Wright State University

EE480/680
Micro-Electro-Mechanical Systems (MEMS)
Summer 2006

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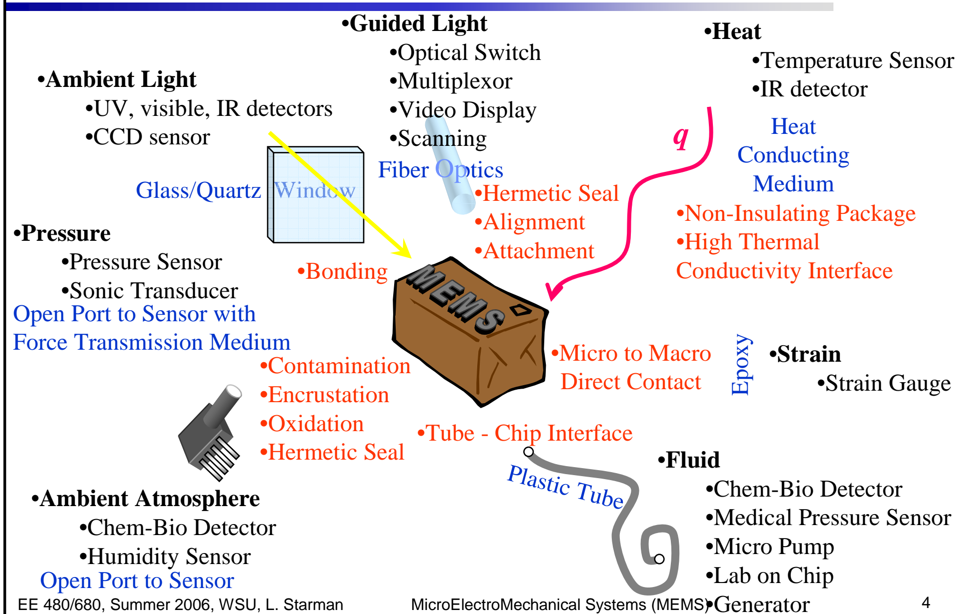
Packaging

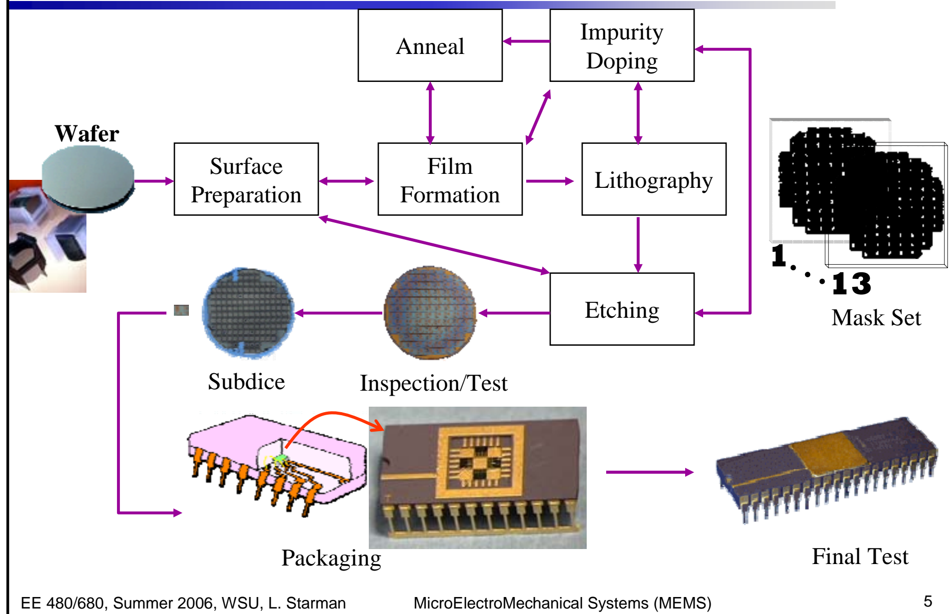
Overview

- Considerations when packaging MEMS
- Self-Assembly of MEMS
- Integration

Packaging: Considerations

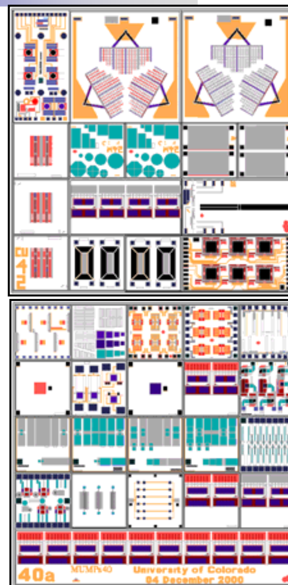


Fabrication Sequence



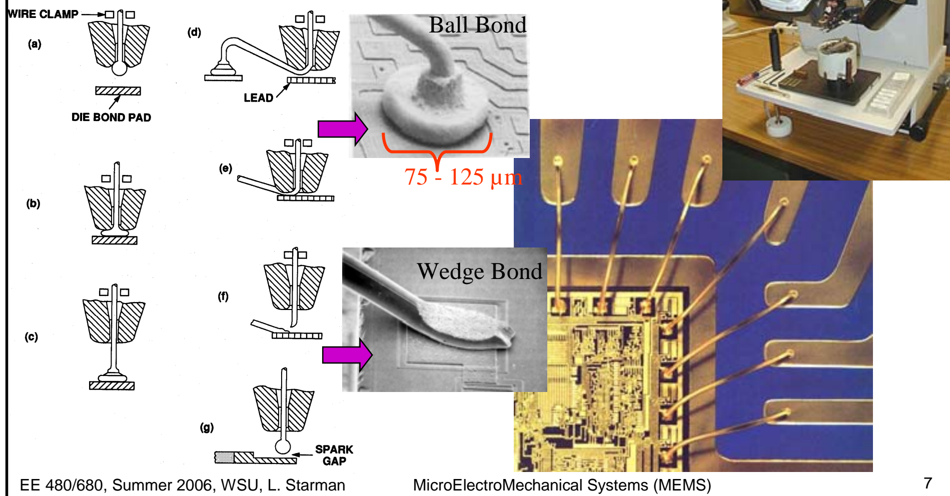
Dicing

- Precision slices of semiconductor or ceramic wafers
  - 100 µm wide cuts in Si with a diamond blade



Wire Bonding

- To connect electrical contacts on chip to package or other chips
  - Gold or Aluminum wires 25 μm in diameter



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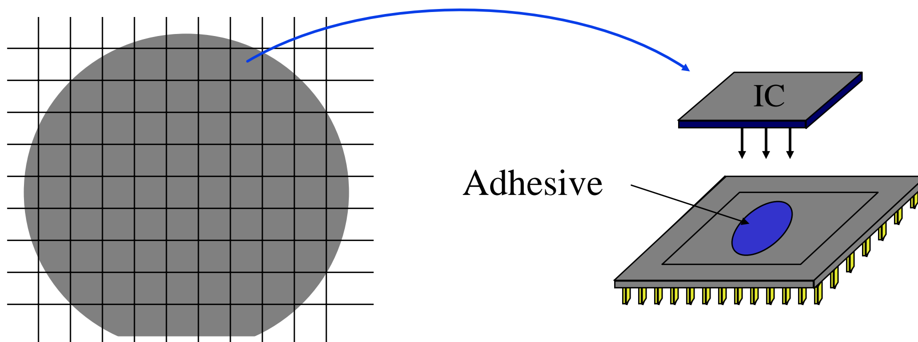
Packaging



Wirebonding

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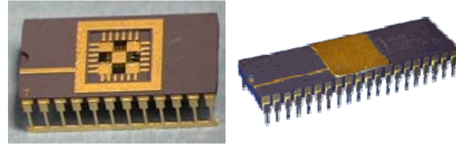
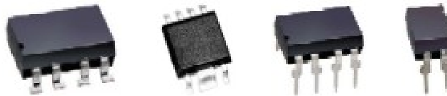
Packaging

- Common Types of Packages
  - Ceramic with brazed cap



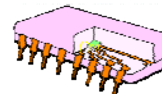
  - Molded



  - Metal Can

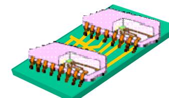
Microelectronic Packaging Classifications

- As defined in the packaging text by Pecht, packaging is done on five levels, each with its own requirements:
  - Zero-level packaging – The die itself that includes interconnections between different components on the die.
  - Level 1 packaging – The die is put in a larger package made of metal, ceramic, plastic, or other materials, and the die is wired to the package.

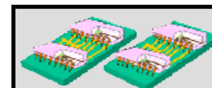


  - Level 2 packaging – Multiple chips are packaged together into one module. This level of packaging is sometimes not used or needed.

  - Level 3 packaging – Several Level 1 and/or Level 2 packages, along with discrete circuit components, are integrated into a circuit board, often with interconnections printed on it.

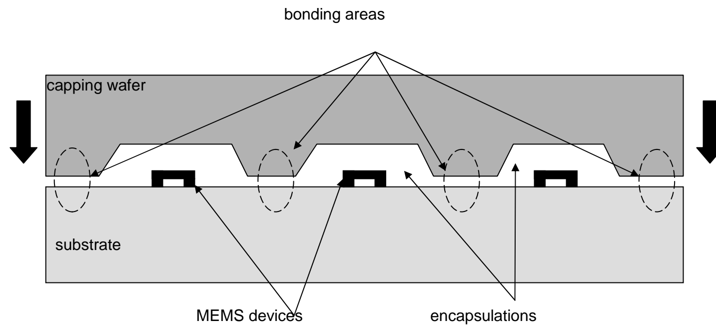


  - Level 4 packaging – Several circuit boards are integrated together, along with associated power circuits, cooling, and an enclosure, to create a fully packaged working product.



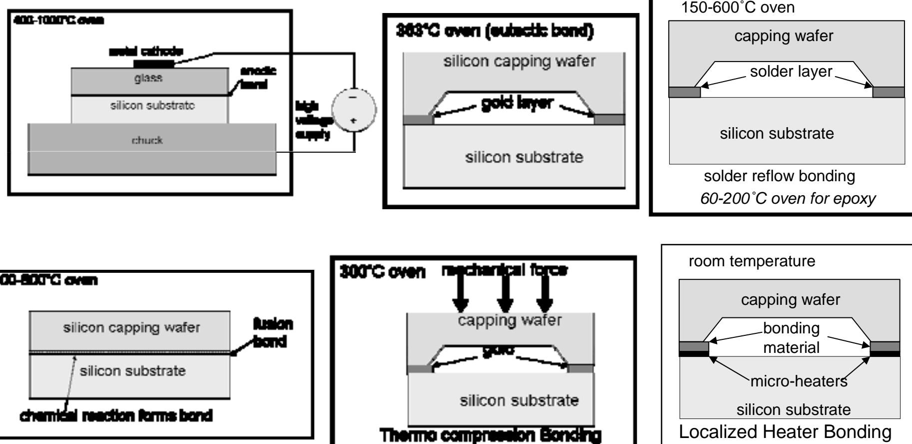
0-level

- Wafer Bonding – massively parallel encapsulation



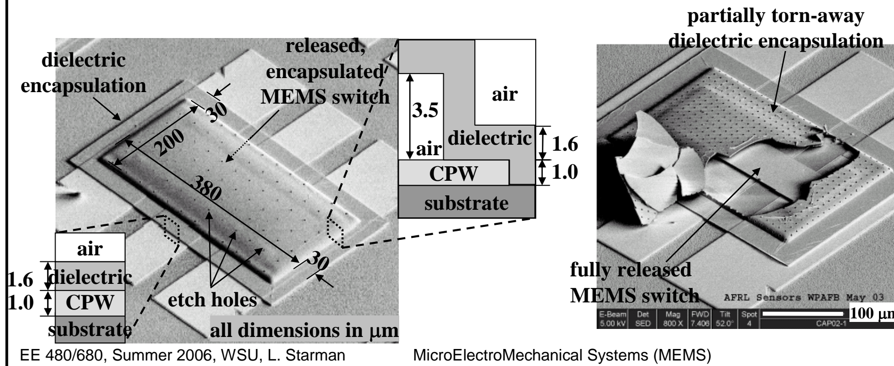
0-level

- Wafer Bonding Techniques



0-level

- Thin Film Encapsulation
  - (1) Microstructure Fabrication, (2) Additional Sacrificial Layer, (3) Encapsulation Layer, (4) Release of (2).
  - Encapsulation Layer is either full of holes or "porous"
  - A solid encapsulation can be use if sacrificial layer can be decomposed or diffuse out of encapsulation.



0-level

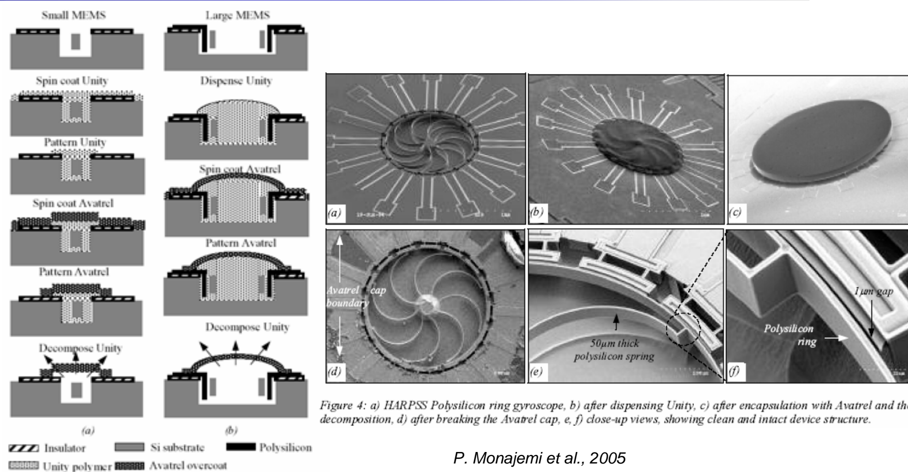
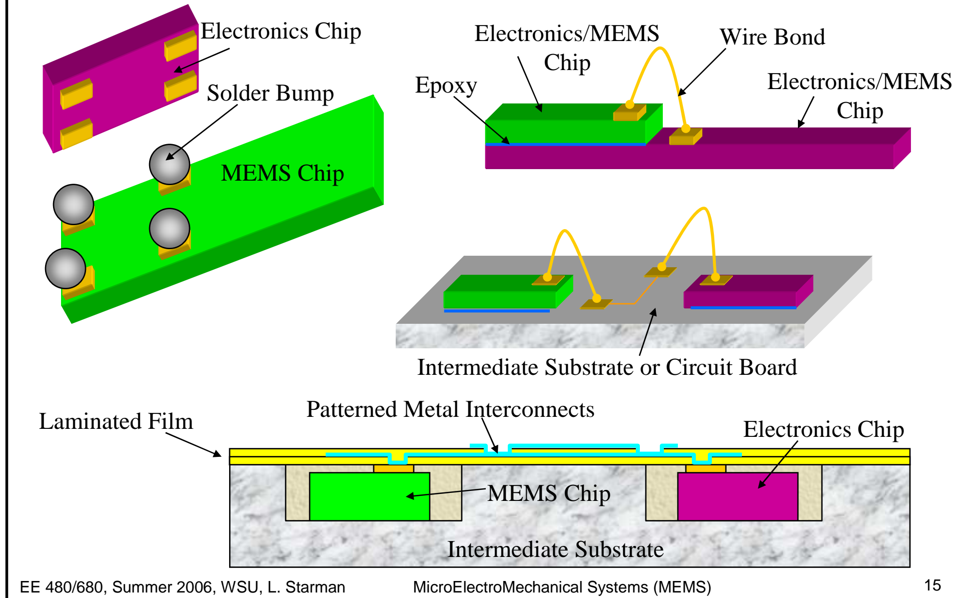


Figure 4: a) HARPSS Polysilicon ring gyroscope, b) after dispensing Unity, c) after encapsulation with Avatrel and thermal decomposition, d) after breaking the Avatrel cap, e, f) close-up views, showing clean and intact device structure.

P. Monajemi et al., 2005

Decompose Unity @ 200-300 °C

Level 2



Packaging: Examples

Motorola MPX4080D series piezoresistive differential pressure sensor

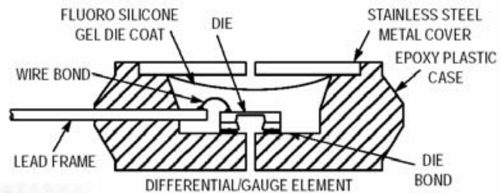
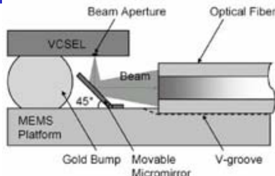


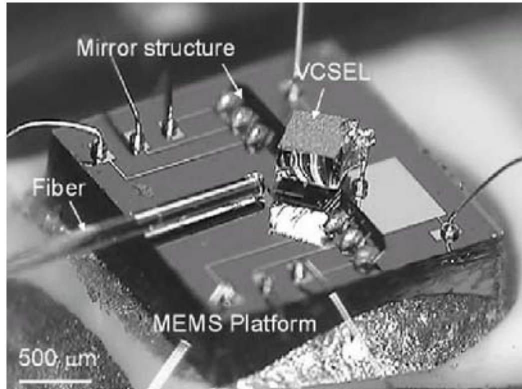
Figure 3. Cross–Sectional Diagrams (Not to Scale)

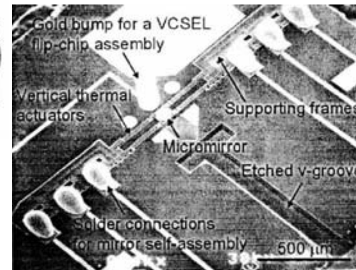
Open port to sensor and open port with transmission medium.

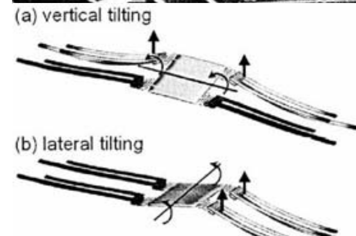
Packaging: Examples

K. Ishikawa et al., “An Integrated Micro-Optical System For Laser-to-Fiber Active Alignment,” MEMS 2002.









DMD Packaging

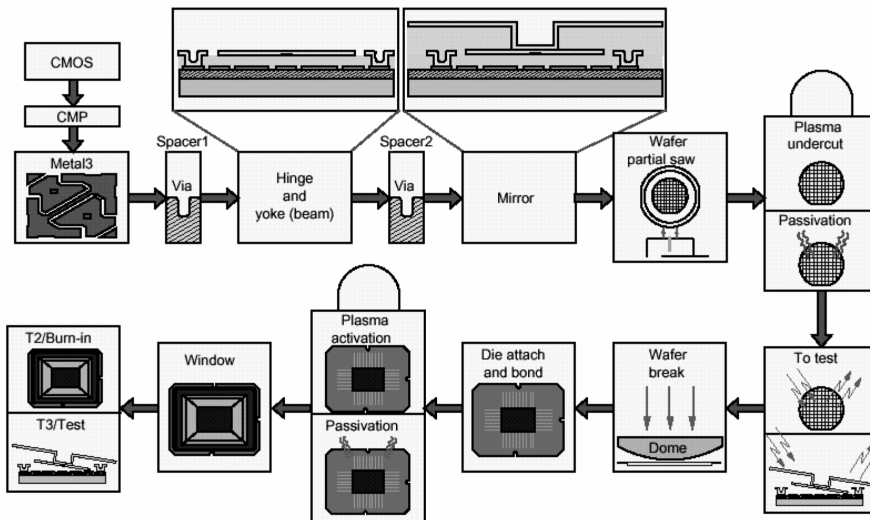
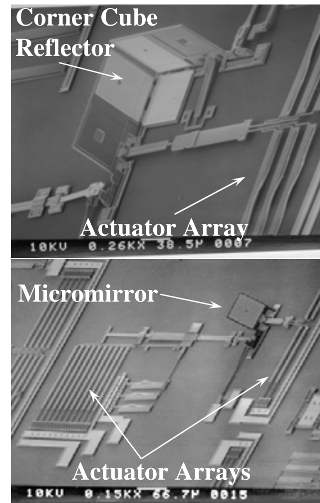


Figure from: Michael A. Mignardi, “From ICs To DMDs,” TI Technical Journal, Jul-Sep, 1998, pp. 56–63.

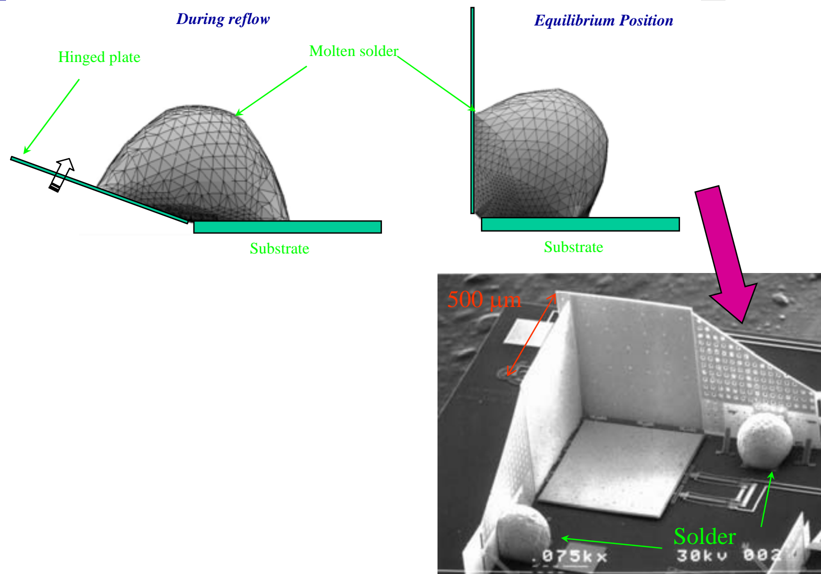
Self-Assembly

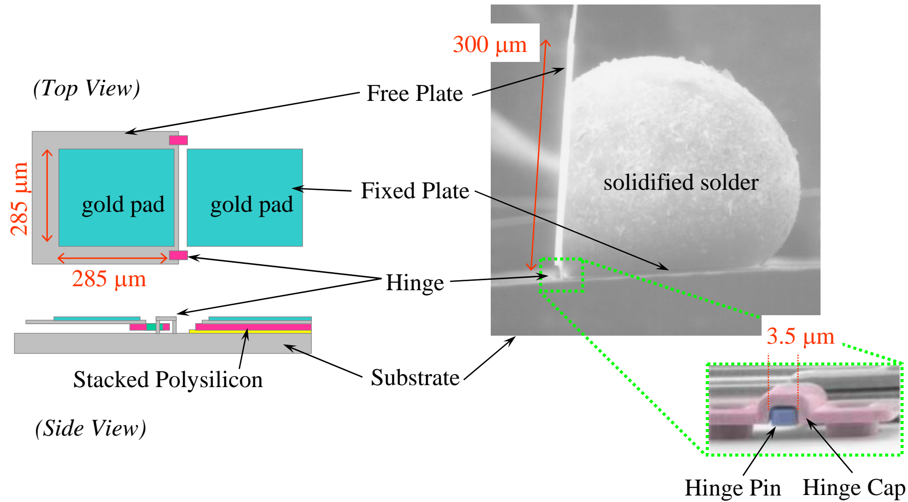
- Problem:
  - Surface micro-machining creates planar structures.
  - The assembly (lifting) of hinged micro-structures is commonly used to achieve 3-D functionality.
  - Current assembly methods are complex, difficult, real-estate consuming, impractical, unreliable, and/or not fit for commercial production.
- Solution -- Solder Self-Assembly:
  - Simple, Compact, and Powerful
  - Existing Processing Step
  - No External Control Wiring
  - Good Electrical, Mechanical, and Thermal Connection
  - Suited for Mass Production



Example of self-assembly using MEMS

Solder Self-Assembly




Description of Solder Self-Assembly of MEMS
• The surface tension of molten solder is harnessed to pull micro-structures together.
300 µm
(Top View)
Free Plate
285 µm
gold pad
gold pad
Fixed Plate
solidified solder
285 µm
Hinge
3.5 µm
Stacked Polysilicon
Substrate
(Side View)
Hinge Pin
Hinge Cap
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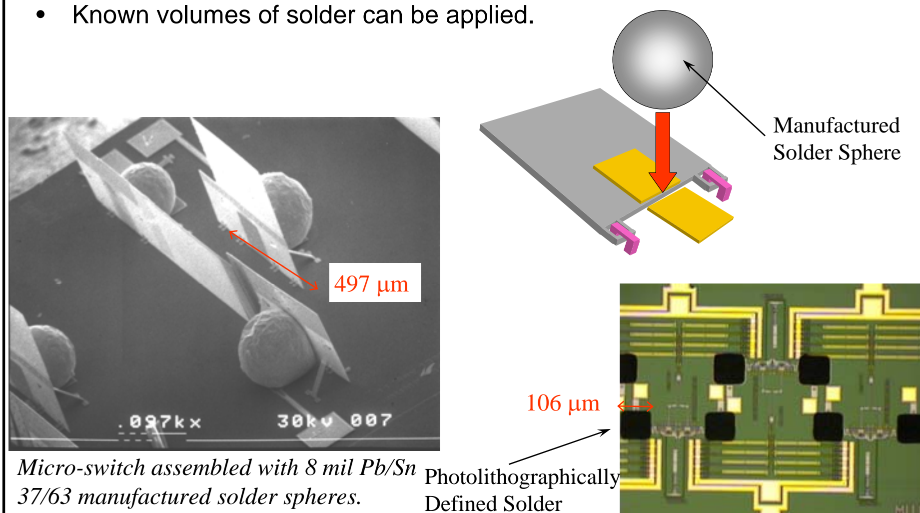
Description of Solder Self-Assembly of MEMS
• The basic solder assembly element can be attached to larger structures.
• Known volumes of solder can be applied.
Manufactured
Solder Sphere
497 µm
.097kx
30kv 007
106 µm
Micro-switch assembled with 8 mil Pb/Sn 37/63 manufactured solder spheres.
Photolithographically
Defined Solder
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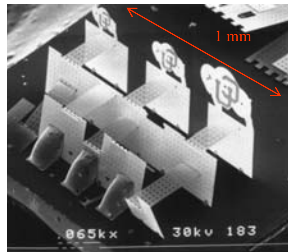
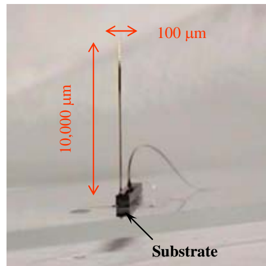
Solder Self-Assembly Examples

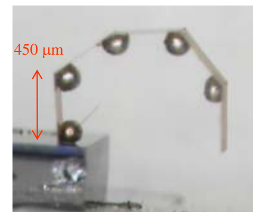
- Complex hinged structures and arrays can be created that were previously unrealizable using standard micro-machining processes.
  - The following examples were assembled using volumes of solder equivalent to 8 mil diameter spheres.



14 Hinged-Structure



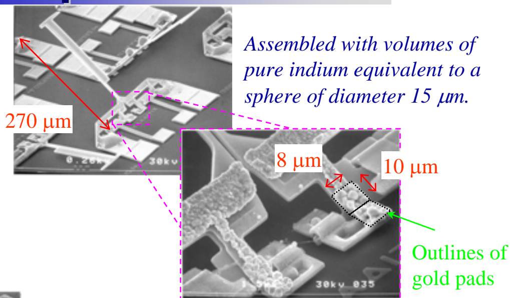
2 Dipole Antennas



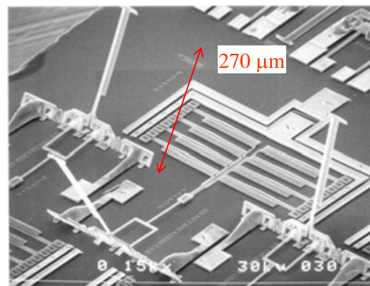
5-plate structure

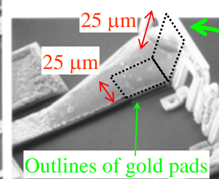
Solder Self-Assembly Examples

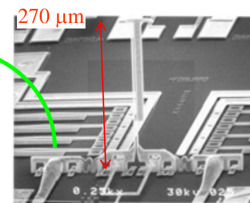
- Deposition & Microrobot Legs



Assembled with volumes of pure indium equivalent to a sphere of diameter 15 µm.



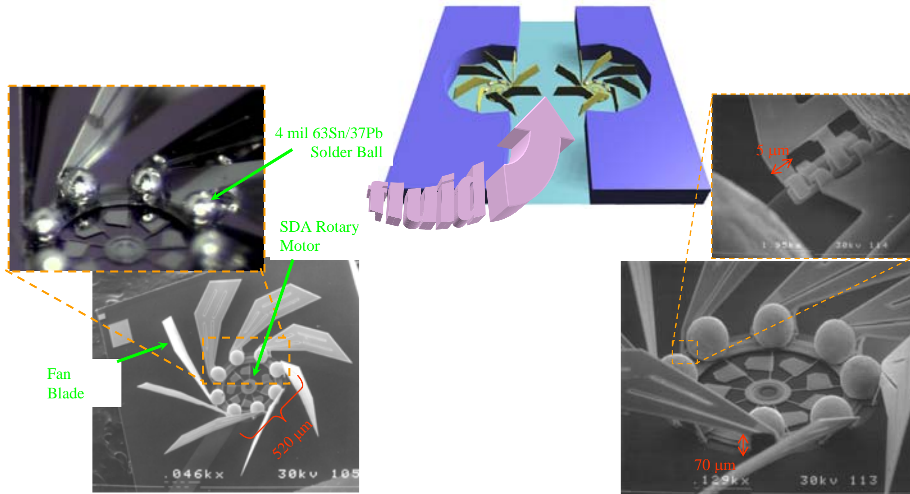




Assembled with volumes of pure indium equivalent to a sphere of diameter 37 µm.

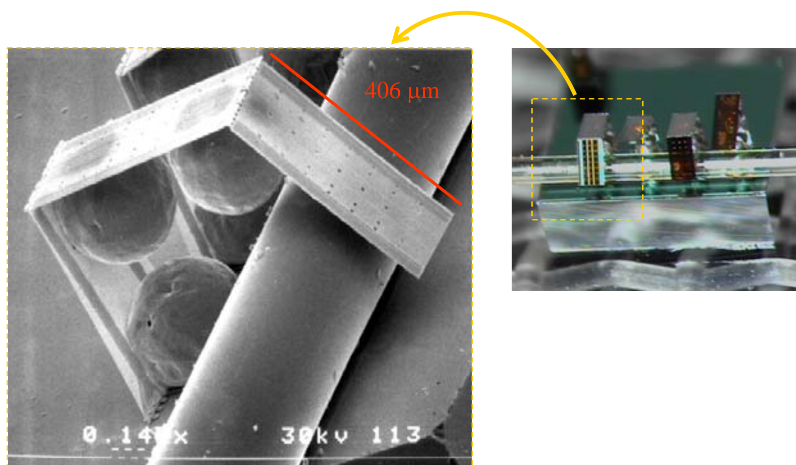
Solder Self-Assembly Examples

- Solder self-assembled micro axial flow fan



Solder Self-Assembly Examples

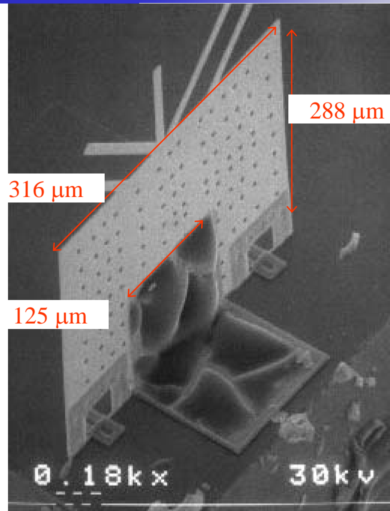
- Fiber Optic Cable Gripper



Assembled with 8 mil 63Sn/37Pb manufactured solder spheres

Polymer Self-Assembly Examples

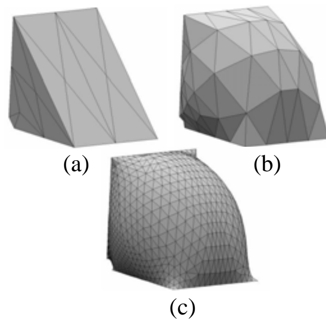
- Photoresist



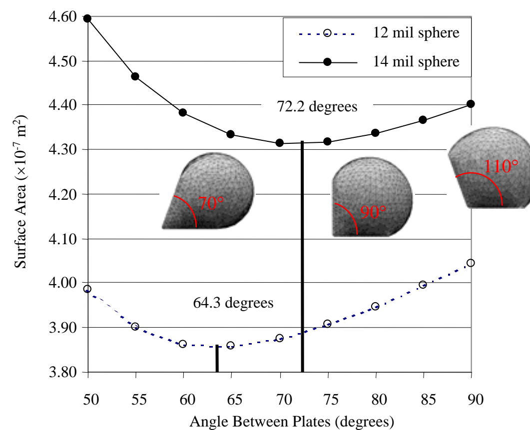
- Structures can also be assembled using deposited and patterned polymers -- in this case, AZP4620 positive photoresist, initially 20 µm thick.

Solder Shape Modeling Using Minimum Surface Energy

- *Surface Evolver* can be used to find the shape of molten solder in two stages:



Stage 1 -- One Solder Joint: Fixed plate angle, fixed plate dimensions, fixed solder volume.



Stage 2 -- Vary the plate angle only.

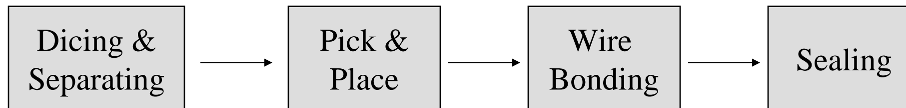
IC Integration

- **MEMS First**
  - + **IC fab is not compromised**
  - + **Allows high temperature anneals**
  - – **Can result in difficult interconnects**
  - – **Complicates release**
- **IC First**
  - + **IC Fab is not compromised**
  - + **Most expensive processing done first**
  - – **Limits processing temperatures and thus material choices**
- **Integrated Process**
  - + **Fewest number of steps**
  - – **Greatest complexity**

Packaging

- Packaging
  - Puts devices into an easily manipulated container
  - Provides the system with the proper environmental interaction
- Cost of Packaging is non-trivial
  - often 70%-80% of total unit cost
- IC Packaging
- MEMS specific Packaging

Packaging



- Where do we release
  - What about dust particles
- How do we seal
  - Must maintain free motion
- What about access
  - Optical or pressure interconnects

Primary IC Issues

- Electrical Connectivity
  - Interconnects
  - RF?
- Reliability
  - Au/Al
- Thermal Management
  - Heat Sink/Fan
- Environment
- COST!!!
- Automation