Microelectronics Packaging
Processing Overview, Industry Trends and ESH Issues

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Outline

• Major packaging functions and key issues
• Wire bonding and wireless bonding process flows
• Industry trends in packaging processes
• ESH issues
Key Packaging Functions

1. I/O connection
2. Power delivery
3. Heat dissipation
4. Die protection

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Critical Packaging Functional Issues

- Heat dissipation: increase in transistor density causes increased power density
- I/O: number of terminals continues to rise even as package size decreases
Technology Roadmap
Heat Dissipation Requirements

Key:
- Server
- Desktop
- Bars → W
- Lines → W/cm²

10^5 W/m²

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I/O Solutions

- **Wire bonding:** number of terminals limited by pad density at perimeter

- **Wire-less bonding:** no perimeter limitation -- terminals limited only by areal density (or pitch) of solder bumps
Packaging Process Flow: Saw wafer into individual die

- bad die
Wire bonding packaging process

attach die to package with adhesive

wire bond pads to package shelves

seal package

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Wire bonded die
(one corner shown)

- adhesive
- bond pads
- package shelves
Wire bonding
wedge bond closeup

Au wire
package shelf
Wireless bonding solder bumps

Test chip showing bumps completely covering surface of chip

Connections not limited by die perimeter
Wireless bonding: redistribution layer fabrication

Finished multilevel interconnection ULSI chip

Passivate, pattern deposit via metal

Redistribution layer with vias
Wireless bonding: bonding pad fabrication

multilevel interconnection
ULSI chip

Redistribution layer with vias

Sputter deposit Al / pattern
Wireless bonding: bump via fabrication

CVD SiO$_2$ / pattern
Wireless bonding: barrier layer fabrication

barrier layer sputter pattern
Wireless bonding: solder bump fabrication

deposit solder through mask or plate
Wireless bonding: flip-chip bonding

Align and heat

- Plated solder bump
- Solder dam
- Cu pad
- Package substrate

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Wireless bonding: bonded package
**Wireless bonding: underfill**

**Purpose:** minimize induced stress
enhance mechanical integrity
encapsulate

Self-filleting capillary flow
Liquid epoxy encapsulant
Package Cross Section

- die
- die attach
- package seal (lid)
- package substrate
- Ball grid array (BGA)
- solder joints to PWB

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Package with Heat Sink Cross Section

- Cooling fins
- Spreader
- Heat sink attach
“New” Packaging Process Directions

- **Wafer Scale Packaging (WSP)**
  - ✔ IC packaging performed on wafer
  - ✔ low-to-moderate I/O density applications

- **System-on-a-Chip (SOC) Packaging**
  - ✔ multiple chips in single package
  - ✔ multiple functions
    - » RF and mixed signal (incl. embedded passives)
    - » MEMS
    - » bio-chips
WSP Implications

- Known-good-packages vs. known-good-die
- Economics of wafer-scale interconnect processing
- Blurring of the boundaries between chip manufacture and packaging
  - Cu / Ag ECD metallization
  - Barriers
  - CMP

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Principal ESH Issues

- Pb-free solders
- Pb-free lead frames
- ECD baths (Cu, Ni, Au, Ag, Co)
- Flame retardants
  - Bromine-containing
  - Antimony trioxide
- Water use (plating)
- Energy use
- Heat sink attach materials
Wireless bonding: bump via fabrication

1. Deposit dielectric
2. Apply photoresist
3. Soft bake
4. Align & Expose
5. Develop image
6. Hard bake
7. Etch
8. Resist strip

Subtractive Flow

Additive Flow

Photo-BCB

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Photosensitive Benzocyclobutene

- Single-step, low T cure
- Moisture resistant
- Thermal stability
- Film retention
- Low dielectric constant

CLA photosensitizer

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Spin Coat ESH Liabilities

Polymer Slurry Production

- monomer in solvent
- Volatile solvent air emissions
- N₂ blanket
- Polymer in solvent liquid waste
- Self-life expiration: polymer in solvent liquid waste
- Bottle, ship and cold storage
- Spin coat
- Volatile solvent air emissions
- dispense
- Polymer in solvent liquid waste
- Hot Plate
- Volatile solvent air emissions

Polymer in solvent liquid waste
Overlapping Performance Metrics

Product Performance

Environmental Protection

Cost

Target

product architecture
materials properties

emissions
energy use
water use
product life-cycle

yield
scale-up
throughput
efficiencies

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Autophotosensitive Photoimageable Polyimide Vapor Deposition

heating to convert polyamic acid to polyimide

monomer condensation and polyamic acid formation

vapor transport

monomer sources

diamine

dianhydride

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Environmentally Benign Pb-free Solders for Microelectronics Packaging Applications

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