

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**

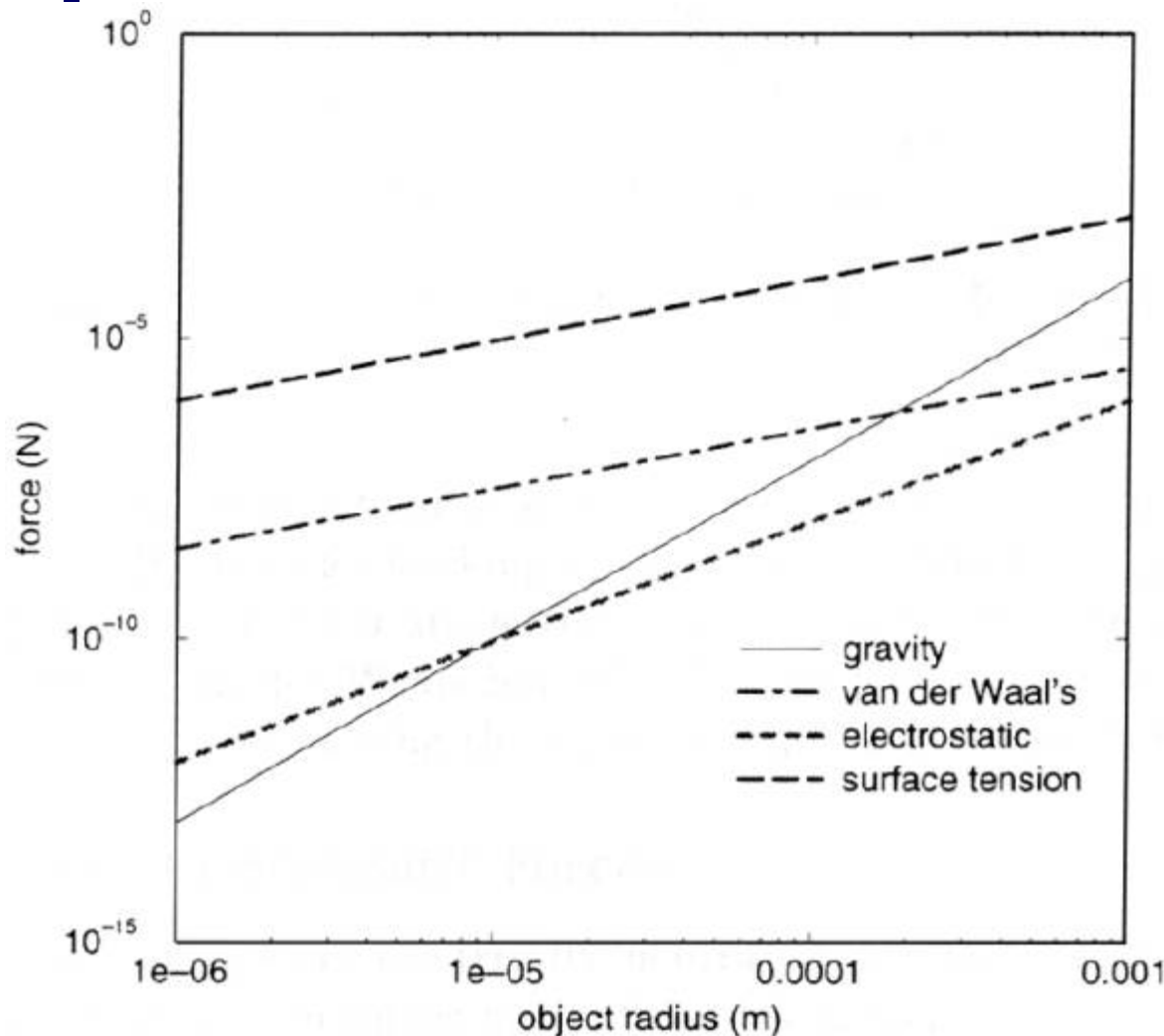
Microrobotics

	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

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

Van Der Waals

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

Surface Tension

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

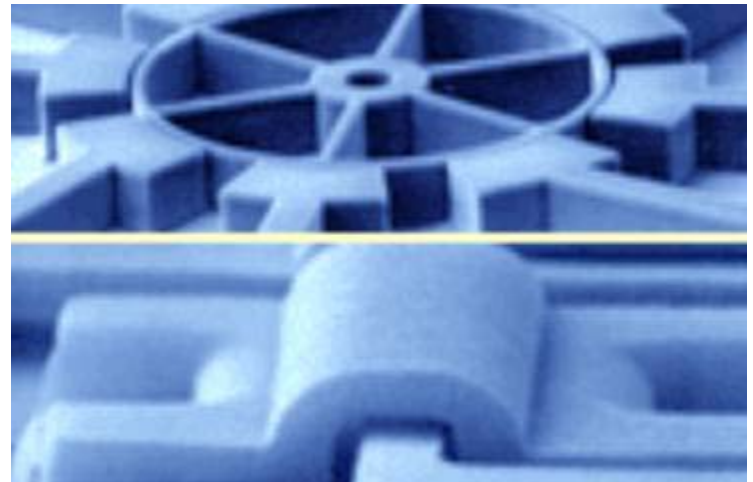
Gravity

Image: Heikki Koivo
Helsinki U. Of Tech.

A 3D perspective view of the proposed bridge deck cross-section. The model shows a wide, flat deck surface with a central longitudinal groove or channel. The deck is supported by a series of vertical structural elements, likely piers or abutments, which are shown in a light gray color. The deck itself is colored in a dark gray or black. The overall structure is symmetrical and appears to be a cross-section of a larger bridge.

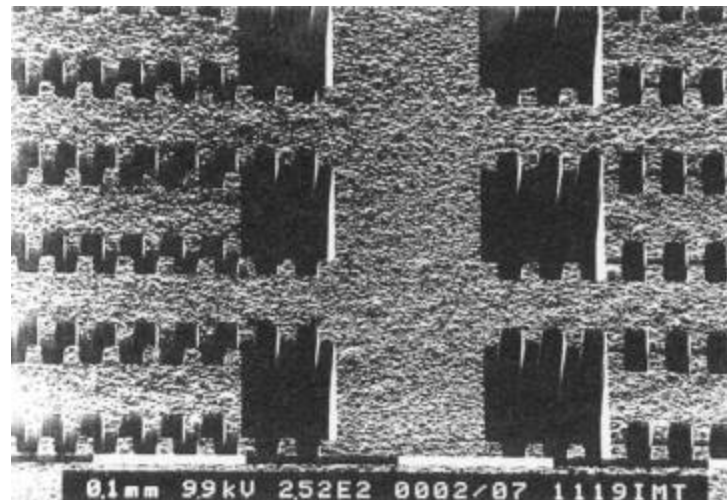
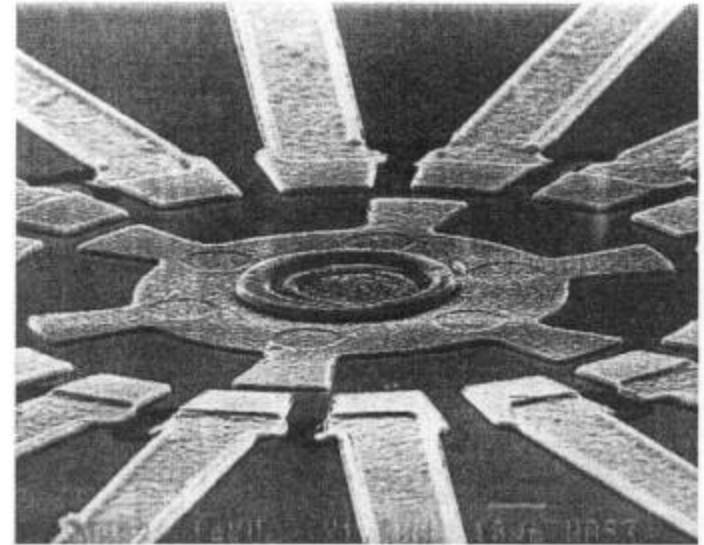
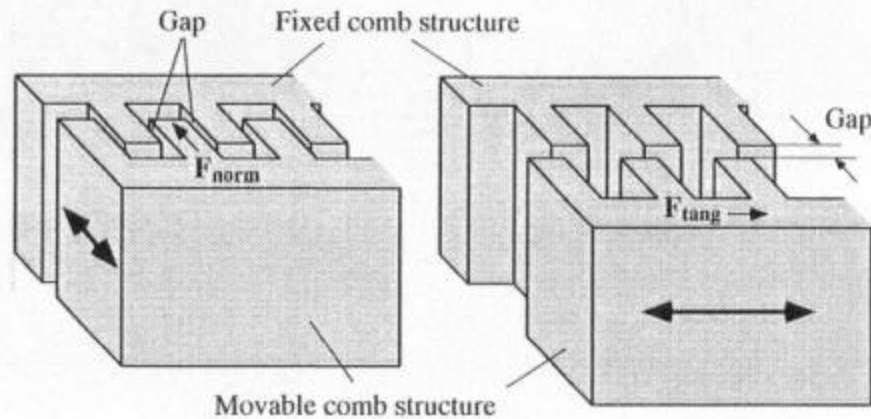
The diagram illustrates a two-link manipulator. The base is a horizontal beam with a revolute joint at its right end, labeled with axes x_0 , y_0 , and z_0 . A circular disk represents the joint, with a rotation angle θ_H indicated. A distance L is marked from the base to the joint. The first link has length l_1 and is oriented at an angle θ_v relative to the horizontal. The second link has length l_2 . The end effector is at the tip of the second link, with local axes x_2 , y_2 , and z_2 . A coordinate system x_1 , y_1 , z_1 is also shown at the joint. A horizontal arrow labeled d_1 and "DRIVE 1" indicates the prismatic joint's direction. A vertical arrow labeled z_0 and "DRIVE 2" indicates the revolute joint's axis.

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Design Issues: Actuator Design Example

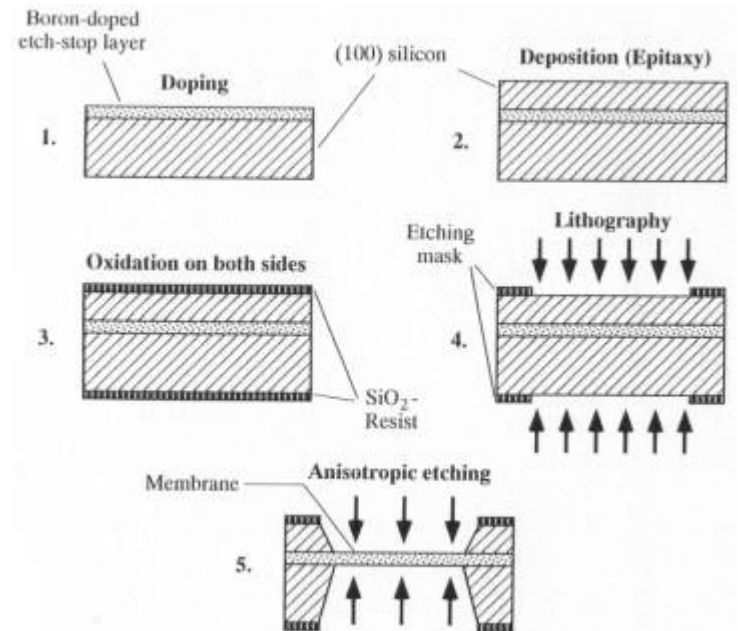
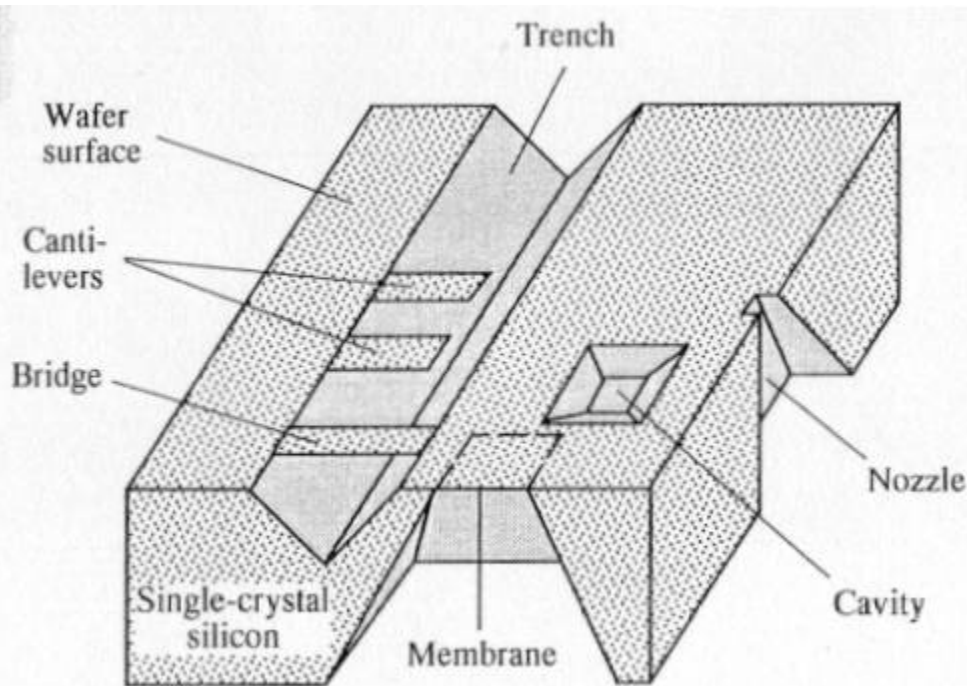
*Fatikow, Rembold
Microsystem Technology
and Microrobotics*



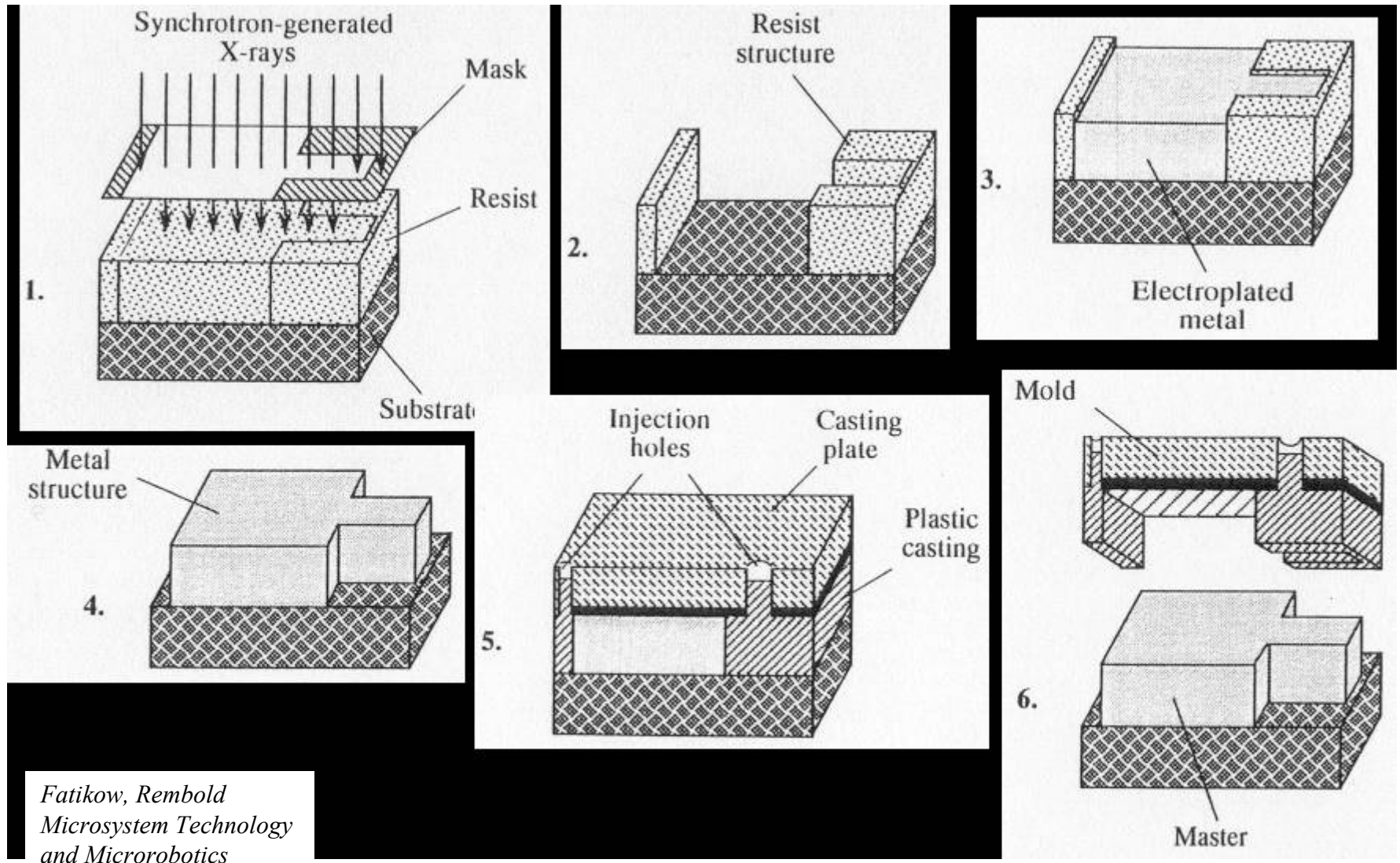
Fabrication Issues

- Basic MEMS fabrication:
Micromachining
- Most common Micromachining
 - Bulk Micromachining
 - **Surface Micromachining**
 - LIGA Technique

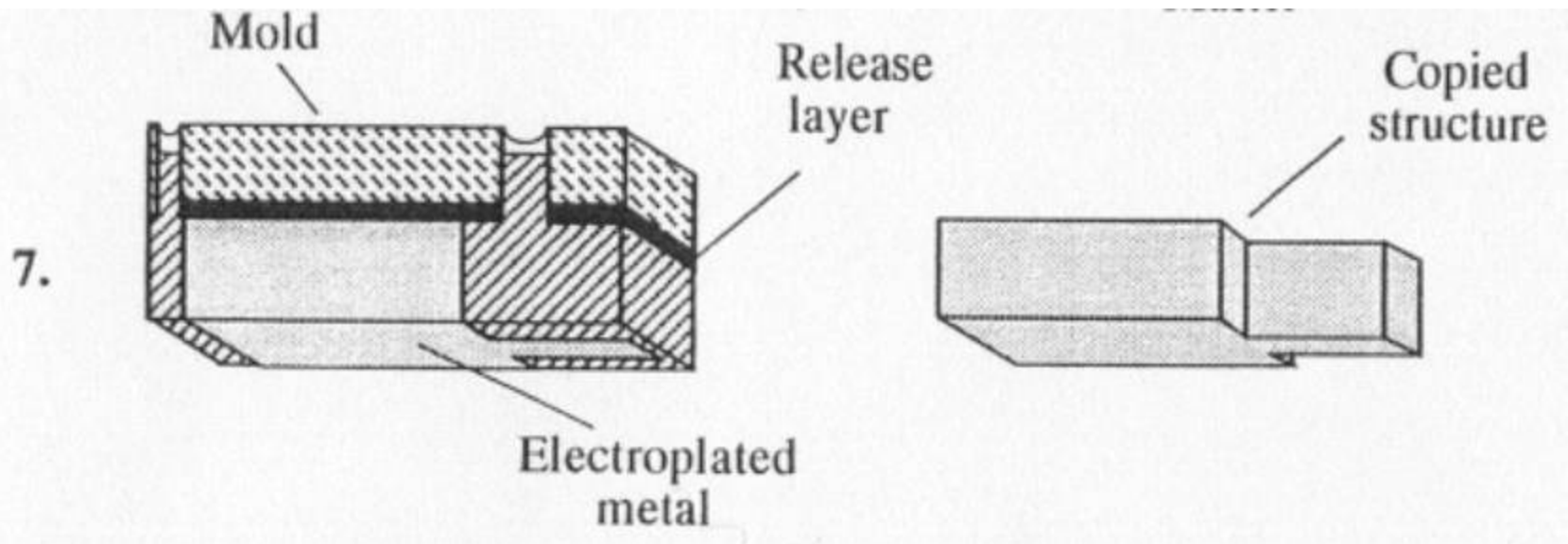
Bulk Micromachining



LIGA Technique

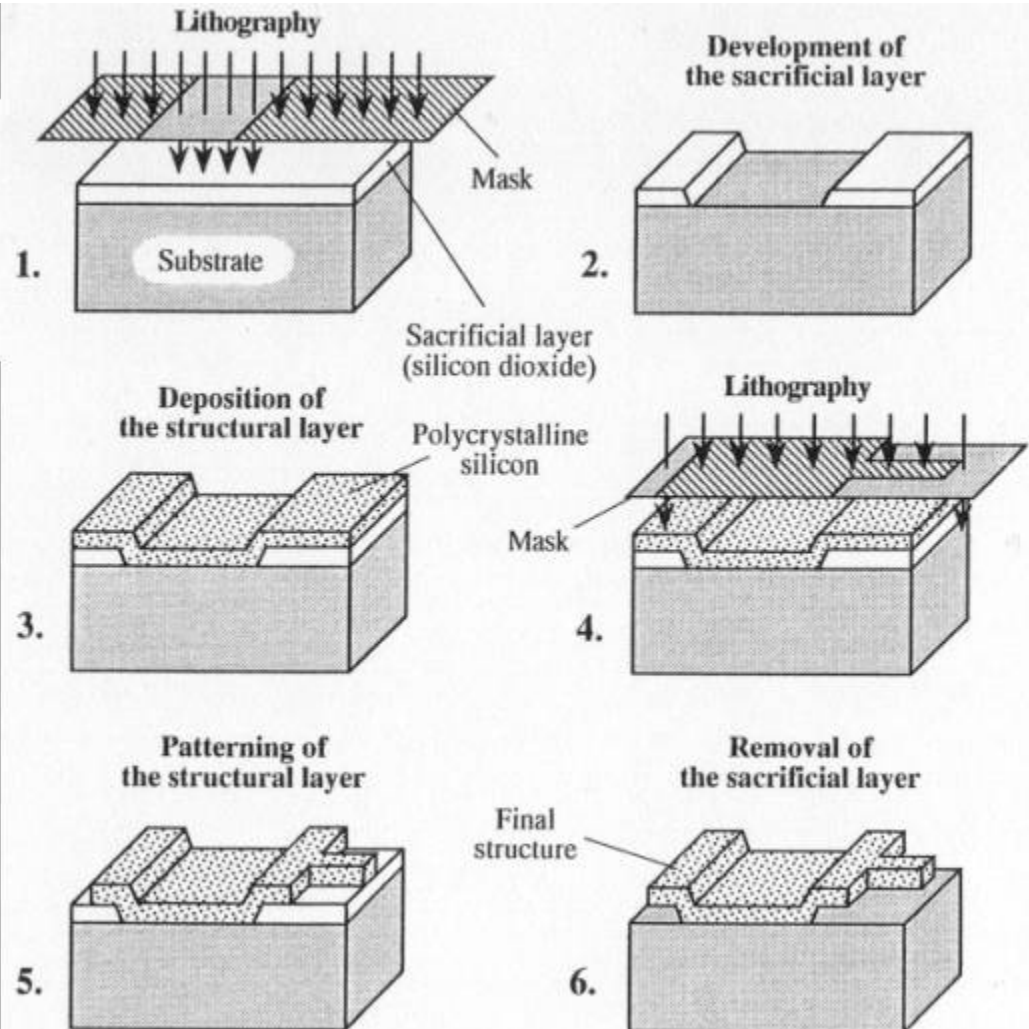
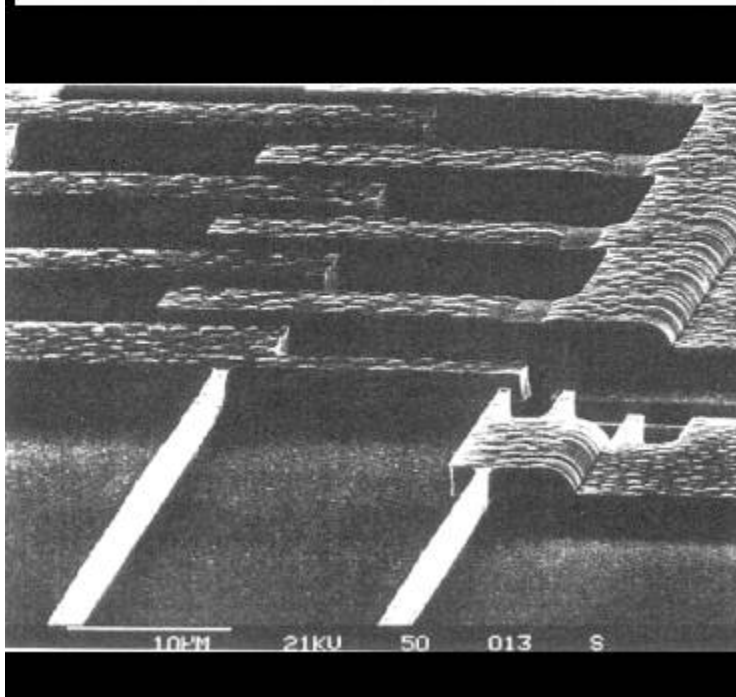
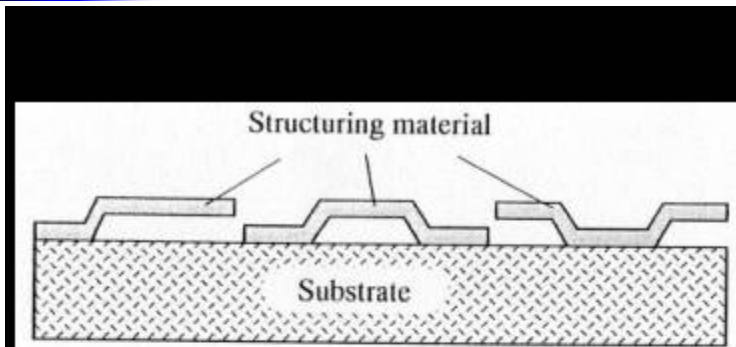


LIGA Technique

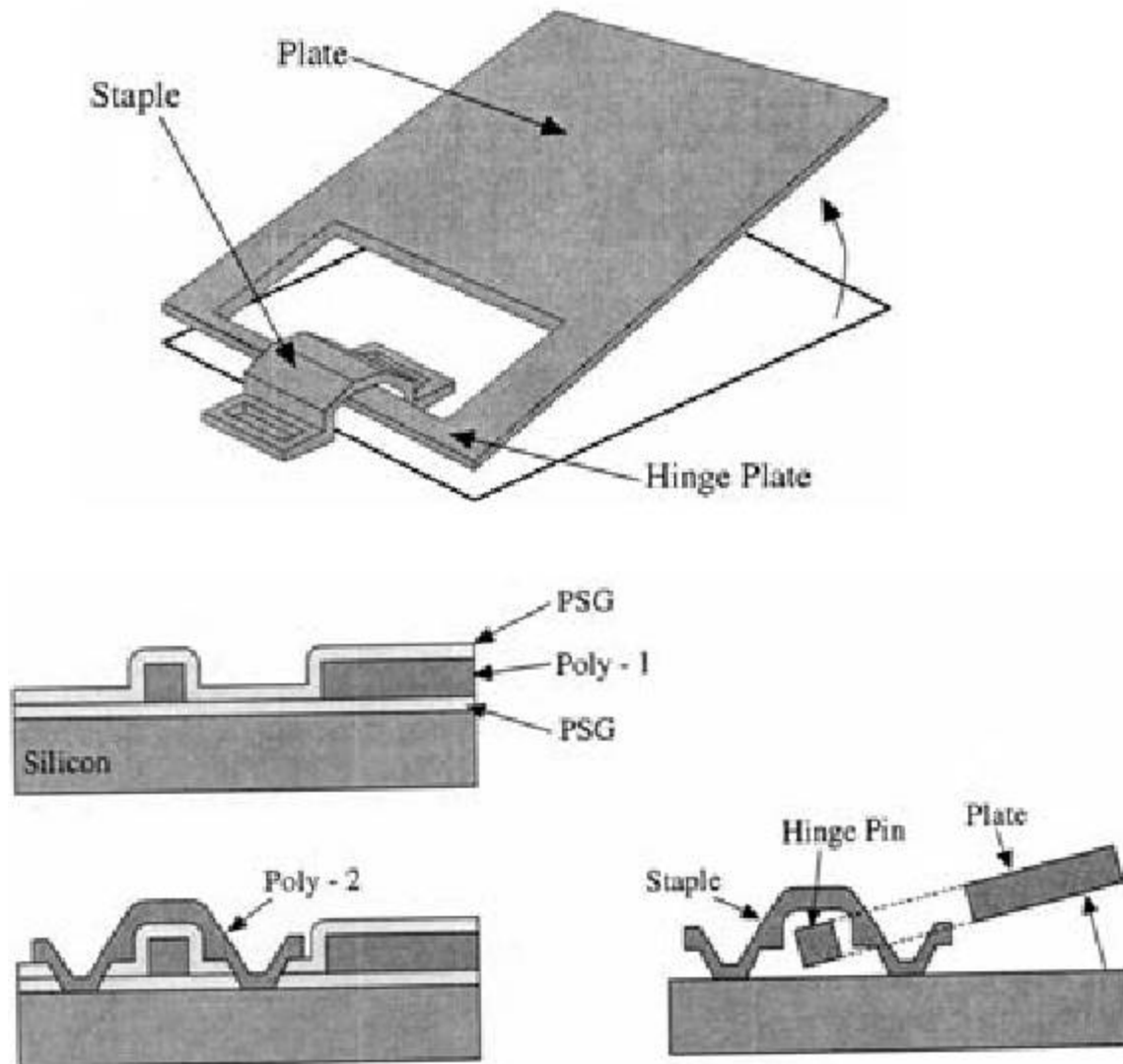


Surface Micromachining

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Example on how to build a Hinged Mechanism

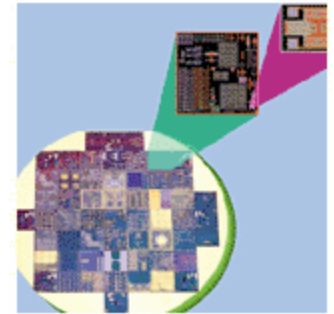


Some MEMS Foundries and Fab Processes

- 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 ea. additional cut	\$250 \$100
▲ International first cut ea. additional cut	\$300 \$150

HF Release

▲ US/Canada per 15 chips/subchips	\$375
▲ International per 15 chips/subchips	\$425

HF Release & Supercritical CO₂ Dry

▲ US/Canada per 15 chips/subchips	\$1325
▲ International per 15 chips/subchips	\$1625

Cronos Integrated Microsystems, A JDS Uniphase Company: Services, PolyMUMPs Reservation - Microsoft Internet Explorer

Address: <http://www.memsrus.com/svcsres.html>

1. Services Overview
2. Bulk Micromachining
3. Surface Micromachining
4. LIGA
5. MEMS Prototyping - PolyMUMPs
6. MEMS Prototyping - SOIMUMPs
7. MEMS Prototyping - MetalMUMPs
8. Short Course

5E. PolyMUMPs Die Site Reservations

Fill out and submit the following form to reserve PolyMUMPs die locations. A current price list of PolyMUMPs services can be found on the [main PolyMUMPs web page](#).

(NOTE: All fields with a "*" must be filled out)

*Number of Die Locations to purchase

*Number of Subdicing Cuts needed per die

*Number of Chips/Subchips to release using HF

*Number of Chips/Subchips to release using HF and dry using Supercritical CO₂ Dry process

*PolyMUMPs Run#

*Name

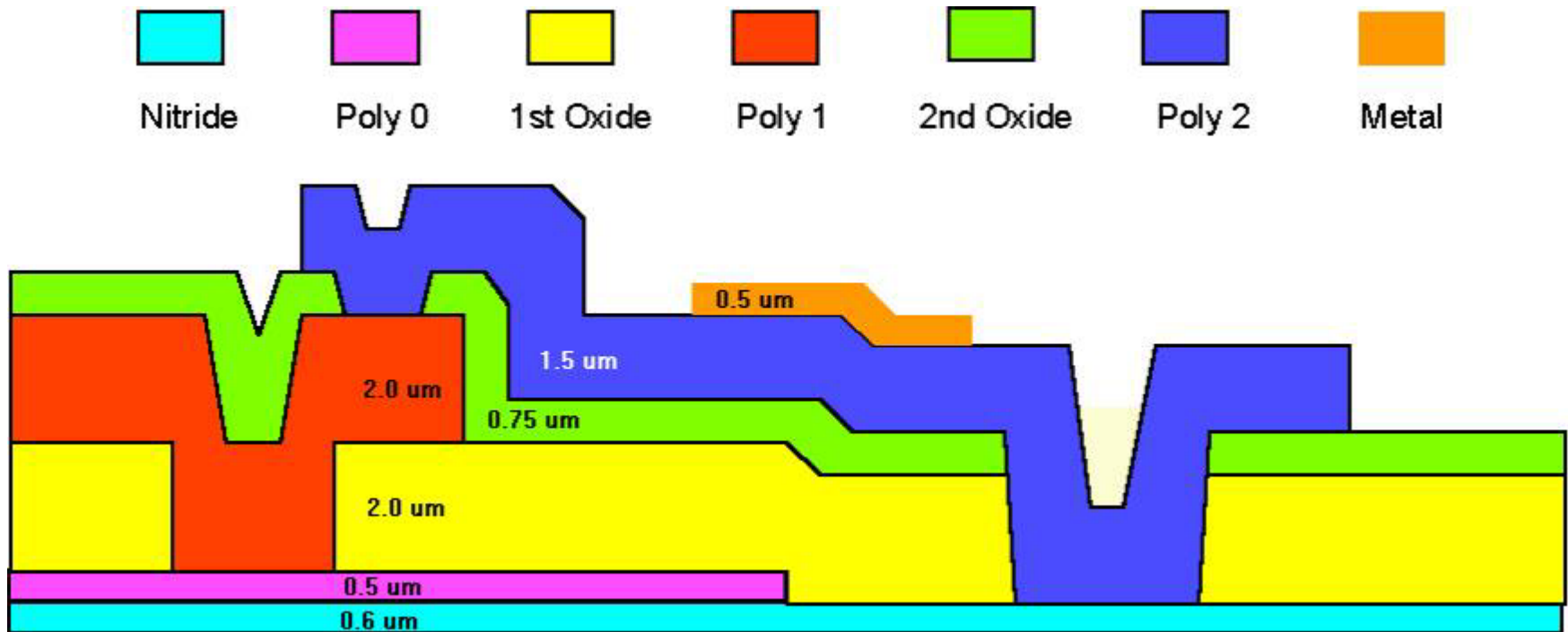
*Organization

*Address

51 - deadline July 30, 2002
52 - deadline September 10, 2002
53 - deadline October 22, 2002
54 - deadline December 3, 2002

Done Internet

PolyMUMPs



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

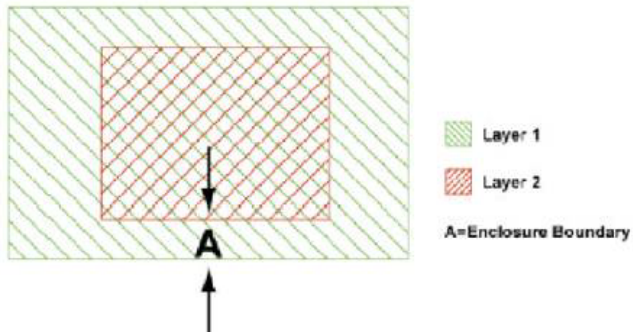
- “Light” Fields: Mask is a drawing of remaining features after etch
- “Dark” Fields: Mask is a drawing of features that are removed by etch

Minimum Features

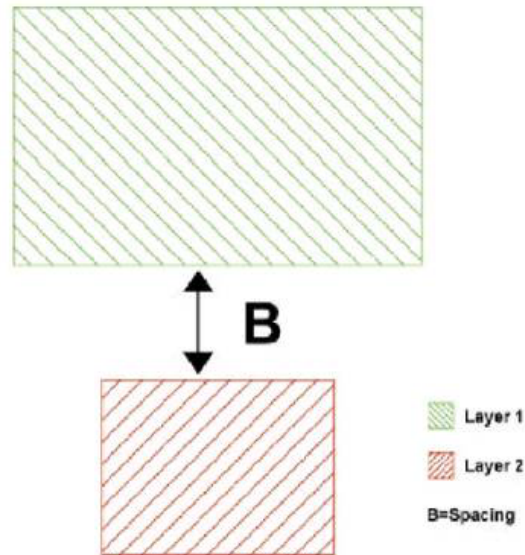
Mnemonic level name	CIF level name	GDS level number	Nominal line/space	Minimum feature	Minimum space
*POLY0	CPZ	13	3.0	2.0	2.0
*ANCHOR1	COF	43	3.0	3.0	2.0
*DIMPLE	COS	50	3.0	2.0	3.0
*POLY1	CPS	45	3.0	2.0	2.0
*POLY1_POLY2_VIA	COT	47	3.0	2.0	2.0
*ANCHOR2	COL	52	3.0	3.0	2.0
*POLY2	CPT	49	3.0	2.0	2.0
*METAL	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

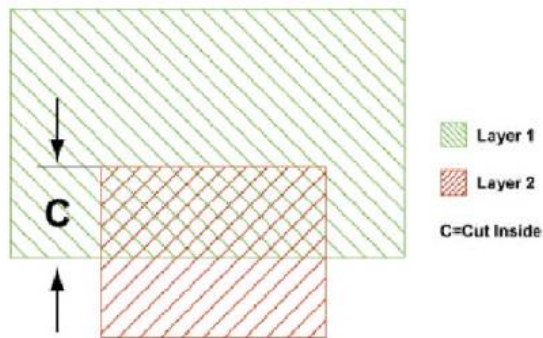
(1) Enclosure:



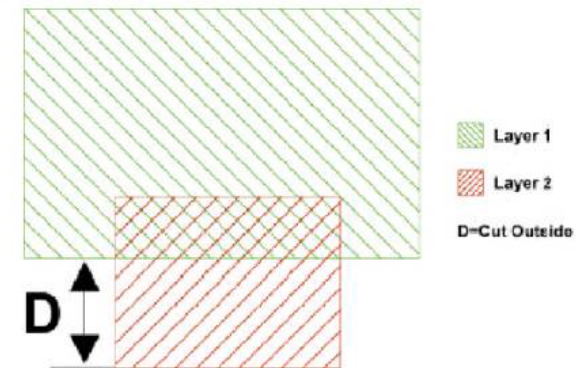
2) Spacing:



(3) Cut-in:

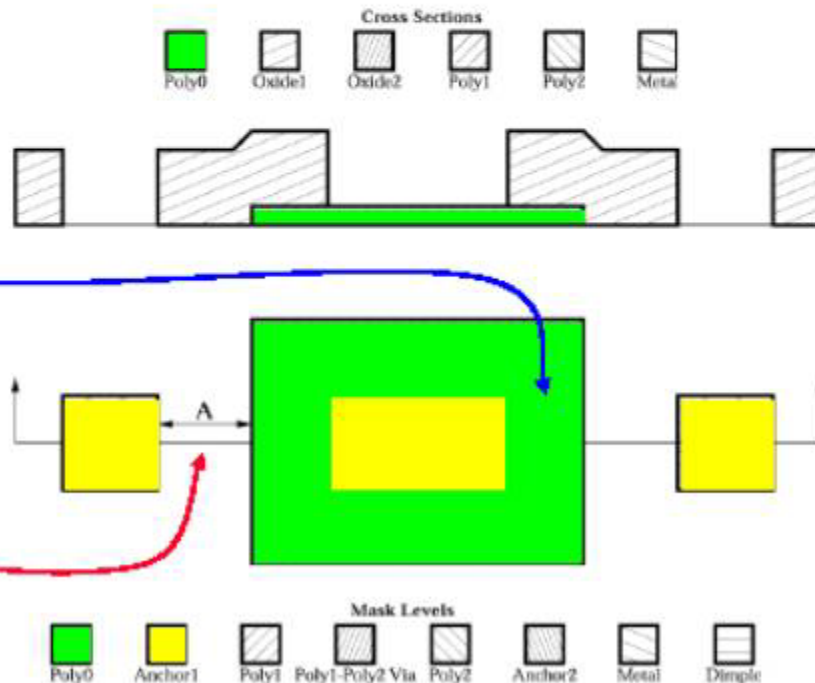


(4) Cut-out:

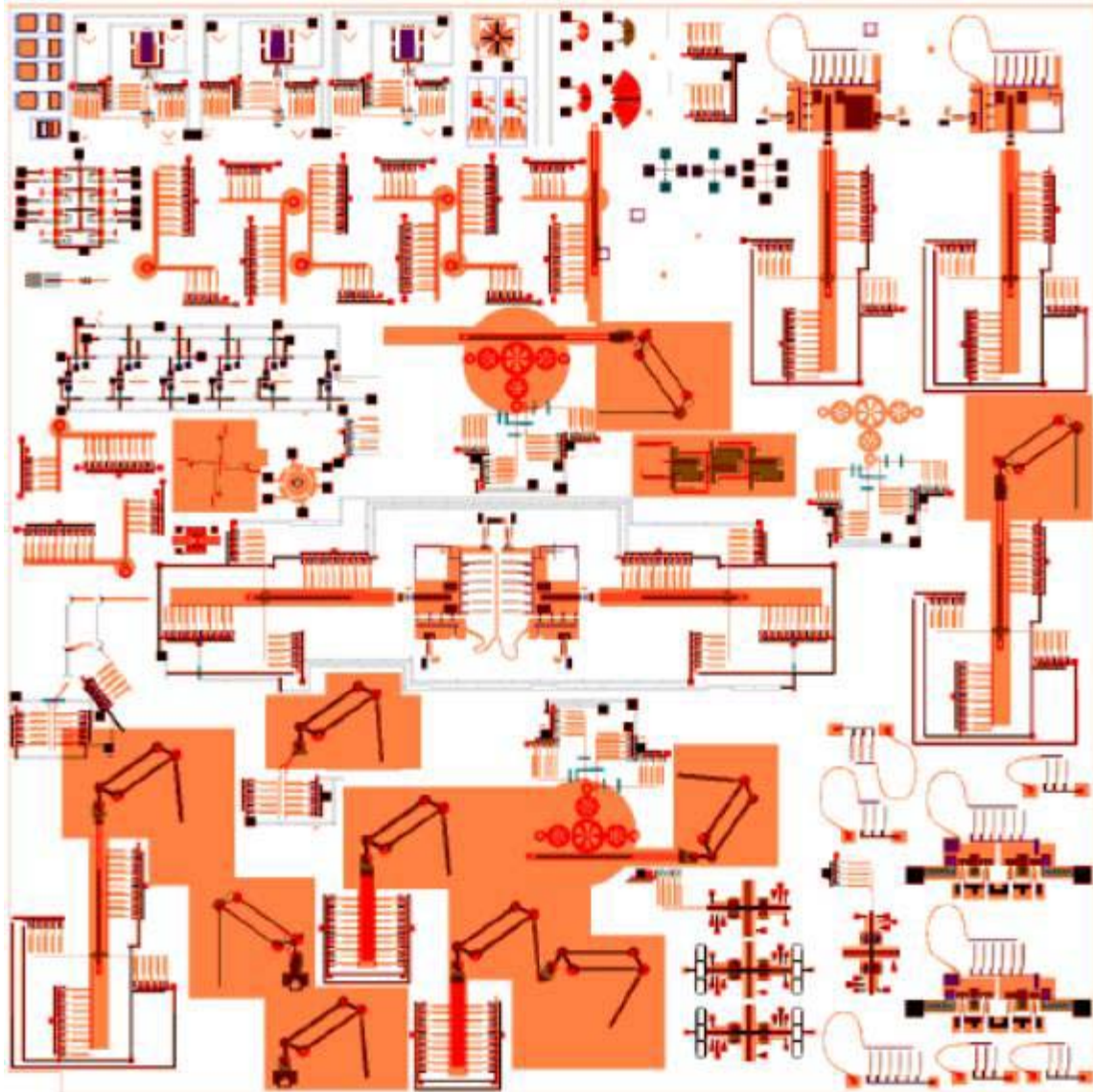


Poly0 design rules

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



Design example



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CAD/CAE and Simulation

■ Rapidly Growing:

- MEMSPro

- ANSYS

- IntelliSuite

- Others

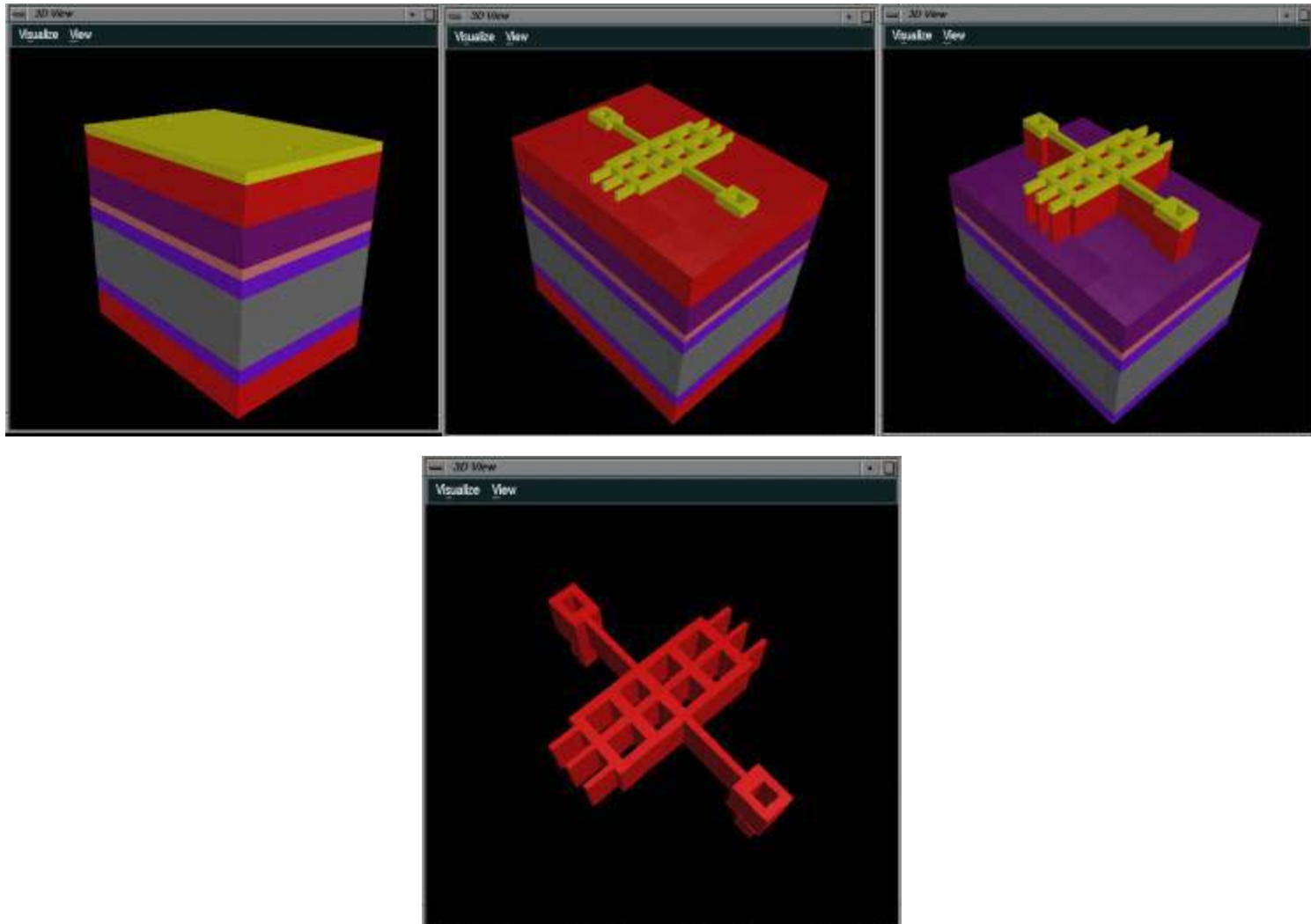
■ Uses:

- Visualize device geometry before fab

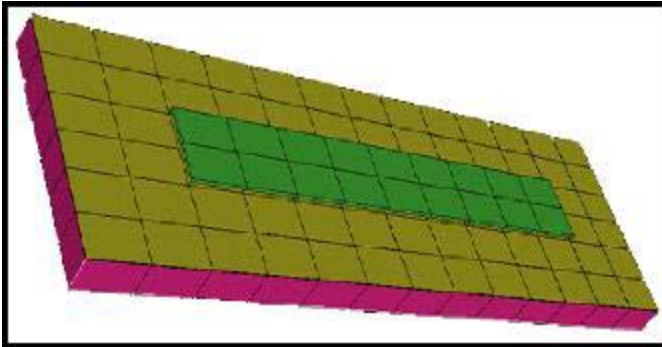
- Predict and quantify performance

- Reduction of time, costs

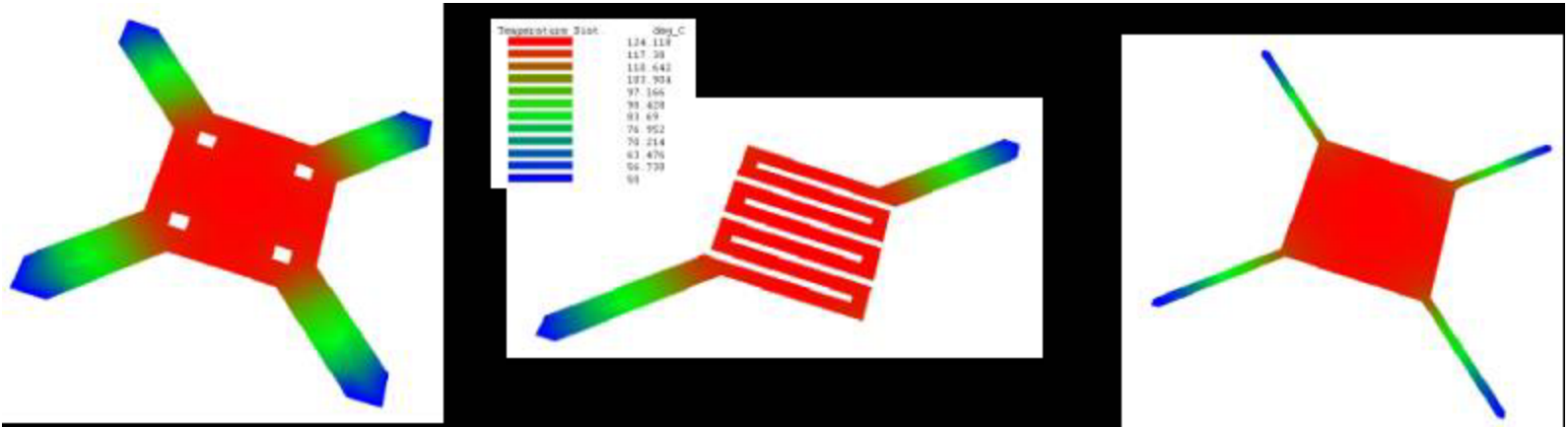
Examples



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 standardization are developing to support this growing technology