EBP 412 Polimer Khursus
What is electronic packaging?

Electronic packaging consists of 5 key function in electronics;

1) Power distribution
2) Signal distribution
3) Thermal management
4) Design and test
5) Protection
The Key Link in the Chain

Chip-to-Package

Package-to-Board

Board-to-System
Silicon ↔ Package Relationship

**Silicon Processor:**
The “brain” of the computer
(generates instructions)

**Packaging:**
The rest of the body
(Communicates instructions to the outside world, adds protection)
Package Assembly

Die bump

Underfill

Die

Substrate

Motherboard

Flip Chip Interconnect

- **Function of a Package:**
  - Provides housing for the Si Chip
  - Provides circuit path from Si Chip to Motherboard and outside world
  - Manages heat generated by chip
  - Prevents signal loss during transmission
Package configurations

Configuration: Wirebond

Die
Mold compound
Wire
Adhesive
Substrate
Ball

Configuration: Flip Chip

Die bump
Underfill
Substrate
Ball
Polymers in a Flip Chip Package

- Silicone Sealant
- Silicone Thermal Interface
- Epoxy underfill
- Bismaleimide Triazine/Epoxy core
- Epoxy solder resist
Polymer in Wirebond Package

Phenolic mold compound

Bismaleimide die attach

Bismaleimide Triazine core

Epoxy solder resist
Demand For Polymer

- The industry needs polymers to fulfill its high reliability requirements and demanding environment requirements.

- Requirements:
  - High dimensional stability
  - Excellent thermal-oxidative resistance
  - Good chemical resistance
  - Low moisture absorption
  - High mechanical strength
  - Excellent stiffness
  - High compressive strength

High performance thermoset polymers
What kind of polymers used for electronic applications?

What are the important properties?
Polymers in a Flip Chip Package

Silicone Sealant

Silicone Thermal Interface

Epoxy underfill

Epoxy solder resist

Bismaleimide Triazine/Epoxy core

Underfill; epoxy resin + low CTE filler

Thermal Interface material; silicone rubber + high thermal conductive filler

Core of the Substrate; Bismaleimide/epoxy + woven glass fabrics
Polymer in Thermal Packaging

- Material that thermally bonds components in an enabling assembly to ensure good heat transfer path between the die and the enabling solution.
- TIM fills-up the interfacial gaps between 2 components ensuring a continuous path for conduction heat transfer.
- TIM serves two functions on flip chip packages
  - Maximize the transfer of heat away from the chip so that the chip will function properly.
  - Absorb stress due to the mismatch of thermal expansion between chip, substrate and the IS (integrated heat spreader).
TIM M Materials

- **Thermal grease** -- is a silicone oil containing conductive fillers such as aluminum, nickel or copper.

- **Gels** -- A crosslinked silicone polymer filled with a metal (typically aluminum or silver) or with a ceramic (aluminum oxide or zinc oxide) particles. Gels are greases that are cured to prevent them from migrating out of the material.

- **Elastomers** - A thermally conductive adhesive pad that can be cut into desirable shape/pattern.

- **Polymer phase change materials** -- Materials that undergo a transition from solid to liquid phase when heat is applied. They are solids at room temperatures and thick liquids (paste-like) at die operating temperatures.

- **Solder TIM** - Metallic preform that has excellent bulk thermal conductivity and low melting point metal
Polymer in Substrate

Core material
Made out of multi-layer glass fiber with resin
Can have various specifications for the glass fiber dimensions and layer count
Can also specify various types of resin (e.g. BT, epoxy, etc)
Function: provide stiffness to the substrate
What is an underfill?

In flip-chip technology, the gap between substrate and chip is underfilled with highly filled epoxy system

- High modulus, low CTE adhesive which couples the die and substrate

Role of underfill:

- Provides reliability to the flip chip package
  - By redistributing the stress due to CTE mismatch
  - Prevents interconnect fatigue by applying compressive stresses to the bumps
Mechanism of UF Encapsulation

The mechanism of underfill encapsulation for solder joint protection

Substrate and chip are interlocked by underfill
The strain on joint is converted to deformation
Joint is compressed and protected by underfill
Underfill Technology Options

Capillary Underfill (CUF)

Flow of underfill material underneath die is due to capillary action.

1) Underfills are normally premixed and supplied by supplier
2) Packed in plastic syringes, frozen packed at -40ºC to prevent curing
3) In shipping, these underfills need special handling
4) Upon receiving the package, unpack the package, take out the syringes quickly, and store in a freezer at temperature of -40ºC
Typical formulation and it’s function

- Filler, SiO₂
  - Control viscosity and CTE
  - Must be small enough, so that it will not block flow
  - Approximation, particle size should not exceed 1/3 of the gap size
- Resin
  - Base material and to provide interfaces adhesion
- Hardener
  - To provide impact toughness and final property
- Catalyst
  - Initiate reaction and control x-linking rate
- Elastomer
  - To provide stress absorber and toughness
- Additives:
  - Dye/Pigment: Color
  - Surfactant: homogeneity
  - Adhesion promoter: increase interfacial adhesion
Various CUF Chemistries

Epoxy Chemistries
Epoxy-anhydride – industry standard workhorse
Epoxy-amine – offers improved toughness, moisture resistance
Epoxy homopolymers – offers outstanding moisture resistance
Epoxy-phenolic – offers improved toughness, flexibility, adhesion
Key parameters to consider before selecting an underfill material

- **Flow properties**
  - Flow time/flow distance
  - Rheology
  - Viscosity

- **Thermal properties**
  - CTE1/CTE2
  - \( T_g \)
  - Gel time

- **Mechanical properties**
  - Modulus
  - Toughness

- **Ionic contents**
  - K, Cl, Na

- **Environment**
  - Moisture uptake

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**Modulating factor:**
- Filler loading/type
- Catalyst
- Resin
- Toughener
How to select underfill materials

1) Low CTE, can reduce thermal expansion mismatch between chip/solder bump and solder bump/substrate
2) High modulus, leads to good mechanical properties
3) High glass transition temperature, withstand high temperature environment
How to select underfill materials

4) Good adhesion, improve product lifetime
5) Low moisture absorption, extend shelf life
6) Low viscosity (fast flow)
7) Low curing temperature/fast curing time, can reduce cost, and less harmful to other components
Thermoset Polymers

Silicones, polyimides, epoxies, phenolic, etc

Performance criteria

Physical properties
Processability condition
Manufacturability procedure
Reliability stress test
Cost

Epoxy
Phenolic
Imide/Maleimide
Resin

- Typically, base resin is comprised of epoxy system
  - i.e. naphthalene epoxy or bisphenol F
- Posses the epoxy groups, and are convertible in 3-D structure by variety of curing reactions.
- It provides good adhesion to the chip and substrate interfaces
- Bisphenol resin is the most commonly used epoxy resin due to attractive properties; fluidity, low shrinkage during cure & ease of processing

DGE of 1,6-dihydroxynaphthalene

Bisphenol F
Epoxies

Advantages
- excellent chemical and corrosion resistance
- superior mechanical properties
- Excellent adhesion
- Low shrinkage
- Reasonable material cost

Disadvantages
Brittle & poor resistance to crack propagation
(therefore catalysts/blend hardeners & reactive diluents are added into the formula)
Types of epoxy resins

Bisphenol, commercial epoxy

Novolac (Phenol-formaldehyde)- Phenolic groups in a polymer are linked by a methylene bridge, provide highly cross-linked system, for high temp and excellent chemical resistance

Resole (base-catalyzed phenol-formaldehyde), high temp. curing, and excellent chemical resistance
Crosslinking agents

- To provide a 3-D network system to enhance the toughness of the underfill material
- i.e. amines, anhydrides, dicyanodiamides, etc.
- Plays an important role in determining the properties of final cured epoxy
- It effects the viscosity and reactivity of the formulation, determined types of chemical bonds formed and degree of cross linking that will occur (thus effect the Tg)
Figure 9.8. Formation of an epoxy prepolymer by reaction of bisphenol-A and epichlorohydrin.
Figure 9.9. Cure of an epoxy resin by reaction of the prepolymer with an amine.
Figure 9.10. Cure of an epoxy resin by reaction of the prepolymer with an anhydride.
Effect of curing agent on the Tg of epoxy resin

![Diagram showing the effect of different curing agents on the glass transition temperature of epoxy resin.](image)

- Amidoamines
- Aliphatic Amines
- Cycloaliphatic Amines
- Aromatic Amines
- Latent Amines

The graph shows the glass transition temperature in °C for cold and hot curing conditions.
Polyimides

- Superior thermal stability (up to 500ºC)
- Excellent solvent resistance
- Ease of application
- Excellent mechanical properties

Disadvantages
- Affinity for moisture absorption due to carbonyl polar groups of polyimide
- High temp. cure
- High cost
Polyimides

- Polyimides are formed by a 2-stage process
- The first stage involves polycondensation of an aromatic dianhydride and aromatic diamine to form an intermediate poly(amic acid).
- Dehydradition of poly(amic acid) at elevated temp. yields the polyimide (PI) structure
Polymerization of a polyimide
Bis-maleimide Triazine (BT)

- Mainly produced by Mitsubishi Chemicals in Japan
- High Tg (> 230°C)
- Good thermal-mechanical properties
- Good toughness
Silicones

- High thermal stability
- Superior electrical, physical and chemical properties
- Non corrosive
- Low level of ionic contamination (ionic contamination effect the electrical reliability of the device)