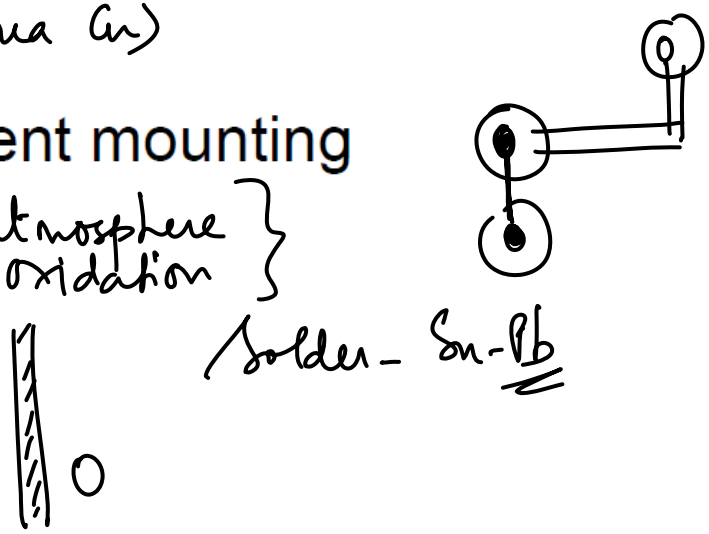
Continuing..

PRINTED WIRING BOARD TECHNOLOGIES

Basic Steps in Manufacture
Single sided board

- Design — DFM, DFR, DFT
- Photo-tooling (1:1) "MASK" – film (several)
- Image/ Print (Photoresist, CCL(Cu),)
- Etch (non-circuit area Cu)
- Drill holes for component mounting
- Protect Cu (Solder) : atmosphere, oxidation
- Solder mask (epoxy)
- Assemble



Double sided board manufacture

- Design
- Photo-tooling (1:1)
- Drill holes (PTH)
- Plate (electroless)
- Image circuit
- Plate (Cu electroplate)
- Plate (Sn or Sn-Pb electroplate)
- Strip
- Etch
- Strip and Protect before assembly

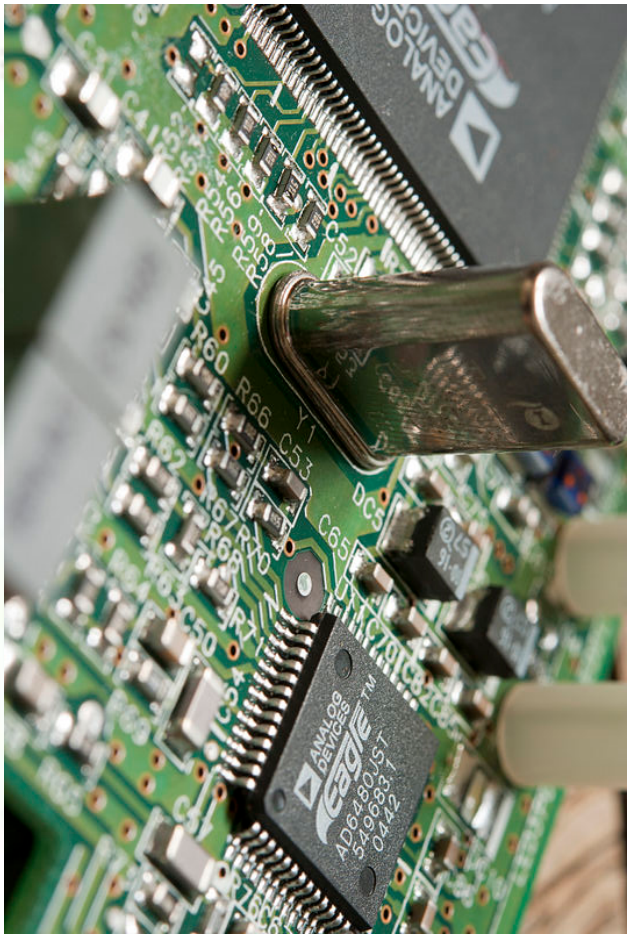


Fig. source: Wikimedia Commons 2011

Basic approaches for Fabrication

- Subtractive Process

Etching

- Additive Process

- Semi-additive Process

8μ, 18μ

Plating

Copper

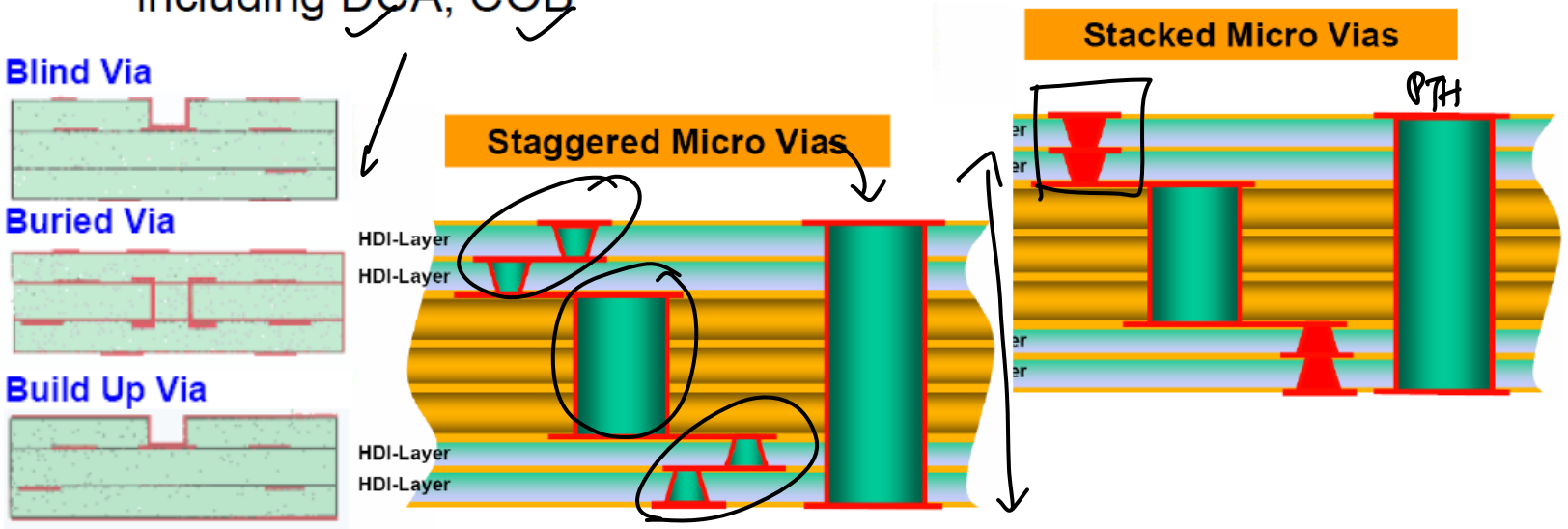
Electronics Interconnection

- Reduced size of the board, high density
- Low weight and cost factors
- Cheaper and newer materials with improved properties
- Finer lines, smaller vias on board
  - aspect ratio on board
  - use of more blind or buried vias
  - ability to house low-pitch components including DCA, COB

organic / thickness – multilayer boards

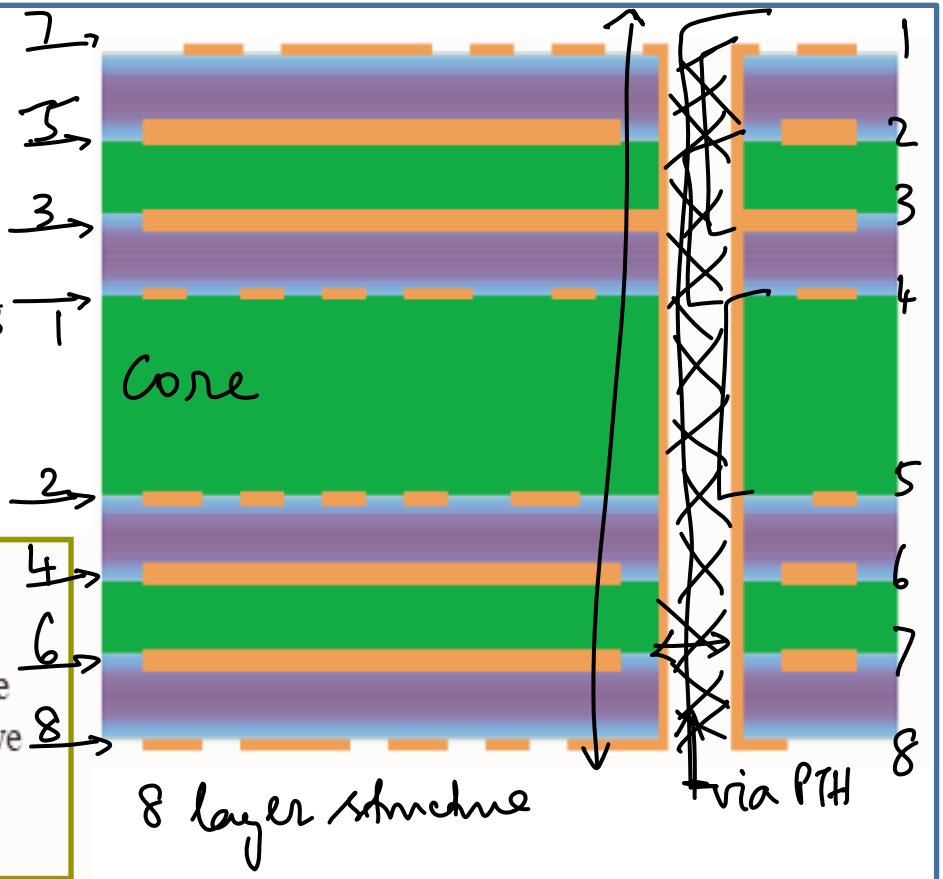
4mil line / 12 mils (12×25)

(high reliability)



PCBs and Vias:

- ❑ Interconnect layers through mechanically drilled vias which are plated through
- ❑ Aspect ratio restrictions apply during manufacturing
- ❑ Designers need to understand Aspect Ratio concept



Aspect ratio of a via: Ratio of board thickness to via diameter. Allows judgement of manufacturability. The larger the aspect ratio, the more difficult it is to achieve reliable plating. Premium charge for aspect ratios > 8.

Example:

Board thickness= 1.6mm

Minimum via dia on board=0.4mm

Aspect Ratio is 4

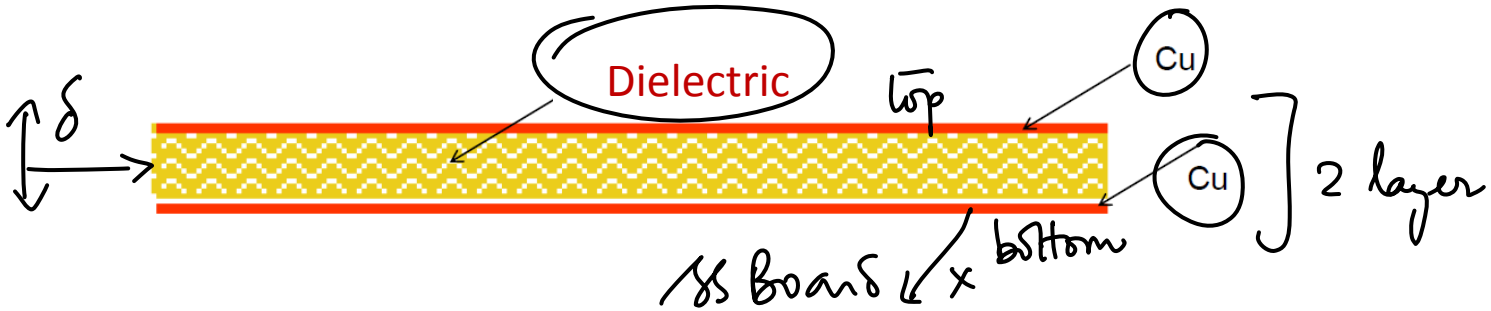
No major issues in plating can be expected!

AR = Board thickness / min via dia

0.2 → 0.8mm

Substrate

- Select a Copper clad laminate (CCL)
  - metallic conductor is Cu in most cases
  - Electro-deposition and Electroforming process
  - dielectric material thickness
  - Cu foil thickness (ounce per square foot area)



Conductor Plane - Thickness ?

Expressed as Ounce per Square Foot

ONE Ounce = 28.33 grams

1	Oz/Sft 35 u	35 u
1/2	Oz/Sft 17.5 u	18 u
1/4	Oz/Sft 8.75 u	10 u
1/8	Oz/Sft 4.375 u	5 u
2	Oz/Sft 70 u	70 u
3	Oz/Sft 100 u	100 u

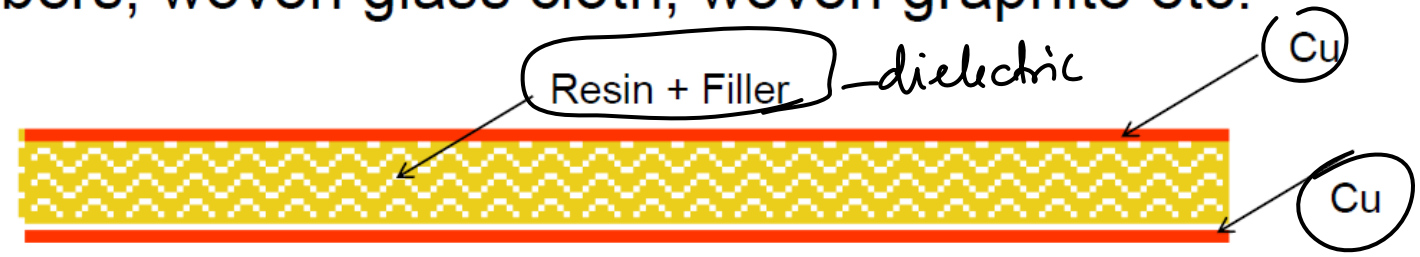
1 oz of Copper will cover 1sq ft when rolled out
to a thickness of 0.0014” or 1.4mil or 35um

Substrate material...

CCL

epoxy-glass CCL

- Three components
  - Copper, Resin and Filler → organic / inorganic
    - Copper is the conductor
    - Resin provides insulation and electrical characteristics (epoxy, polyimide, PTFE*, polysulfone, BT-epoxy etc.)
    - Filler gives the required mechanical strength
- Organic fillers are usually Kraft paper, glass fibers, woven glass cloth, woven graphite etc.

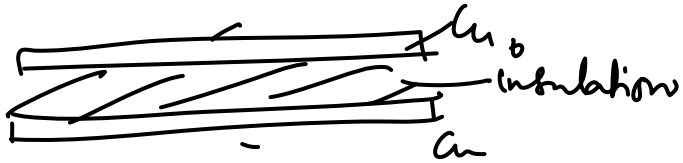


* Teflon

Basic Functions

- Support Components
- Insulate between tracks and layers
- Provide electrical interconnections

Substrate



Desired functions

Mechanically strong to support components

Dissipate heat and have low thermal expansion

Drill and Punch through

Resist degradation by heat and process chemicals

Low dielectric constant (electrical requirement)!

Should not absorb excessive moisture

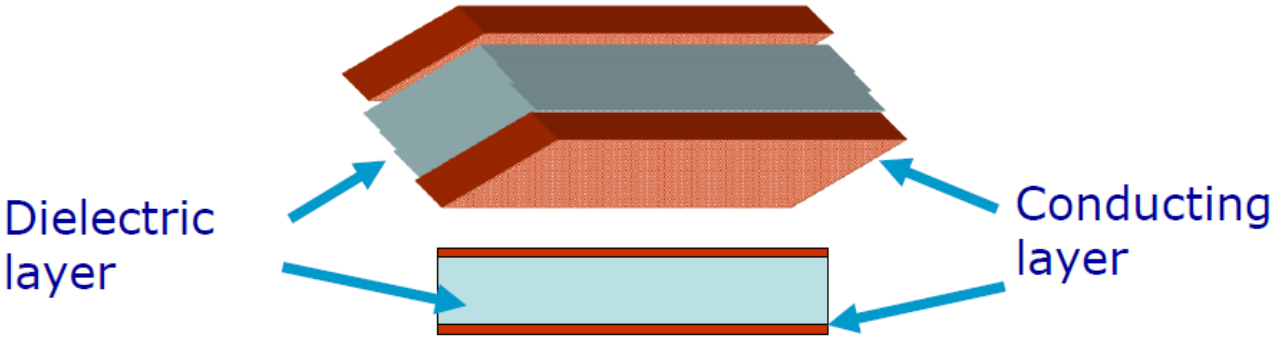
Dielectric should receive plating → electroless plating, electroplating

The Anatomy of laminates

rigid, rigid-flex & flex

Conductor bonded on to the surface of Insulator: Sandwich structure

Components of a CCL: Copper, Resin and Filler



Electrical conductivity of Copper is 59 x 10^6 S/m
Electrical conductivity of Silver is 63 x 10^6 S/m

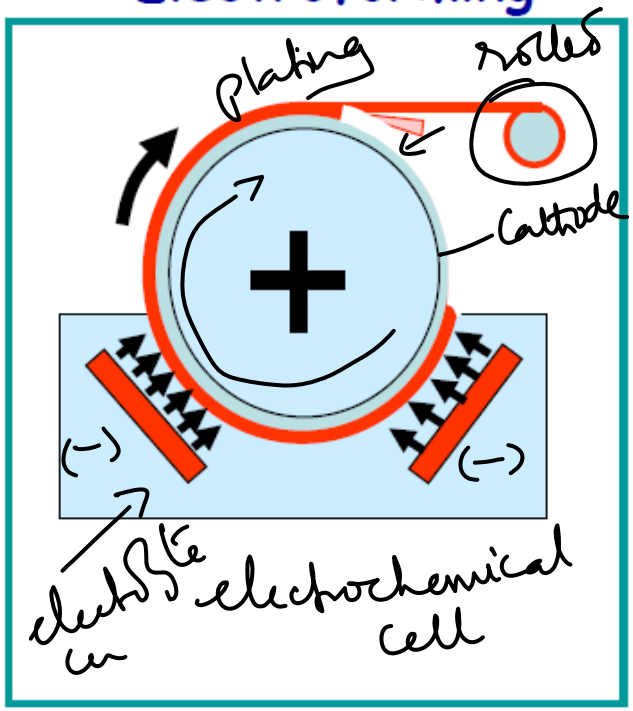
The Conducting Plane-

Why copper ? Why not Au, Ag, Al?

Copper is a good electrical conductor, good thermal conductor, antibacterial, easily joined, ductile, tough, non-magnetic, easy to alloy, easy to recycle, catalytic…

How to produce thin foils ?

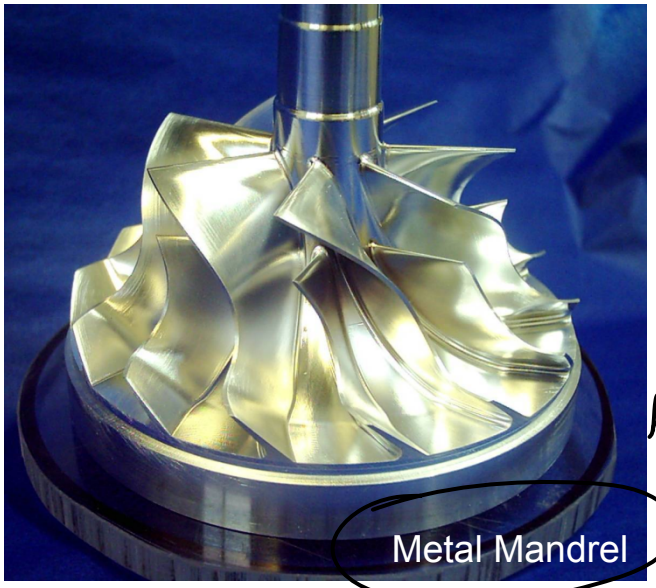
Electroforming



Electroforming is a metal forming process that forms thin parts through the electroplating process. The part is produced by plating a metal skin onto a base form, known as a mandrel, which is removed after plating. This process differs from electroplating in that the plating is much thicker and can exist as a self-supporting structure when the mandrel is removed.

Electroforming- Advantages

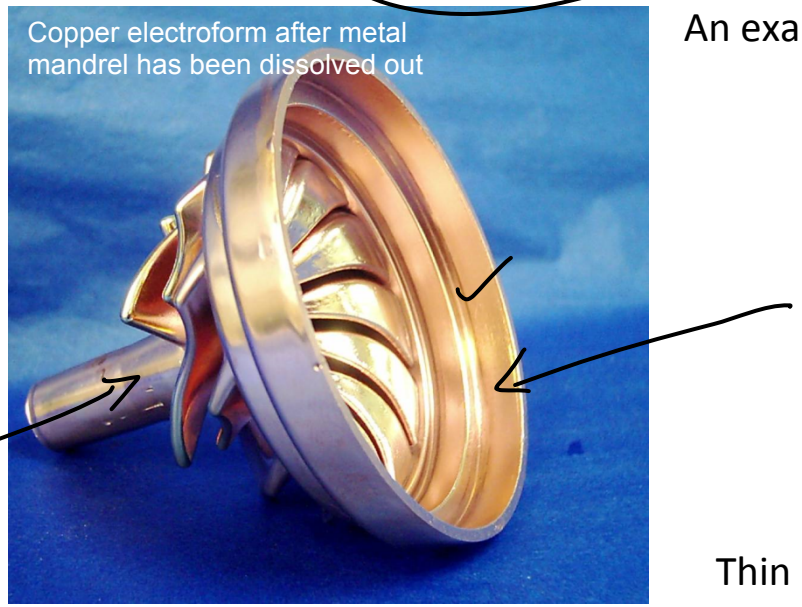
- Large width possible- 1 to 2 meter wide
- Grain structure favorable for etching
- Higher purity - better conductivity
- Thinner the foil more economical is electroforming
- Large surface roughness

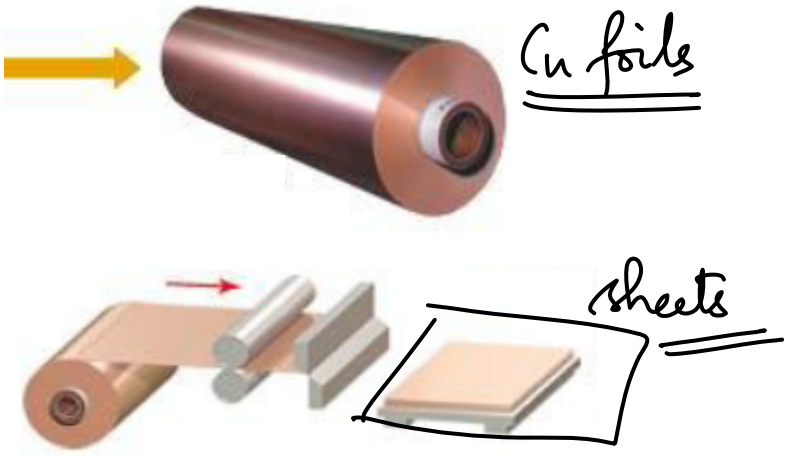


Al

plating

An example of mandrel used in electroforming





Cu foils

sheets

Thin Copper foils from electroforming process

Figure Source: thanks to BJS Co Ltd UK

Organic substrate material characteristics

Material	DEC @1MHz	CTE	Tg degrees C	Water Absorption
BT Epoxy (bismaleimide triazine epoxy)	3.9-4.3	15-16	180	0.05
FR-4 (glass epoxy resin)-flame retardant/fire retardant	3.6-4.2	13-18	125, 180	0.10
Polyimide	3.5-3.6	10-14	250	0.35
Cyanate ester	3.6	8-10	230	0.08
Fluoropolymer (PTFE/Teflon)	2.9	16	327	0.05
Epoxy non-woven	3.9	6-9	180	0.85

FR-4 clarification

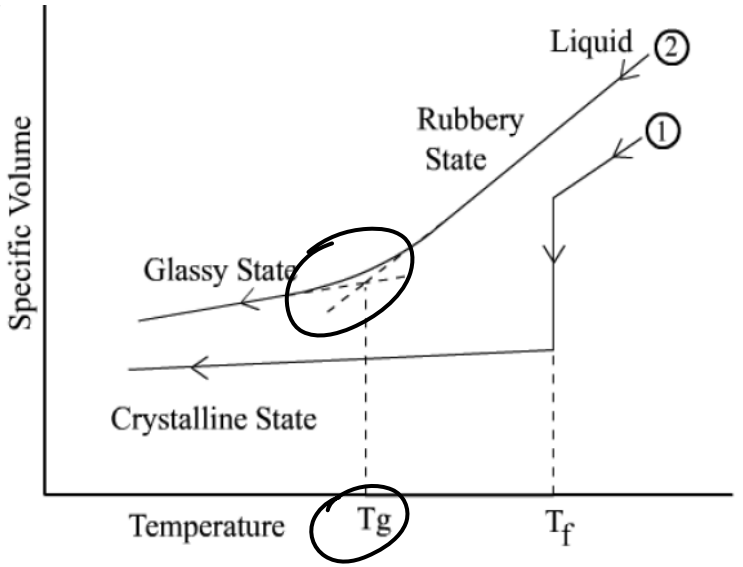
125–190°C

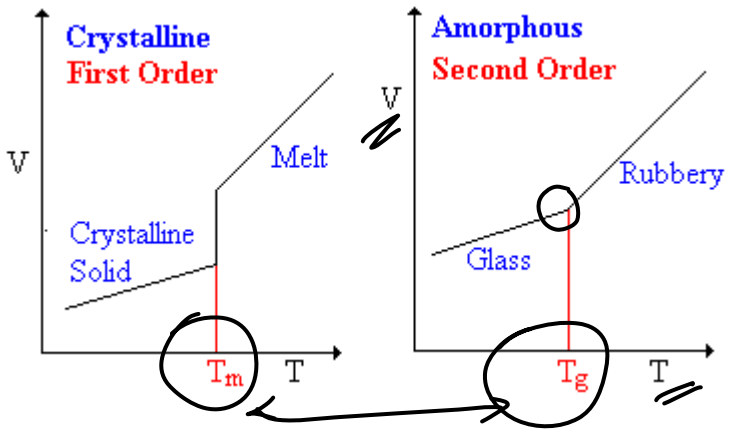
Glass Transition Temperature

Temperature at which the polymer begins to soften…glassy state – denoted by Tg.

Significant because the laminate see a series of "heat shocks"- Soldering and repair.

- Semi-crystalline solids have both amorphous and crystalline regions. According to the temperature, the amorphous regions can be either in the glassy or rubbery state.
- The temperature at which the transition in the amorphous regions between the glassy and rubbery state occurs is called the **glass transition temperature**.
- This is not the same as melting temperature.
- The value of Tg depends on the mobility of the polymer chain - the more immobile the chain, the higher the value of Tg. In particular, anything that restricts rotational motion within the chain should raise Tg.
- A polymer chain that can move easily will change from a glass to a rubber at a low temperature. If the polymer chains don't move as easily, then it will require a relatively high temperature to change the compound into a rubbery form.
- Tg of the organic substrate material is crucial in deciding various process temperatures especially in assembly/soldering. Tg decides reliability!





Why is Tg important?

The Insulating Plane

Organic Insulators - Known by generic names

1. Hylam	Phenol-Formaldehyde
2. Epoxy	Bisphenol-Epichlorohydrin
3. Epoxy-Novolac	Bisphenol-Epichlorohydrin-Phenol
4. Polyimide	Aromatic imide
5. PTFE	Poly tetra fluoro ethylene (Teflon)

Other polymers used are : Cyano-ester

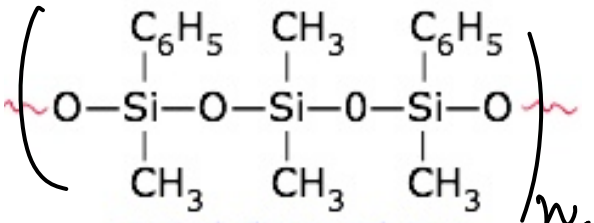
Poly-etheramide

Poly-phenlyene-oxide

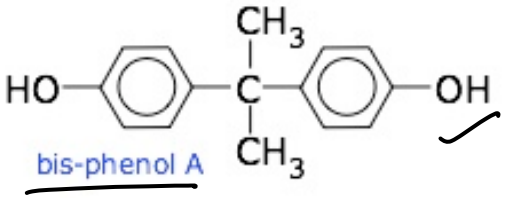
Epoxy

The properties are determined by the:

- Resin type
- Crosslinking Agent
- Degree of crosslinking Tg
- Thermal decomposistion temperature of the resin Td
- Adhesion between resin and reinforcement
- Adhesion of resin to metal foil
- Additive fillers CTE

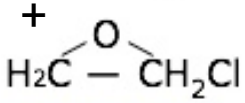


a typical silicone polymer

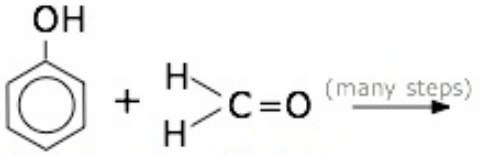


bis-phenol A

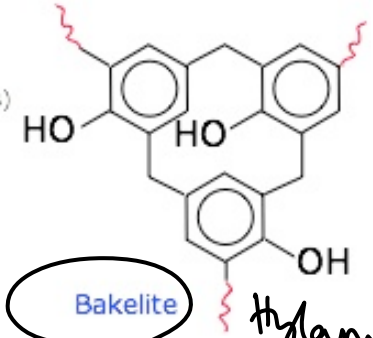
+



epichlorohydrin

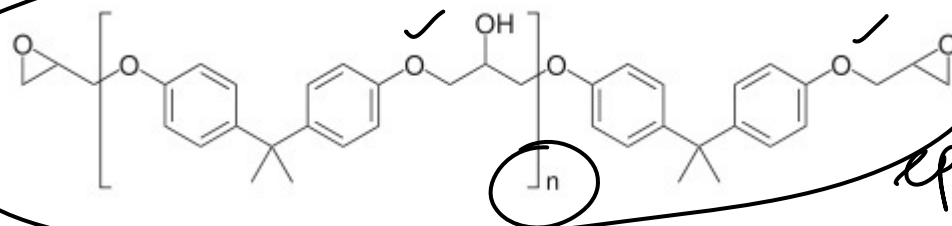


phenol + formaldehyde



Bakelite

EPOXY



epoxide

Polymers change dimensions ..on application of heat

Reinforcement is required to impart stability

Fillers are used

CTE issue is important

Kraft Paper/Cloth ✓

Random Glass Fibers ✓

Woven Glass Cloth

Aramid Fiber/Cloth-Trade name Kevlar- high Tg (180-190C)

Metal

Metal Core PCBs

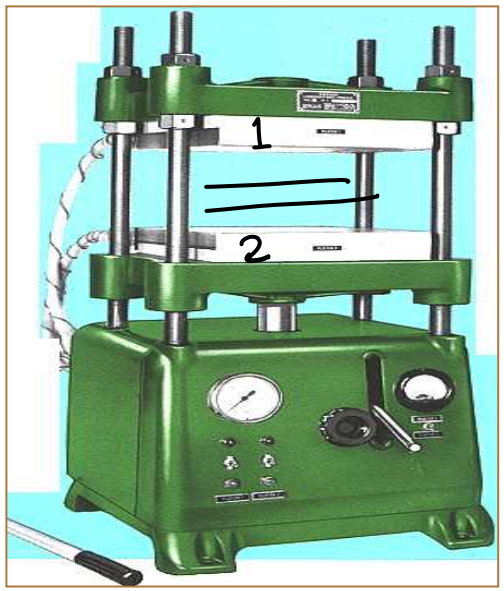
- Graphite Fiber/ Cloth
- Metal Cores - Mo, Invar*, Cu-Invar-Cu (heat-sink) core
- Ceramic spheres
- Quartz fibers

Improve mechanical strength
Improve temperature resistance
Improve dimensional stability
Improve thermal conductivity
Improve drill/punch character

*alloy of Iron and Nickel: FeNi36 very common.

Manufacture of RIGID Laminate

Formulate resin mix + solvents



Simple Multilayer Press

Select glass cloth

Coat glass cloth with resin

Remove solvents by drying → *Prepreg* *B-stage resin*

Lay copper foil on "prepreg" sheet

Press together at 400-700 psi pressure and 180 C

Slowly cool and cut to size

Fig. source: unknown