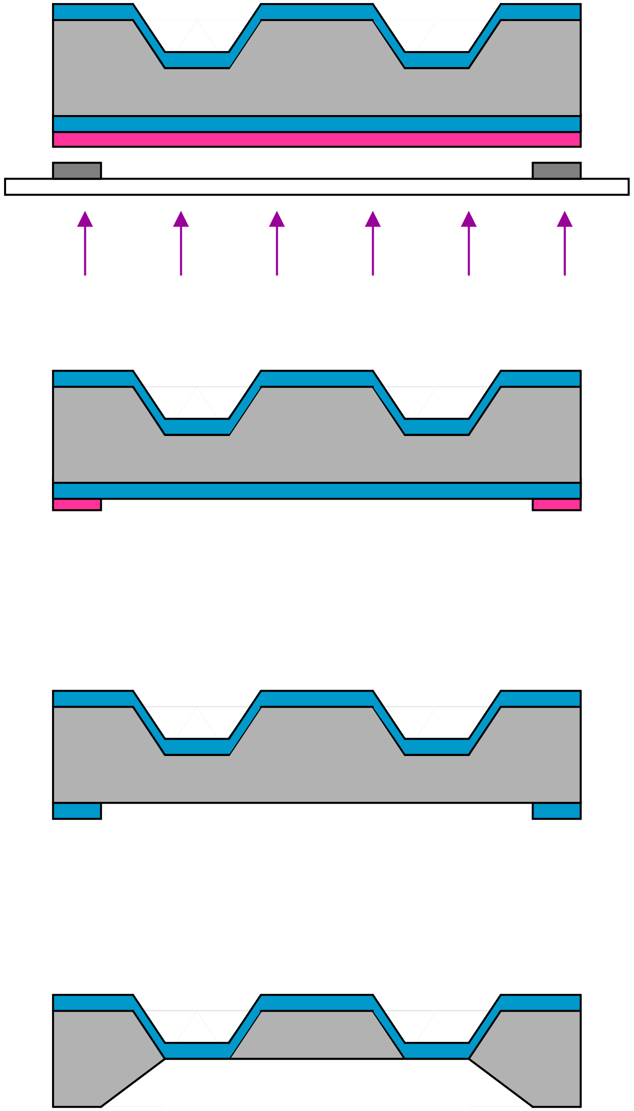
- **Corrugated plate**



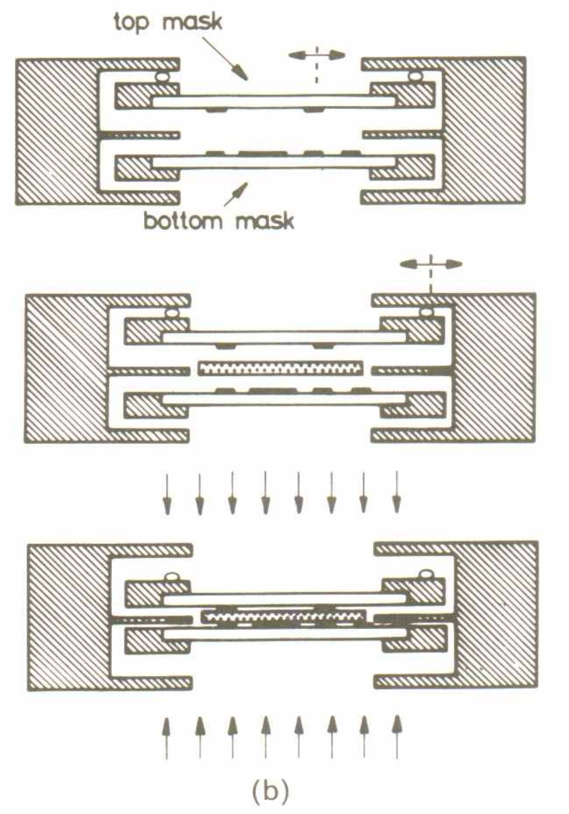


- **Si plate with lump mass (mesa)**





- **Double side mask aligner**

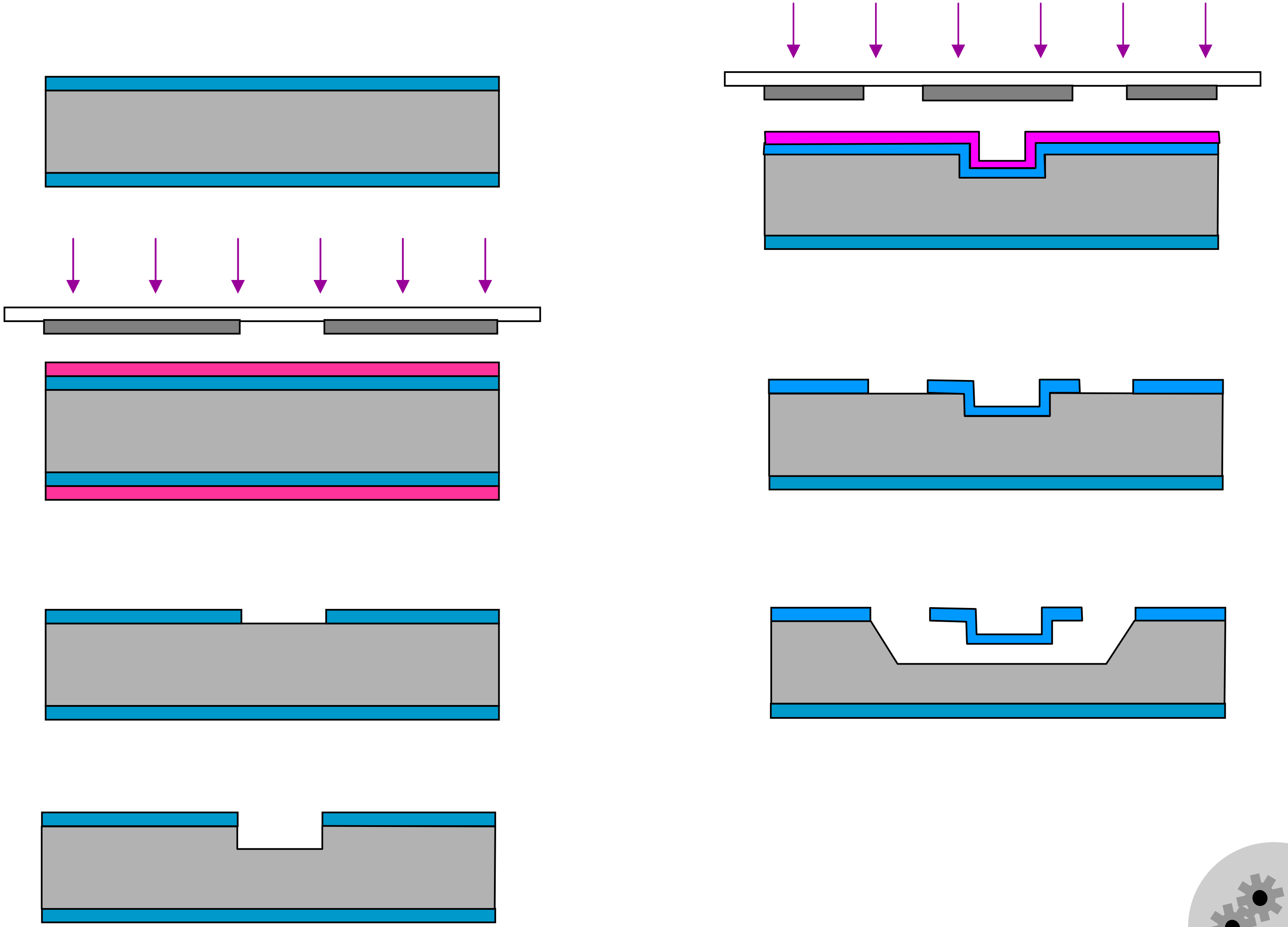


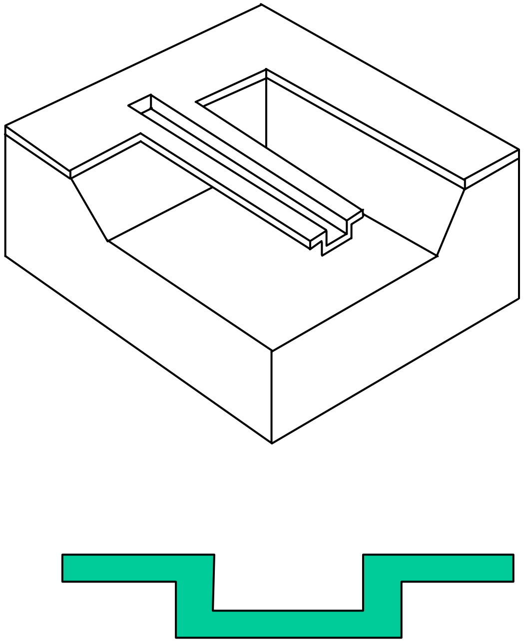
Semiconductor sensors,
edited by S.M. Sze, 1994

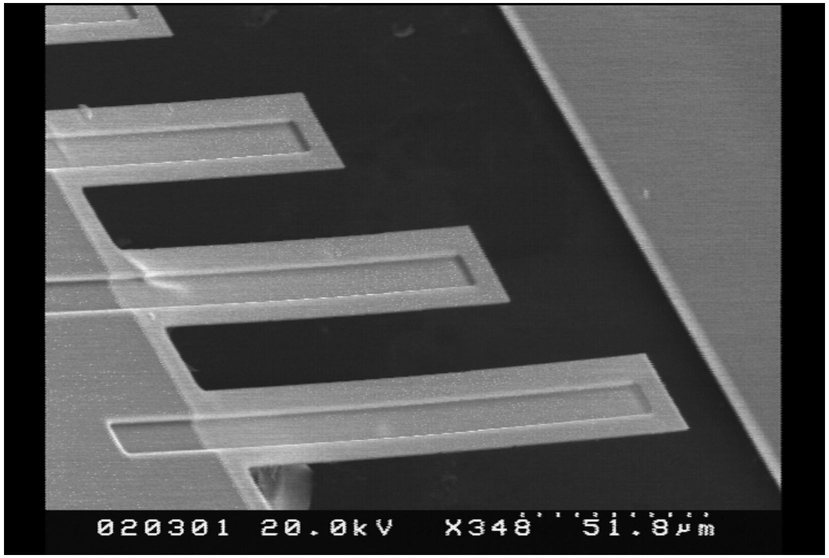
- **Infrared – light microscope**

- **Open an alignment hole on substrate**

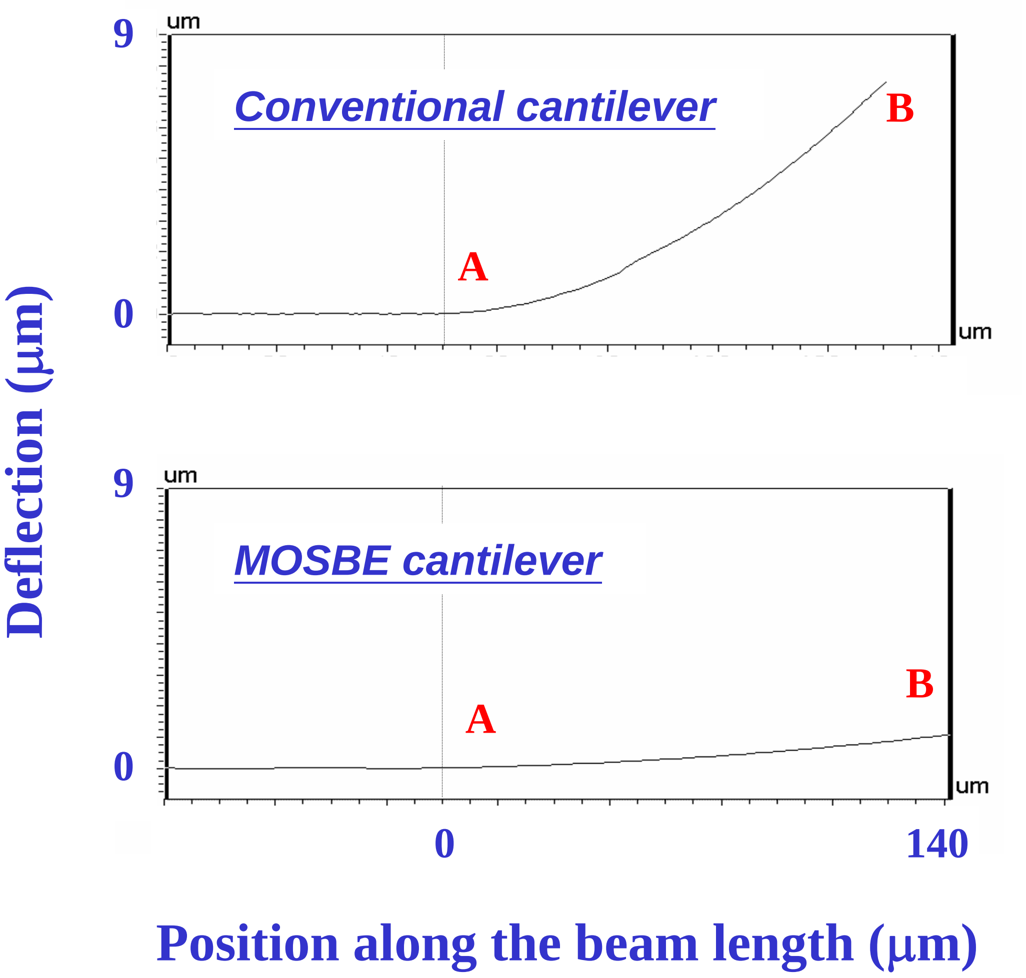
- **Rib-reinforced beam**

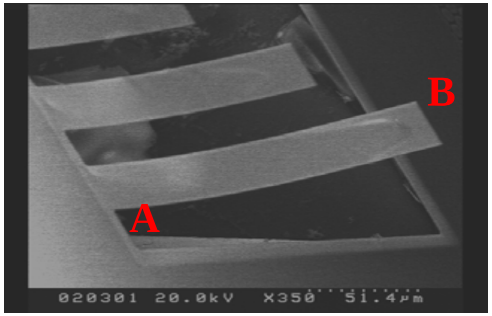


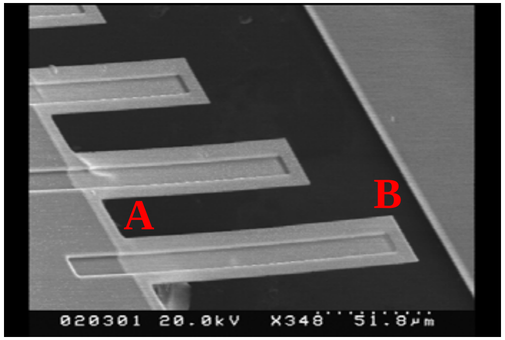


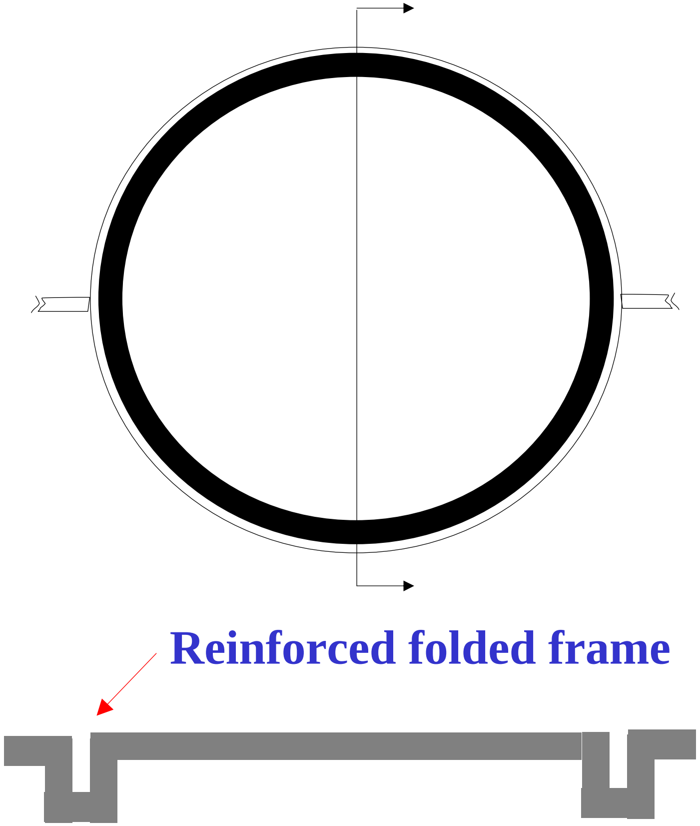


H.-Y. Lin and W. Fang, *J. of Micromechanics and Microeng.*, 2000

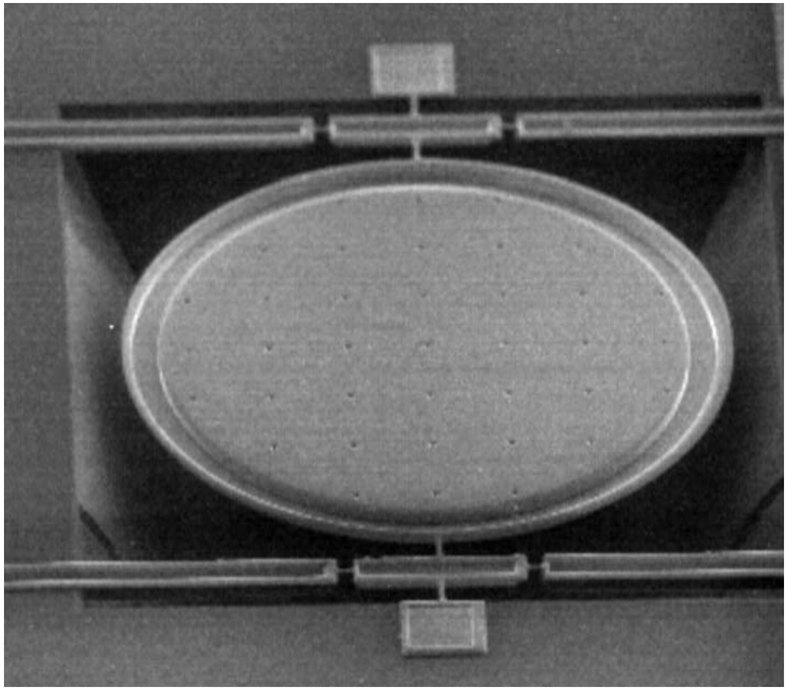
Deflection (µm)
9
um
Conventional cantilever
B
A
0
um
9
um
MOSBE cantilever
B
A
0
um
0
140
Position along the beam length (µm)

B
A
020301 20.0kV X350 51.4µm

A
B
020301 20.0kV X348 51.8µm



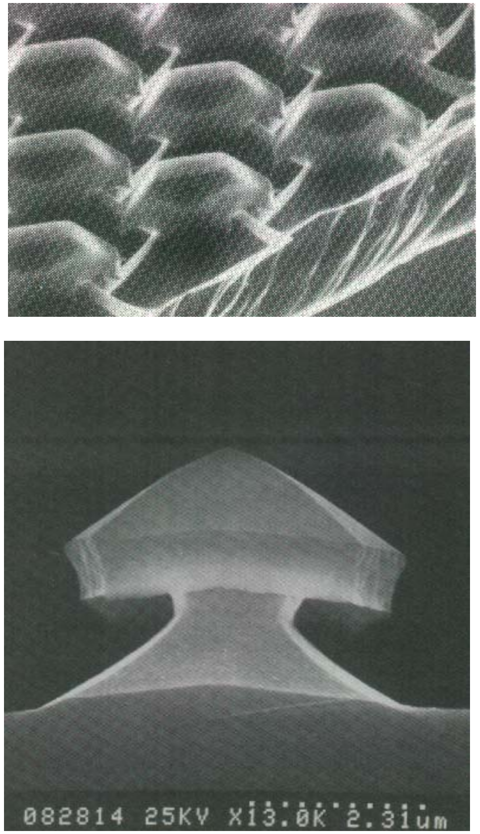
Reinforced folded frame



H.-Y. Lin and W. Fang, the *ASME IMECE*, Orlando, FL, 2000

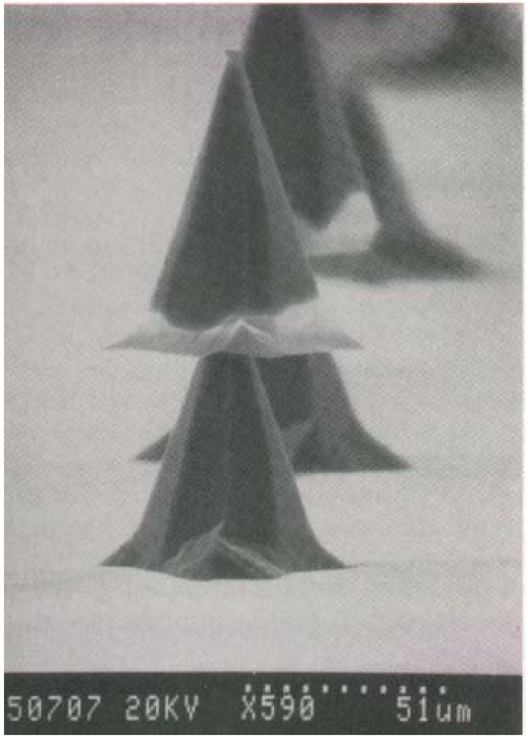
Micro Velcro

- **Type I**



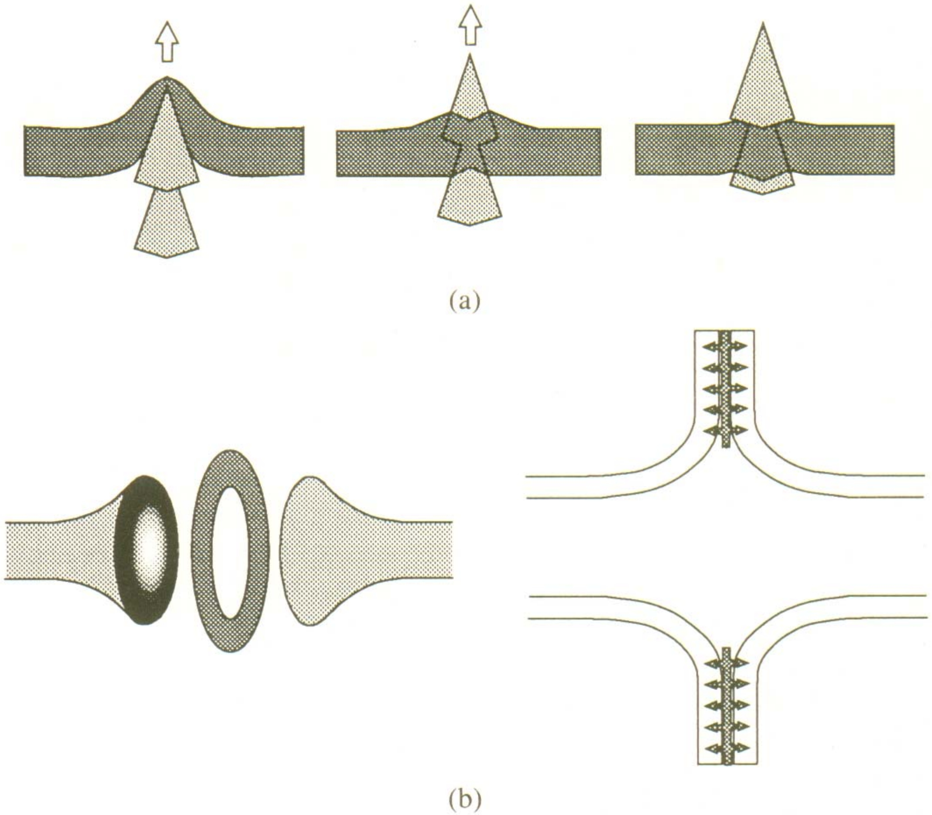
H. Han, et.al., J. of MEMS, 1992.

- **Type II**



R. Dizon, et.al., J. of MEMS, 1992

- **Application of the velcro**

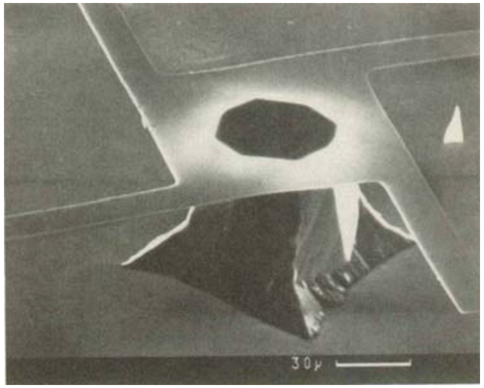


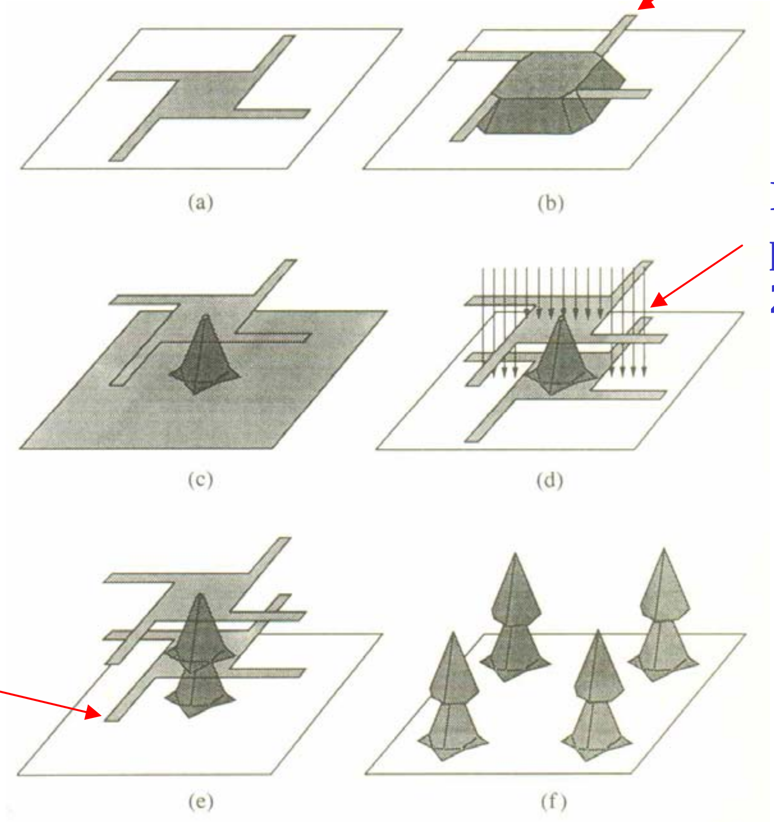
(a)

(b)

H. Han, et.al., J. of MEMS, 1992.

- **Fabrication processes for type II velcro**





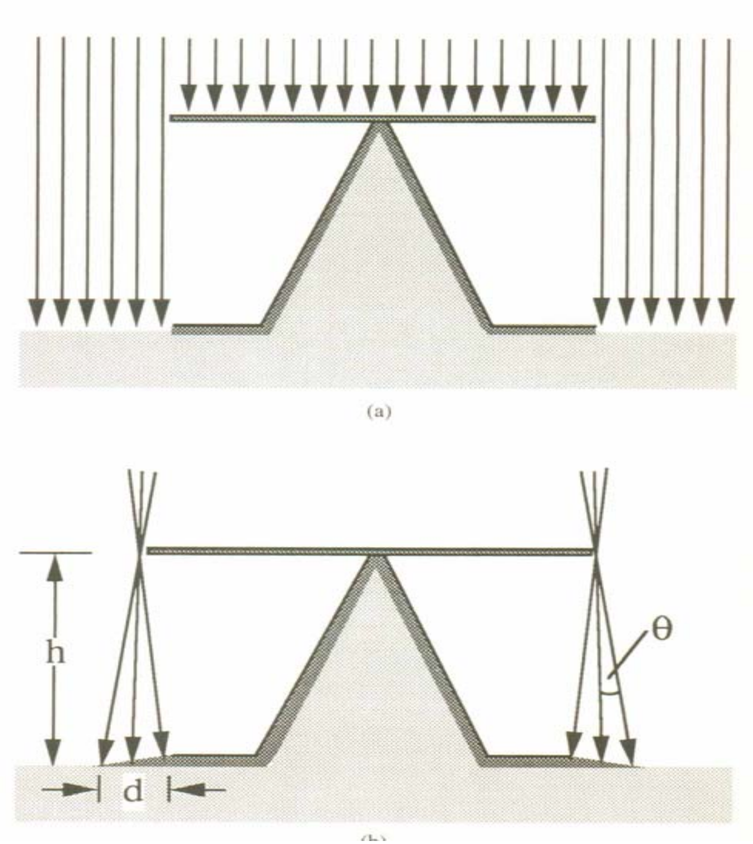
1^{st} SiO_2 mask

Ion milling to pattern the 2^{nd} SiO_2 layer

2^{nd} SiO_2 mask

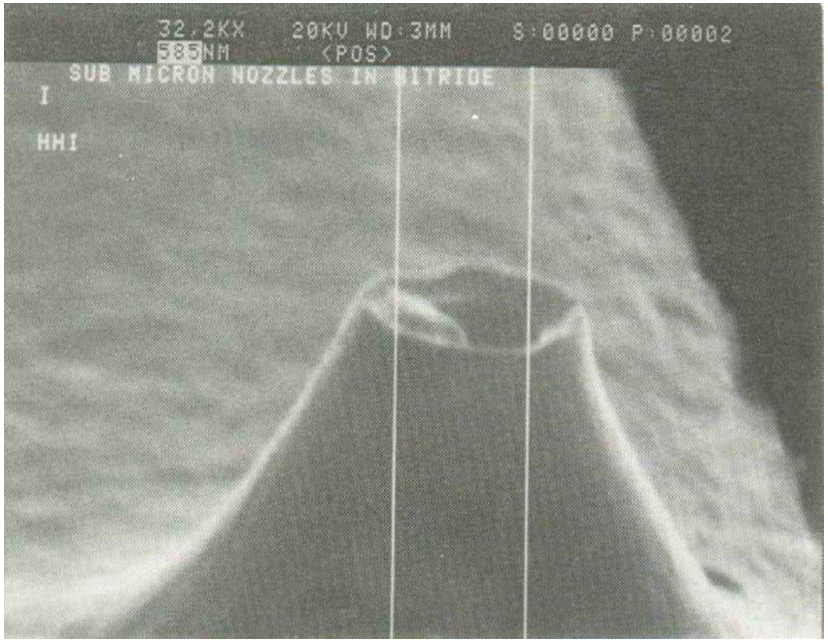
R. Dizon, et.al., J. of MEMS, 1992

- **Use ion milling to pattern the 2nd SiO_2 layer**



R. Dizon, et.al., J. of MEMS, 1992

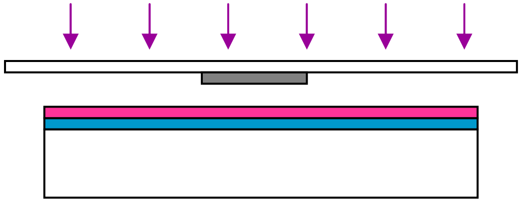
Circular nozzle



M.M. Farooqui and A.G.R. Evans, J. of MEMS, 1992

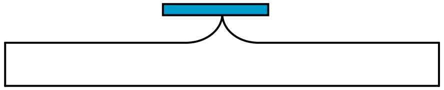
- **Fabrication processes**

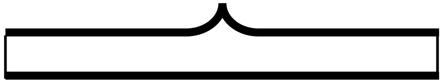

Thermally grown SiO_2

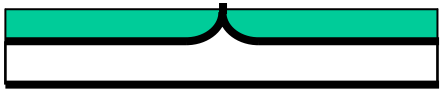

Spin coat PR and expose to UV light


PR is patterned after develop

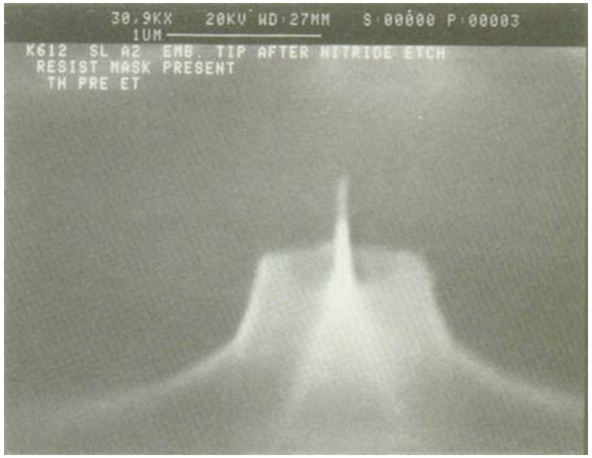

Pattern SiO_2 by HF and remove PR


Etch Si isotropically to make a cone


Thermally grown SiN_2 , and then LPCVD Si_3N_4

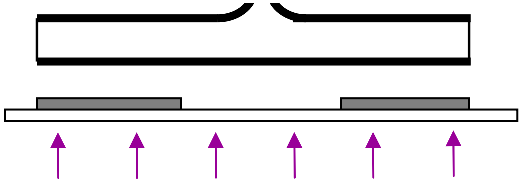


Coat a polymer layer

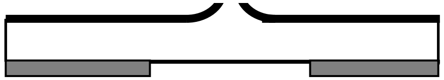


Etched by oxygen plasma to define the nozzle size

Remove the polymer layer



Photolithography the backside



Pattern the backside and remove PR

Anisotropic etch Si from backside