LIGA process

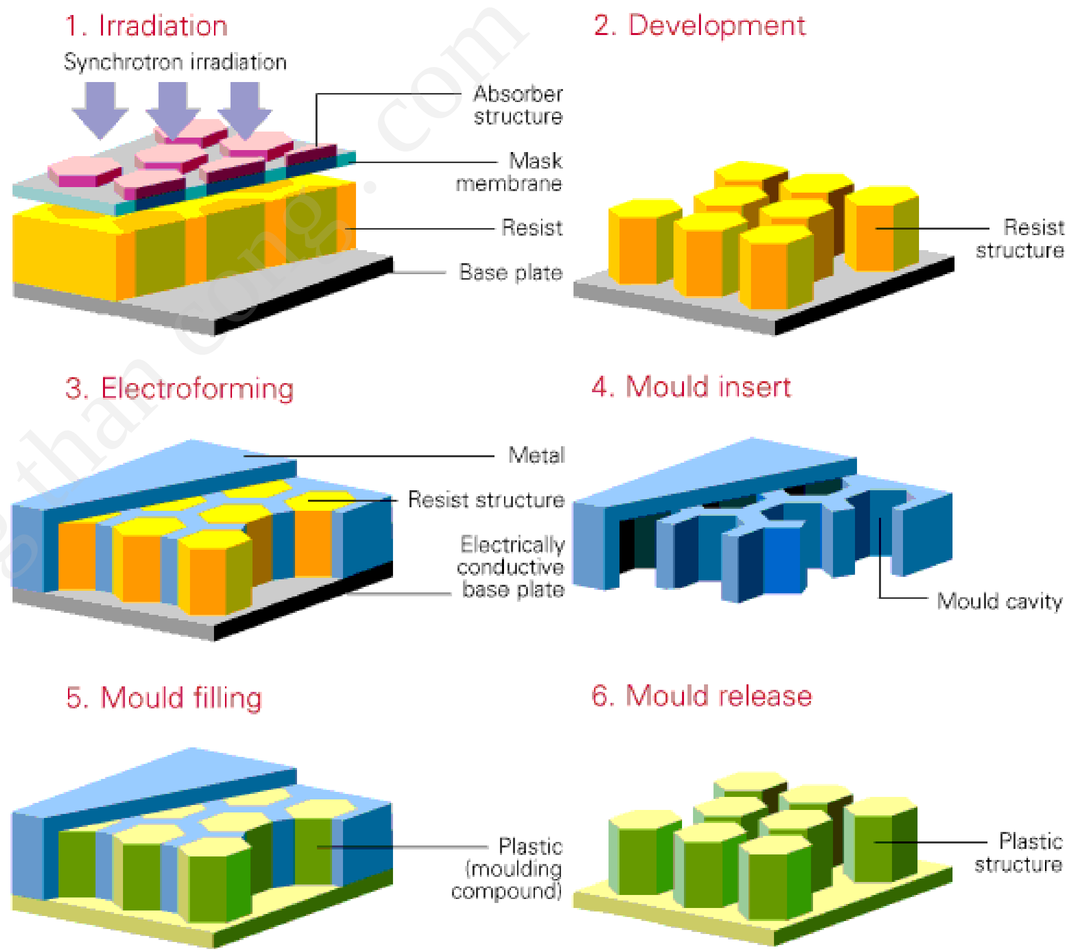
High Aspect Ratio Molding

LIGA process is used for high aspect ration molding; typical Materials are Ni, NiCo

- Micromachining; typical Materials are Brass, Al alloys
- Si Micromachining; typical Materials Si, Ni
- Combination of Various Techniques Followed by Electroplating: Ni, NiCo

LIGA process

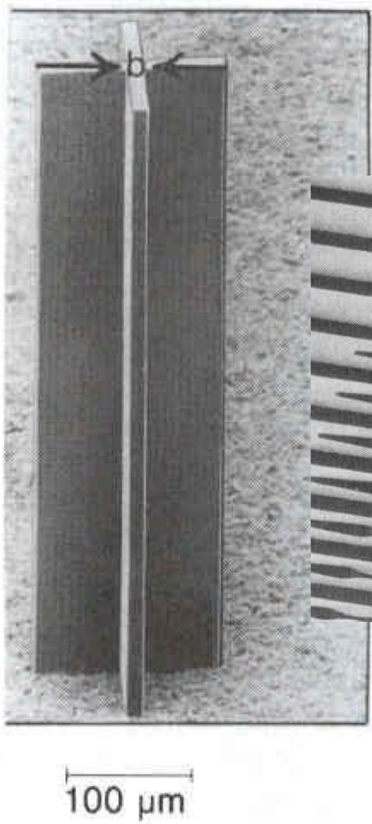
- LIGA
  - German term
    - Lithographie, Galvanoformung, Abformung ➔ Lithography, electroplating, molding
  - Also called DXRL (Deep X-ray lithography)
  - XRL
    - MEMS: Very thick structures using high energy

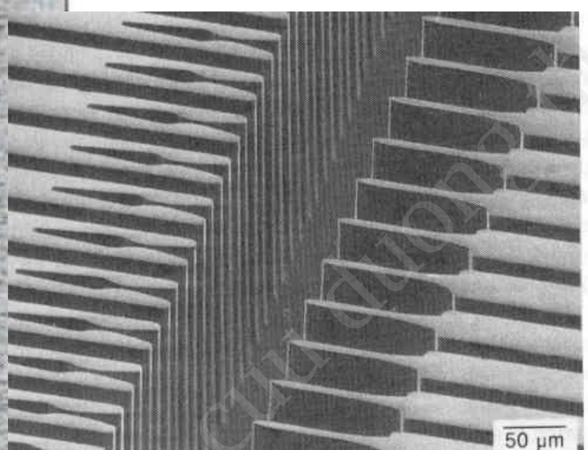


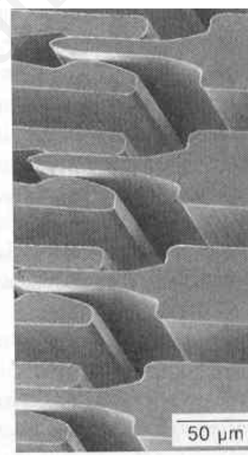
Source : IMM, Institut für Mikrotechnik mainz Gmbh

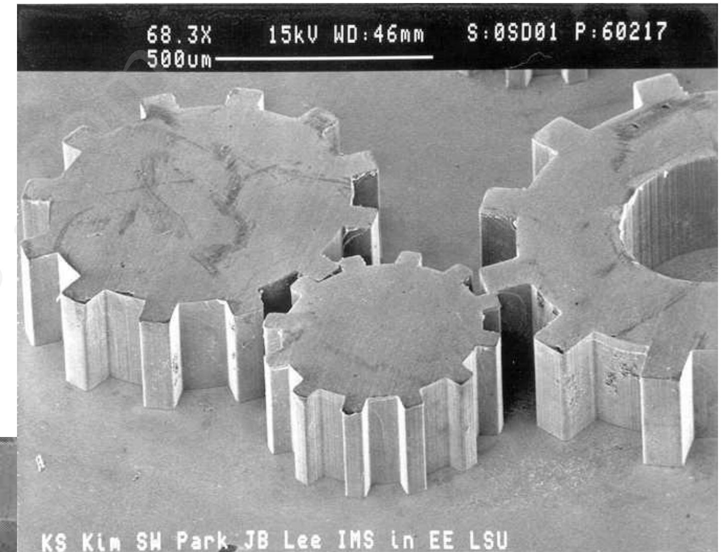
LIGA examples

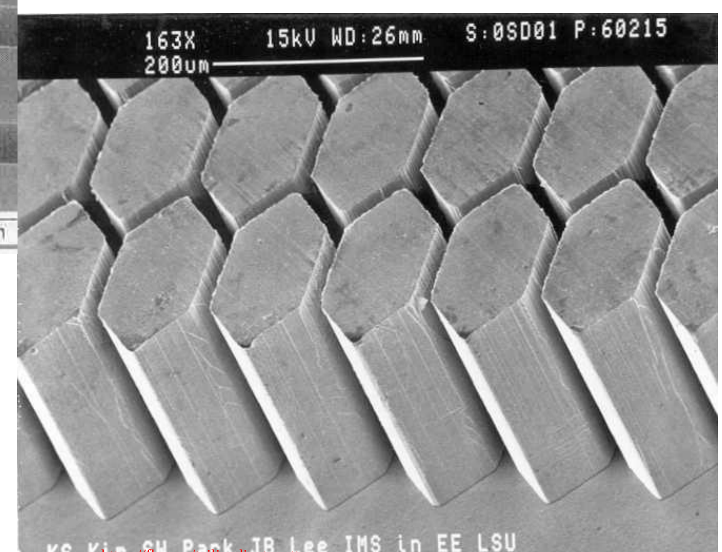
- High aspect ratio microstructures (HARMs)
  - Thickness: ~2 mm
  - Aspect ratio: > 10:1





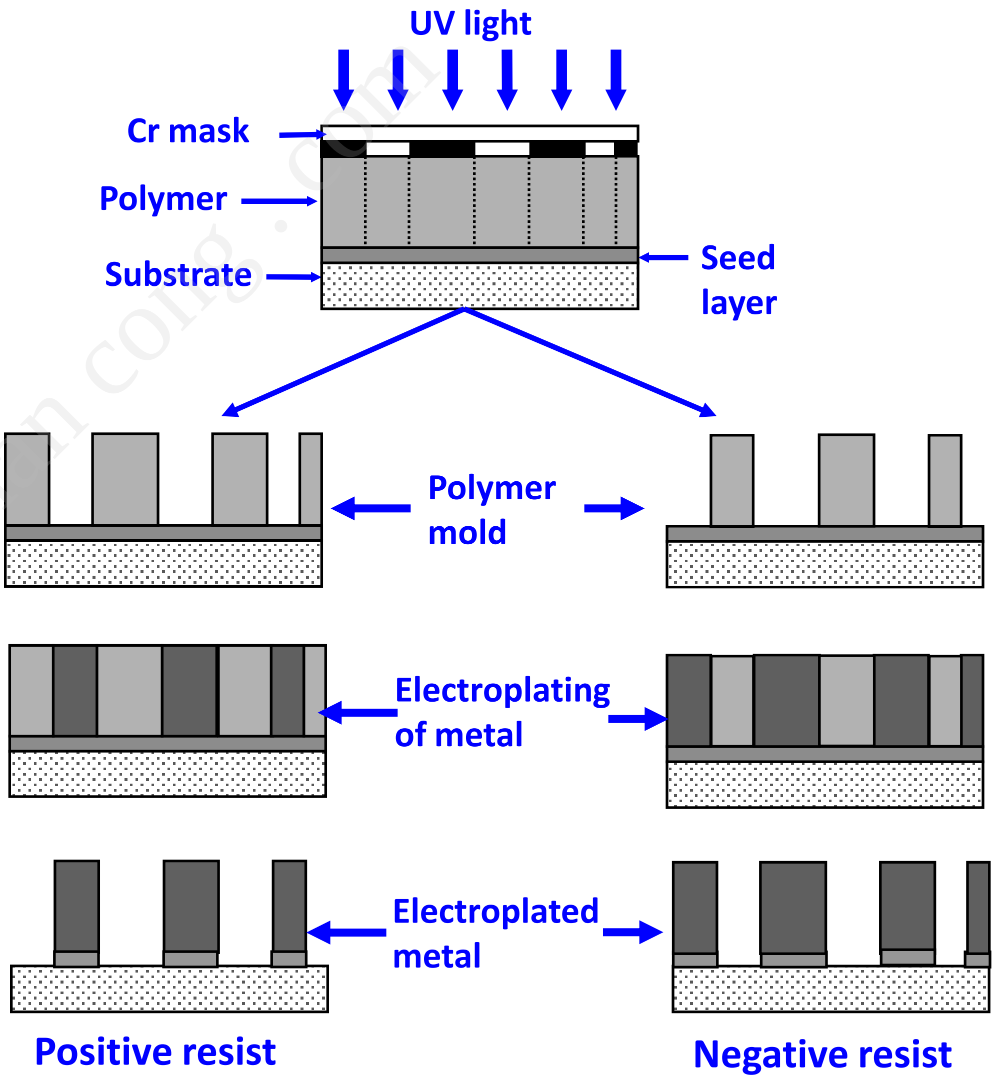




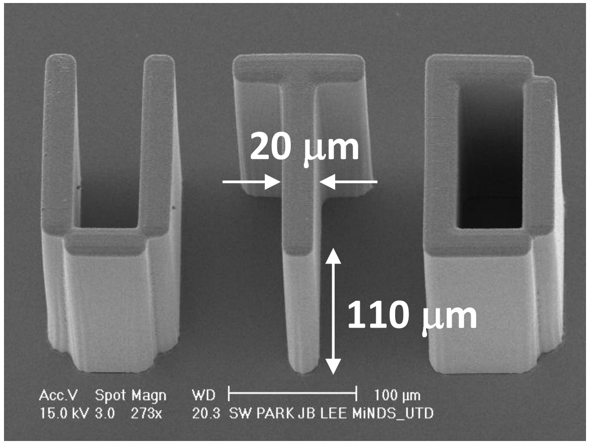


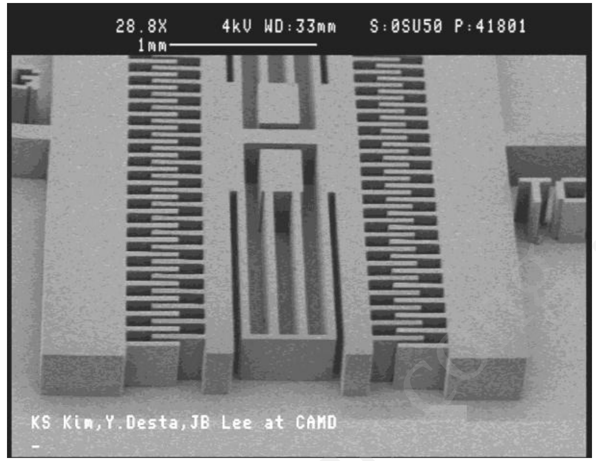
UV-LIGA process

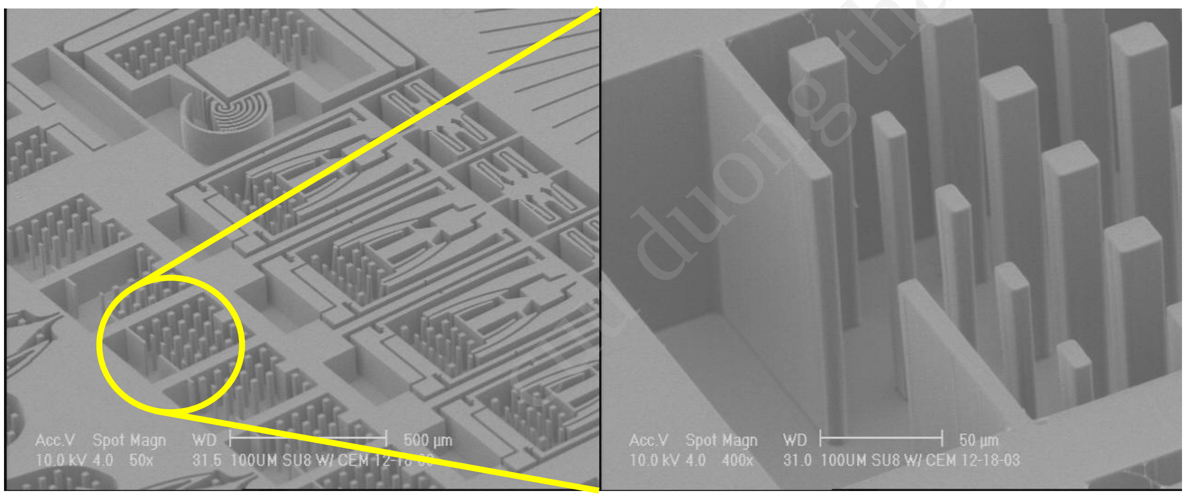
- UV-LIGA
  - Standard UV lithography
  - UV-sensitive polymeric resists: +ve PR, -ve PR (SU-8 epoxy, polyimide, thick photoresist)
  - Multi-layer possible
  - Cost-effective compared to LIGA (Also called LIGA-like or poor man's LIGA)
- Polymer as electroplating mold
  - PR
    - Low aspect ratio (< 1:1)
    - ~40 μm thick
  - Polyimide
    - Low aspect ratio (< 3:1)
    - ~80 μm thick
  - SU-8 epoxy
    - High aspect ratio (~10:1)
    - ~ 500 μm thick



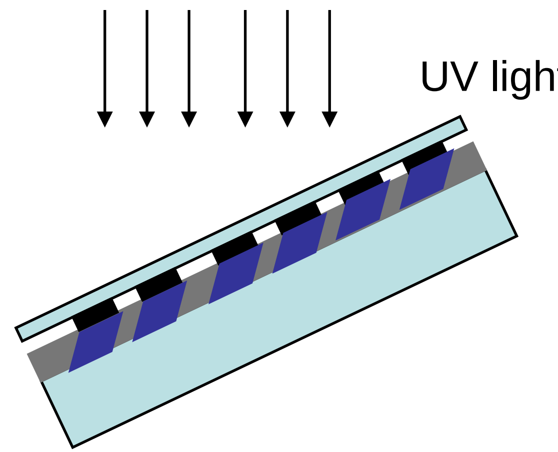
Examples of UV-LIGA processed SU-8

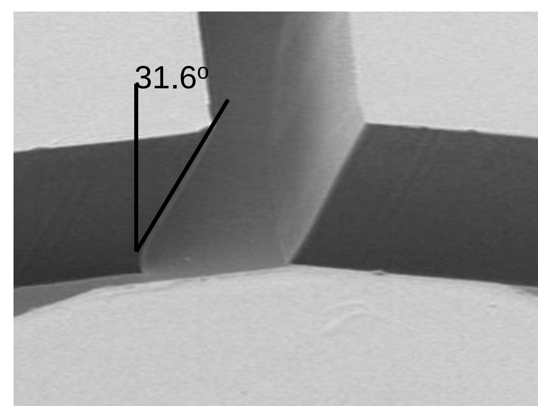






Tilted SU-8 exposure





Mold Inserts

Basic requirements

- Low mechanical stiction and friction
- No deviation from vertical sidewalls (no undercuts)
- Avoid surface oxidation

  Chemically inert

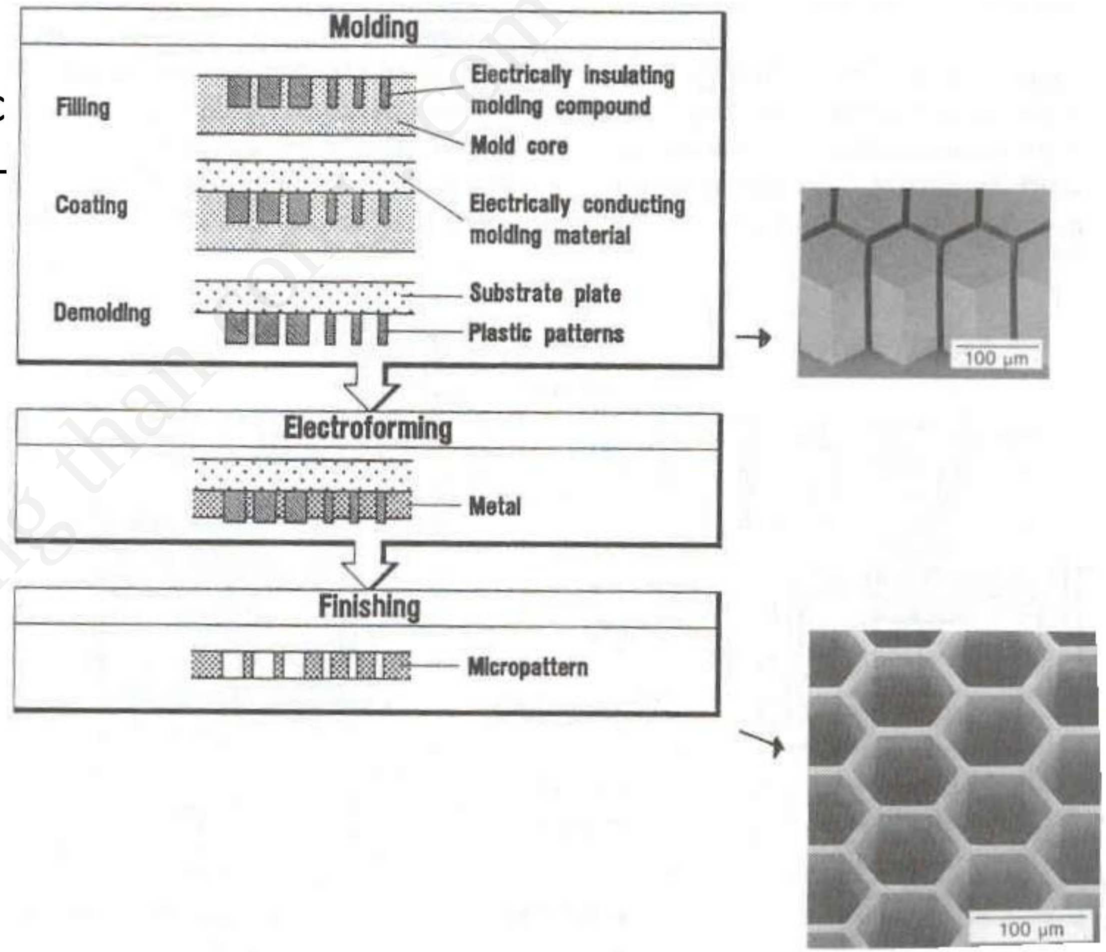
  Smooth surfaces

  Defect free sidewalls

  Homogeneous material properties

Molding

- Molding
  - Low cost massive production of precise plastic parts using LIGA or UV-LIGA-processed metallic mold inserts
- Injection molding
  - Molten plastic is injected onto a metallic mold insert
  - Heated above glass transition temperature (T_g) of the plastic
  - Polymers
    - PE, PP, PC, PMMA, COC, or biodegradable polymers (e.g. RESOMER®)



General Design Rules for Mold

- Round the corners where the polymer will shrink onto the metal
- Avoid patterning numerous aspect ratios in one sample (ie. Use AR that deviate +/- 2 from the average AR in the pattern)
- Centralize the patterns that are most critical.

Deviation further from center are more difficult to emboss

General Design Rules for Mold

- Sidewall quality is critical
  - Surface roughness > 500 nm
  - Perpendicularity >85° with >2 ° center bowing
- Bottom surface quality less critical
  - Surface roughness > 10 mm

Common Molding Materials

PMMA
Poly(methyl methacrylate),
Tg 100°C, Tproc 170°C-210°C
Transparent, brittle, sensitive to crack
optics, lost mold for production of metallic microstructures

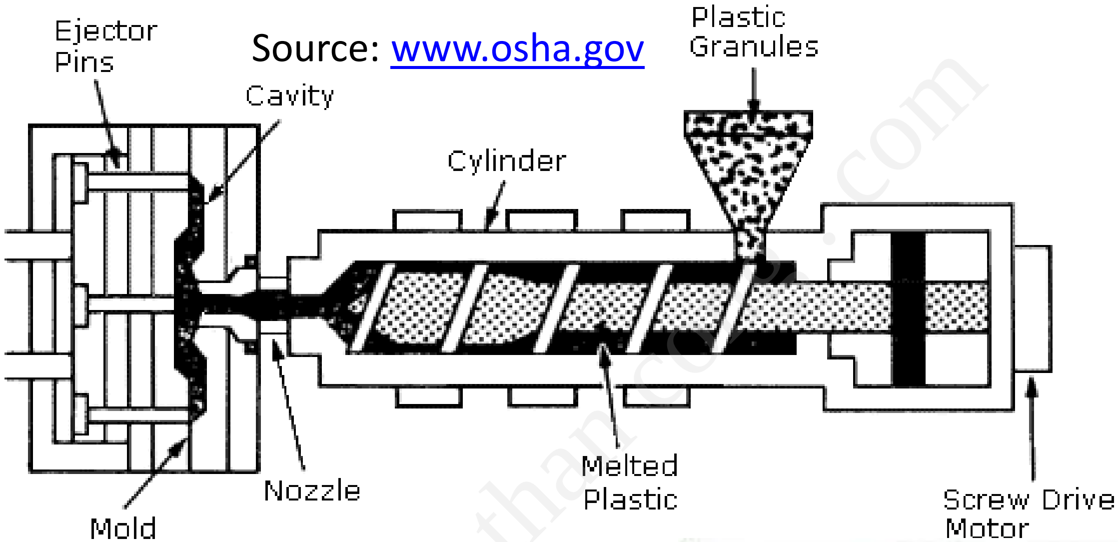
PC
Poly(carbonate),
Tg 148°C, Tproc 180°C-200°C
Transparent, good hardness and impact strength
optics, medical

POM
Poly(oxy methylene),
Tm = 156°C (Copolymer), Tproc 180°C
Tm = 175°C (Homopolymer)
Low friction, good impact strength, critical decomposition into formaldehyde, critical cavitation due to crystallization
mechanical applications (gear wheels)

PSU
Poly(sulfone),
Tg 190°C, Tproc 250°C
Transparent, high strength
for use at higher temperatures up to 180°C,
microfluidic pump

Injection molding system

Source: www.osha.gov

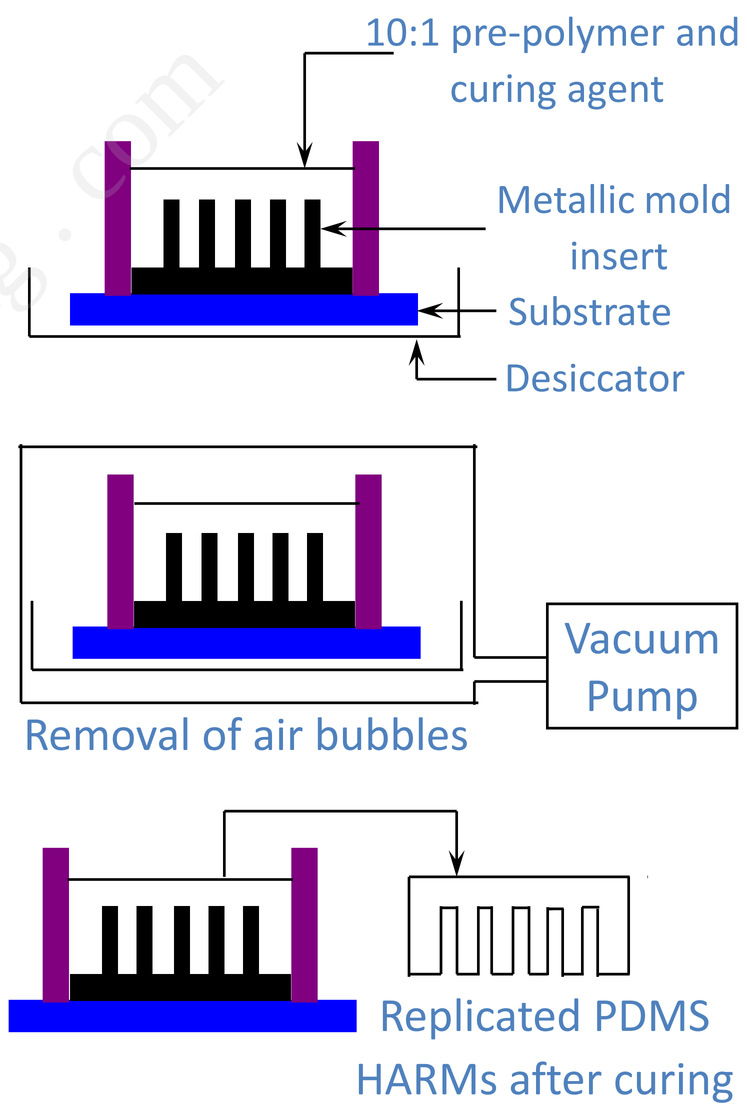


Injection molded plastic toys

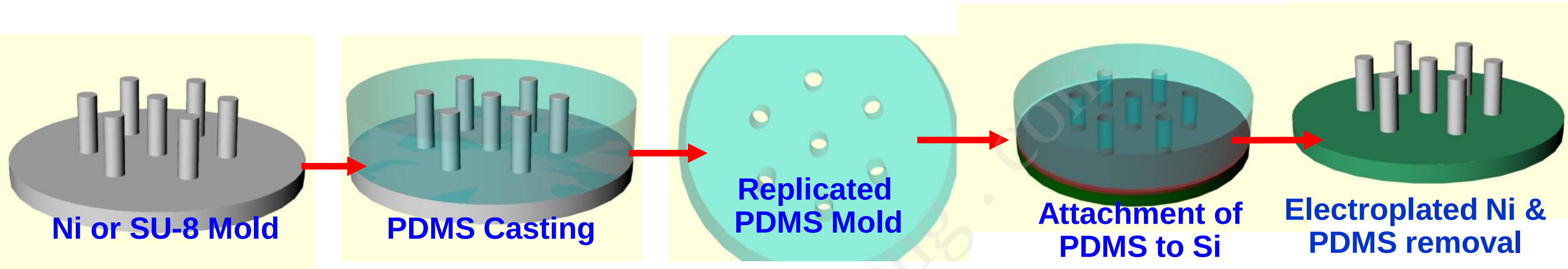
www.toysrgus.com

PDMS molding process

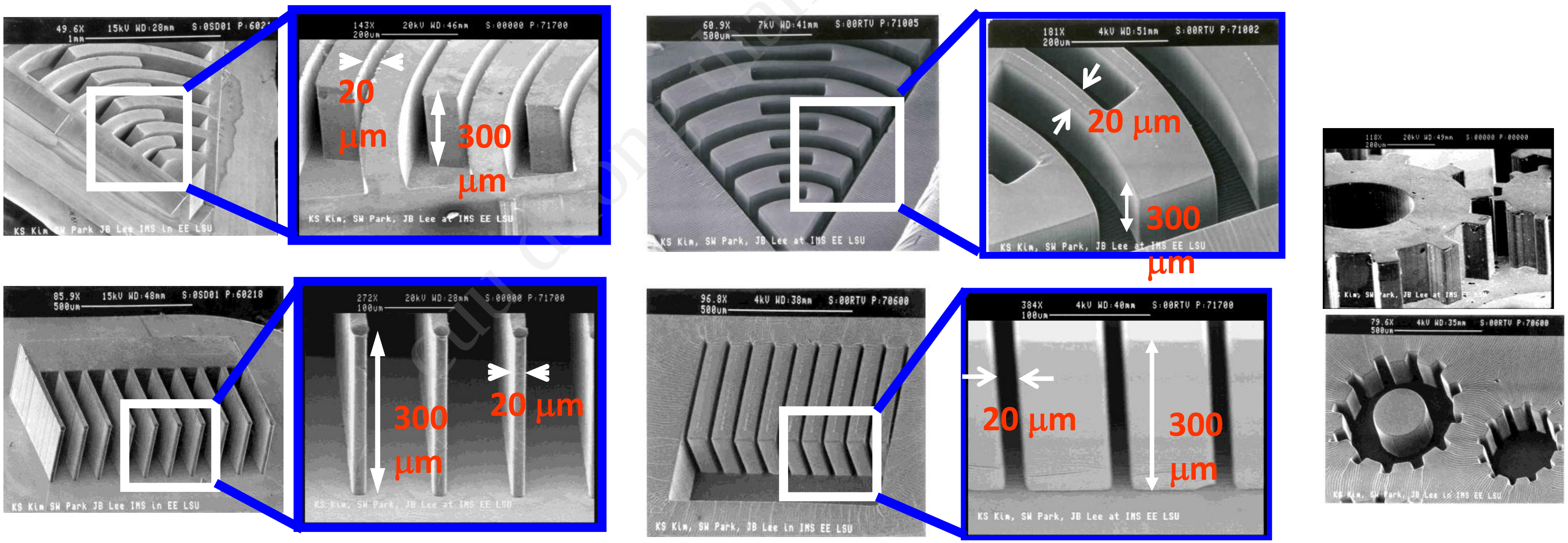
- PDMS (polydimethyl siloxane)
  - Microelectronics compatible silicone elastomer, durable, optically transparent, and inexpensive
- Process
  - A mixture of PDMS pre-polymer and a curing agent cast or spin-coated onto master molds
  - Cured at 100 °C for ~1 hour (65 °C for 4 hours)
  - Replicated PDMS peeled off from master molds
- Advantages
  - No need of expensive equipment such as injection molding and hot embossing machines for polymer replication
  - Low temperature processing for curing PDMS (65 °C)



PDMS replication and pattern transfer process



Application : massive replication of precision PDMS microstructures, pattern transfer of MEMS components on circuit

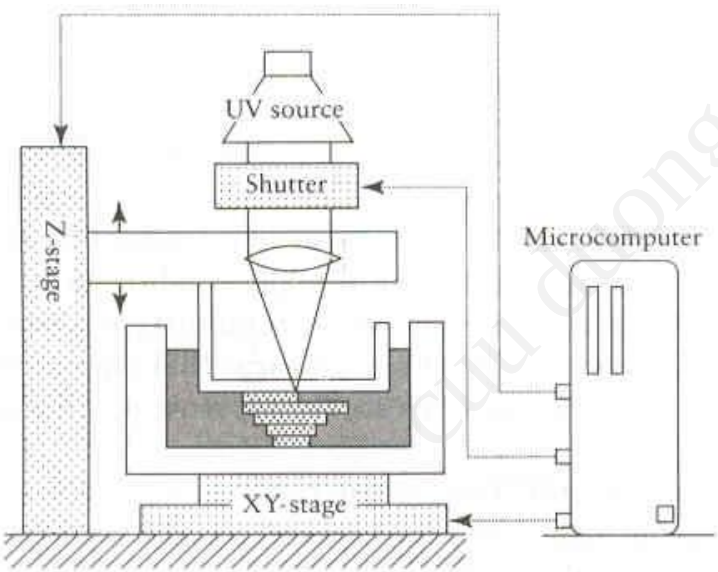


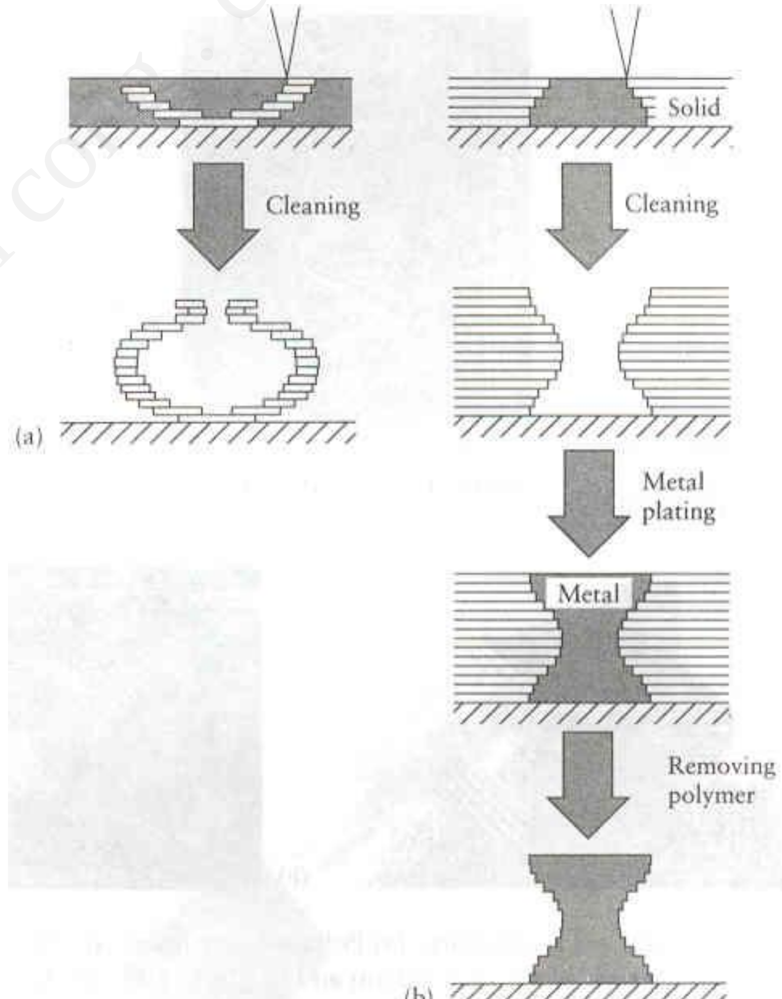
Ni mold

Replicated PDMS

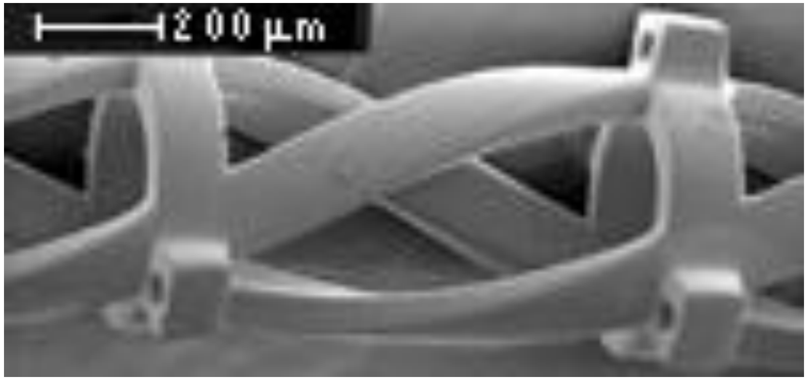
Stereolithography (SL)

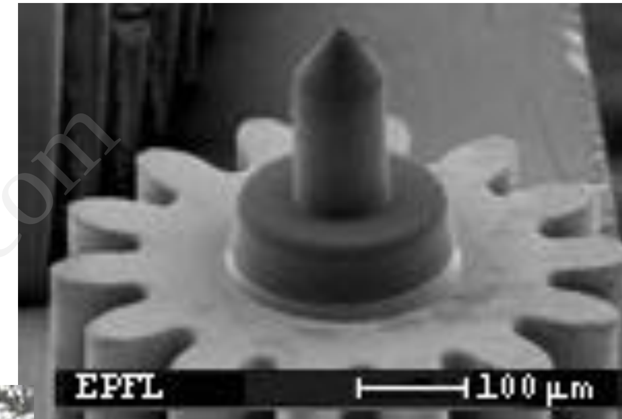
- Stereolithography
  - Repeatedly print layers that become part of a final microstructures
  - Freeform 3D structures made of polymers
    - Optical energy is focused and locally hardens a photopolymer
  - Rapid prototyping
  - Low cost
  - No integration w/ electronics

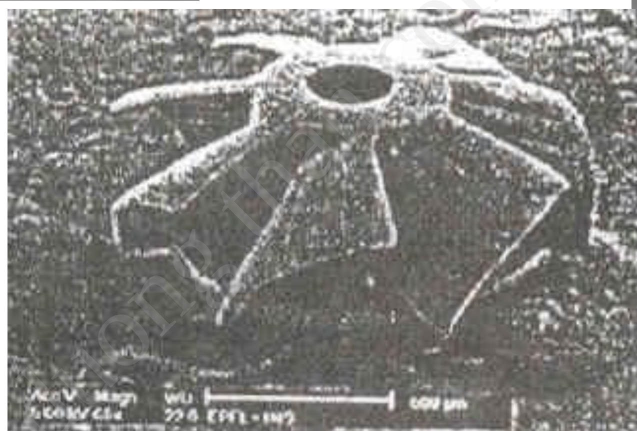


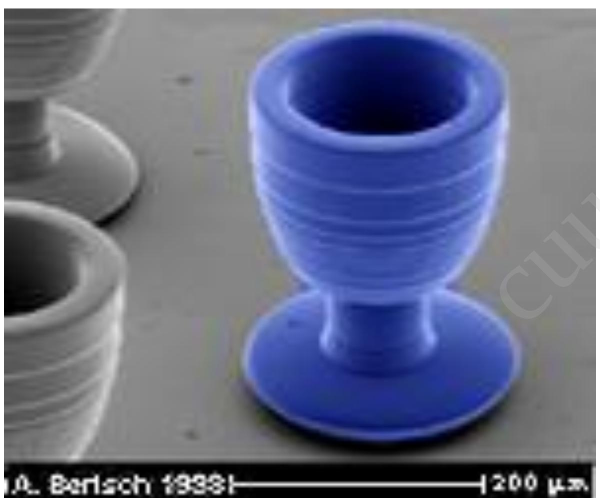


Micro SL examples









Source: http://dmtwww.epfl.ch/ims/micsys/

Miscellaneous micromachining techniques

- EDM (Electro-discharge machining)
  - Also called spark machining
    - Metal is locally removed by high frequency electrical sparks
  - Used for unusual designs in hard, brittle metals

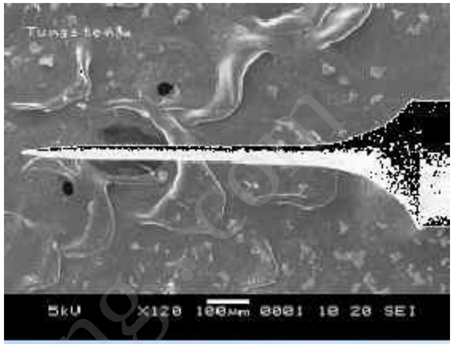
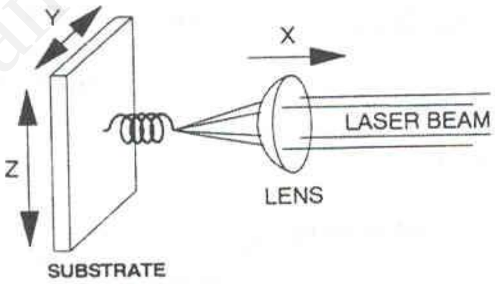
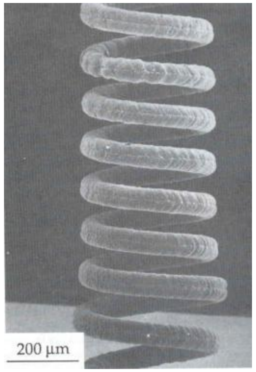


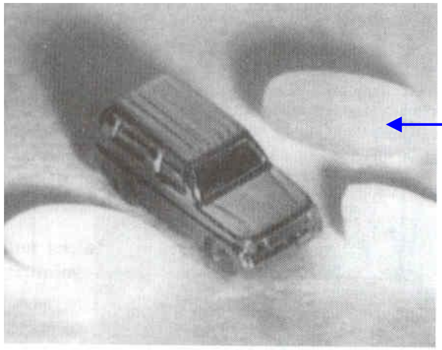
Figure 1: Cylindrical electrode (Φ30µm). The scale of the picture is as indicated.

Source: http://www.eng.nus.edu.sg/EResnews/0601/sf/sf_4.html

- LCVD (Laser-assisted chemical vapor deposition)
  - Energy needed for deposition is provided by photons
  - Complex 3D structures
    - Adjusting the focal point of the laser continuously







A 7-mm car fabricated by precision machining

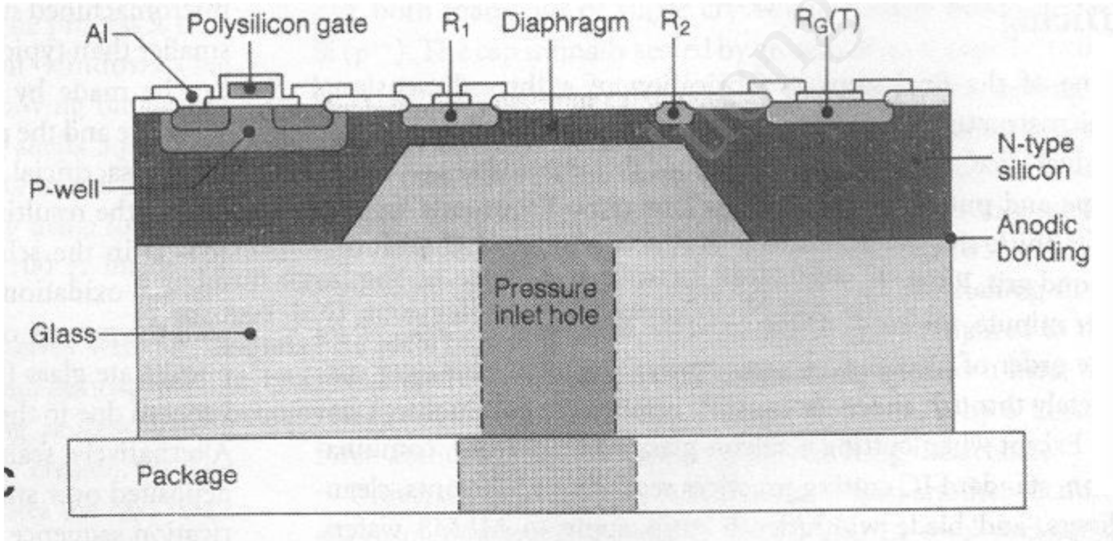
Packaging Technology

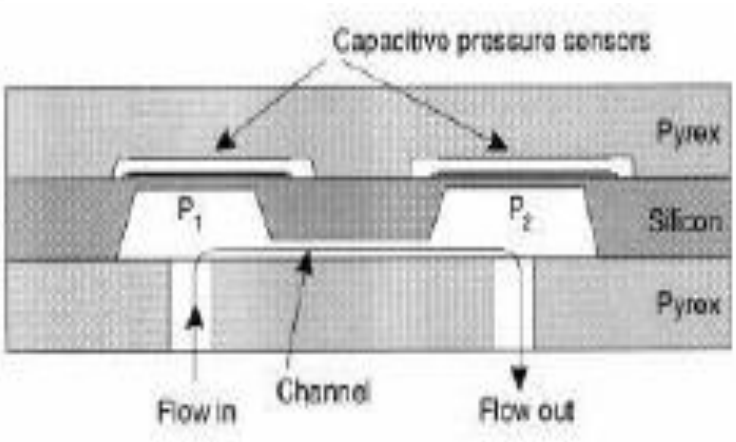
Bonding techniques

- Wafer bonding
- Plasma bonding
- Anodic bonding
- Adhesive bonding

Wafer bonding

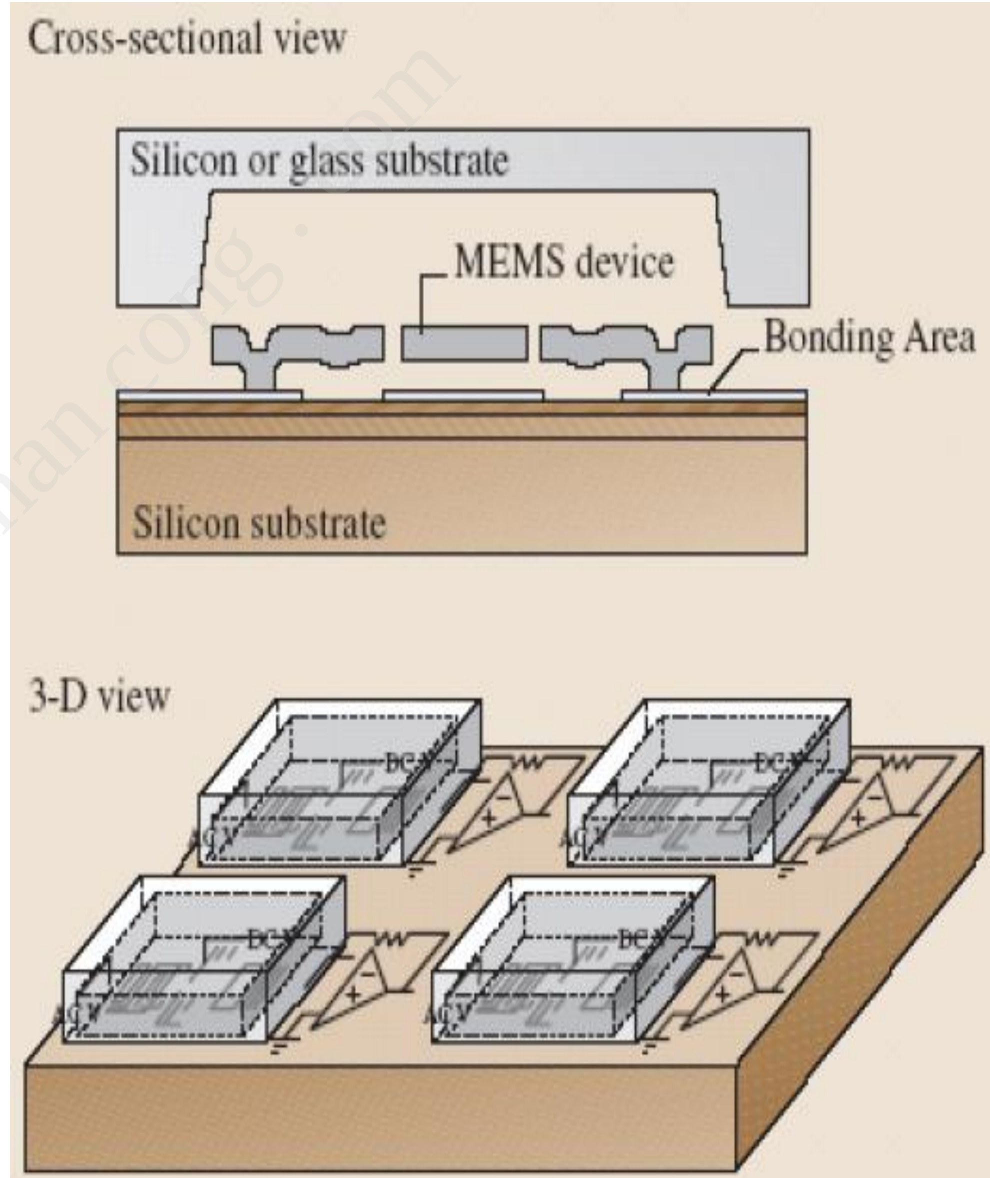
- Wafer bonding technique
  - A technique to create cavities or channels
  - Joint wafers together to provide hermetic sealing
  - Bond similar or dissimilar substrates permanently
  - Various bonding techniques are used
    - Anodic bonding, fusion bonding, eutectic bonding, glass frit bonding, ….





IC vs. MEMS packaging

- IC packaging
  - ICs are 2D planar devices and immoveable
  - Standardized process
  - Well established mass production technology
  - 1/3 ~2/3 of the total manufacturing cost
- MEMS packaging
  - MEMS devices are mostly freestanding and moveable
  - Non-standardized process
    - Packaging requirement different from one MEMS device to another
  - Easily takes up 2/3 or more of the manufacturing cost for initial commercialization



TI DLP packaging process