Microrobotics Fabrication

MUMPs Process as an example

Microrobotics fabrication: MUMPs process as an example

- Microrobotics
- MEMS Foudries and Fab Processes
- MUMPs process
- Bridging the gap between Design and Fabrication: Design Rules
- CAD & Simulation

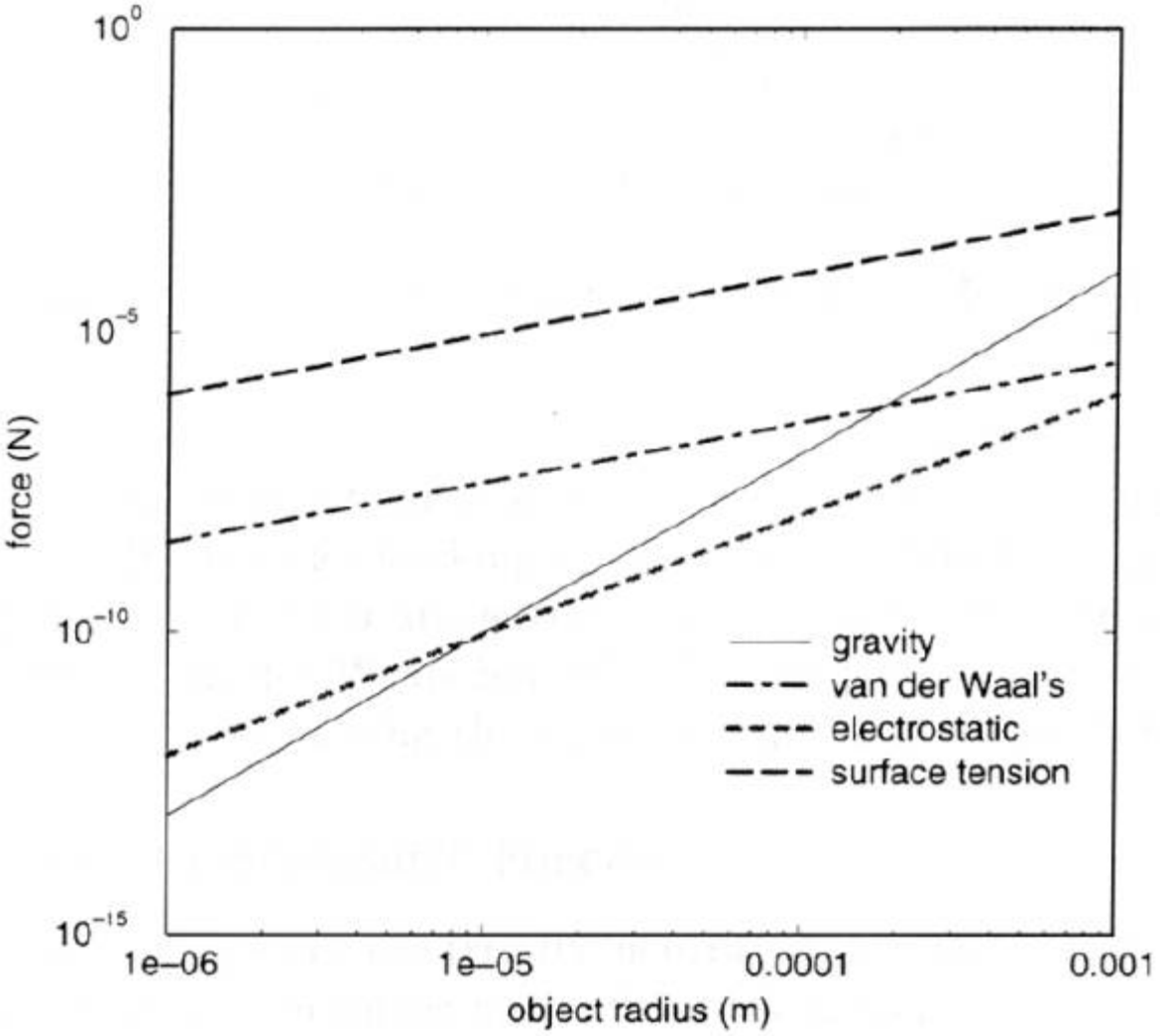
Microrobotics

	Feature Sizes	Operation	Fabrication
Miniature robots	1-10 mm	Workspace and forces comparable to **Precision Engineering**	Miniature assembly with **Conventional Techniques**
Micro-robots	1-10 μm	Microactuators, sensors and signal processing → **MEMS**	**Micromachining** (Bulk, surface, LIGA)
Nano-robots	<100 nm	Classical Mechanics principles do not apply anymore. Electrochemical principles?	Solid-state techniques no longer suitable Polymer chemistry?

MEMS development

- Fabrication vs Design
- Design equipment
- Fabrication equipment: Costly!
- MEMS use Microelectronics Fabrication Techniques
- MEMS Foundries

Design Issues: Dominating forces in microscale mechanics



- **Electrostatic Force**

$$F_e = \frac{q^2}{4\pi\varepsilon d^2}$$

- **Van Der Waals**

$$F_{vdw} = \left(\frac{z}{z + b/2}\right)^2 \frac{hr}{8\pi z^2}$$

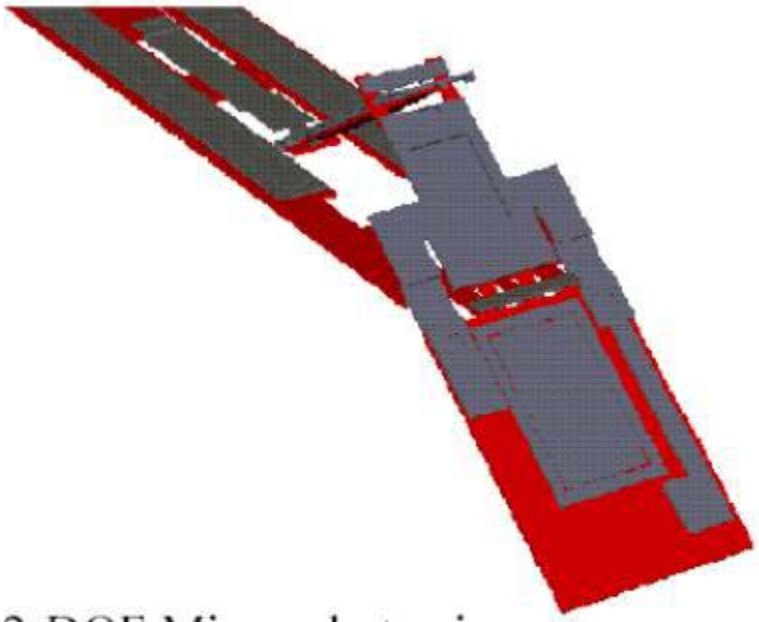
- **Surface Tension**

$$F_{st} = 4\pi\gamma r$$

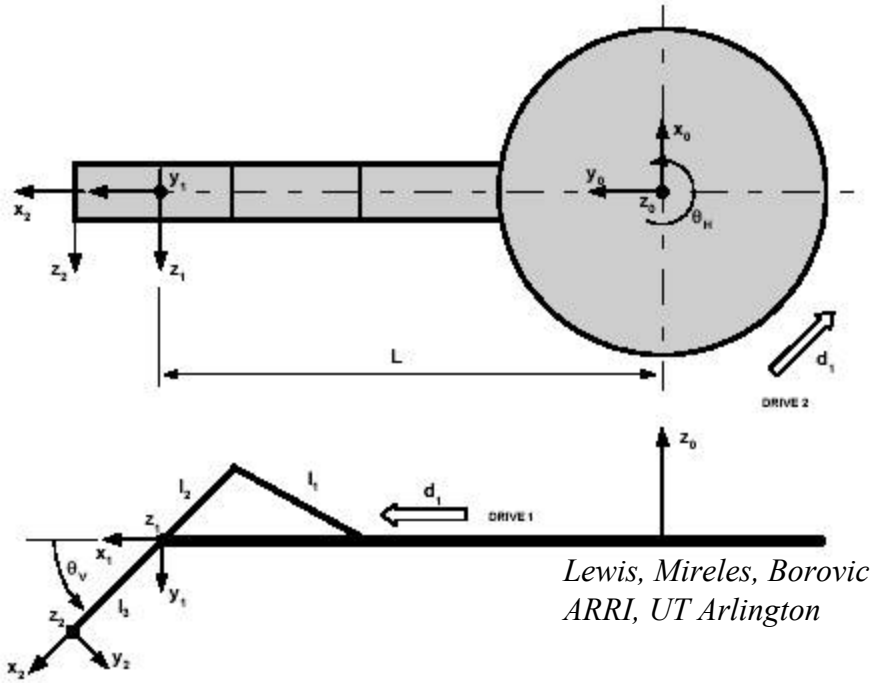
- Gravity

Image: Heikki Koivo Helsinki U. Of Tech.

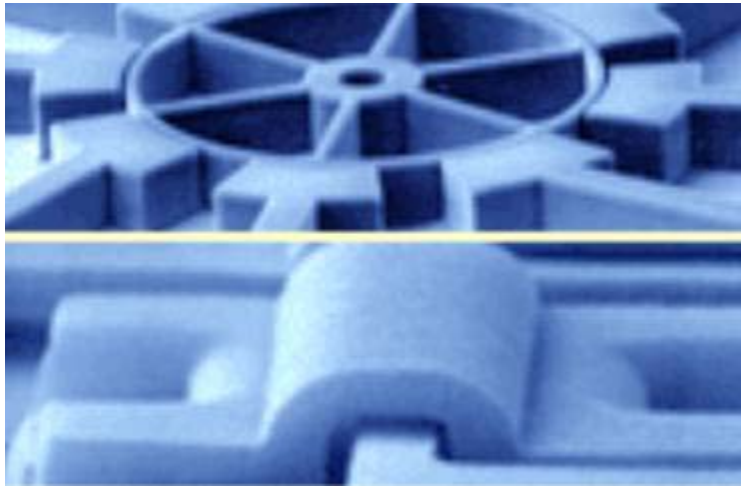
Example of 2 DOF microrobot



2-DOF Microrobot using
Surface Micromachining



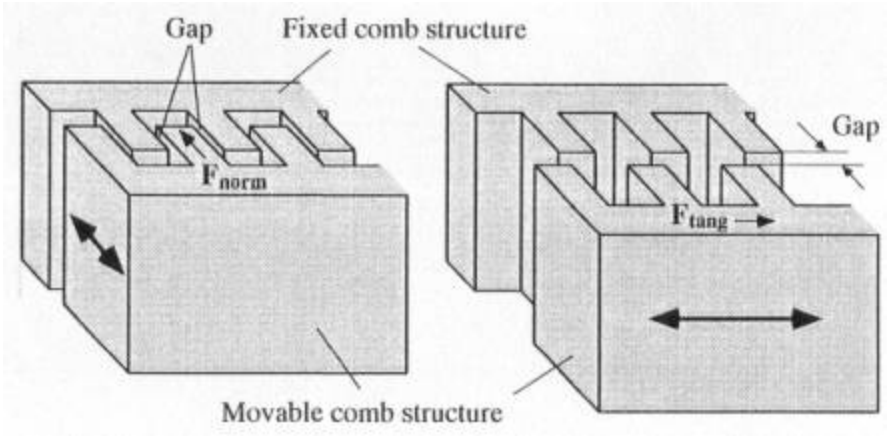
Lewis, Mireles, Borovic
ARRI, UT Arlington

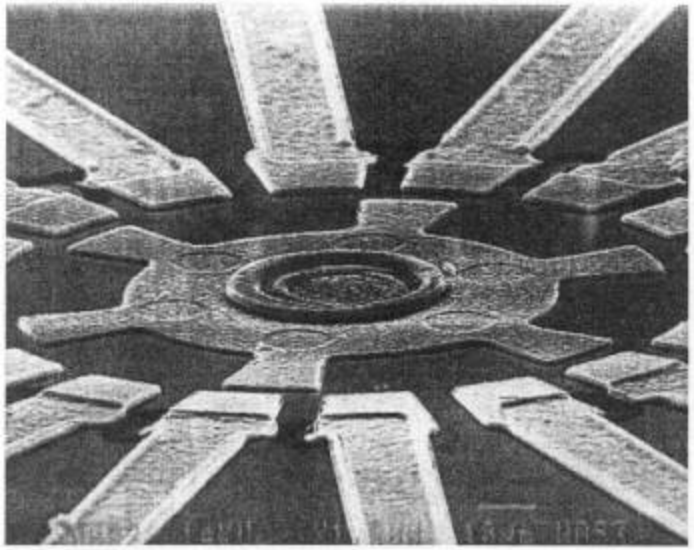


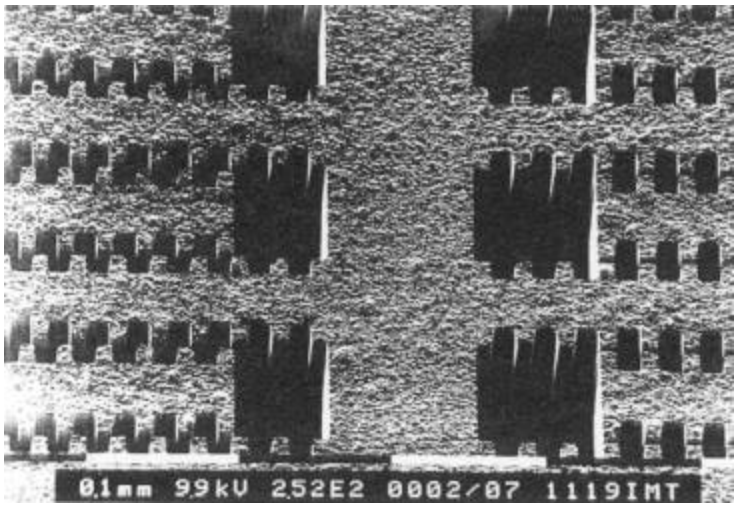
JDS Uniphase

Design Issues: Actuator Design Example

Fatikow, Rembold
Microsystem Technology and Microrobotics





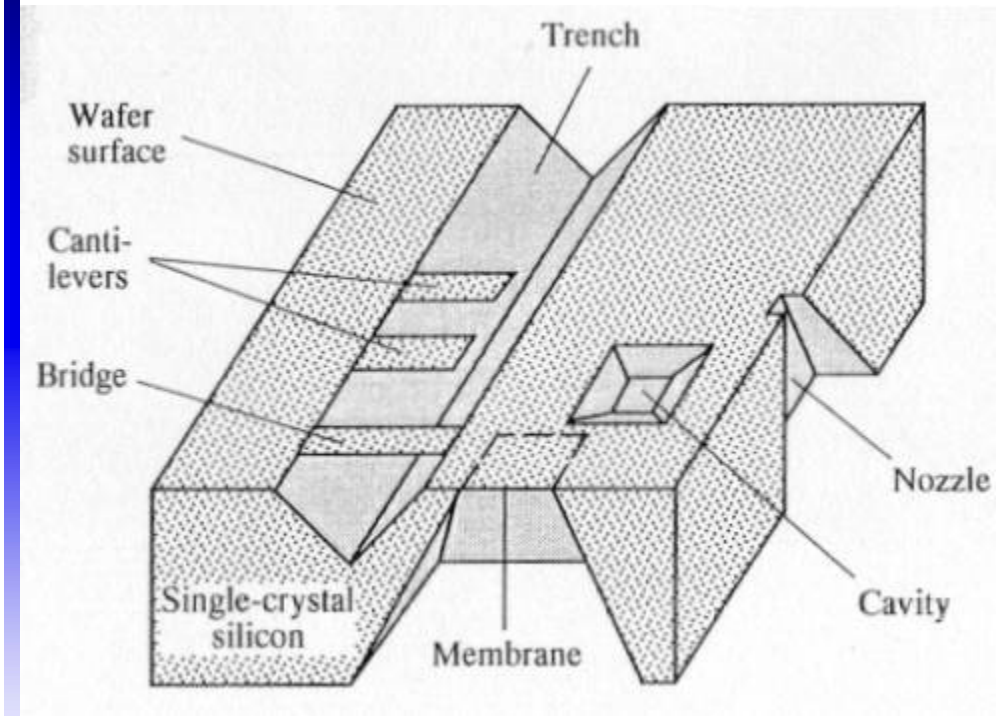


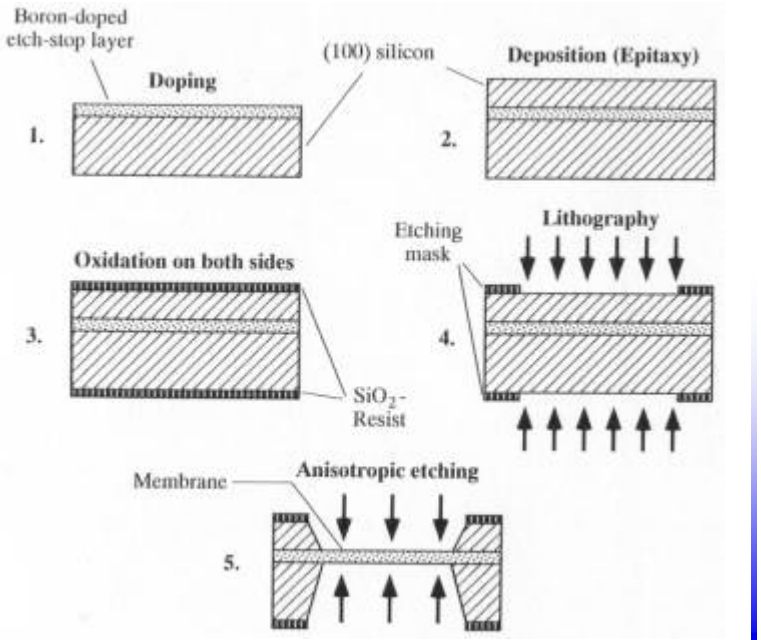
Fabrication Issues

- Basic MEMS fabrication: **Micromachining**

- Most common Micromachining
  - Bulk Micromachining
  - **Surface Micromachining**
  - LIGA Technique

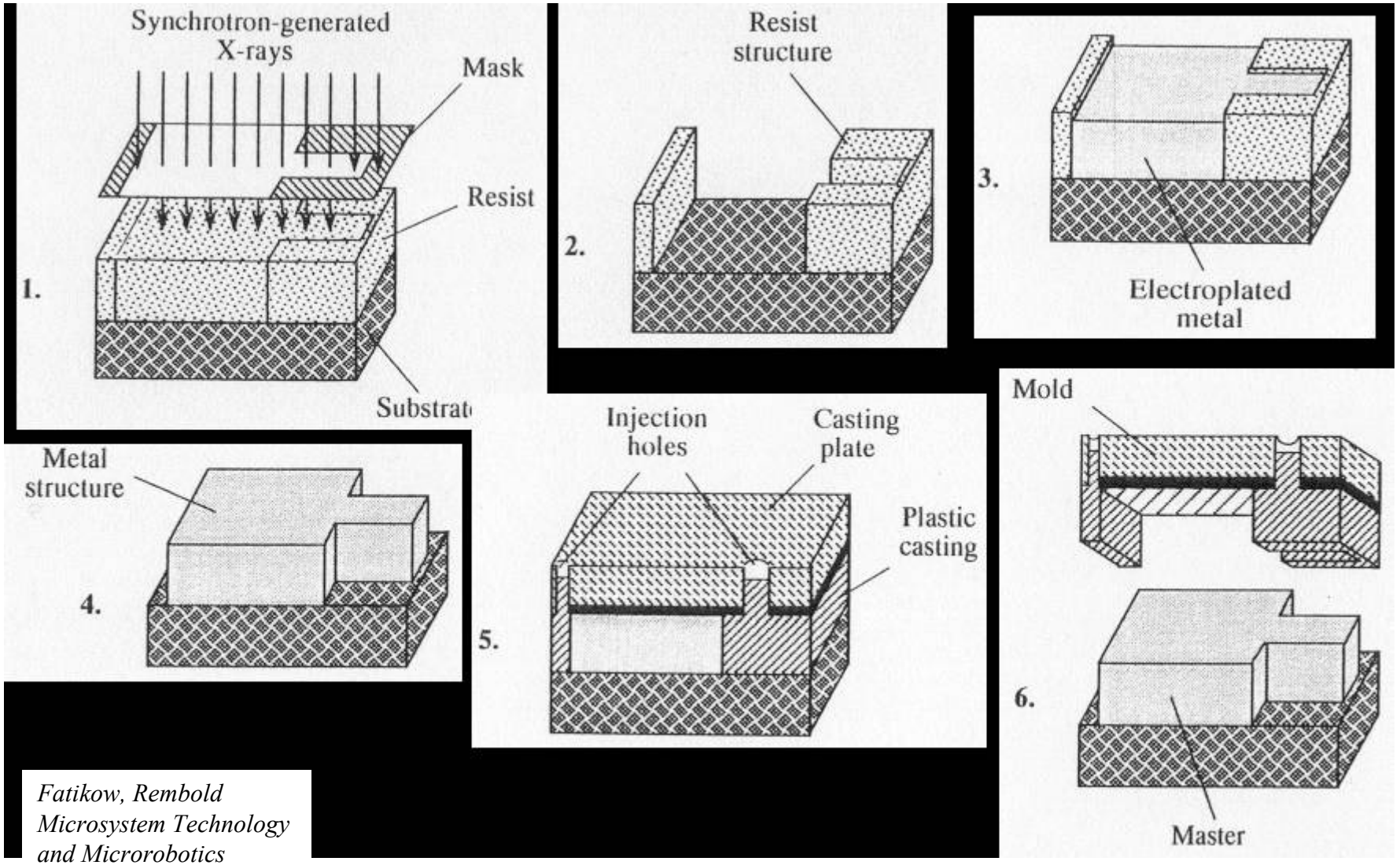
Bulk Micromachining





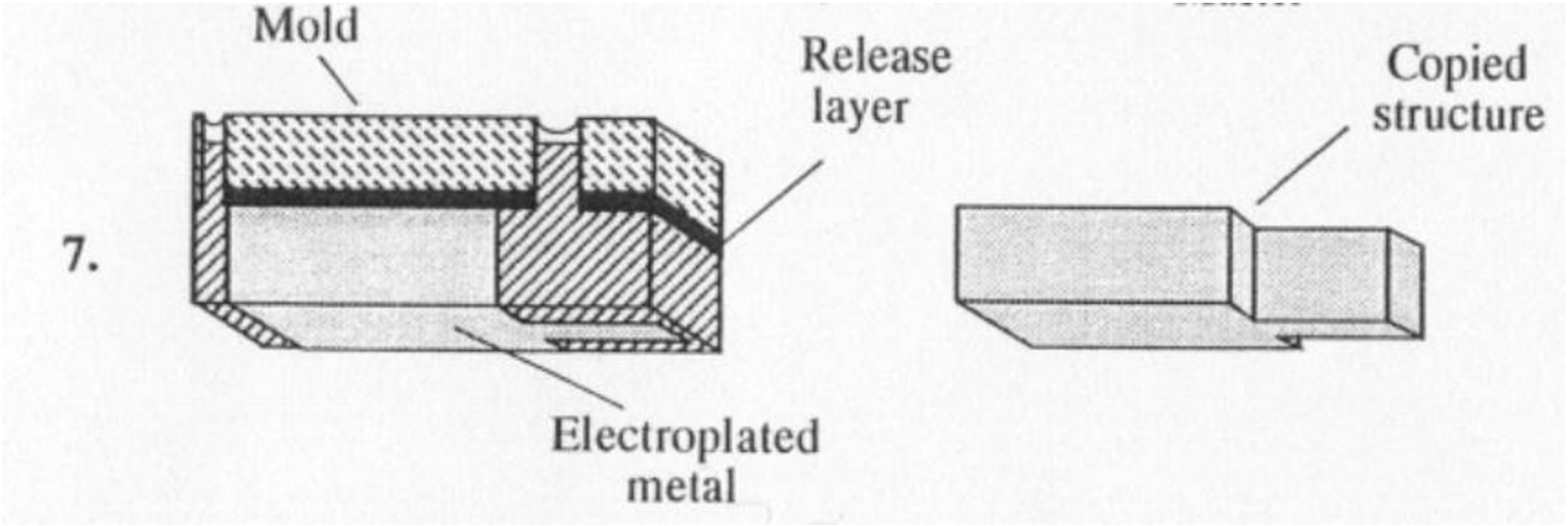
Fatikow, Rembold
Microsystem Technology and Microrobotics

LIGA Technique



Fatikow, Rembold
Microsystem Technology
and Microrobotics

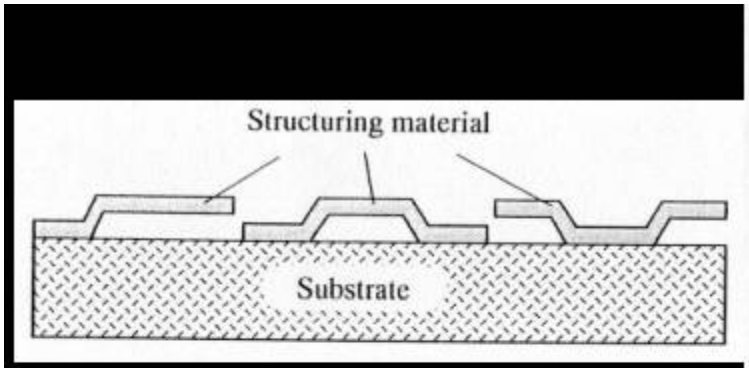
LIGA Technique

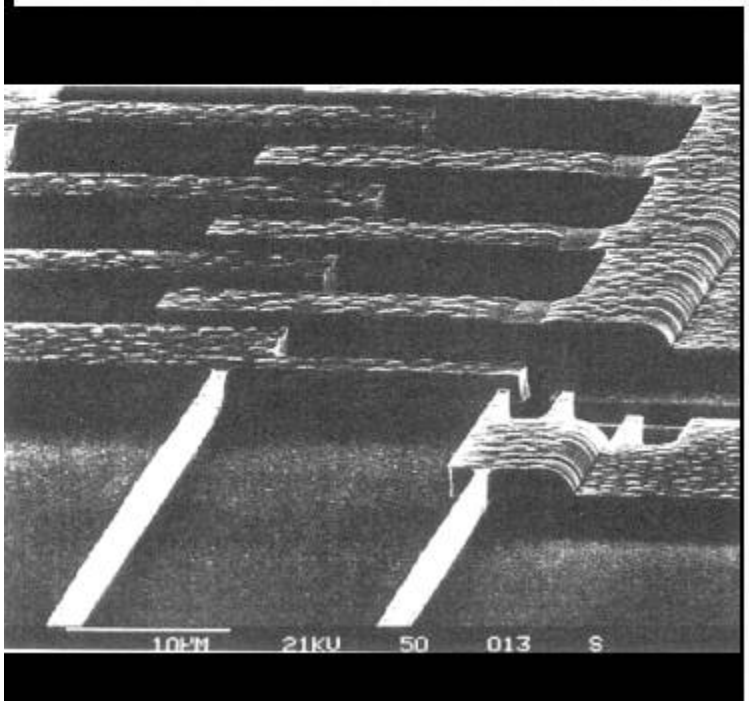


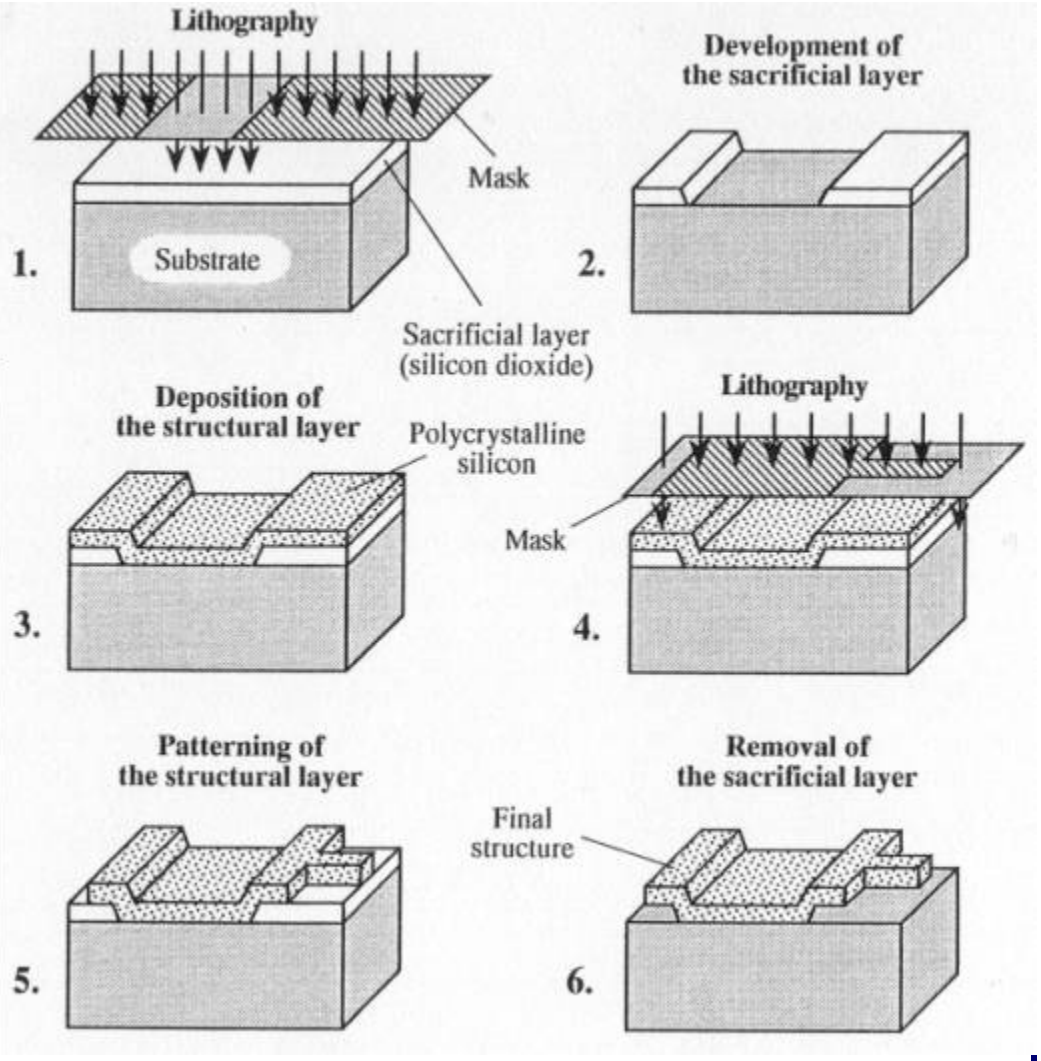
Fatikow, Rembold
Microsystem Technology and Microrobotics

Surface Micromachining

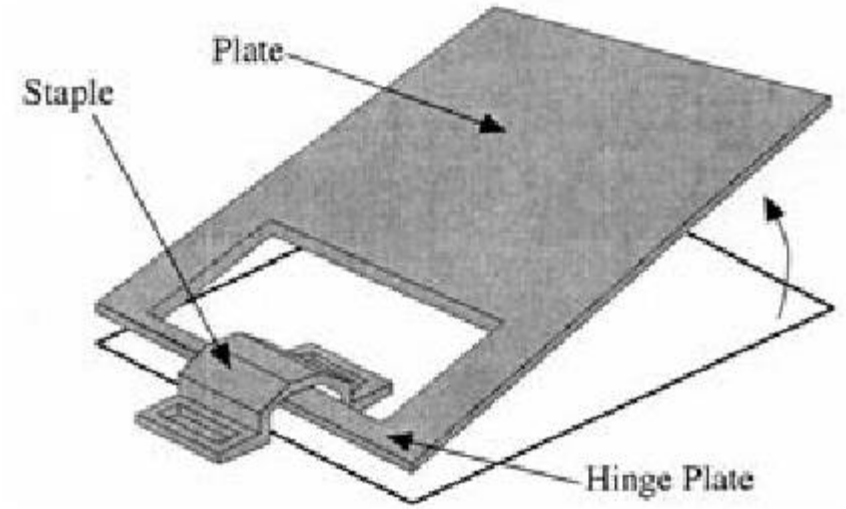
Fatikow, Rembold
Microsystem Technology and Microrobotics

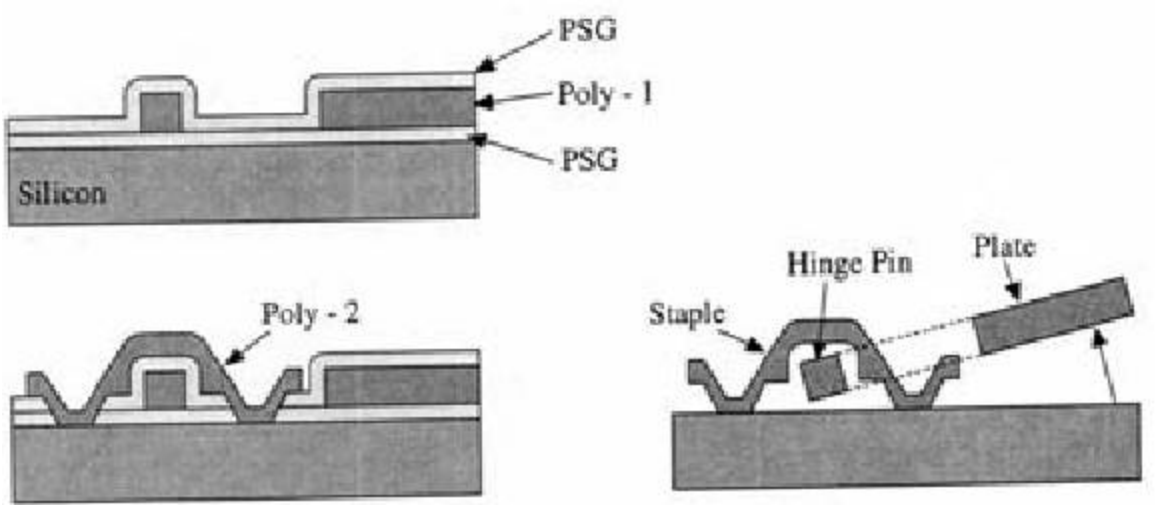






Example on how to build a Hinged Mechanism

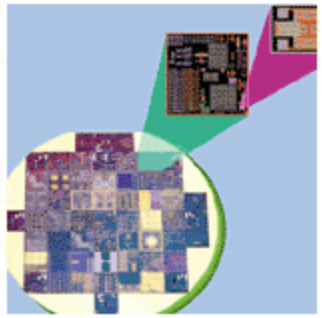




Some MEMS Foundries and Fab Processes

- Cronos (JDS Uniphase)
  - MUMPs
    - Multiple User MEMS Processes
- Sandia Agile MEMS Prototyping, Layout Tools, Education and Services
  - SUMMiT
    - Sandia Ultra-planar, Multi-level MEMS Technology
- Several others throughout the world

MUMPs Procedure

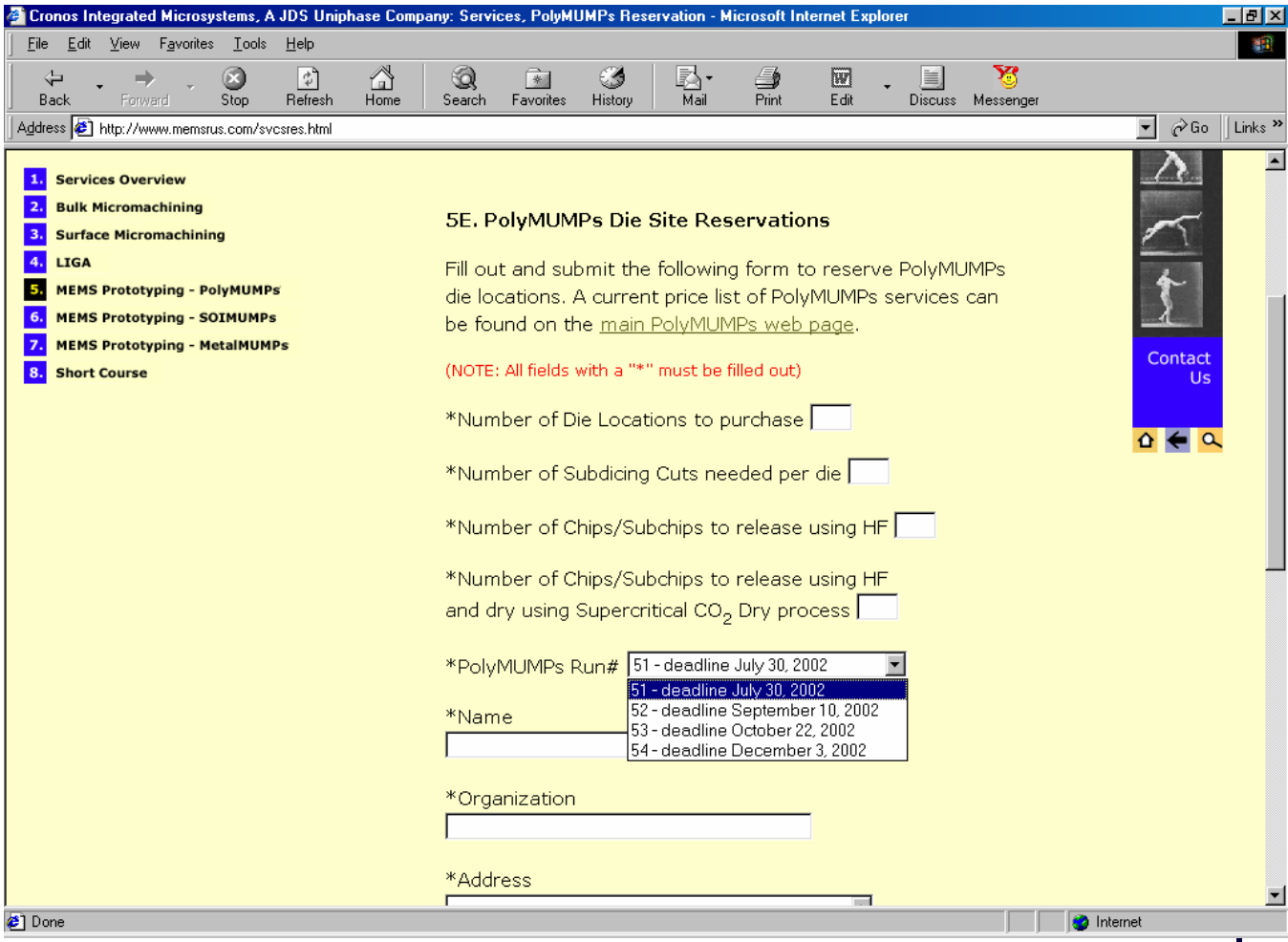


- www.memsrus.com
- User downloads design rules
- User reserves 1cm x 1cm die location on scheduled runs via web
- User submits design and purchase order by set deadlines
- User receives 15 unreleased die 8 weeks later
- Post processing options
  - HF Release
  - Supercritical CO2 drying
  - Sub-dicing

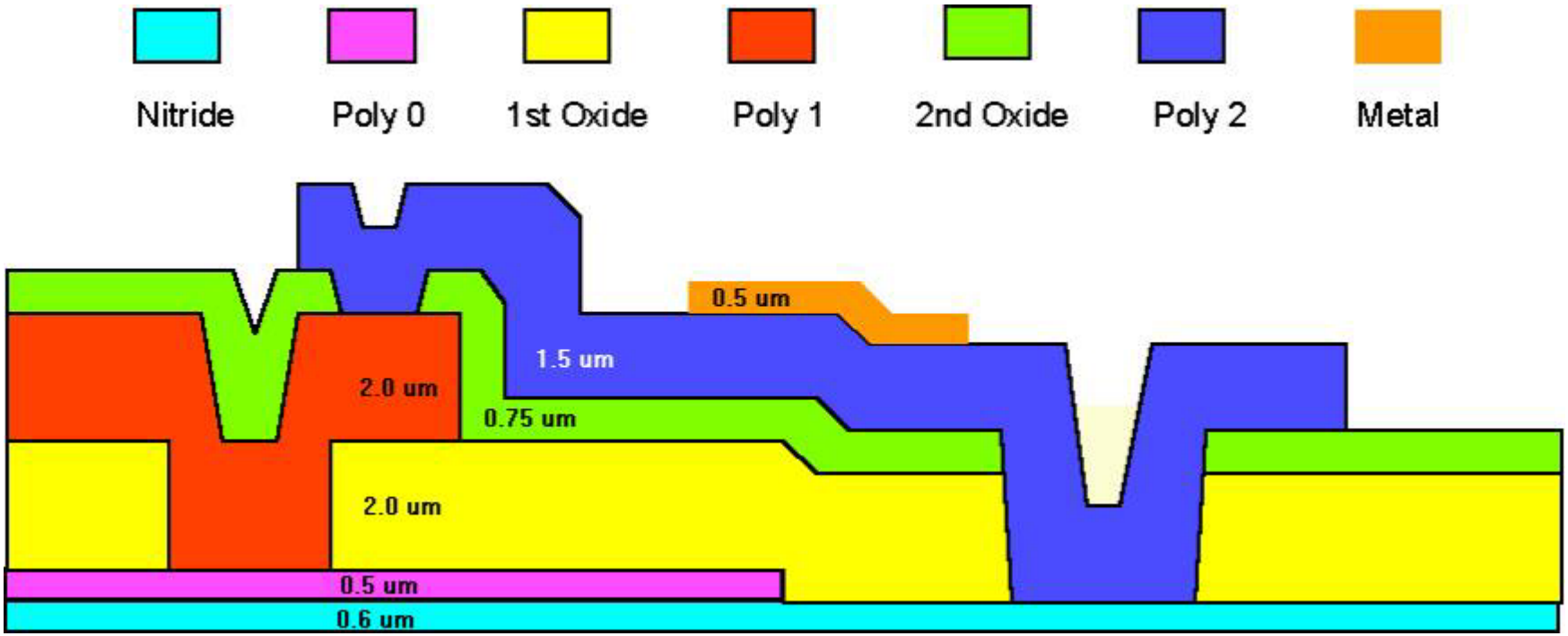
MUMPs Pricing and Scheduling

PolyMUMPs Price List

Single Die Location	
▲ Commercial/Intl.	$4600
▲ Academic (US and Canada)	$3200
Multiple Die Locations (in a single run - cost per site)	
▲ 2-4 sites	$4100
▲ 5+ sites	$3600
Subdicing	
▲ US/Canada first cut	$250
ea. additional cut	$100
▲ International first cut	$300
ea. additional cut	$150
HF Release	
▲ US/Canada per 15 chips/subchips	$375
▲ International per 15 chips/subchips	$425
HF Release & Supercritical CO_2 Dry	
▲ US/Canada per 15 chips/subchips	$1325
▲ International per 15 chips/subchips	$1625



PolyMUMPs


Nitride
Poly 0
1st Oxide
Poly 1
2nd Oxide
Poly 2
Metal
0.5 um
1.5 um
2.0 um
0.75 um
2.0 um
0.5 um
0.6 um

Mask Conventions

Mnemonic level name	Field type	Purpose
POLY0	light	pattern ground plane
ANCHOR1	dark	open holes for Poly 1 to Nitride or Poly 0 connection
DIMPLE	dark	create dimples/bushings for Poly 1
POLY1	light	pattern Poly 1
POLY1_POLY2_VIA	dark	open holes for Poly 1 to Poly 2 connection
ANCHOR2	dark	open holes for Poly 2 to Nitride or Poly 0 connection
POLY2	light	pattern Poly 2
METAL	light	pattern Metal
HOLE0	dark	provide holes for POLY0
HOLE1	dark	provide release holes for POLY1
HOLE2	dark	provide release holes for POLY2
HOLEM	dark	provide release holes in METAL

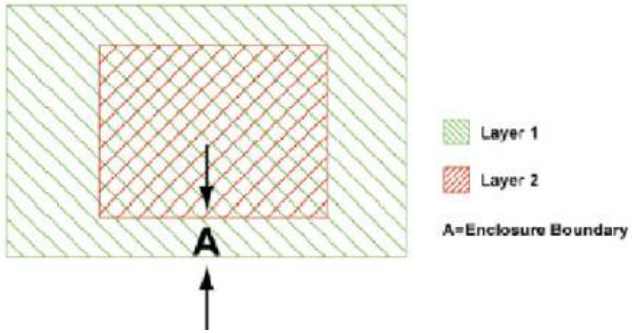
- "Light" Fields: Mask is a drawing of remaining features after etch
- "Dark" Fields: Mask is a drawing of features that are removed by etch

Minimum Features

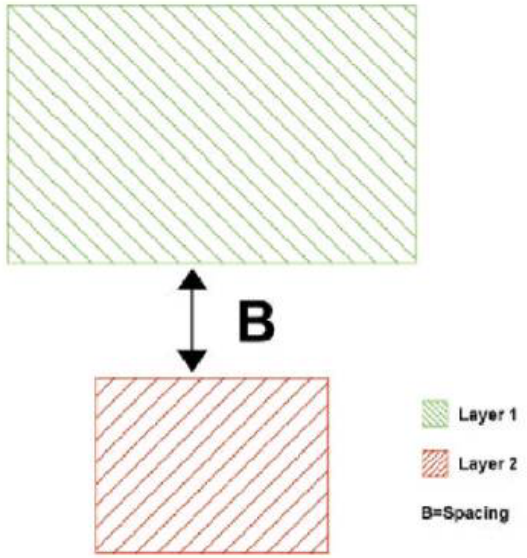
Mnemonic level name	CIF level name	GDS level number	Nominal line/space	Minimum feature	Minimum space
*POLY0	CPZ	13	3.0	2.0	2.0
*ANCHOR1	COF	43	3.0	3.0	2.0
*DIMPLE	COS	50	3.0	2.0	3.0
*POLY1	CPS	45	3.0	2.0	2.0
*POLY1_POLY2_VIA	COT	47	3.0	2.0	2.0
*ANCHOR2	COL	52	3.0	3.0	2.0
*POLY2	CPT	49	3.0	2.0	2.0
*METAL	CCM	51	3.0	3.0	3.0
*HOLE0	CHZ	41	3.0	2.0	2.0
*HOLE1	CHO	0	4.0	3.0	3.0
*HOLE2	CHT	1	4.0	3.0	3.0
*HOLEM	CHM	48	5.0	4.0	4.0

Definitions

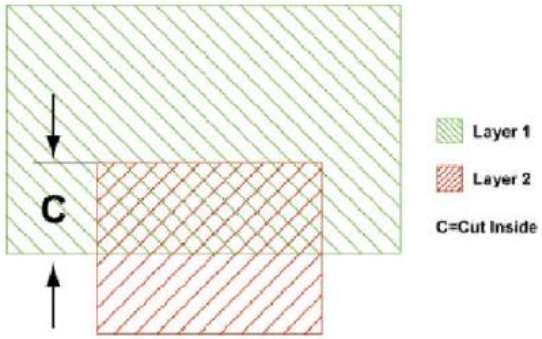
(1) Enclosure:



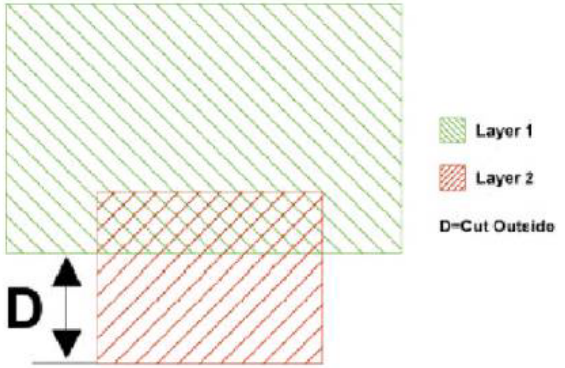
2) Spacing:



(3) Cut-in:

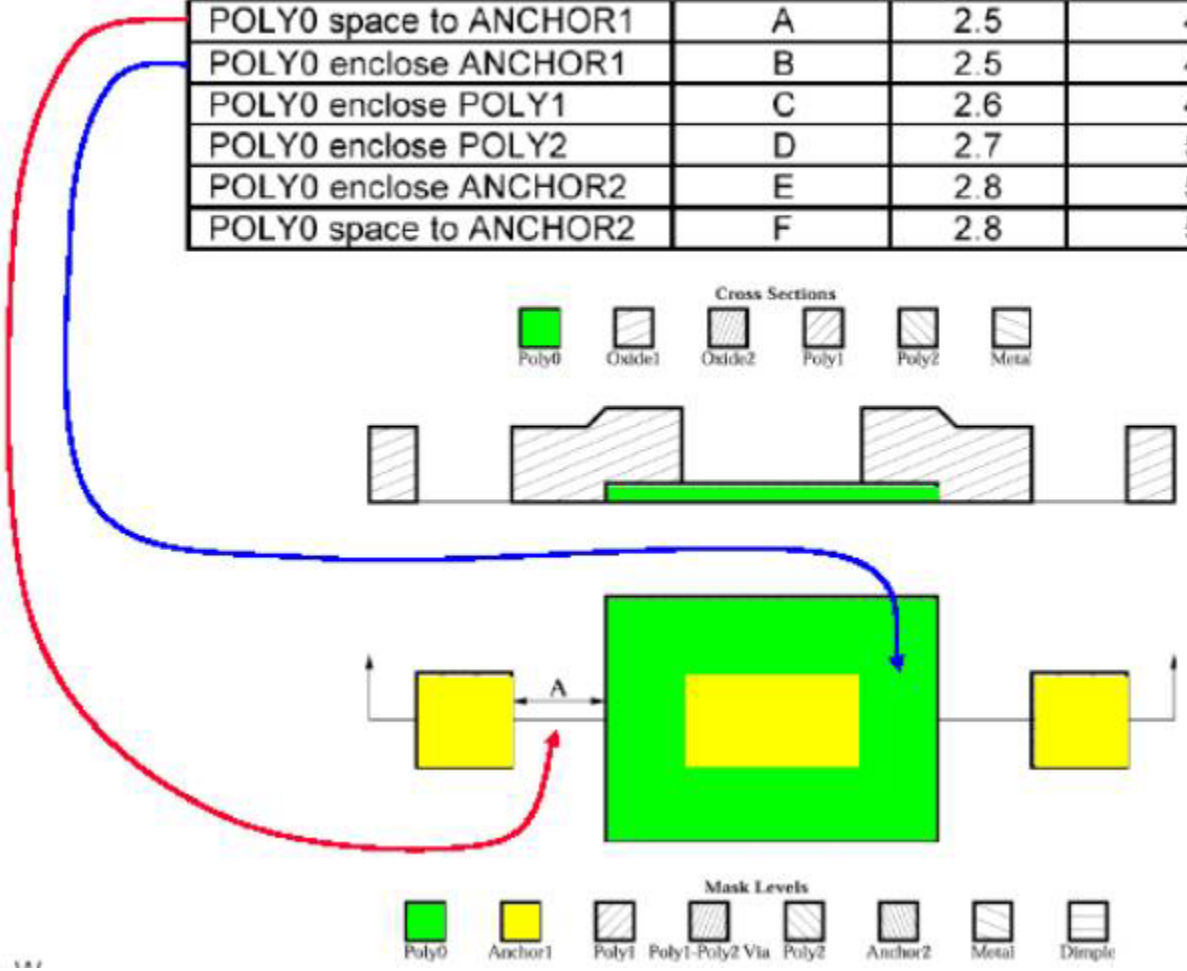


(4) Cut-out:



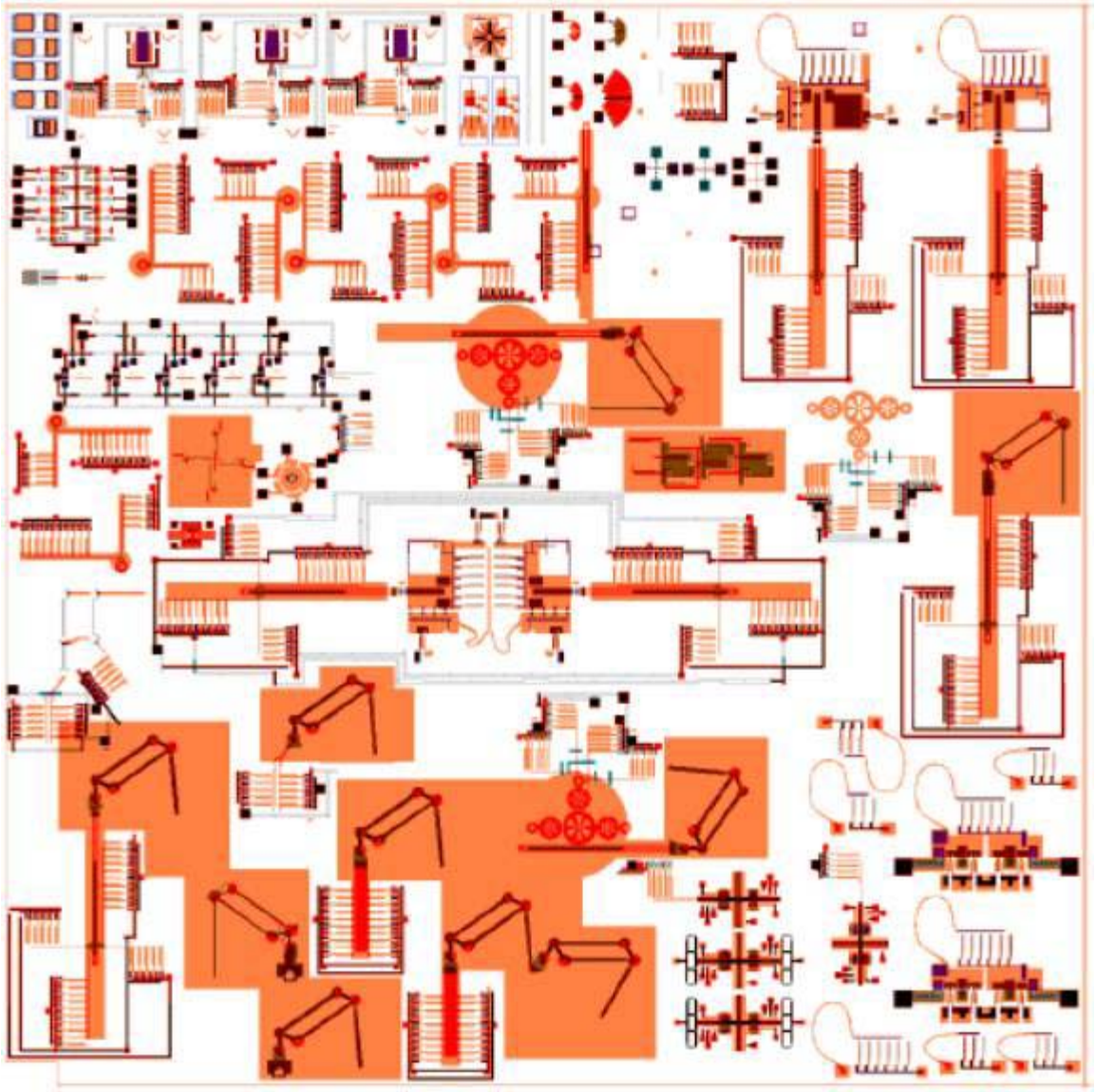
Poly0 design rules

Rule	Rule Letter	Figure #	Min. Value (μm)
POLY0 space to ANCHOR1	A	2.5	4.0
POLY0 enclose ANCHOR1	B	2.5	4.0
POLY0 enclose POLY1	C	2.6	4.0
POLY0 enclose POLY2	D	2.7	5.0
POLY0 enclose ANCHOR2	E	2.8	5.0
POLY0 space to ANCHOR2	F	2.8	5.0



M.C. Wu
U.C.L.A.

Design example

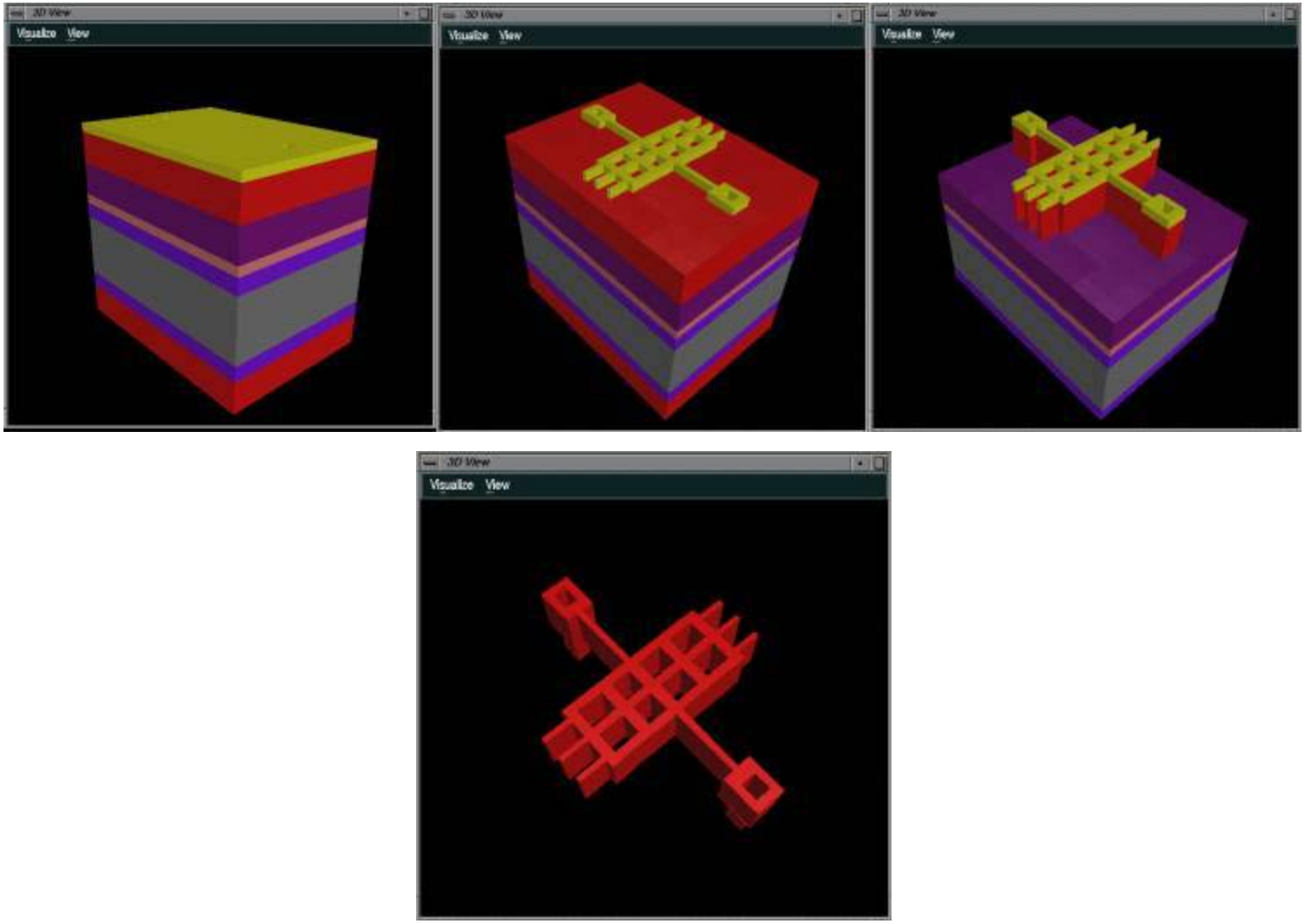


Lewis, Mireles, Borovic
ARRI, UT Arlington

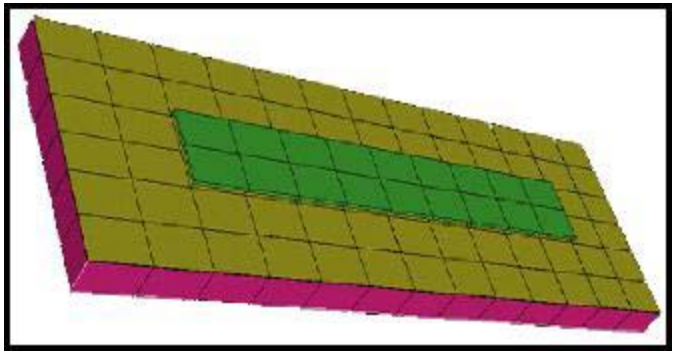
CAD/CAE and Simulation

- Rapidly Growing:
  - MEMSPro
  - ANSYS
  - IntelliSuite
  - Others
- Uses:
  - Visualize device geometry before fab
  - Predict and quantify performance
  - Reduction of time, costs

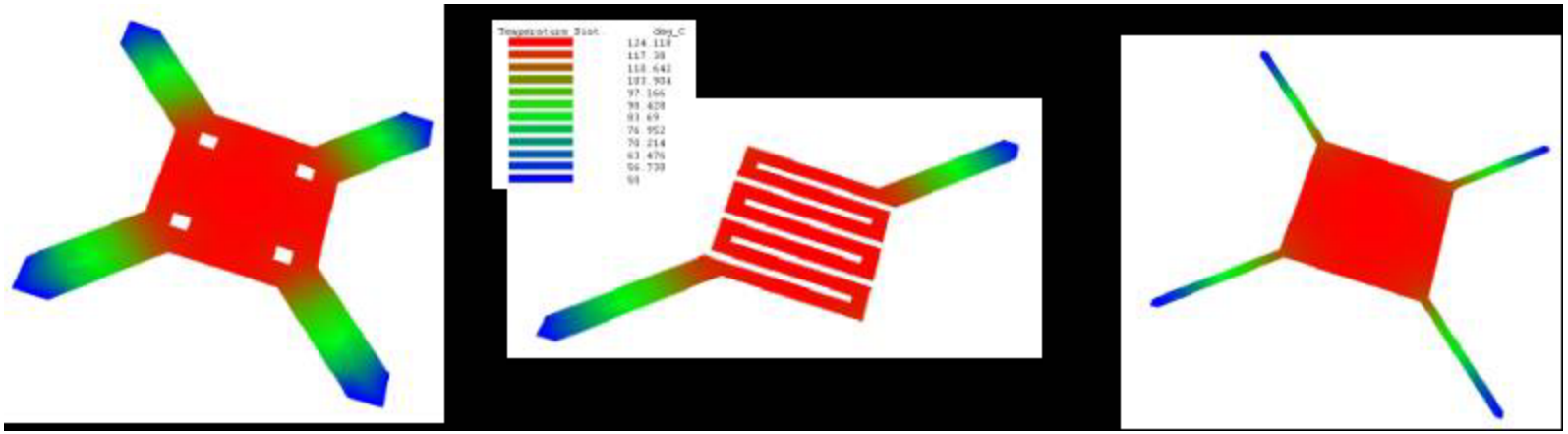
Examples


3D View
Visualize View
3D View
Visualize View
3D View
Visualize View
3D View
Visualize View

Examples



Electrostatics: charge density vs. voltage
Statics: load vs. deflection



Temperature distribution

Conclusions

- MEMS technology is impacting more fields
- Several products have reached commodity status:
  - Pressure sensors, accelerometers
- Many new areas are poised for commercial success
- MEMS as well as design tools and standarization are developing to support this growing technology