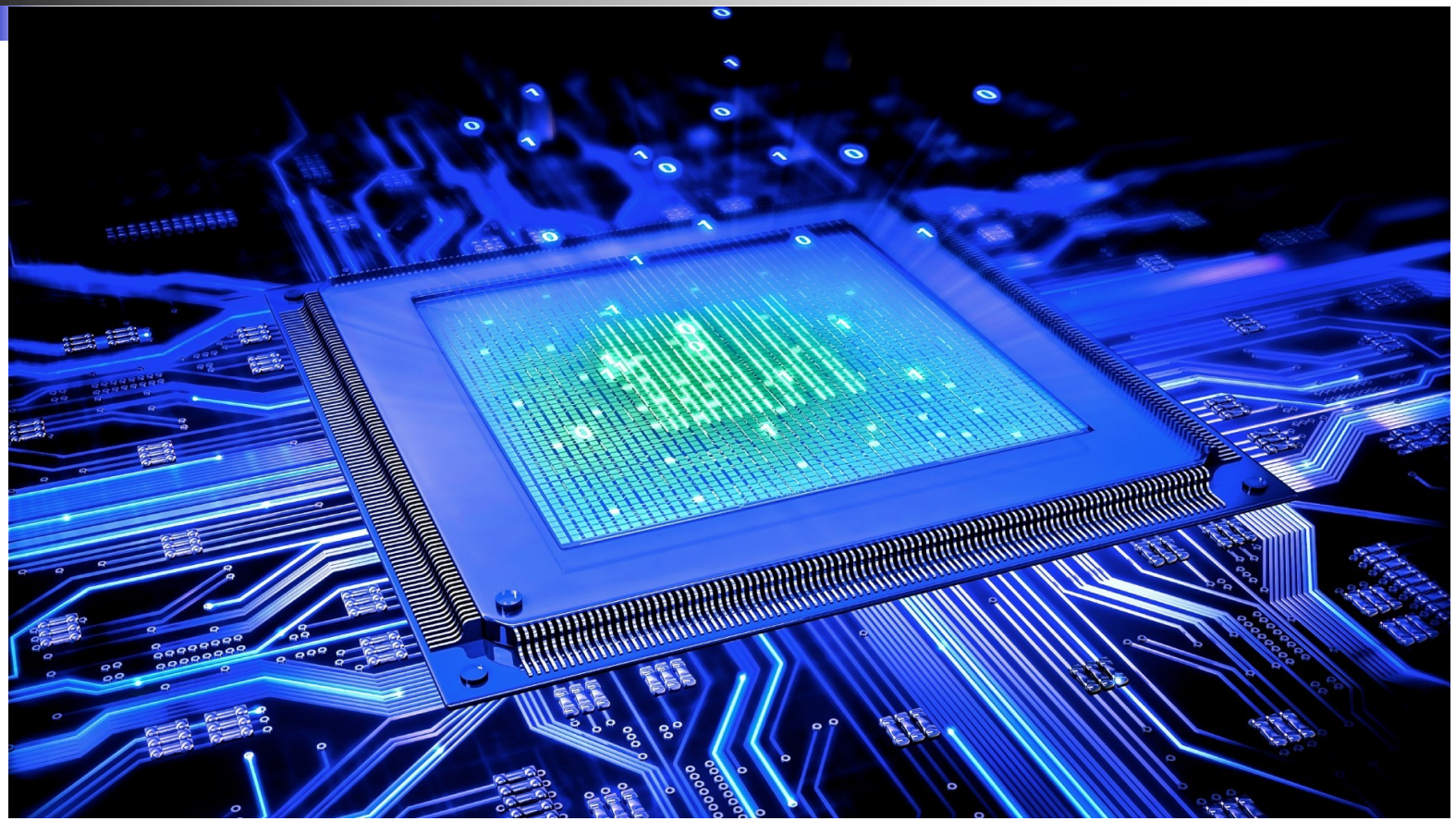
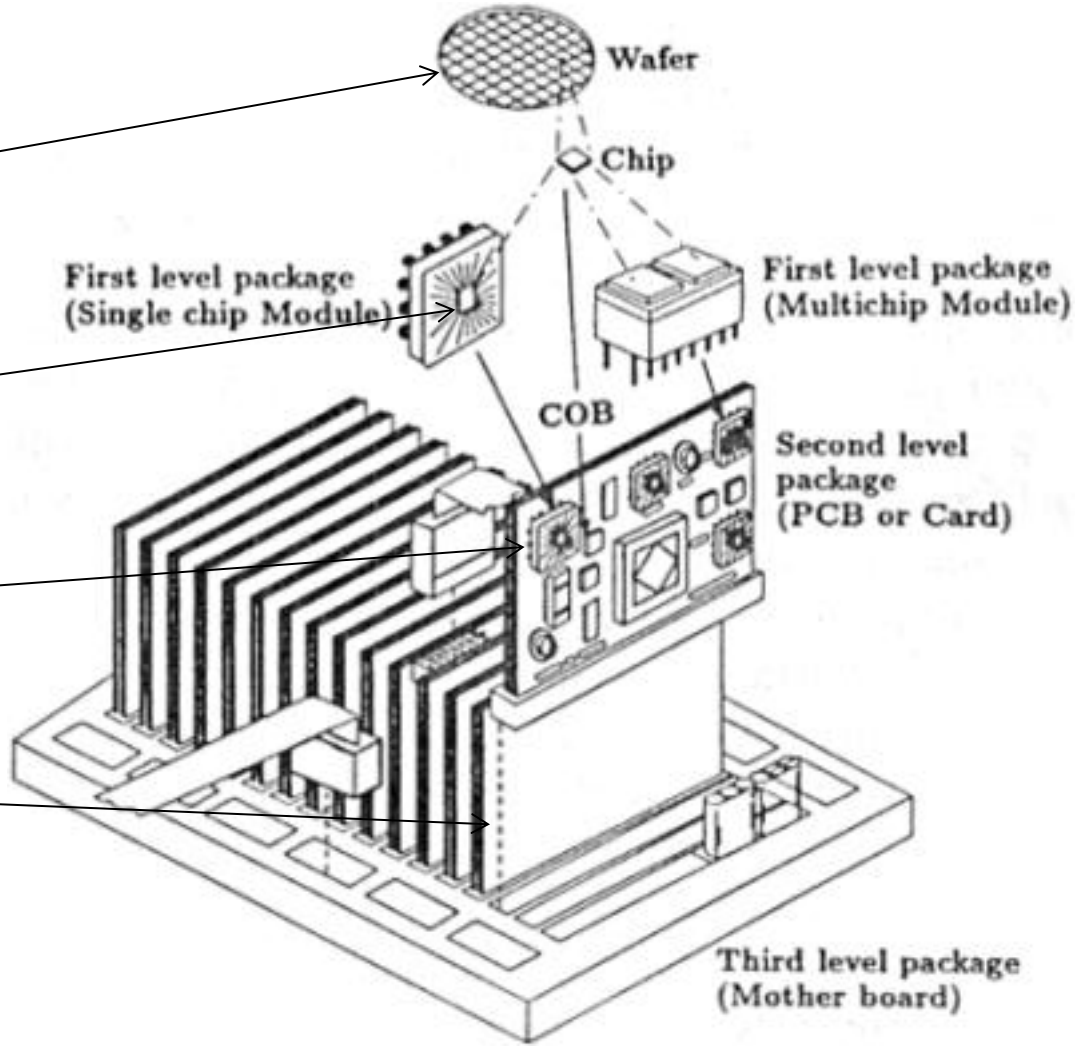
Integrated Circuit Assembly



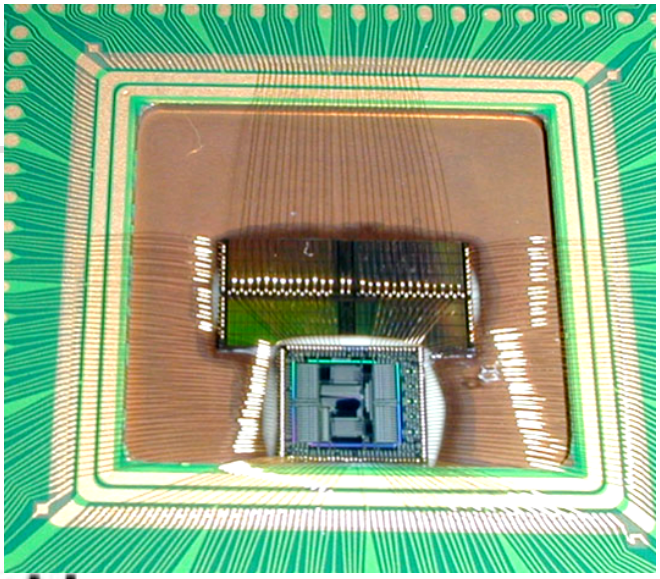
Packaging Hierarchy Review

- Level 0: Wafer level (gate-to-gate)
- Level 1: Chip level (chip-to-package)

  ' IC Assembly' Process
- Level 2: Board level (packaged chip to PCB)
- Level 3: System level (board-to-board)

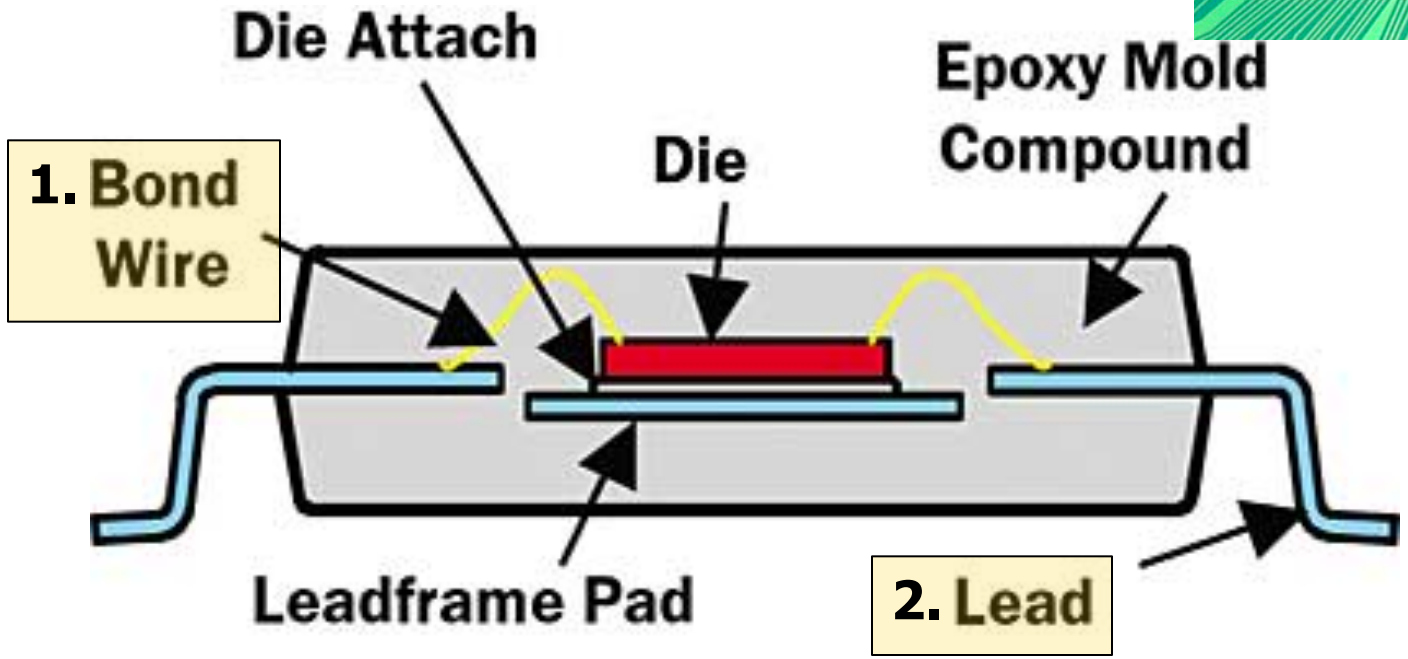


IC Assembly Functions



Provides interconnection:

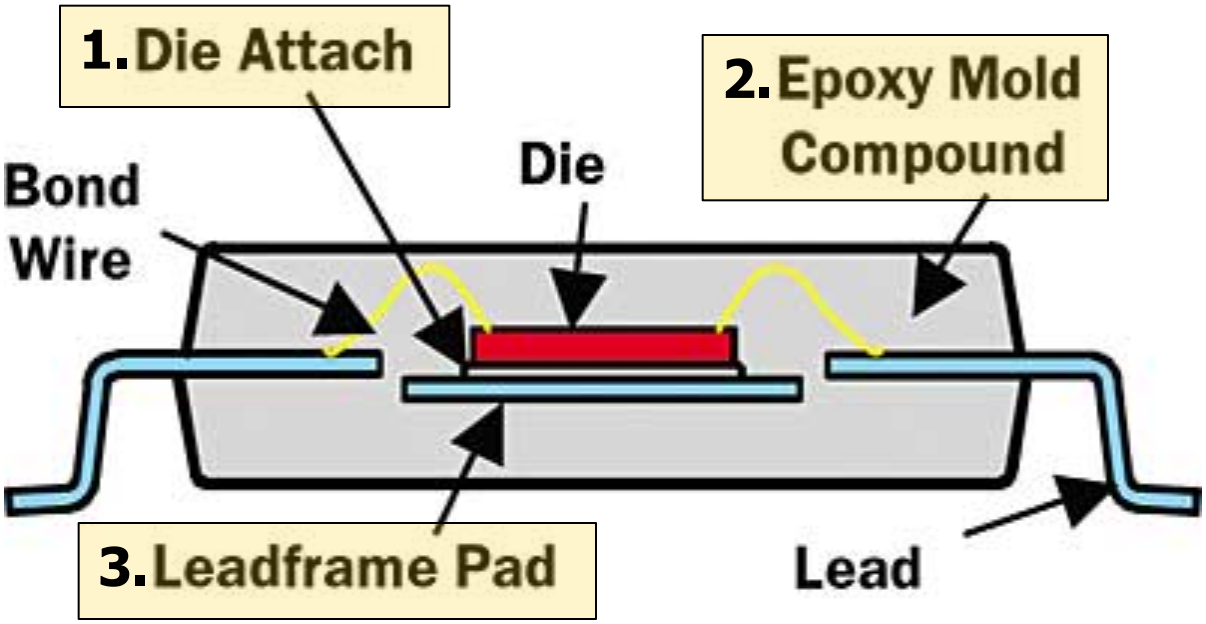
1. Between the die and package leads.
2. Between package and the PCB.

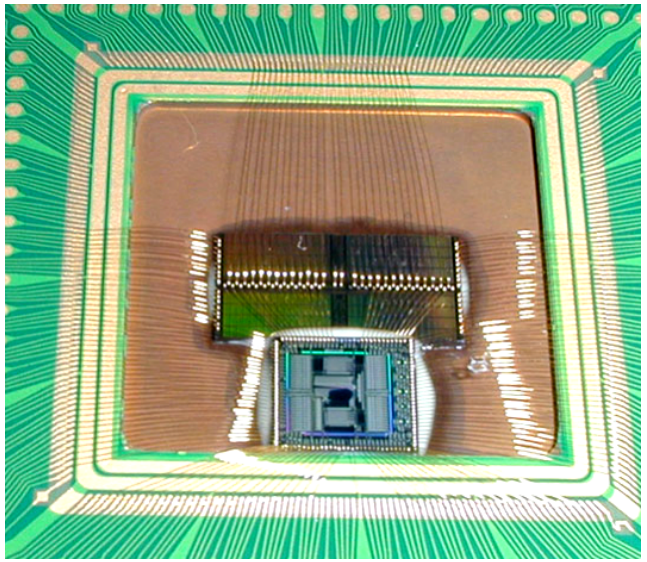


IC Assembly Functions (cont.)

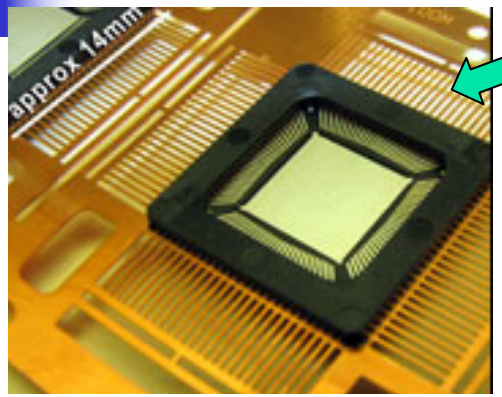
Physically Attach & Thermally Protect

1. Die attachment bonds die to leadframe or substrate.
2. Mold Compound protects die from environment (moisture, dust).
3. Leadframe Pad provides a heat sink for cooling the die.





IC Assembly Processes

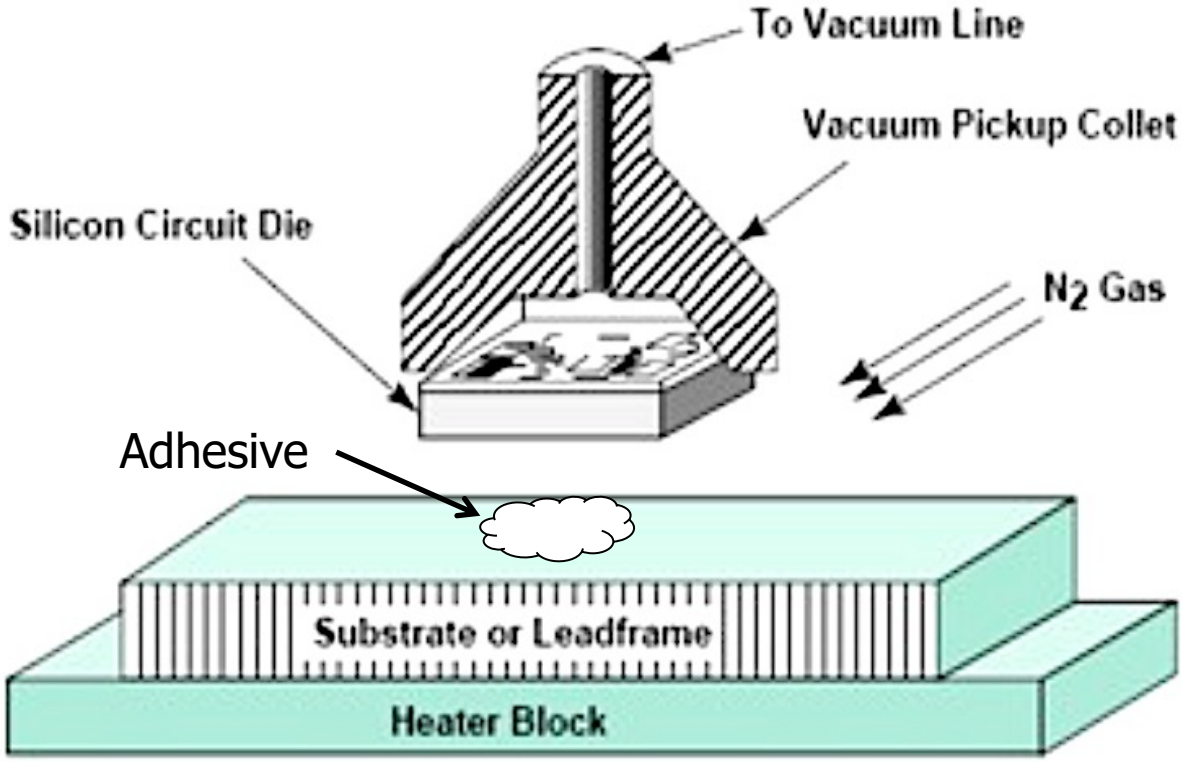


Stamped & Plated QFP Lead Frame

*In addition to wire bonding, there are TAB & flip-chip technologies

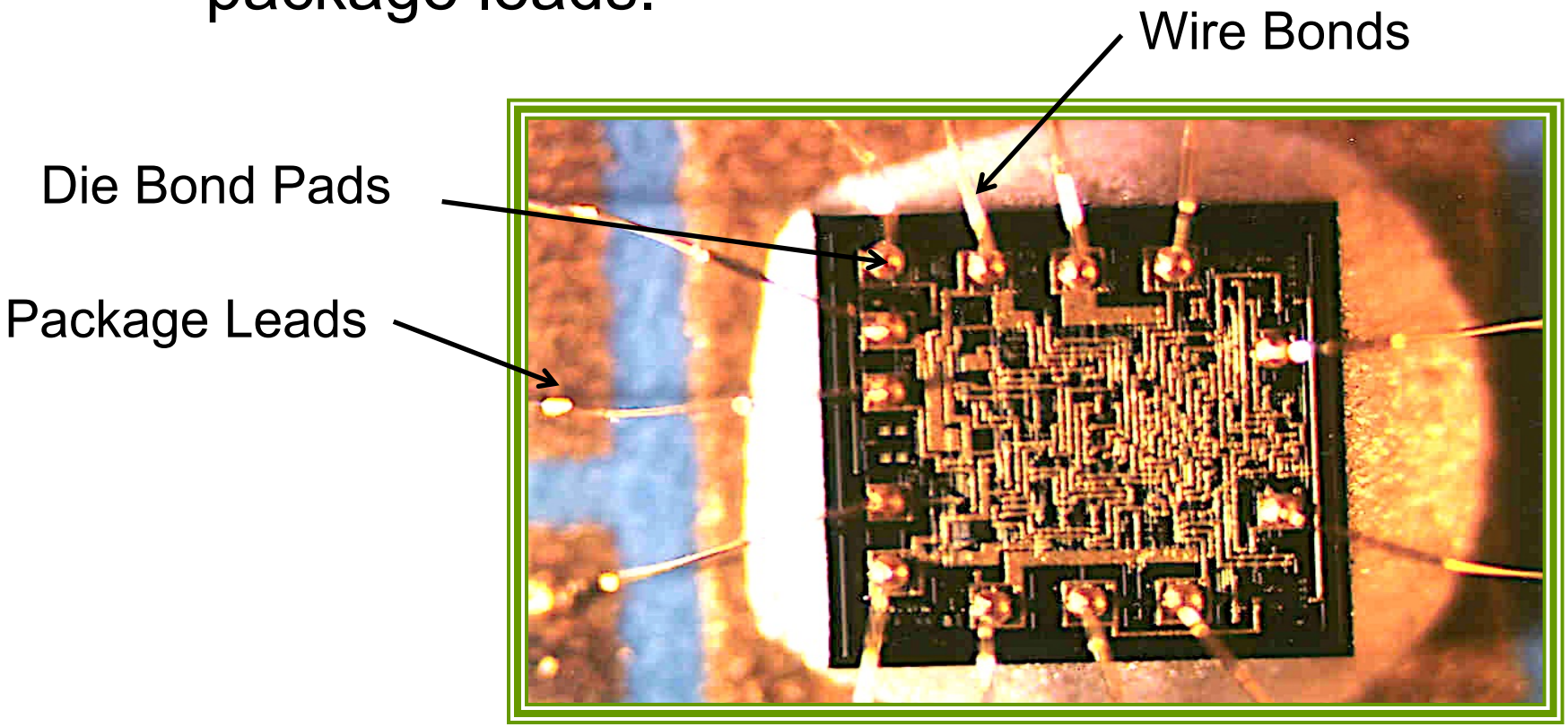
IC Assembly – Die Attachment

1. Apply conductive adhesive.
2. Pick & place die on substrate.

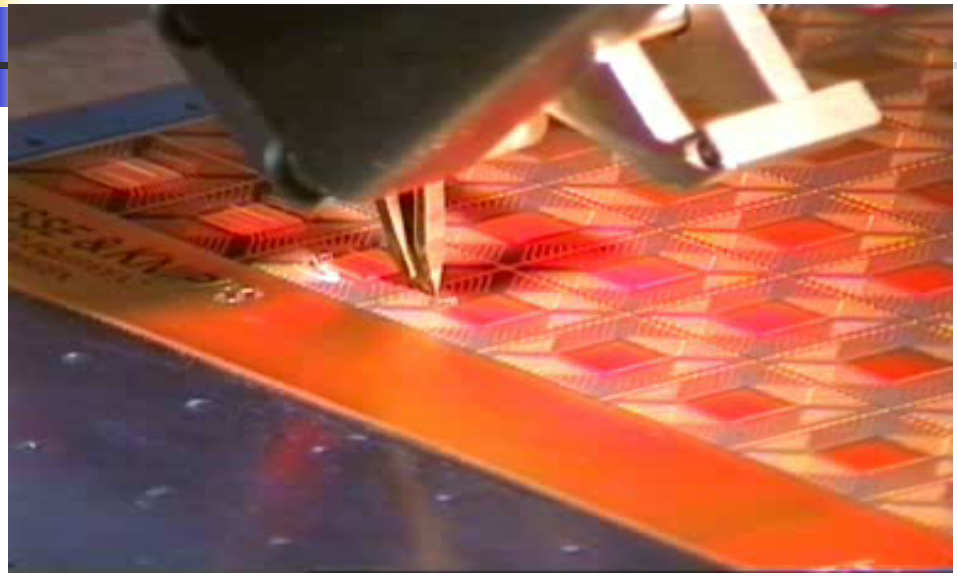


IC Assembly – Interconnection

Electrically connects die pads to package leads.



Wire Bonding Videos



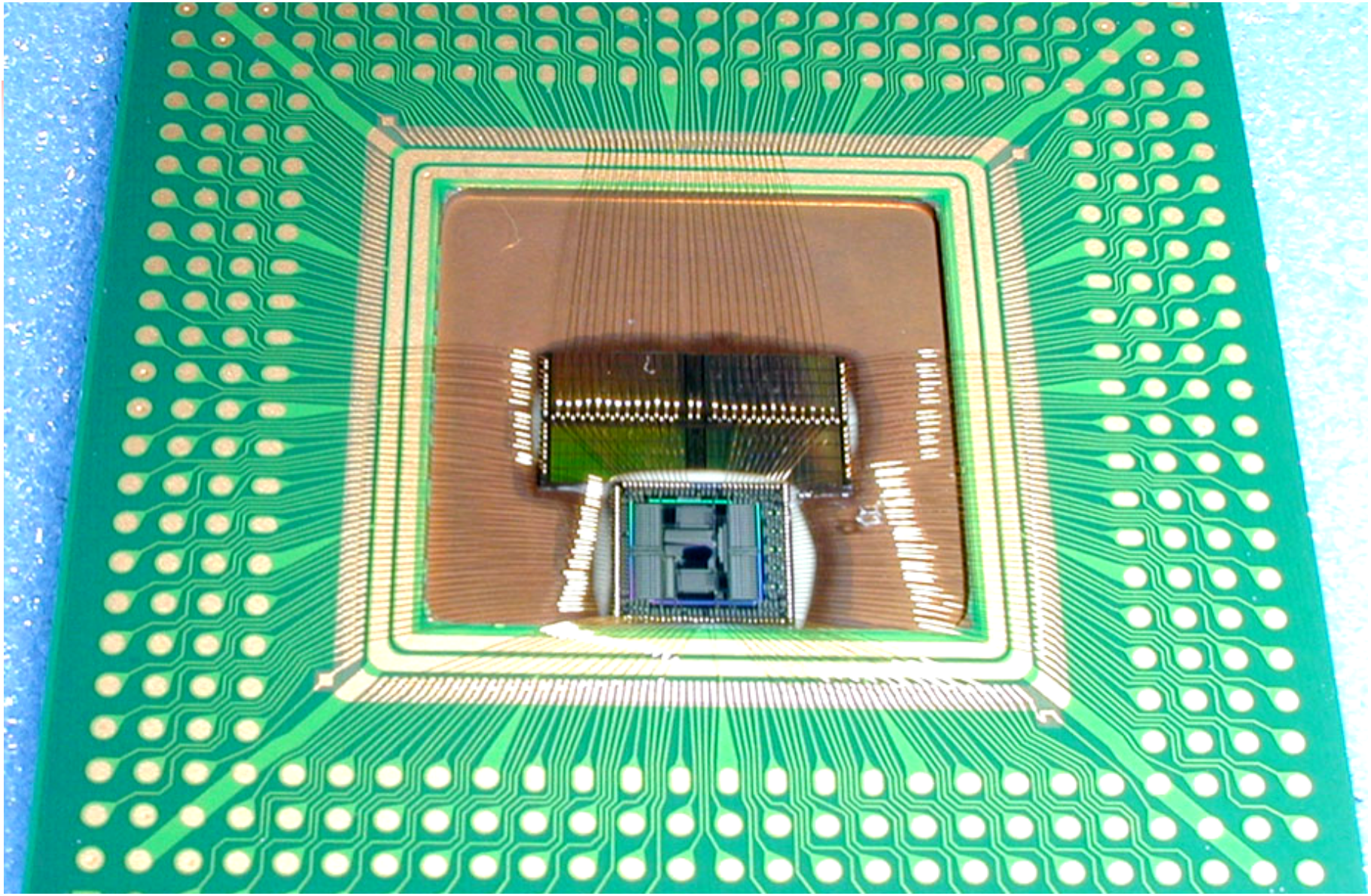
Wirebonding Videos:

Animation
https://www.youtube.com/watch?v=FRvECYvlaT0

Wirebonding Slow
https://www.youtube.com/watch?v=DO104aoscxw

Real Time
https://www.youtube.com/watch?v=V6BA6rSfzjQ

MCM / BGA Package w/ Wire Bonds

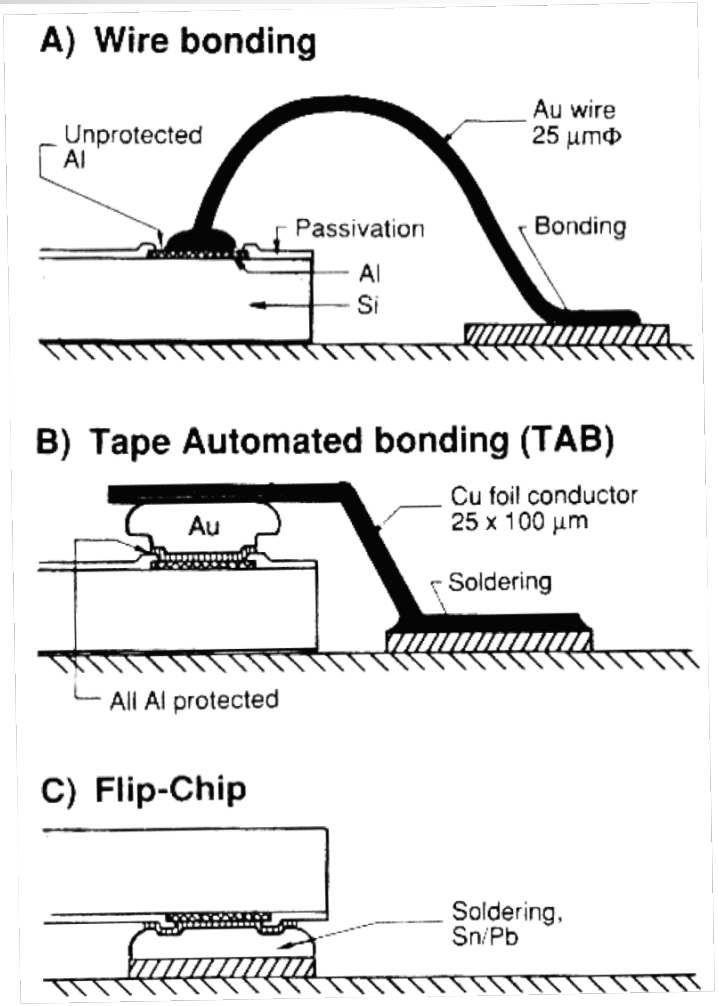


Interconnection Methods

A) Wire bonding
- Fine metal wire between IC pads and package leads or pads

B) TAB (Tape Automated Bonding)
- Metalized polymer tape attached between IC pads and package pads

C) Flip Chip
- IC turned active side down "flipped" and bonded directly to package bond pads or to PWB



Wire Bonding

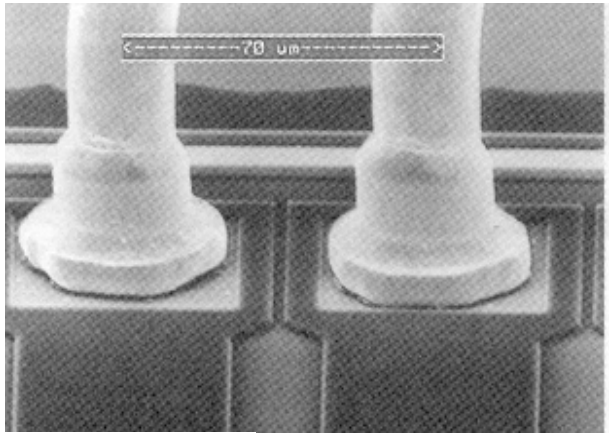
- Interconnects with gold, aluminum or copper wire
- Bond Types (refers to wire end & how it attaches to IC surface)
  - Ball Bonding (90% of all wire bonds)
  - Wedge Bonding (narrower for smaller lead pitches)
- Bonding Methods
  - Thermosonic, Ultrasonic & Thermocompression (rarely used)
    - Ultrasonic energy assists bonding.

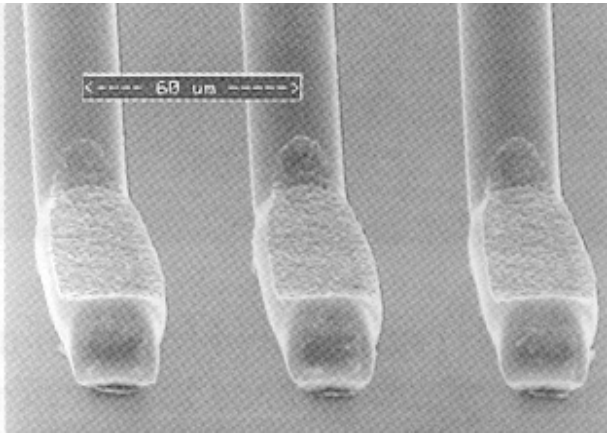
Advantages: Connections can easily be changed, relative low cost.

Disadvantage: Long wire lengths (increases line impedance, time delays (not suited for high speed applications).

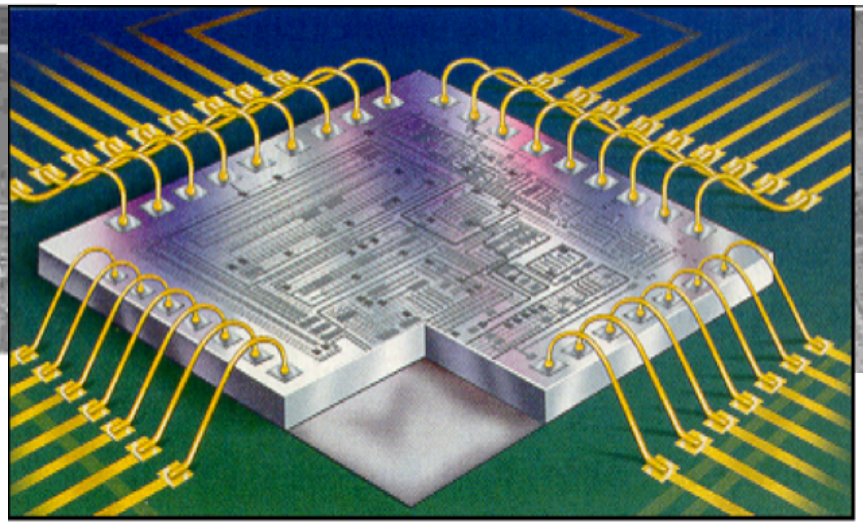
Wire Bonding Examples

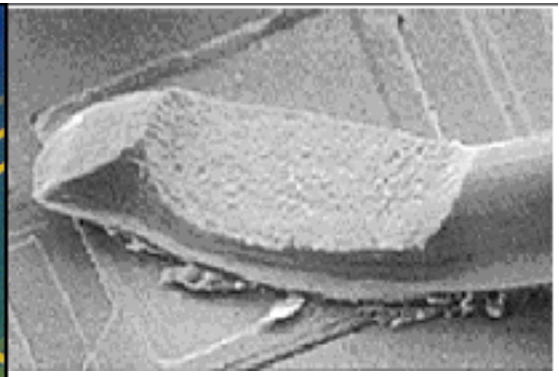
Ball Bonds





Wedge Bonds





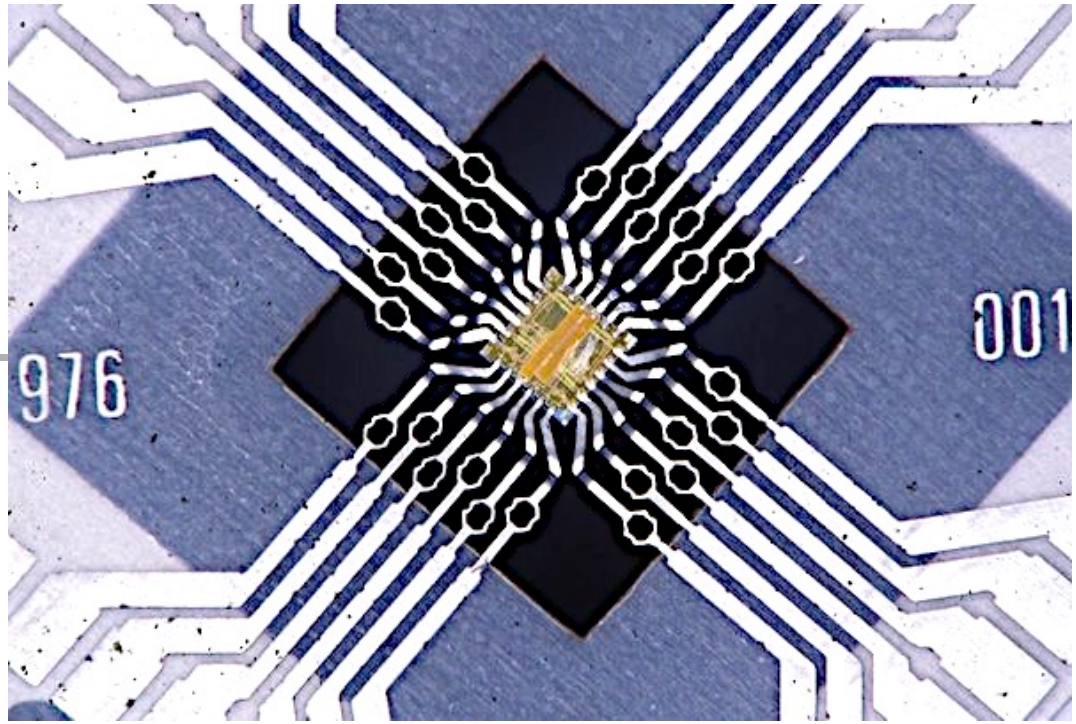
Tape Automated Bonding (TAB)

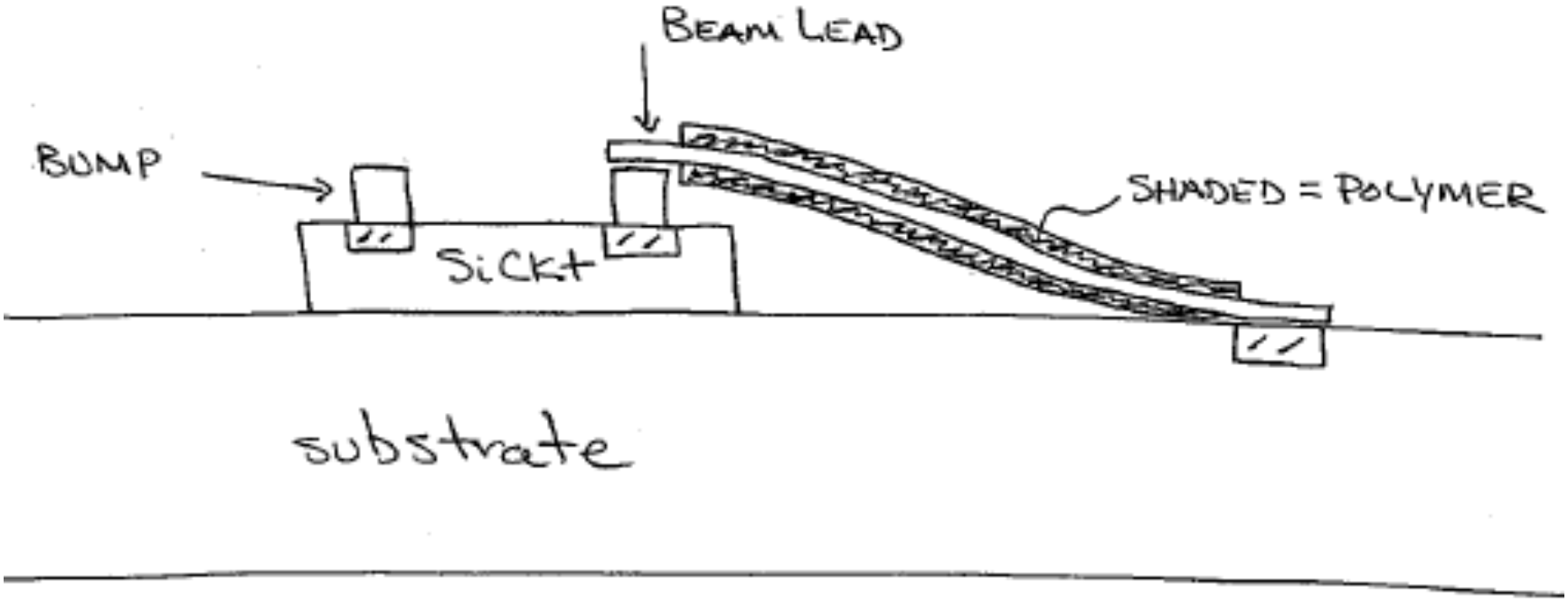
- Interconnecting with metalized flexible polymer tapes.
- Interconnections are thin copper ("beam lead") embedded in polymer tape. Beam lead connected to IC I/O pad with a gold, copper or solder "**bump**".
- Beam lead pattern is chemically etched before embedded in polymer (similar to PCB etching).

Advantages: Simultaneous connections can be made, reduced wire lengths shortens time delays compared to wire bonds.

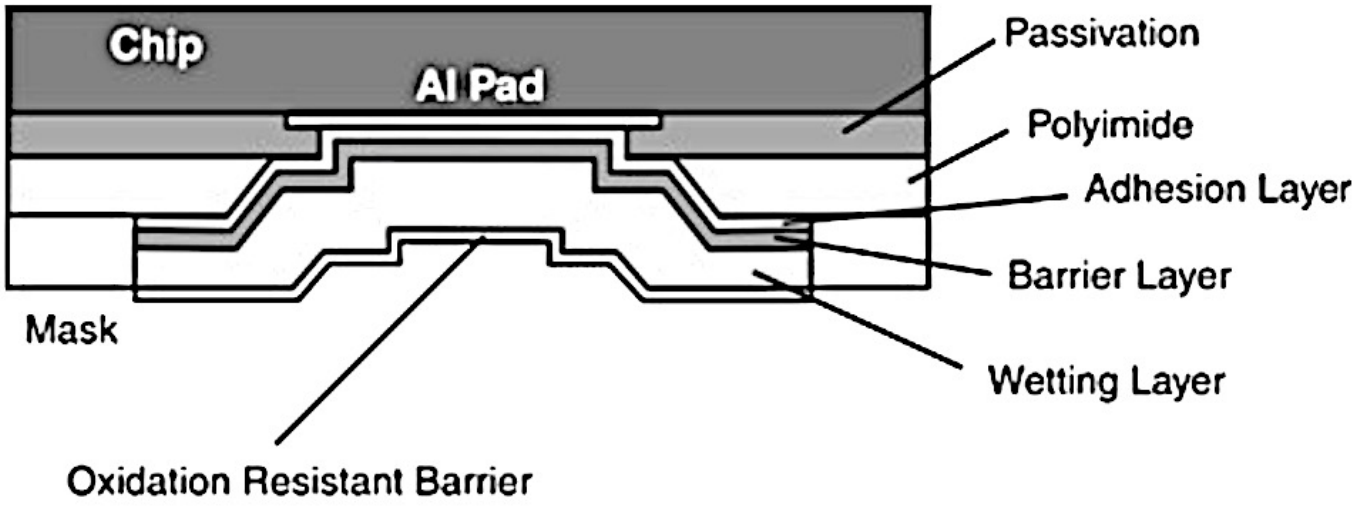
Disadvantages: Expensive automation and not easily changed (predefined connections – etched pattern).

TAB



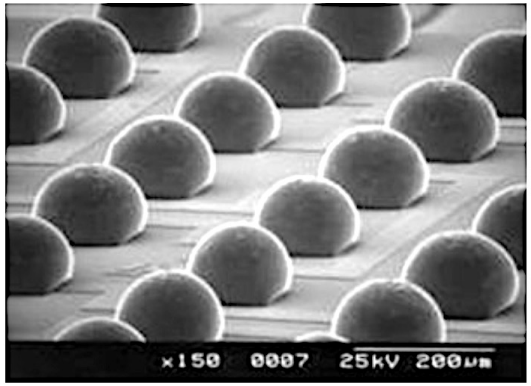


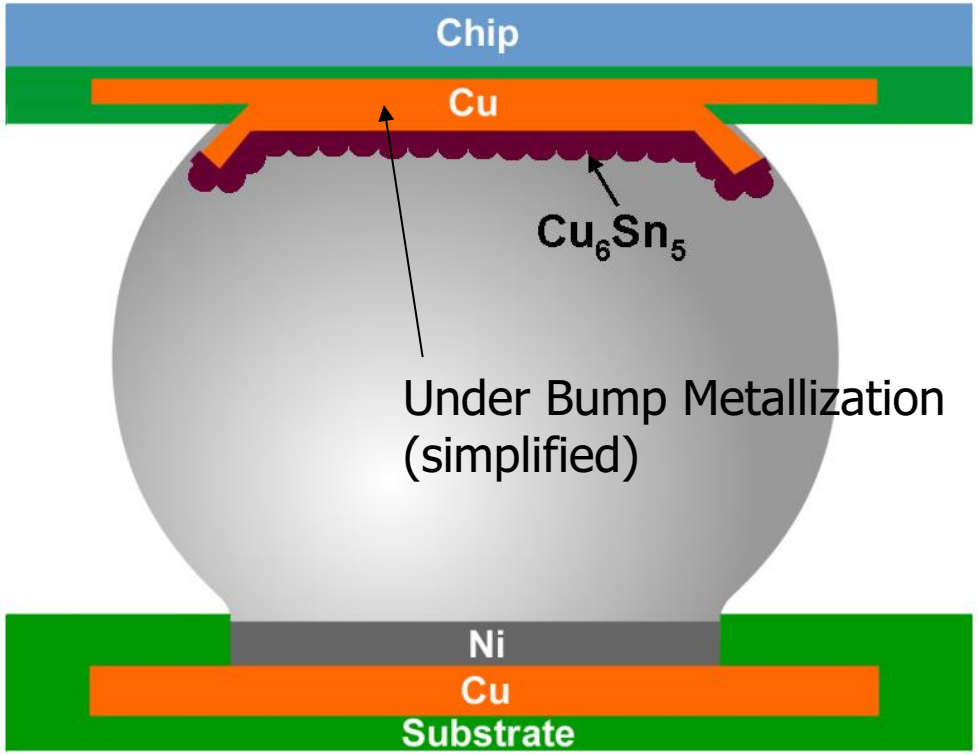
Under Bump Metallization



- Al Bond Pad – highly conductive
- Passivation – insulating $Si0_2$
- Adhesion Layer – Cr, Ti, Ni, W or TiW
- Barrier Layer – Cr, W, Ti, TiW, Ni or Cr-Cu
- Wetting Layer – Cu, Ni, Pd or Pt
- Oxidation Resistant Layer – Au

Metallurgical Bumps

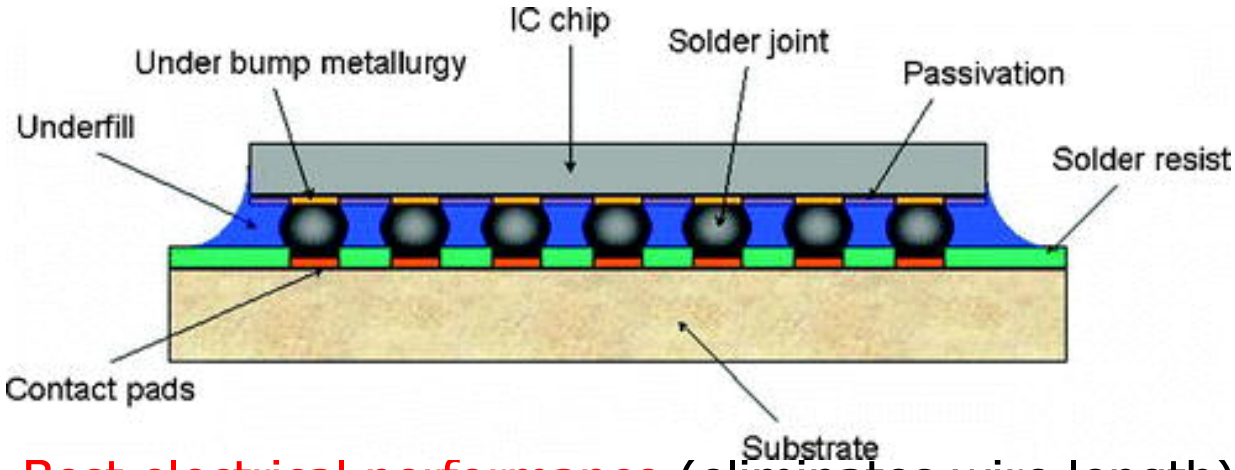




- Solder Bumps (Under Bump Metallurgy/Metallization) consist of layers of various metals.
- Provide interconnection between Die and Package substrate.
- Designed to minimize interdiffusion & provide improved adhesion and wetting.
- Without these layers, connections would likely corrode, crack and have poor bonding.

Flip-Chip

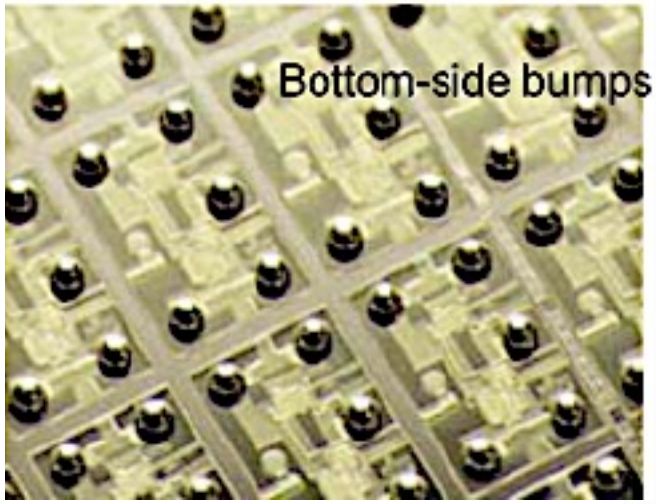
- After inverting (flipping) die, interconnecting IC I/O pads are made directly to packaged bond pads or PCB.
- Metallurgical **bumps** must be used to connect IC

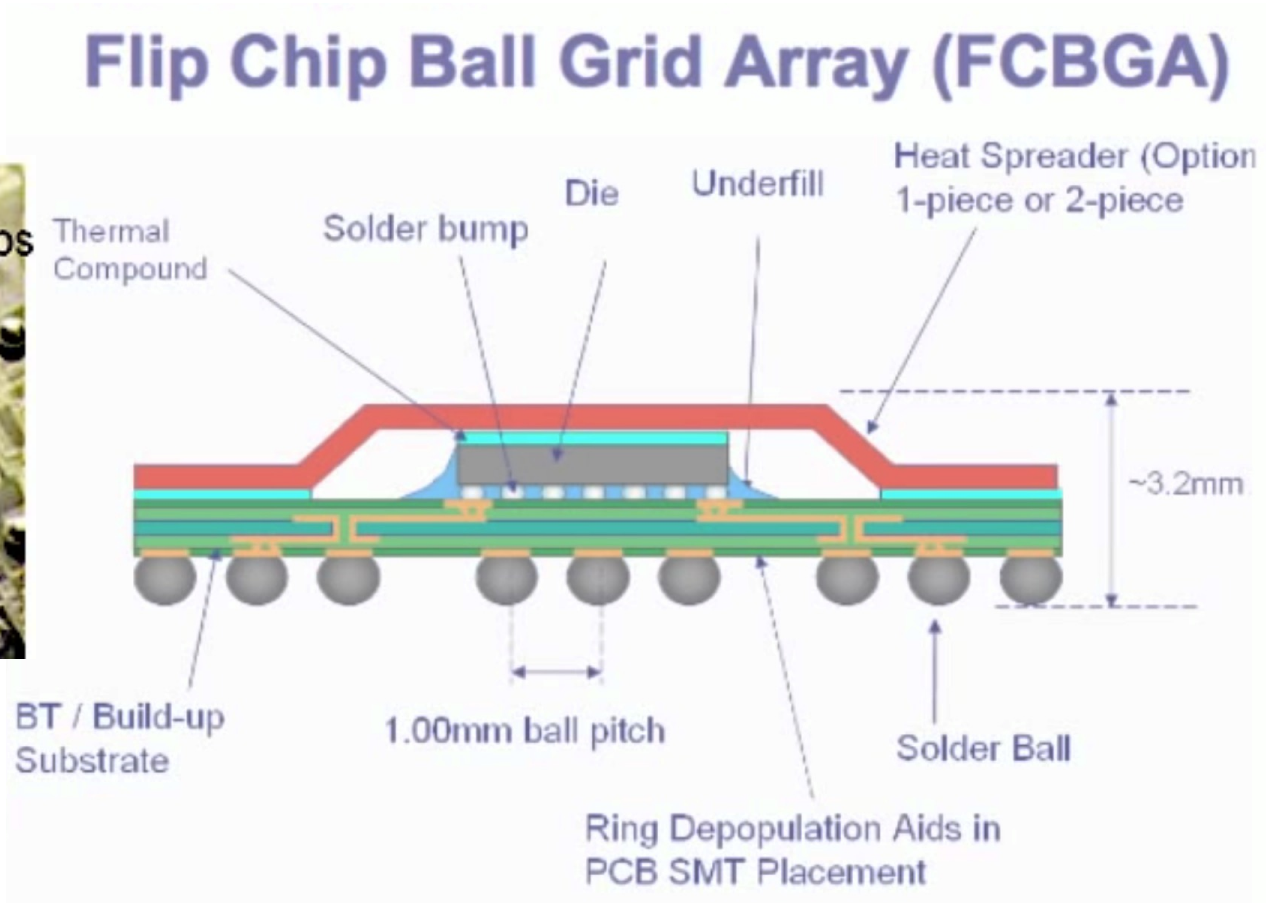


Advantages: Best electrical performance (eliminates wire length), least number of assembly steps and, like TAB, simultaneous connections made.

Disadvantages: Expensive, many processing steps, difficult to inspect (X-ray) and requires accurate placement equipment.

Flip-Chip BGA

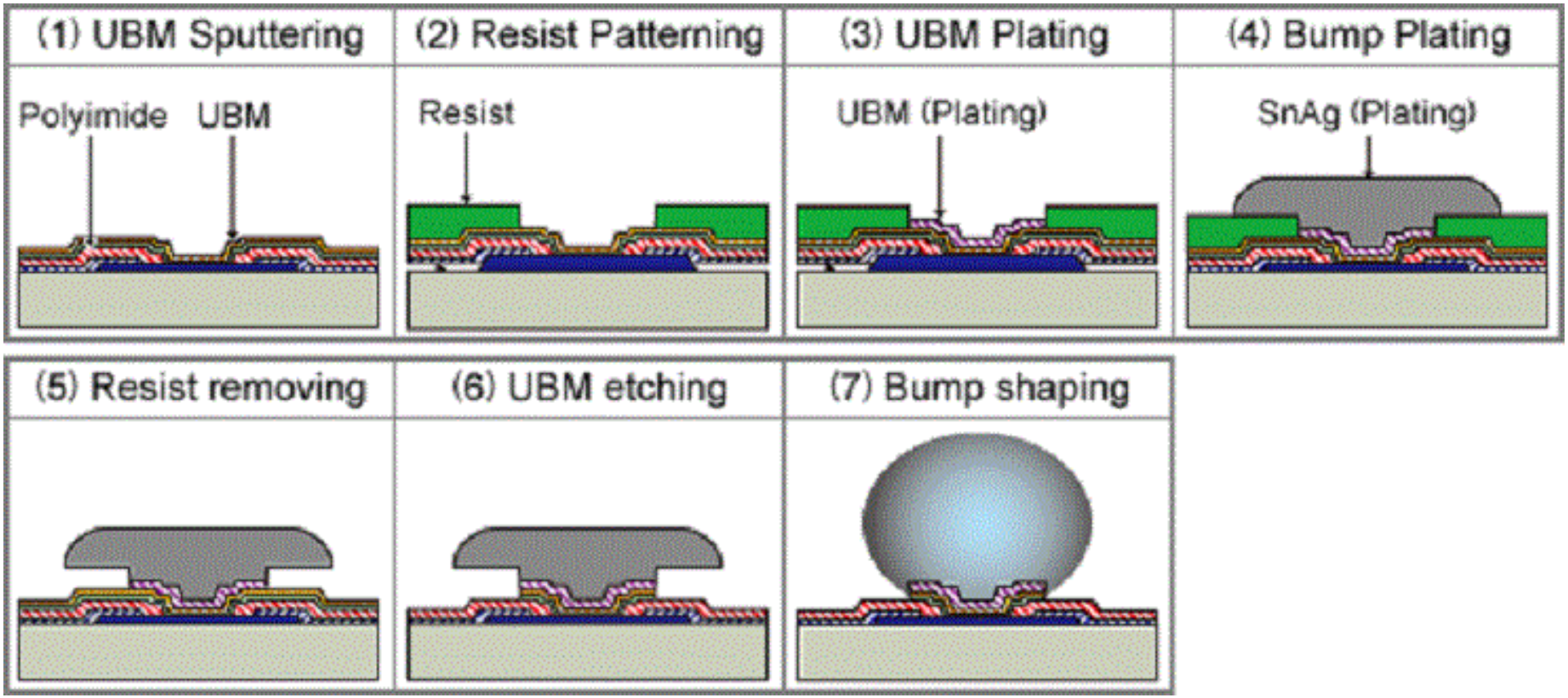




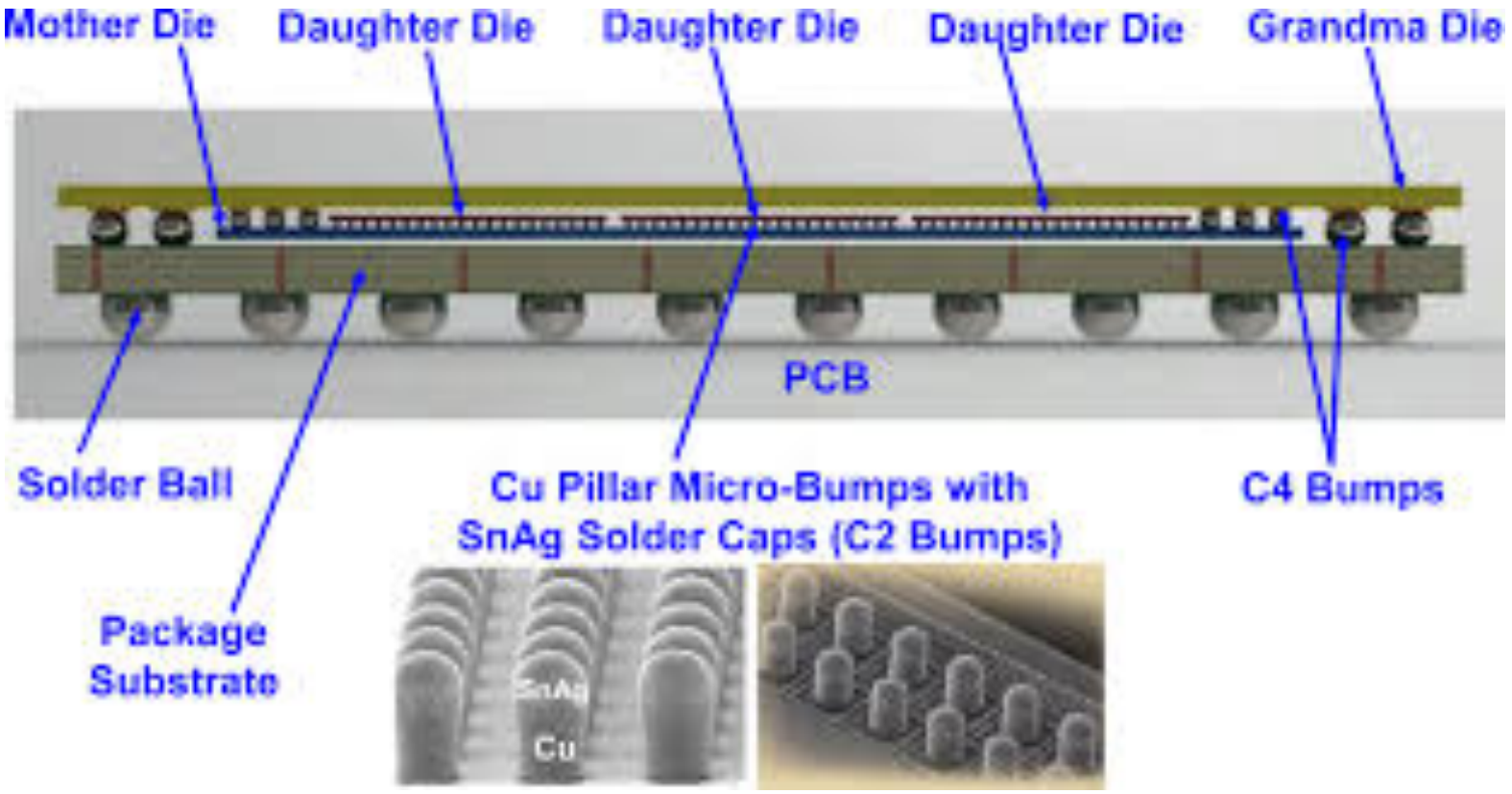
IC Assembly - Encapsulation

- Mechanical Protection
  - IC protected from physical damage
- Chemical Protection
  - IC protected from moisture / other environmental hazards
- Sealing refers to “air tight” hermetic packaging
  - Hermetic materials; ceramic, glass, solder, metal
  - Non-hermetic materials; plastic, epoxy, silicones
- Non-hermetic does not imply non-reliability – hermeticity required for some high-temperature & special applications

Bumping Process

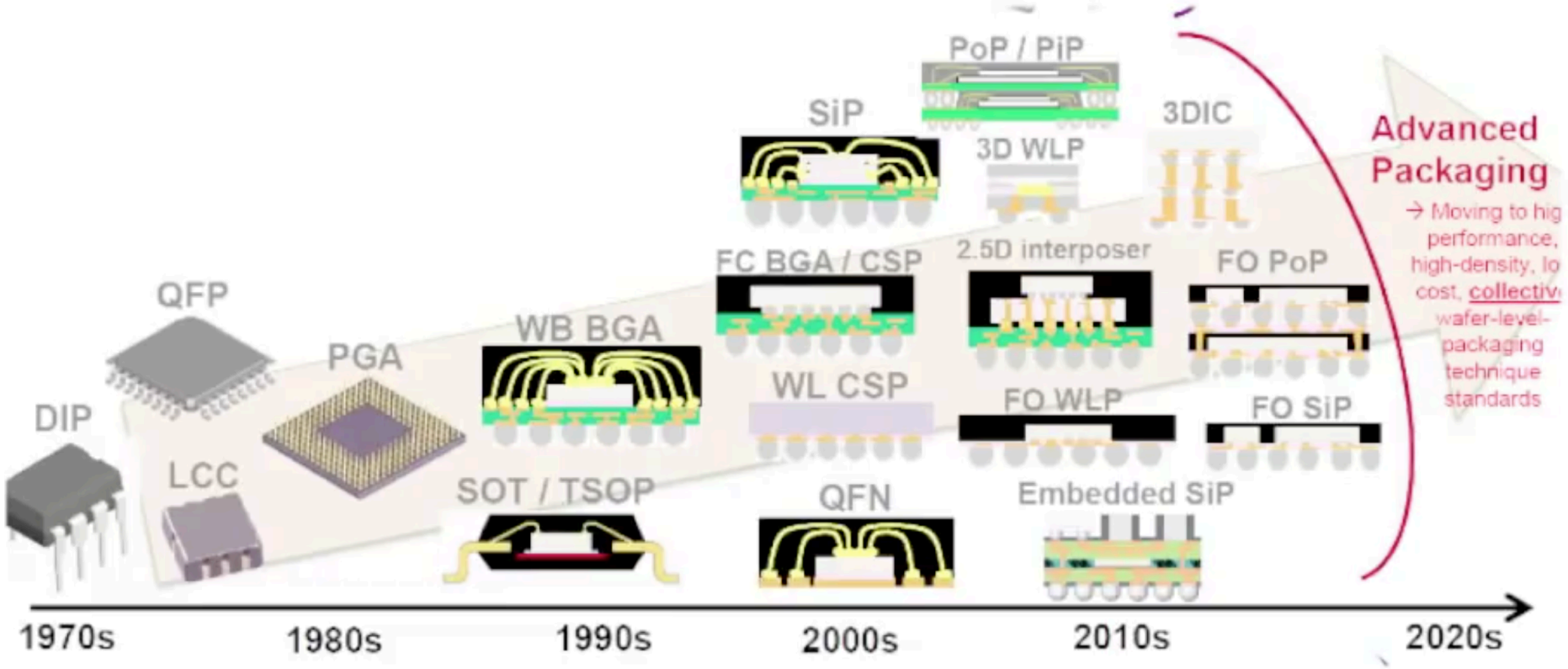


Advanced IC Assembly



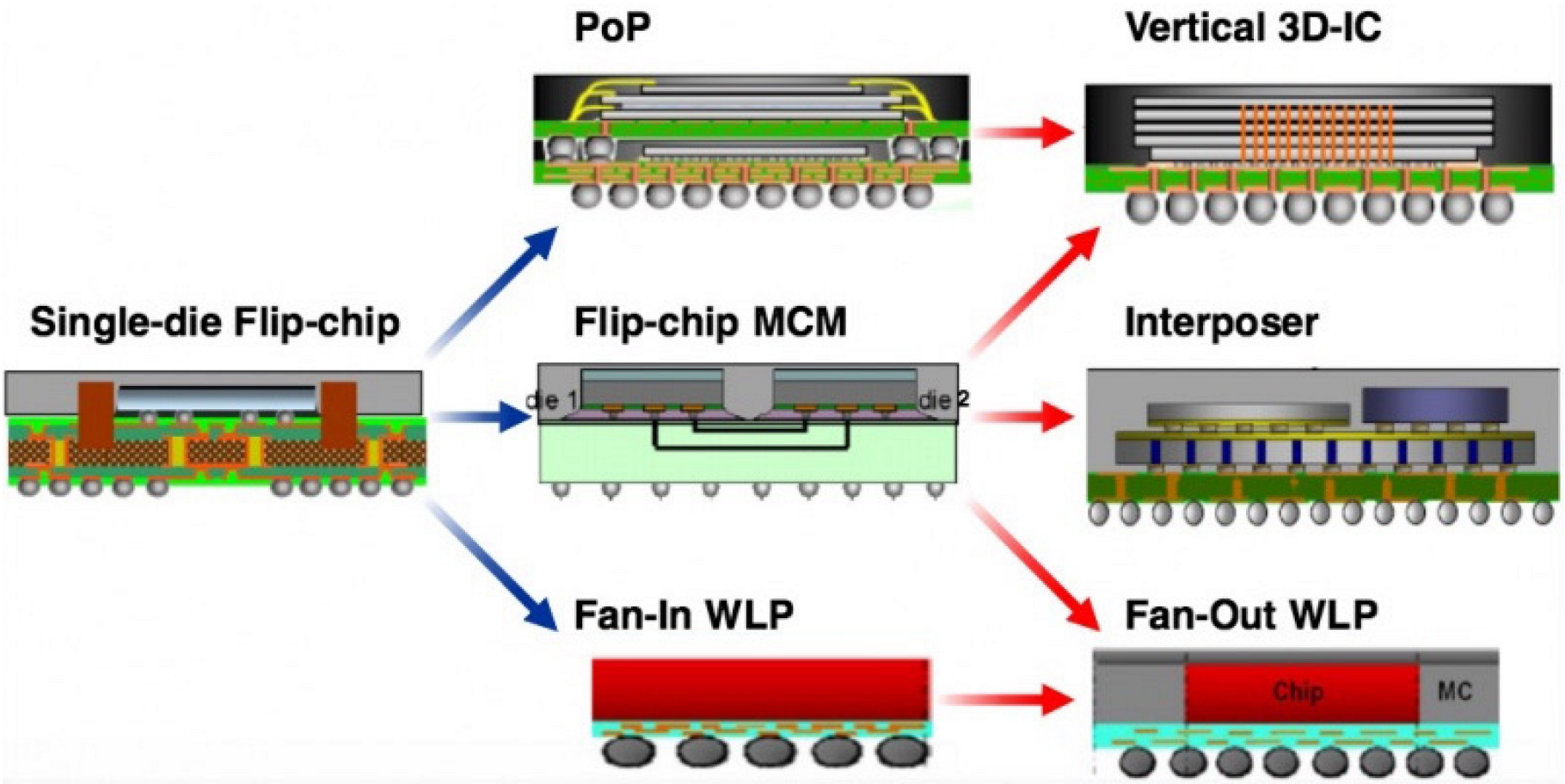
High performance, but high cost

Evolution of Packaging



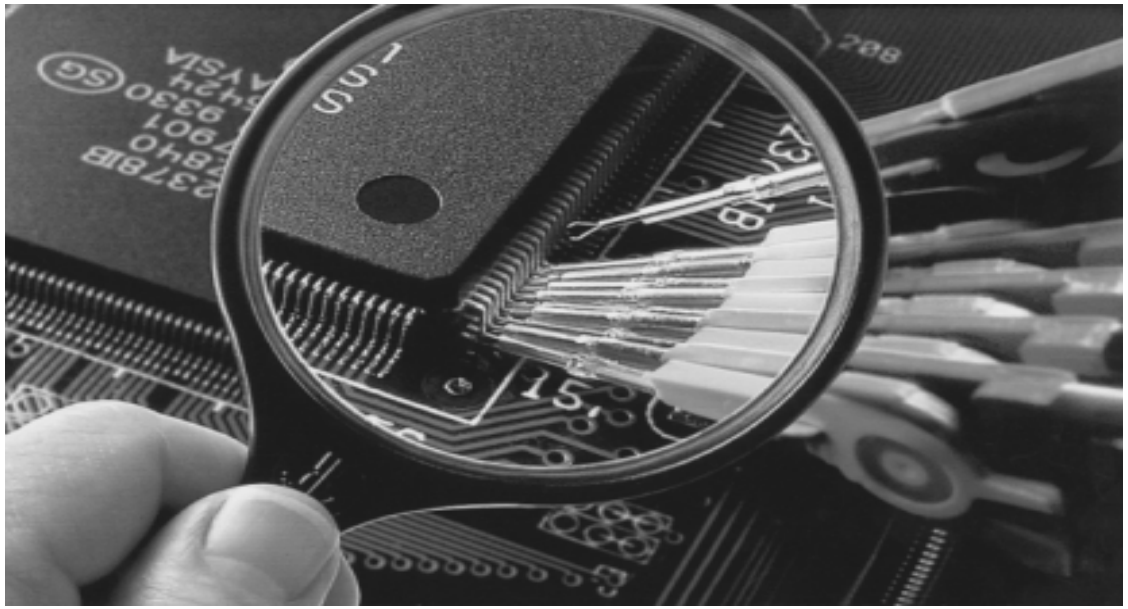
Fan Out: https://www.youtube.com/watch?v=pOBkSEOLqZ8&t=8s

Further Evolution of Packaging



Electrical Testing

Goal: Functional guarantee of a component, board, device or system.

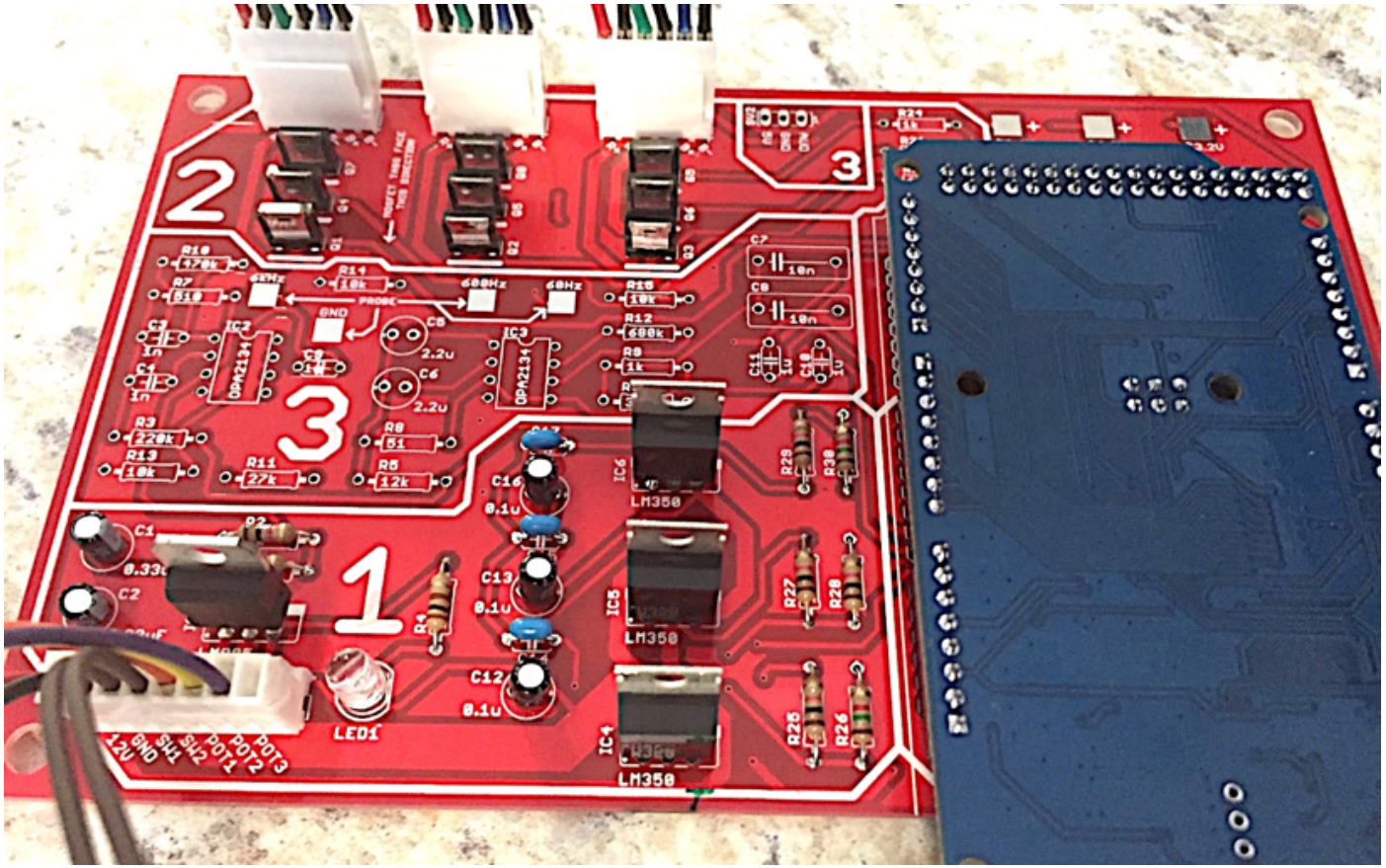


Electrical Testing

- Why do electrical testing?
  - Fabrication/Assembly defects (opens & shorts).
  - Components may not meet specs due to poor process control.
  - Damage may occur during handling and transfer.

Prism Electrical Testing

- What are some of the possible issues here?



Electrical Testing

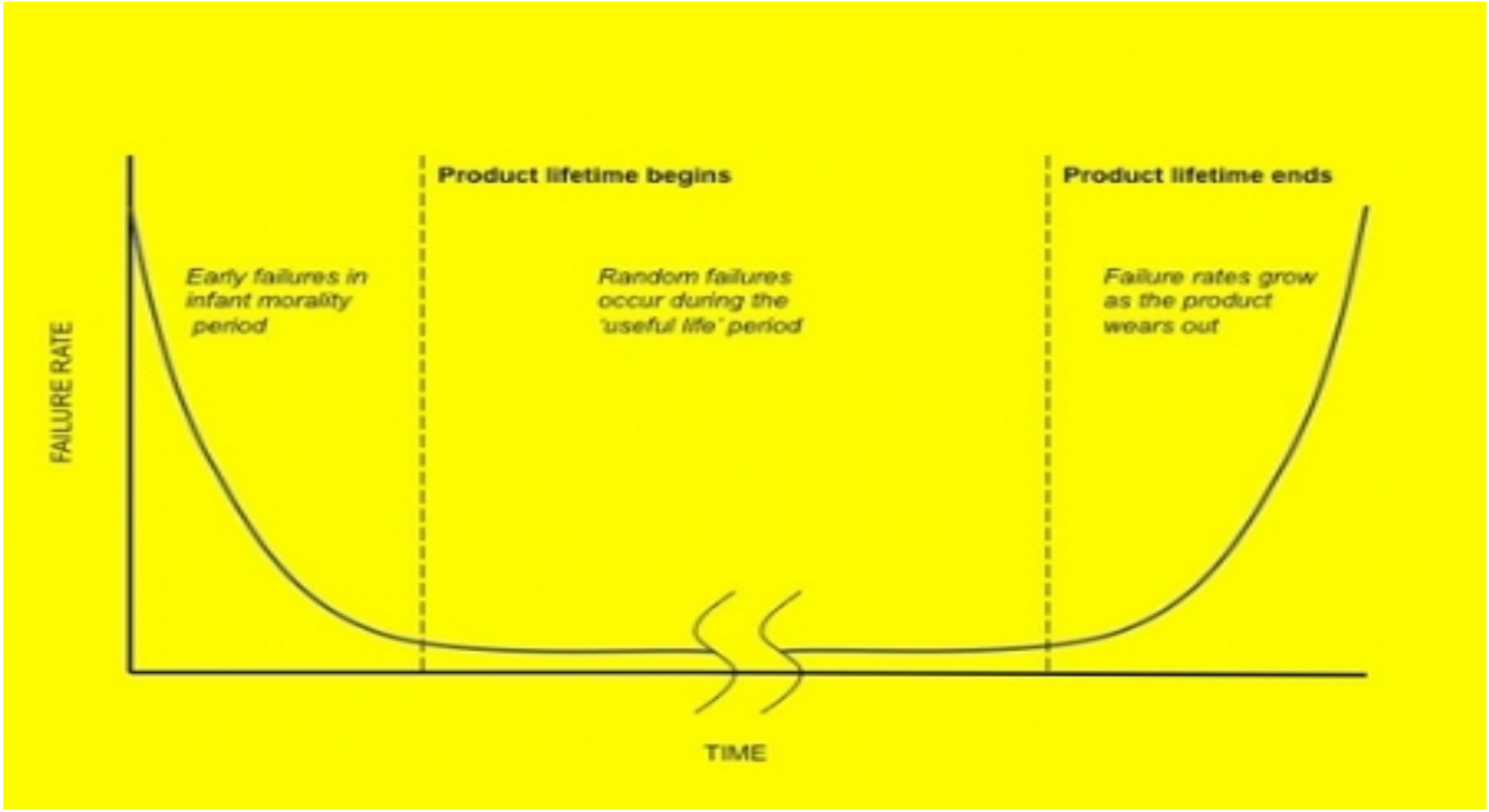
- Si wafers, components (such as ICs), PCBs and systems are tested at each phase of the manufacturing and assembly process.

- Can account for as much as 45% of total product cost.

Electrical Testing

- Starts with design
  - Design simulation (Pspice)
  - ERC (Electrical Rules Check)
  - Built in self test (computer bootup)
- PCB
  - Interconnect test (ohm measurement)
- Components
  - Functional test (“burn-in”) high temp & high applied power

“Bath Tub Curve”



Electrical Testing

- Assembled board
  - Functional test
    - Verification of all circuit functionality
    - Not practical for complex circuits
  - Structural test
    - Verification circuit is constructed as designed
    - Complex circuits tested piecemeal fashion
    - Does not directly demo circuit functionality
  - Often structural & partial functional test

Electrical Testing

- System
  - Testing of connectors & cooling assemblies
    - Examples – Pentium fan, PS heat sinks
    - Cables, harnessed wires, daughter boards
  - Controlled environment
    - Environmental chamber,
- Si Wafer & IC Package
  - Si Run II video (