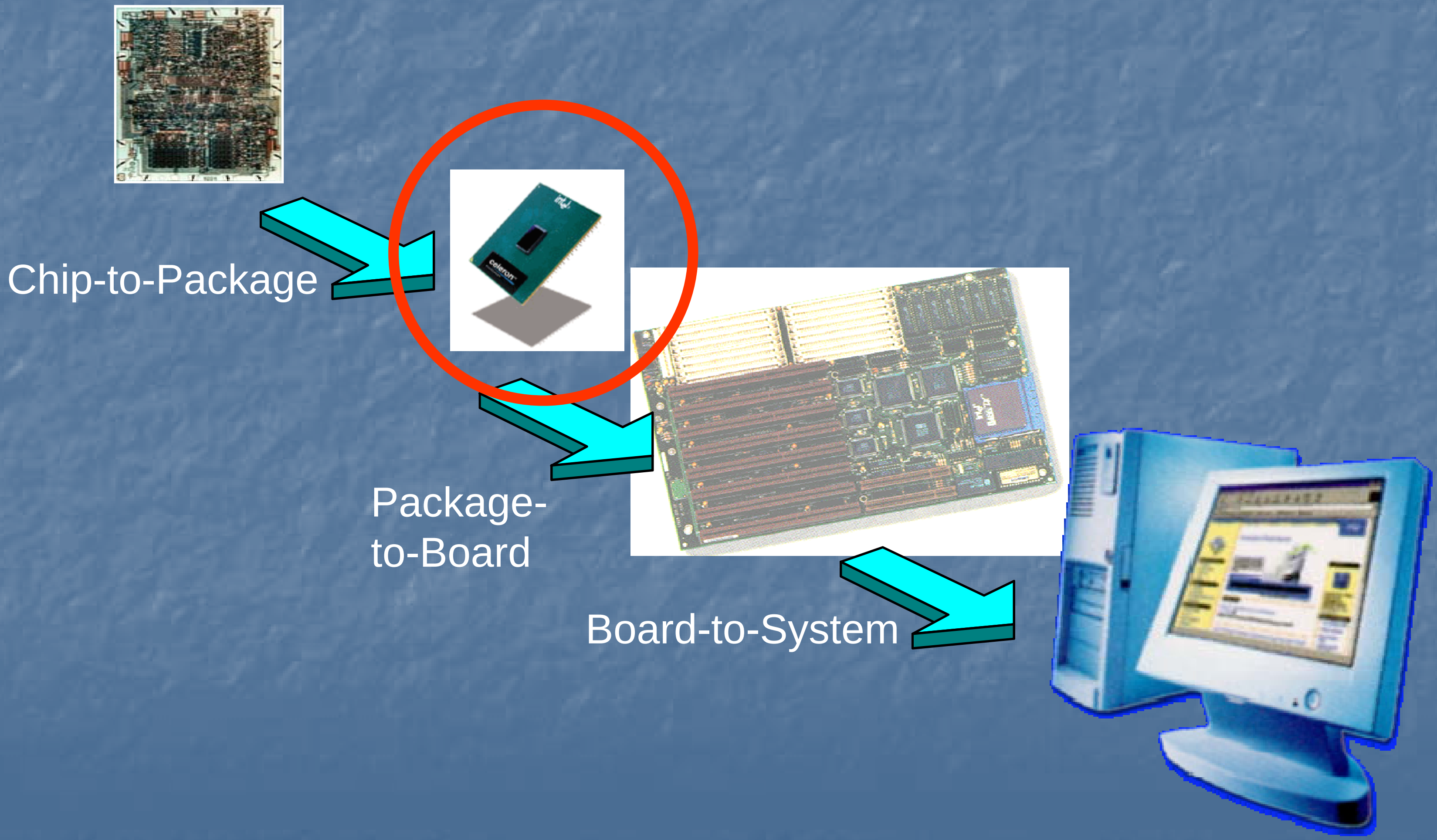
EBP 412 Polimer Khursus

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

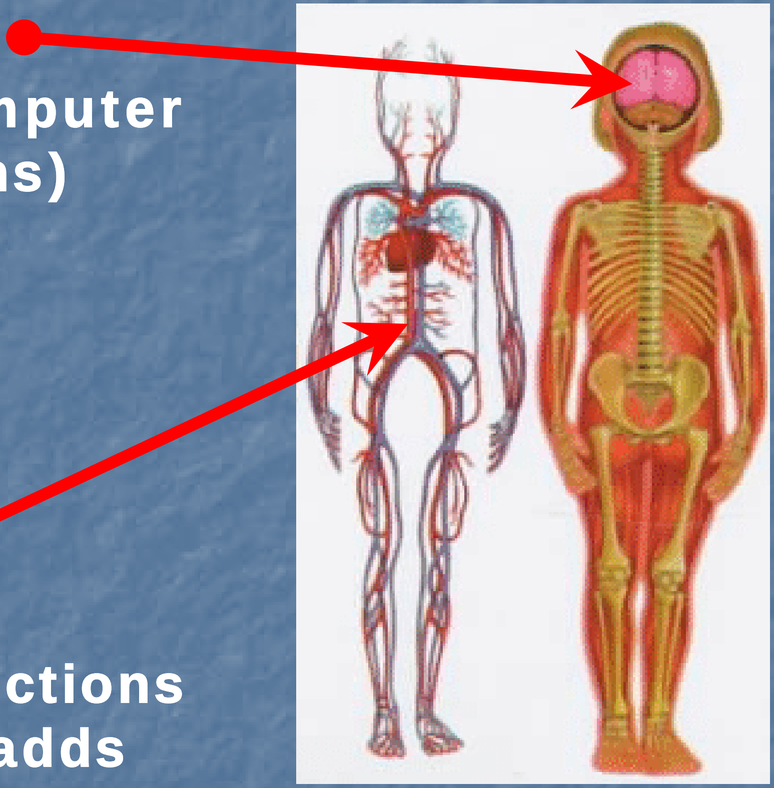


Chip-to-Package

Package-
to-Board

Board-to-System

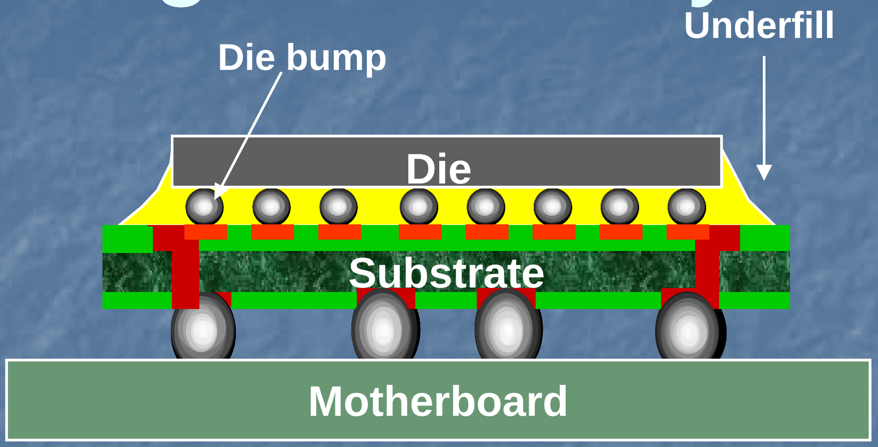
Silicon ⇔ Package Relationship



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

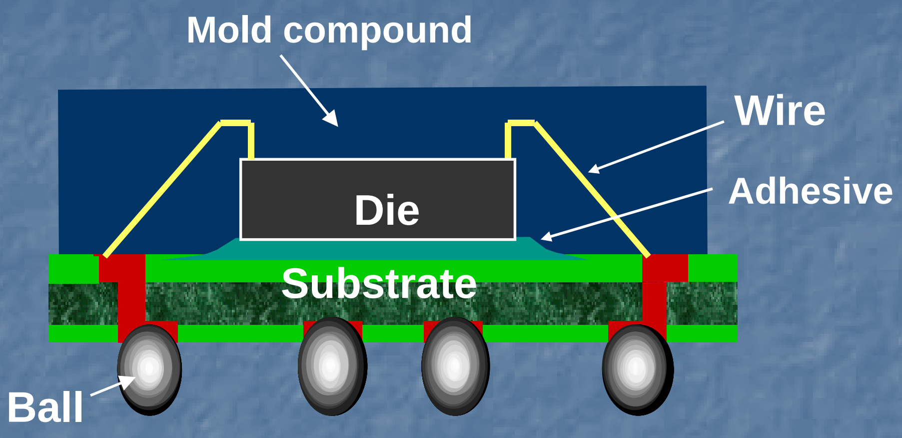


Flip Chip Interconnect

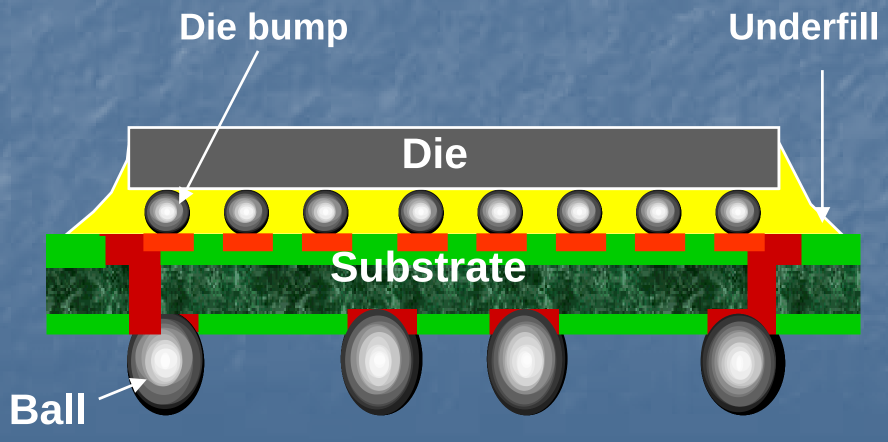
- **<u>Function of a Package:</u>**
- **Provides housing for the Si Chip**
- **Provides circuit path from Si Chip**
- **to Motherboard and outside world**
- **Manages heat generated by chip**
- **Prevents signal loss during**
- **transmission**

Package configurations

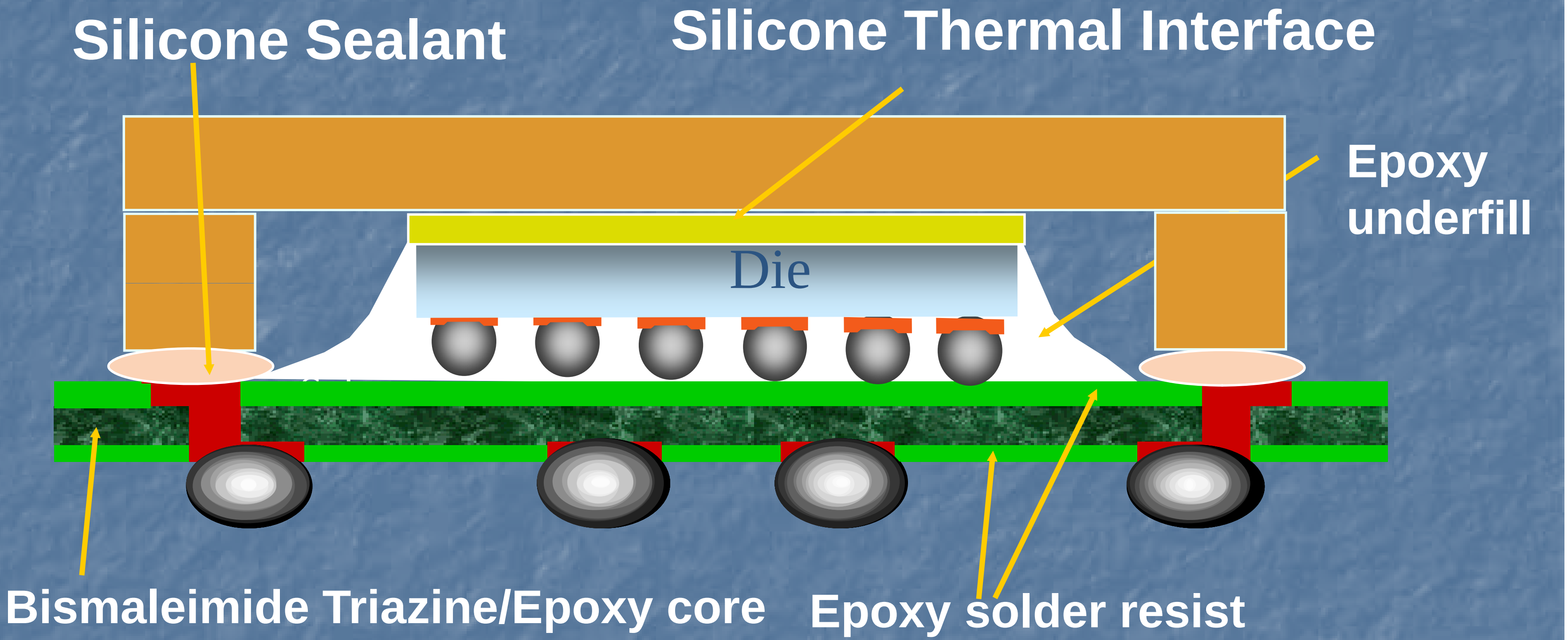
Configuration: Wirebond



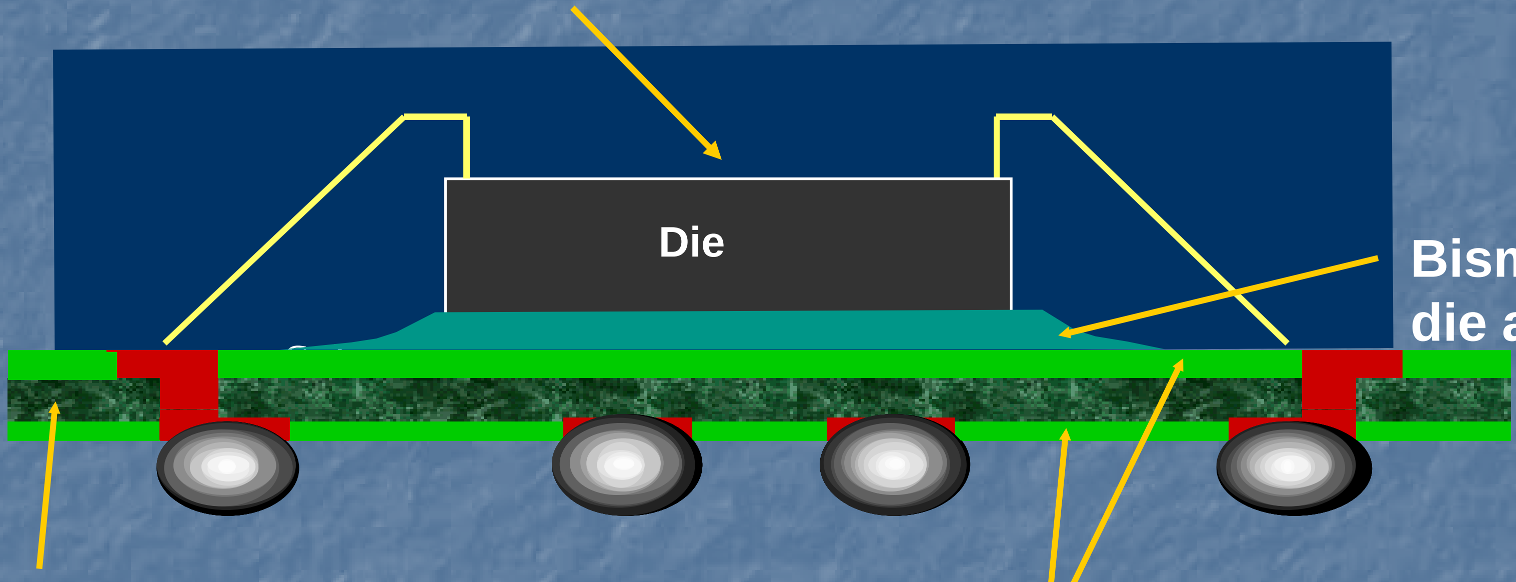
Configuration: Flip Chip



Polymers in a Flip Chip Package



Polymer in Wirebond Package



Phenolic mold compound

Bismaleimide die attach

Bismaleimide Triazine core

Epoxy solder resist

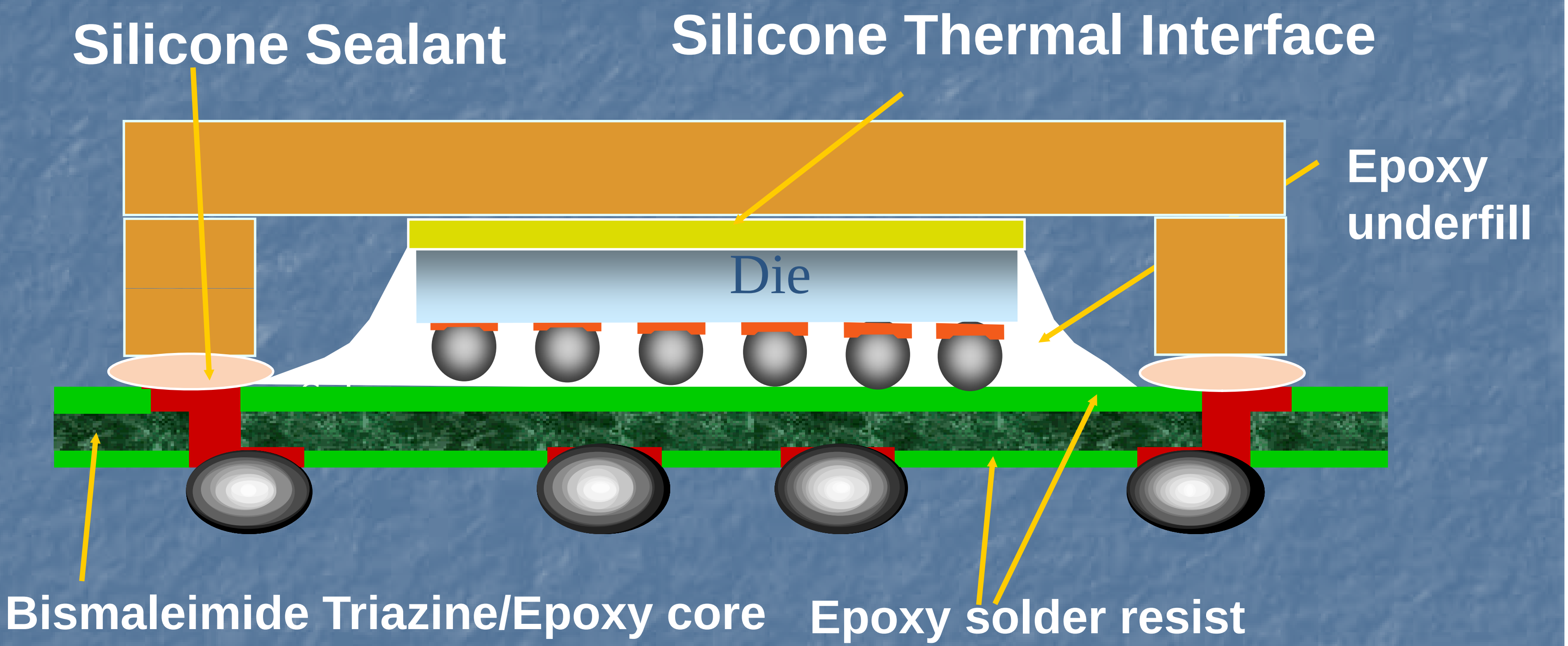
Demand For Polymer

- The industry needs polymers to fulfill its
  - High reliability requirements
  - Demanding environment
- 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?

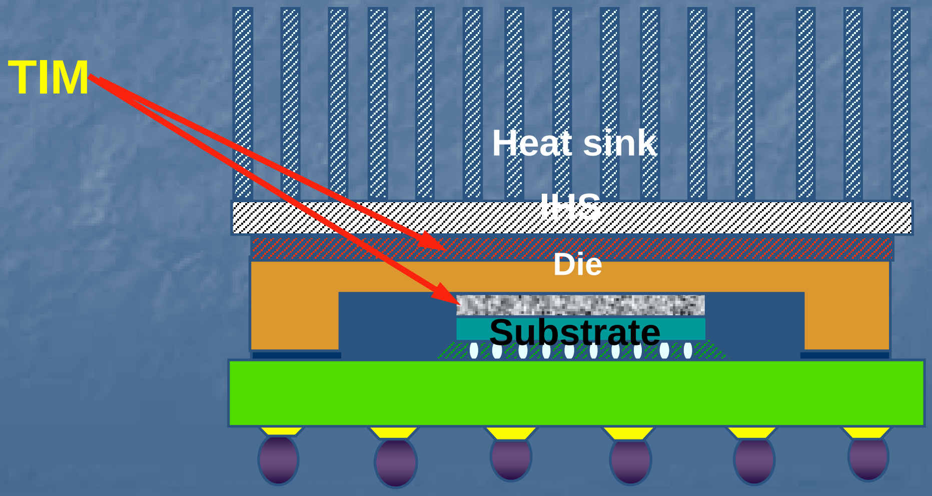
Polymers in a Flip Chip Package



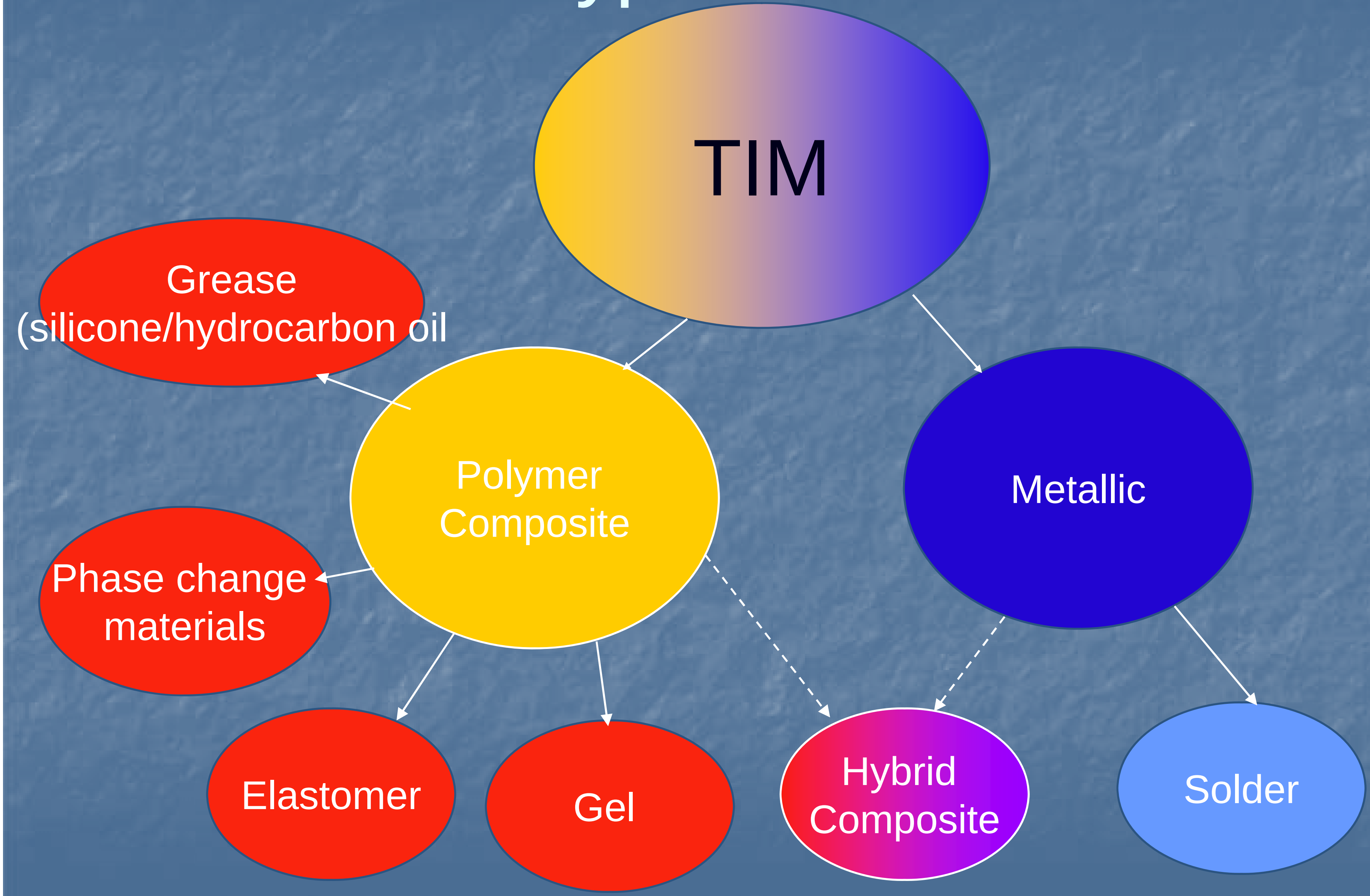
Underfill; epoxy resin + low CTE filler
Thermal Interface material; silicone rubber + high thermal conductive filler
Core of the Substrate; Bismaleimide/epoxy + woven glass fabrics

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).



Types of TIM



TIM

Polymer Composite

Metallic

Grease (silicone/hydrocarbon oil

Phase change materials

Elastomer

Gel

Hybrid Composite

Solder

TIM 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.**

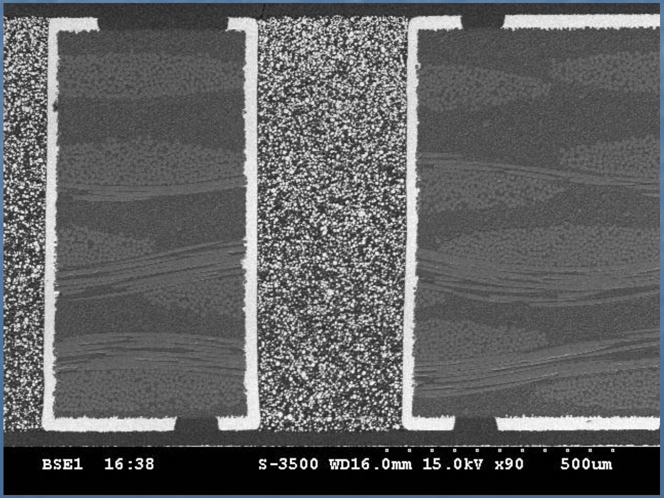
- Elastomers **– A thermally conductive adhesive pad that can be cut into desirable shape/pattern.**

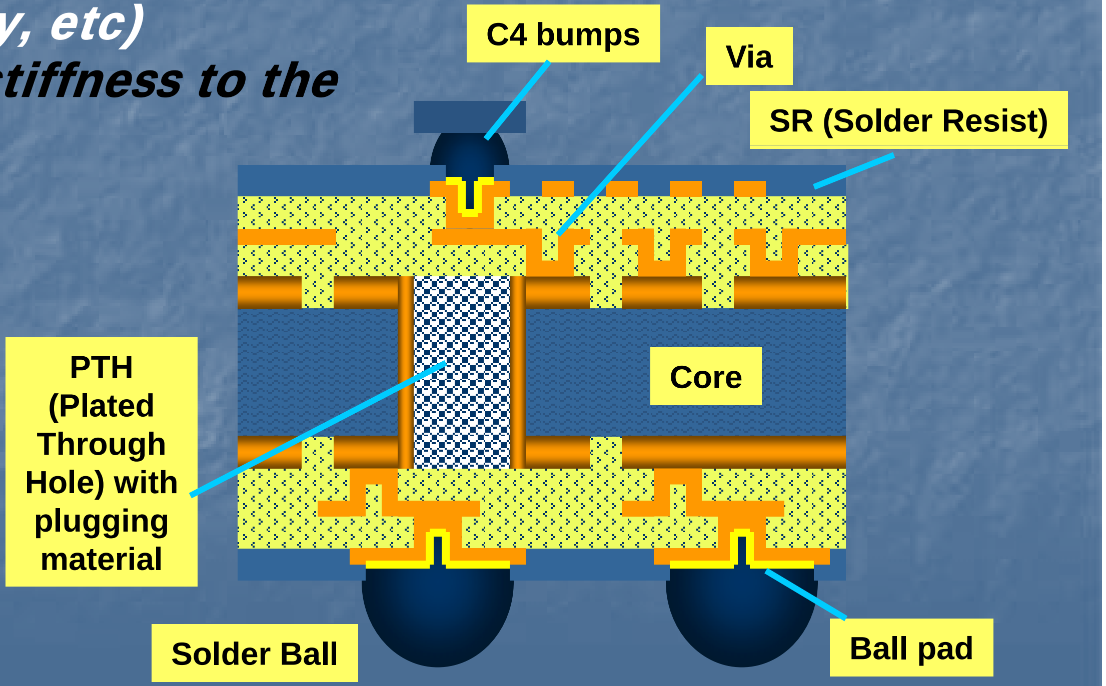
- Polymer phase change materials **-- Materials that undergo a transition from solid to liquid phase when heat is applied. They are solids at room temperatures and thick liquids (paste-like) at die operating temperatures.**

- 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 (eg. BT, epoxy, etc)***
    - ***Function: provide stiffness to the substrate***





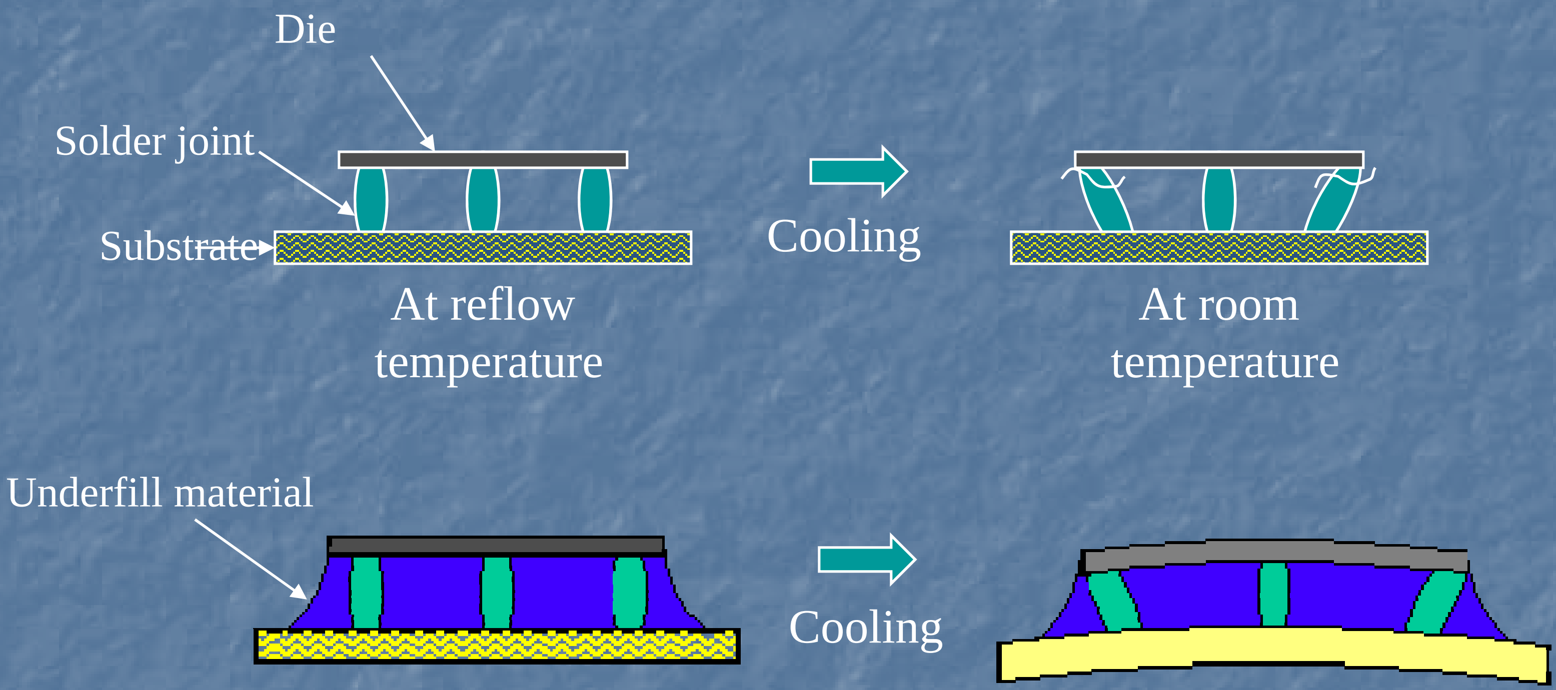
What is an underfill?

Flip Chip Ball Grid Array (FCBGA)

- 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



Die

Solder joint

Substrate

At reflow temperature

Cooling

At room temperature

Underfill material

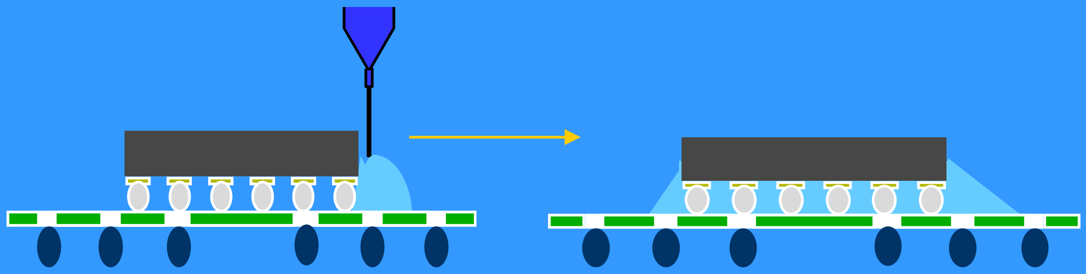
Cooling

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 are 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 storein a freezerat temperature of -40ºC

Typical formulation and it’s function

- Filler, SiO_2
  - 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

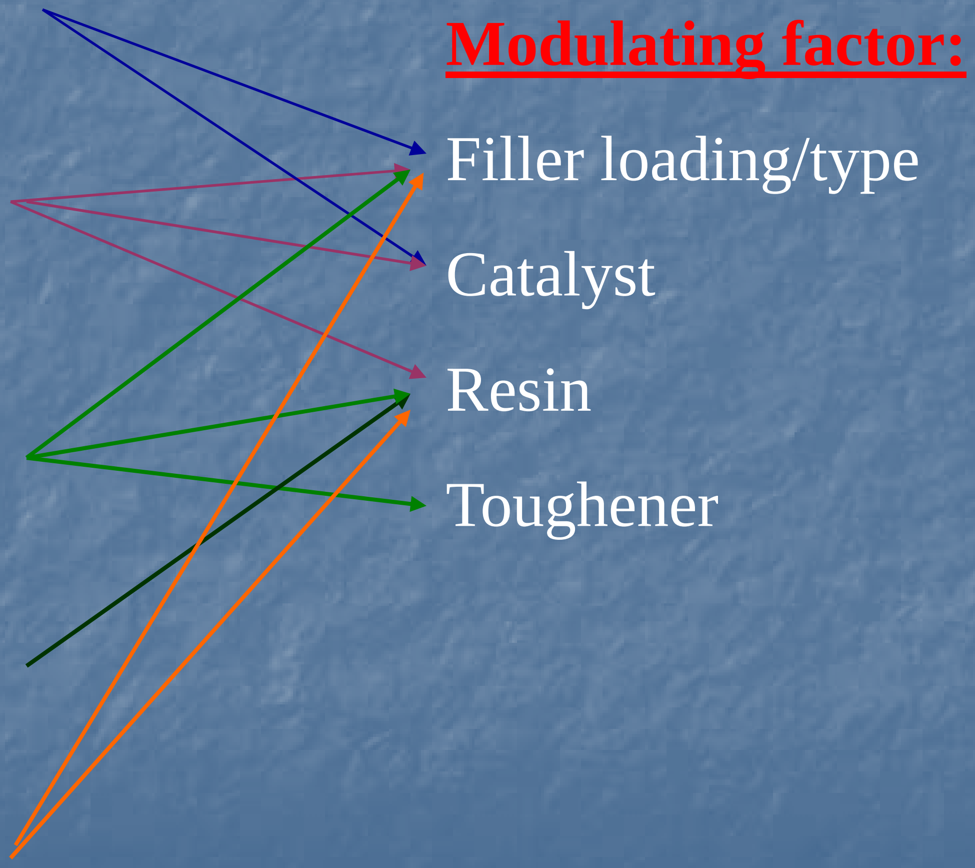
Epoxy-amine – offers improved toughness, moisture resistance

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



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)

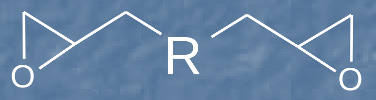
7) Low curing temperature/fast curing time, can reduce cost, and less harmful to other components

Thermoset Polymers

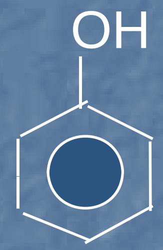
Silicones, polyimides, epoxies, phenolic, etc

Performance criteria

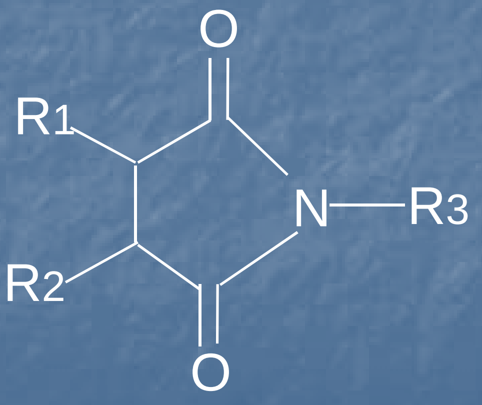
- **Physical properties**
- **Processability condition**
- **Manufacturability procedure**
- **Reliability stress test**
- **Cost**



Epoxy



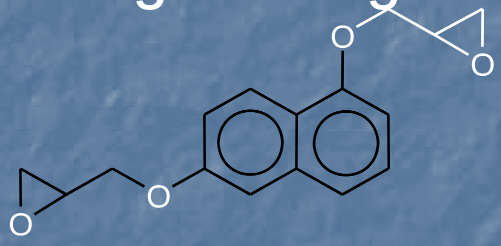
Phenolic



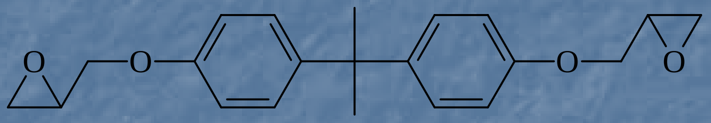
Imide/Maleimide

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 foemula)

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)

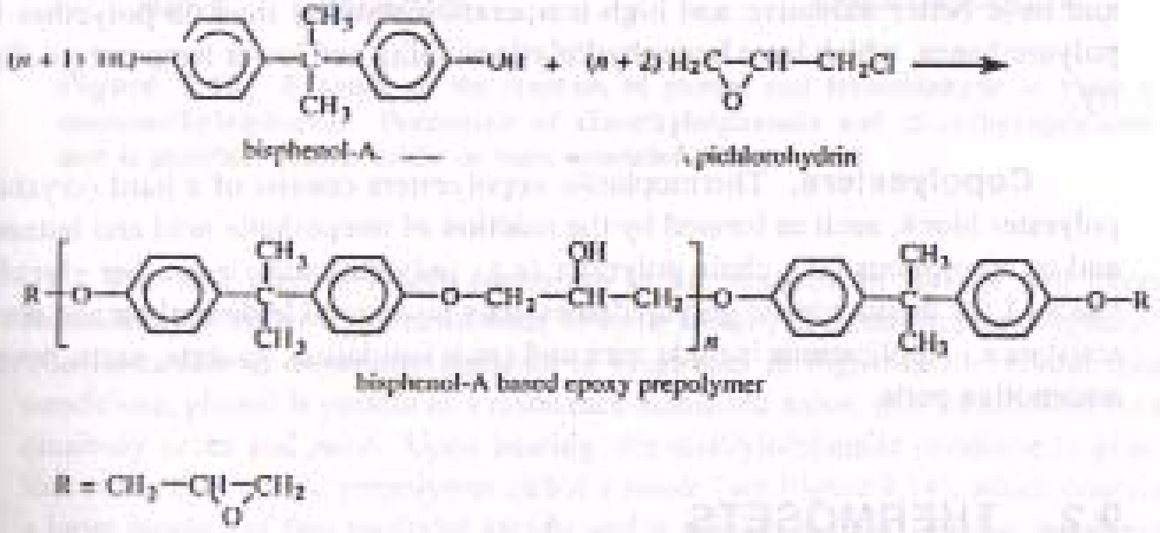


Figure 9.8. Formation of an epoxy prepolymer by reaction of bisphenol-A and epichlorohydrin.

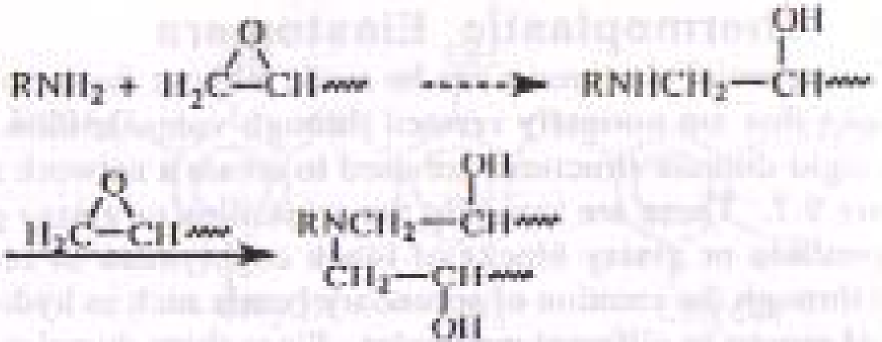


Figure 9.9. Cure of an epoxy resin by reaction of the prepolymer with an amine.

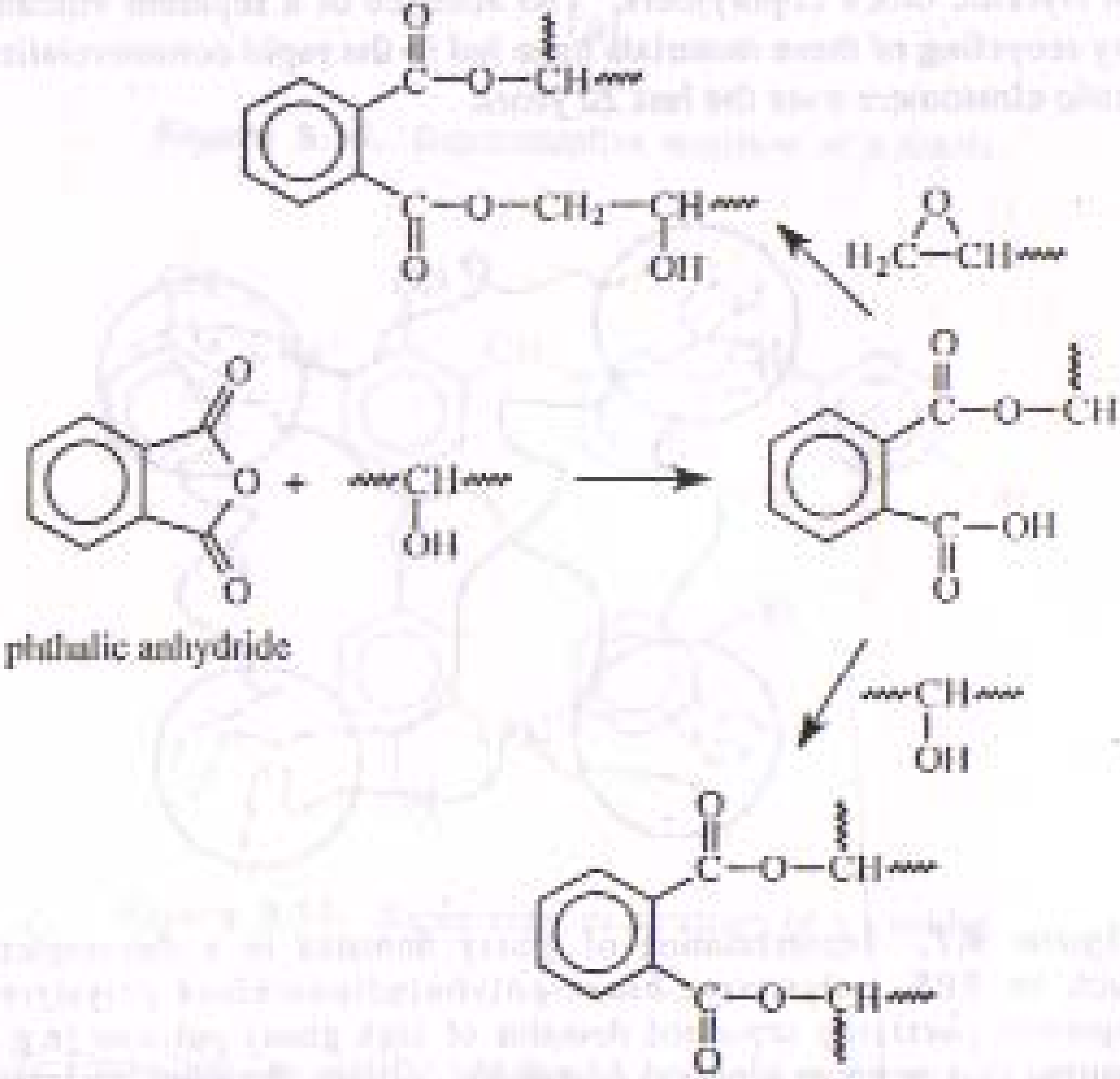
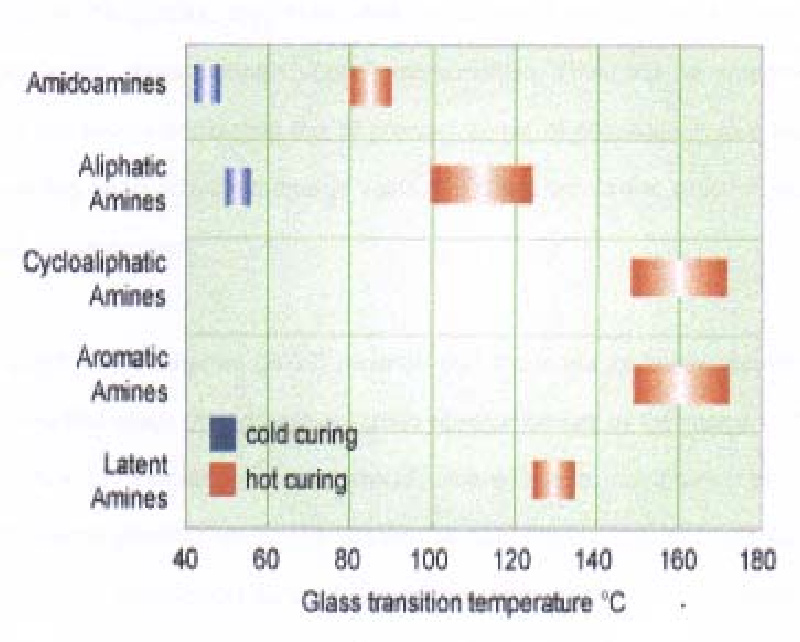


Figure 9.10. Cure of an epoxy resin by reaction of the prepolymer with an anhydride.

Effect of curing agent on the Tg of epoxy resin



Polyimides

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

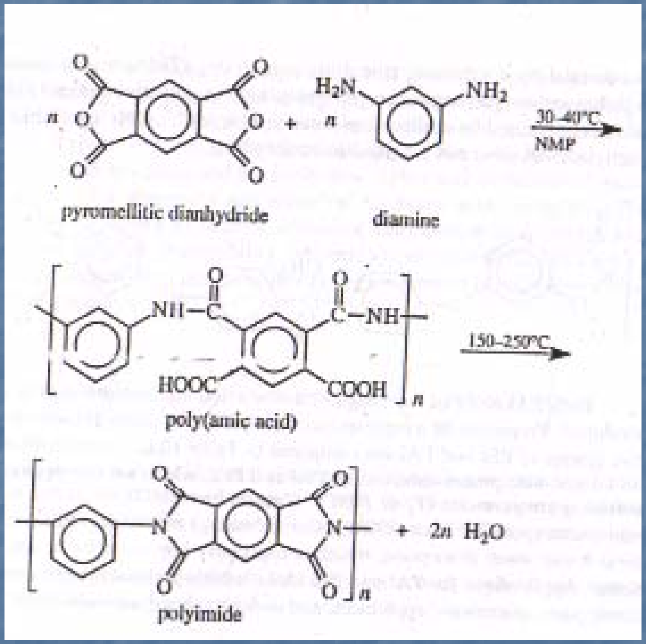
Disadvantages

- 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. yialds the polyimide (PI) structure

Polymerization of a polyimide



Bis-maleimide Triazine (BT)

- Mainly produced by Mitshubishi Chemicals in Japan
- High Tg (> 230ºC)
- 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