Overview

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

Packaging: Considerations

- Ambient Light
  - UV, visible, IR detectors
  - CCD sensor
  - Glass/Quartz Window

- Pressure
  - Pressure Sensor
  - Sonic Transducer
  - Bonding

- Ambient Atmosphere
  - Chem-Bio Detector
  - Humidity Sensor

- Guided Light
  - Optical Switch
  - Multiplexer
  - Video Display
  - Scanning
  - Fiber Optics
  - Hermetic Seal
  - Alignment
  - Attachment

- Heat
  - Temperature Sensor
  - IR detector
  - Heat Conducting Medium
  - Non-Insulating Package
  - High Thermal Conductivity Interface

- Strain
  - Strain Gauge

- Fluid
  - Chem-Bio Detector
  - Medical Pressure Sensor
  - Micro Pump
  - Lab on Chip
  - Generator

- Contamination
- Encrustation
- Oxidation
- Hermetic Seal
- Micro to Macro Direct Contact
- Tube - Chip Interface
- Epoxy
- Plastic Tube
Fabrication Sequence

- Surface Preparation
- Film Formation
- Lithography
- Etching
- Impurity Doping
- Anneal
- Mask Set
- Inspection/Test
- Subdicing
- Packaging
- Dicing
- Final Test

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

Packaging

Wirebonding

Adhesive
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

![Diagram of wafer bonding](image)

- Wafer Bonding Techniques

  - **60-200°C oven**
    - capping wafer
    - solder layer
    - silicon substrate
    - bonding materials
    - room temperature

  - **150-600°C oven**
    - capping wafer
    - solder layer
    - silicon substrate
    - bonding materials
    - 60-200°C oven for epoxy

  - **Localized Heater Bonding**
    - capping wafer
    - bonding material
    - micro-heaters
    - silicon substrate
    - room temperature

  - **Thermo compression Bonding**
    - capping wafer
    - silicon substrate
    - bonding material
    - room temperature
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.

![Etch Holes and Dielectric Encapsulation Diagram]

P. Monajemi et al., 2005

Decompose Unity @ 200-300 °C
Packaging: Examples

Motorola MPX4080D series piezoresistive differential pressure sensor

Open port to sensor and open port with transmission medium.
Packaging: Examples


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
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.

Micro-switch assembled with 8 mil Pb/Sn 37/63 manufactured solder spheres.
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.

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.

Examples:

- 14 Hinged-Structure
- 2 Dipole Antennas
- 5-plate structure
- Outlines of gold pads
**Solder Self-Assembly Examples**

- Solder self-assembled micro axial flow fan

![Micro axial flow fan](image1)

- Fiber Optic Cable Gripper

![Fiber Optic Cable Gripper](image2)

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