COMPOUNDING OF PLASTICS

In order to impart certain properties to finished product, certain additives are added to plastic before moulding. These ingredients either discharge useful function during moulding or imparts some useful property to the finished product. This process is called compounding of plastics.

- The various ingredients added during compounding are:
- 1) Binders
- 2) Fillers
- 3) Plasticizers
- 4) Dyes & Pigments
- 5) Lubricants
- 6) Catalyst
- 7) Stabilizers

- **Functions of various ingredients**

- 1) **Binders**:
- **To hold the other constituents of the plastic together.**
- **It comprises of 30-100% of the plastics.**
- **It also determines the type of the treatment (molding technique) needed to mould the articles from the plastic**
- **There are two types of binders thermosetting & thermoplastics**

- 2) **Fillers**:
- A) They reduce shrinkage & brittleness of plastics during setting.
- B) They reduce the cost of the plastic.
- C) They impart better tensile strength, opacity, finish & workability.
- D) Fillers are added to impart special characters to finished product.
- Barium salts to make plastic X-ray impervious.

- **Asbestos provides corrosion & heat resistance.**
- **Corborundum, mica, quartz provide extra hardness.**
- **Addition of carbon black increases tensile strength.**
- **Shredded textiles increase tensile strength.**
- **Other materials like cotton corn, husks, graphite, paper pulp, metal oxides, metal powders etc also are used as fillers.**

- **Plasticizers:**
- **1) To impart plasticity & flexibility so as to reduce the temperature & pressure required for moulding.**
- **2) They reduce or neutralize intermolecular forces of attraction in the resin molecules.**
- **3) They impart greater freedom of movement between polymeric macromolecules of the resin.**
- **4) They reduce strength & decrease chemical resistance.**

- **Examples of plasticizers:**
- **Vegetable oils, esters of oleic, steric & phthalic acids, tributyl phosphate, triphenyl phosphate etc.**

- **Dyes & Pigments**:
- **Organic dyes as well as inorganic pigments are used for imparting colour to plastics.**
- **Carbon black : Black**
- **Calcium carbonate: White**
- **Chromium trioxide : green**
- **Ferric Oxide : red**
- **Antimony sulphide : Crimson red**

- **Lubricants:**
- **These additives give good finish to plastic material.**
- **They improve flow characteristics & reduce friction in the processing machines.**
- **They make molding of plastics easier & provides glossy finish to the products.**
- **E.g waxes, oils, stearates, oleates, soaps etc.**

- **Catalyst**
- **They are used to accelerate polymerization reaction.**
- **In thermosetting plastics , they are added to accelerate polymerization of fusible resin during molding process to crosslinked infusible form.**
- **E.g hydrogen peroxide, benzoyl peroxide, metals like Ag, Cu & Pb, metalic oxide like zinc oxide etc.**

- **Stabilizers**:

- **They are added to plastic to prevent their degradation.**
- **To improve their thermal stability during processing.**
- **For example, during moulding of vinyl chloride & vinylidine chloride polymers, heat stabilizers are used as these polymers show tendency to undergo decomposition & discolouration at molding temperature.**

- **MOULDING (FABRICATION) OF PLASTICS**

- The technique of giving desired shape to the plastic with the help of a mould is called fabrication.
- This technique involves application of heat & pressure.
- It is applicable to both types of resin thermoplastic & thermosetting resin.

- There are four techniques used for moulding.
- 1) Compression moulding
- 2) Injection moulding
- 3) Transfer moulding
- 4) Powder extrusion moulding

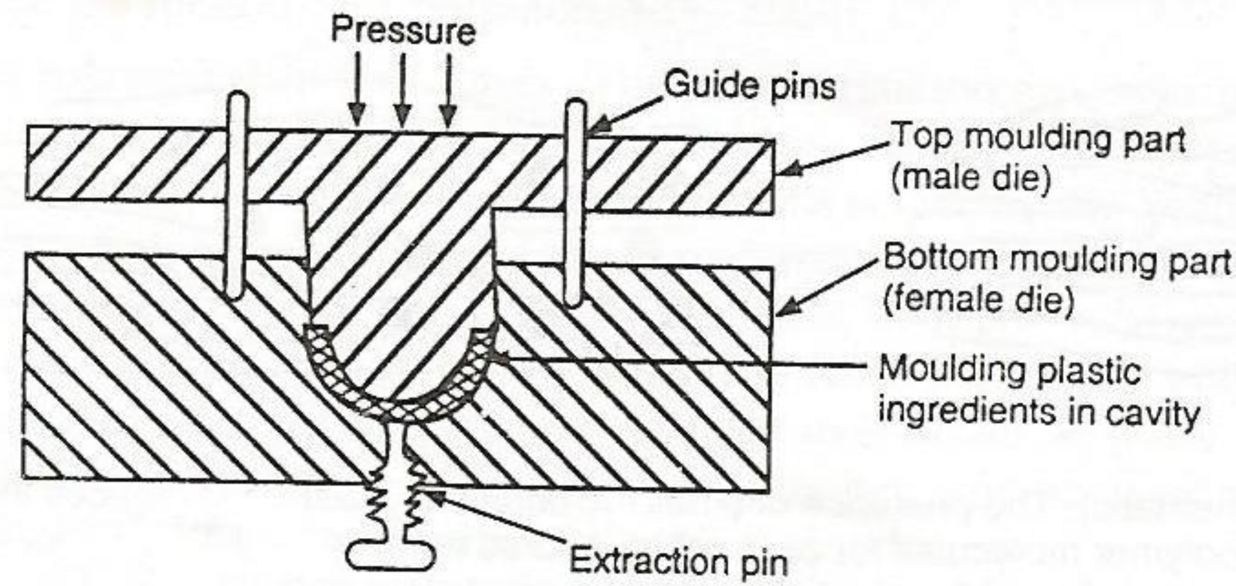
Compression moulding

In this method , plastic powder to be moulded is mixed with filler & other ingredients & then placed in the mould.
The mould is closed under low pressure.
Then it is heated with simultaneous application of the pressure according to specification, 100-500 Kg/cm^2 press & 100-200^{o}C temperature.
The cavities get filled up with fluidized plastic.

Contd.

- Once the moulding is over, the article is withdrawn after cooling.
- Finally curing is done either by heating (in thermosetting) & by cooling (in case of thermoplastics).
- After curing is over, the moulded article is taken out by opening the mould parts.
- Articles like door handles, handles of electric iron, bottle caps, screw caps are made by this method.

COMPRESSION MOULDING



COMPRES SION MOULDING

Mea

Advantages

Faster rate of production

Economic Process

sured quan

f Fastity of plastic ingredients in proper

filled between the two

half pieces of mould.

Disadvantages

Intricate shapes can’t be made

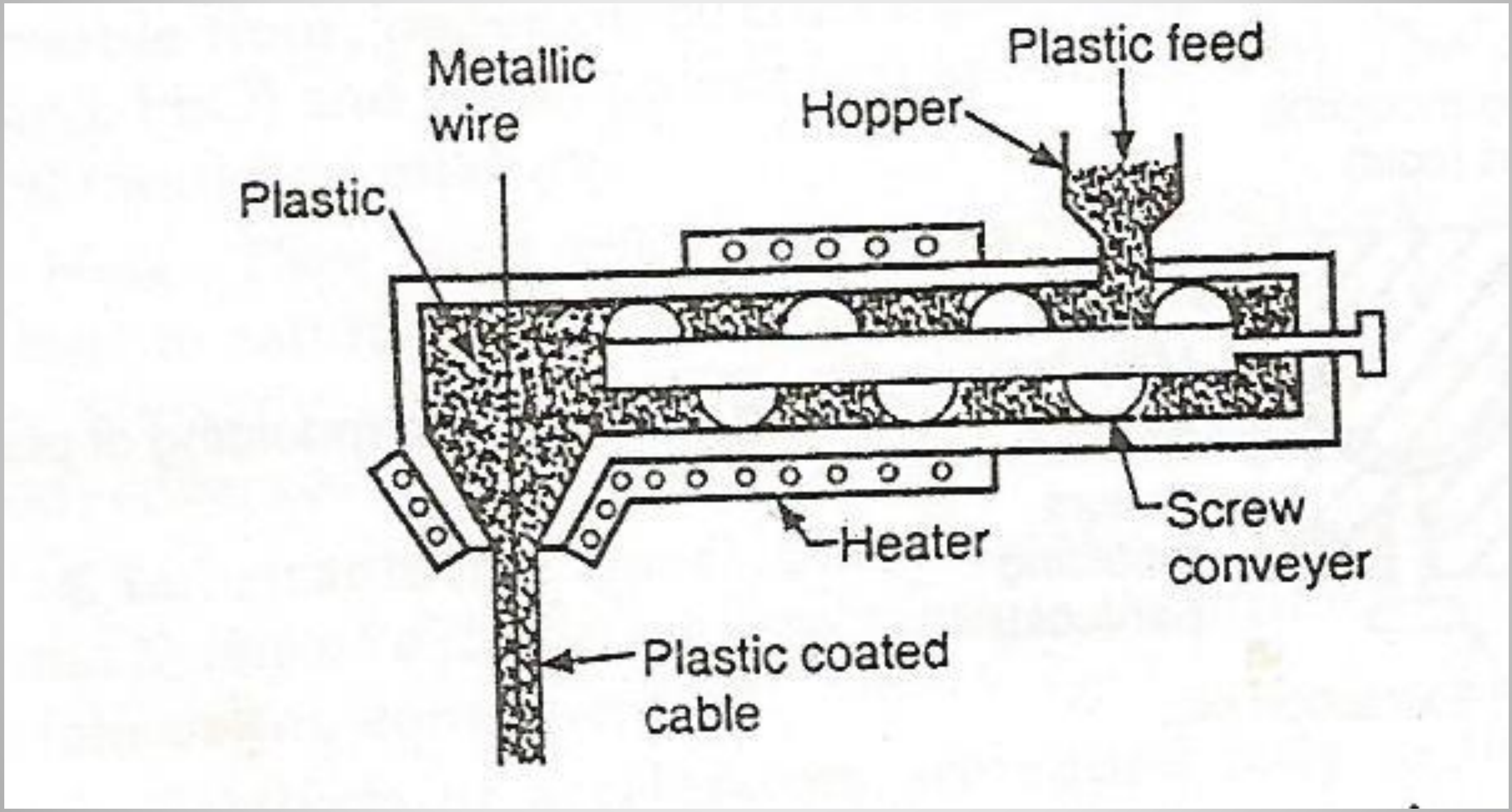
Loss of plastic powder during moulding.

Blisters are formed due to which finishing is required

- **POWDER EXTRUSION MOULDING (FOR THERMOPLASTIC)**
- This is mainly used for making articles with uniform cross section area like tubes, rods, stripes, insulated electric cables.
- **Thermoplastic ingredients are heated to plastic condition & then pushed by means of screw conveyor into a die having the shape of the article to be manufactured**.

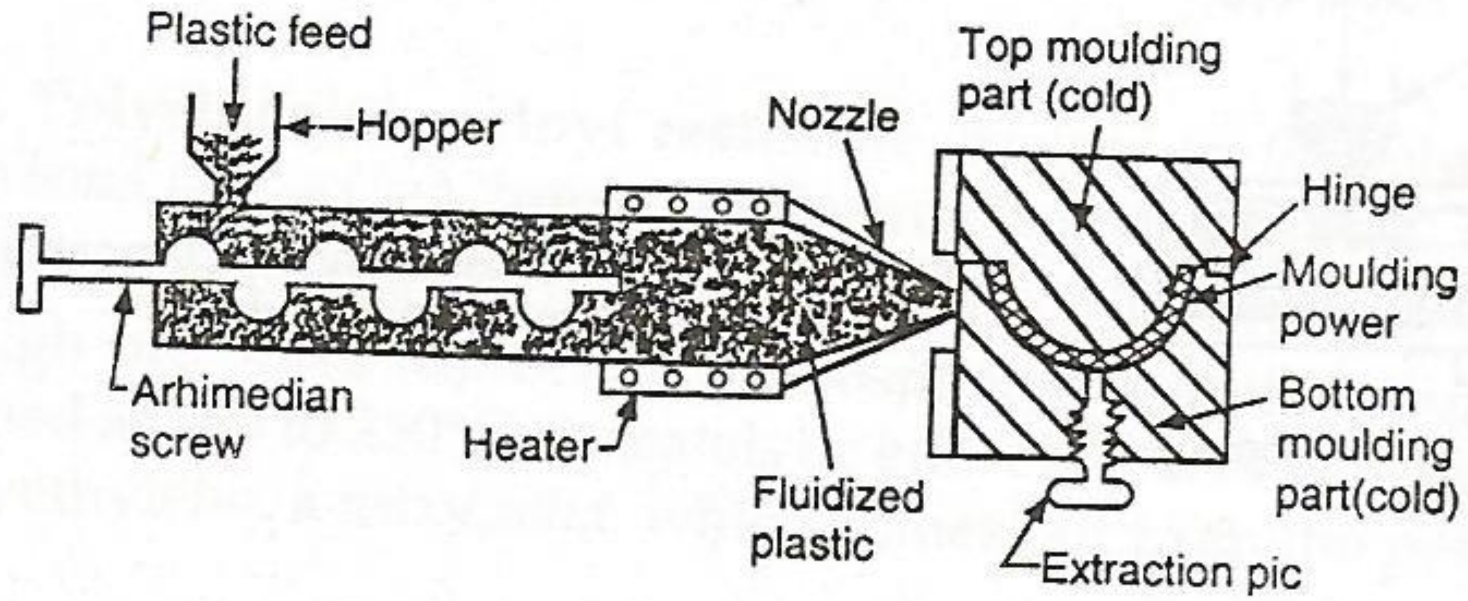
- Here the plastic article gets cooled due to atmospheric exposure or by air jets.
- A long conveyor carries away continuously the cooled product.

POWDER EXTRUSION MOULDING



- **INJECTION MOULDING**
- **Plastic powder is fed into a heated cylinder from where it is injected at a controlled rate into tightly locked mould by screw arrangement.**
- **The mould is kept cold to allow the hot plastic to cure & become rigid.**
- **Cured article is taken out by opening mould parts.**
- **It is applicable for thermoplastics.**

INJECTION MOULDING



- **Advantages of Injection moulding**

- **High speed production**
- **Low loss of material**
- **Low finishing cost**
- **Disadvantages**
- **DISADVANTAGES**
- **As large number of cavities cannot be filled simultaneously so there is limitation of design of articles**

TRANSFER MOULDING (application to thermosetting

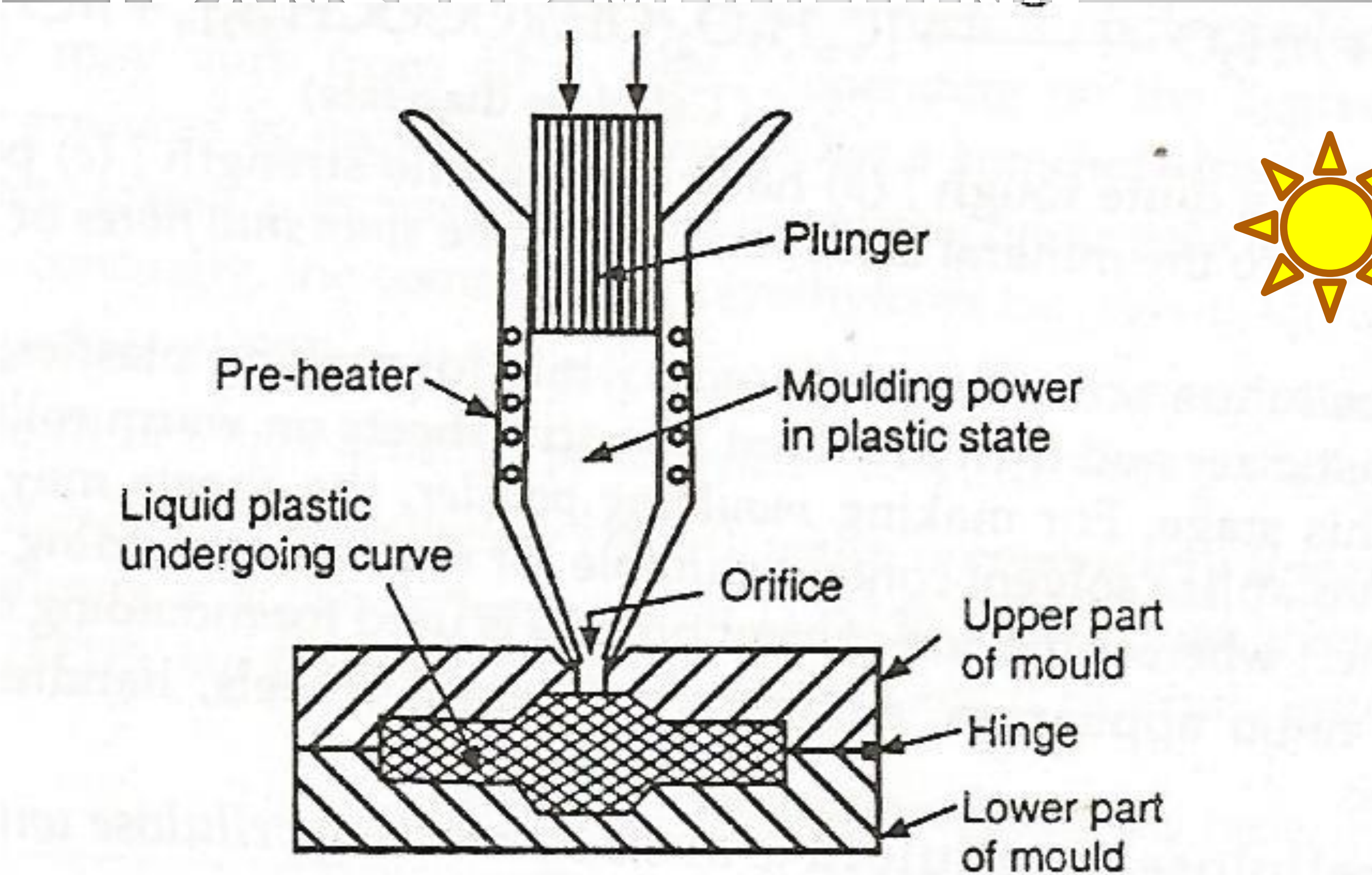
- **The moulding powder is placed in heated chamber maintained at the minimum temperature at which the moulding powder just begins to become plastic.**
- **The plastic material is then injected thro' an orifice into the mould by a plunger working at high pressure.**

Due to great friction produced at the orifice the temperature of plastic increase to such an extent that it become liquid & flows into mould.

-
- **The mould is maintained at high temperature to cure the article.**

The moulded article is then ejected mechanically.

TRANSFER MOULDING



antages : (i) Since the

ADVANTAGES

Intricate shapes can be produced unlike in case of compression moulding.

Mechanical strength of article is more.

Finishing cost of article is eliminated,as blistering is eliminated due to high temp.

Article free from flow marks is obtained.

GLASS TRANSITION TEMPERATURE (Tg)

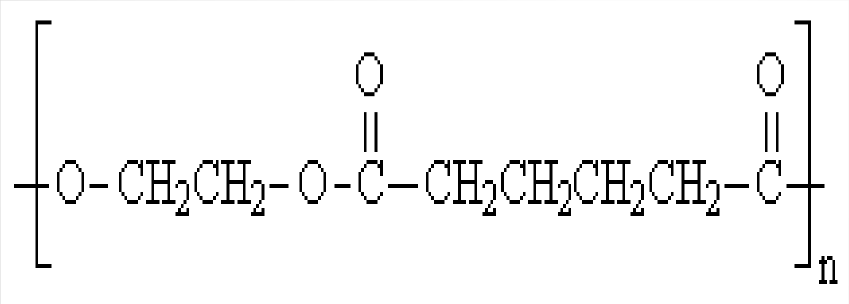
- **Amorphous polymers don't have melting point but softening point.**
- **At low temperature, polymer exists as glassy material. As the temperature of polymer is increased, it eventually softens & become more flexible.**
- **The temp, at which it becomes soft & rubbery is called the glass transition temperature.**

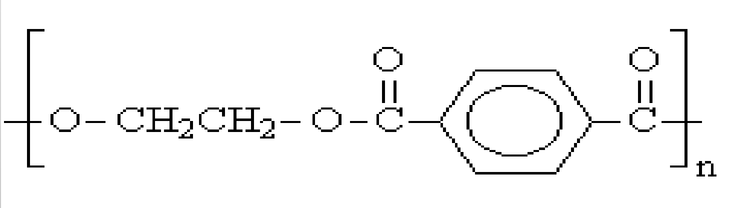
- A) **Amorphous polymers**
- **Glass → Rubber → Gum → Liquid**
- **---→**
- **Tg**
  Increasing temp

- **At glass transition temperature, the internal energy of the molecules of the polymer increases to such an extent that the chain segments of the polymer molecules starts leaving their lattice sites**

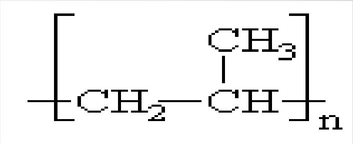
- **Factors affecting Tg** :
- **The value of T_g depends on the mobility of the polymer chain - the more immobile the chain, the higher the value of T_g**[34].
- In particular, **anything that restricts rotational motion within the chain should raise T_g.**
- A polymer chain that can move easily will 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.

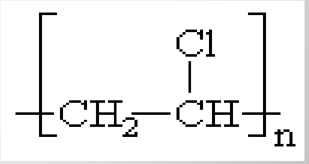
- Chain StiffnessStiffening groups in the polymer chain reduce the flexibility of the chain and raise the value of T_g .
- poly(ethylene adipate) T_g =-70ºC



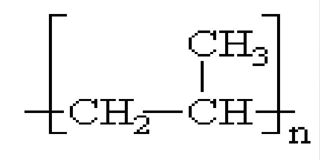
- poly(ethylene terephthalate) T_g = 69ºC
- 

- Intermolecular forces
- Stronger **intermolecular forces** lead to a higher T_g. PVC has stronger intermolecular forces than polypropylene because of the dipole-dipole forces from the C-Cl bond.

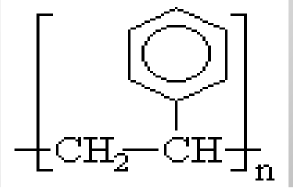
- Polypropylene T_g = -20°C 

- Poly(vinyl chloride)T_g = 81°C 

- **Pendant Groups**The influence of pendant groups on the glass transition temperature is somewhat more complicated.
- 1. *Bulky pendant groups*, such as a benzene ring, can catch on neighboring chains like a "fish hook" and restrict rotational freedom. This increases T_g.
- PolypropyleneT_g = -20°C



- PolystyreneT_g = 100°C

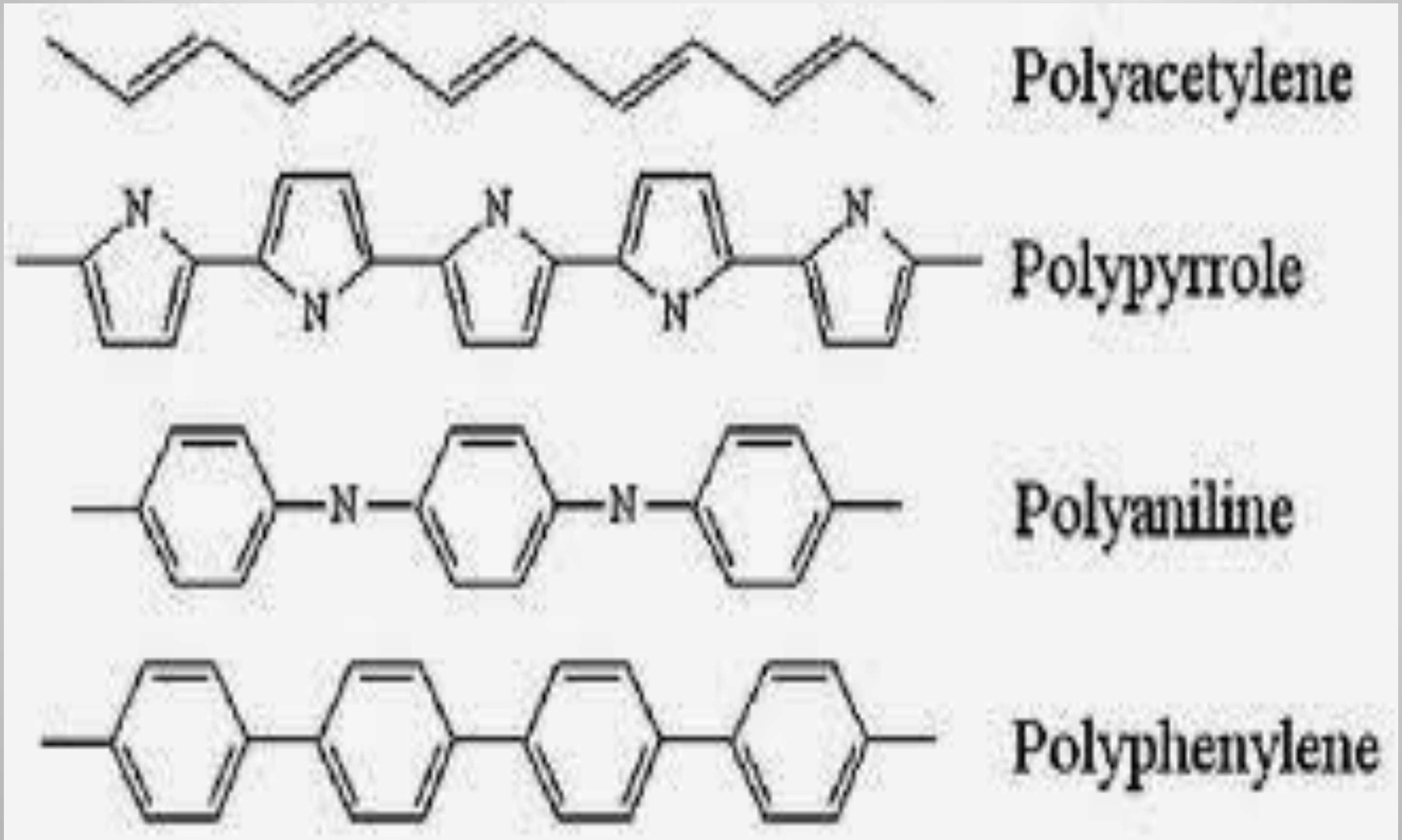


- Cross-Linking
- The presence of **cross-links** between chains restricts rotational motion and raises Tg.

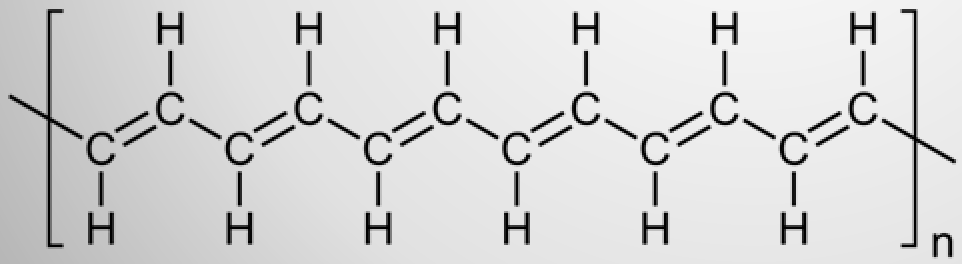
- Plasticizers are low molecular weight compounds added to plastics to increase their flexibility and workability. They weaken the intermolecular forces between the polymer chains and decrease T_g. Plasticizers often are added to semi-crystalline polymers to lower the value of T_g below room temperature. In this case the amorphous phase of the polymer will be rubbery at normal temperatures, reducing the brittleness of the material.

- **Viscoelasticity**
- **All polymers are hard rigid solids at low temperature & changes from the solid ti liquid state either by melting (crystalline polymers) or by softening (amorphous polymers) at high temperature.**
- **Amorphous polymers with random arrangements of their molecular chain soften & become rubber like at a particular temperature. The rubber like polymer softens to viscous liquid as temperature is increased further. The changes from solid to rubbery polymer to viscous liquid are reversible.**
- **Thus this behaviour of the polymer to exhibit different range of viscosities with variation in temperature & the rate of change of temperatures is known as viscoelasticity.**

- **Conducting polymers**



- **Conducting polymers** (CPs) are a kind of materials with π-conjugated polymeric chains, so they are also called as conjugated **polymers.**
- **polymers** with loosely held electrons in their backbones can be called **conducting polymers**. These atoms have always a conjugated backbone with a high degree of π-orbital overlap.
- The first polymer with significant conductivity synthesized was polyacetylene (polyethyne).



- **Types of conducting polymers**
- **1) Intrinsically conducting polymers**
- **2) Extrinsically conducting polymers**
- **i) Conductive elements filled polymers**
- **ii) Blended conducting polymers**
- **3) Doped conducting polymers**
- **i) p-doped polymers**
- **ii) n-doped polymers**
- **4) Co-ordination conducting polymers**

- **Intrinsically conducting polymers**
- **It is a polymer with conjugated π electrons in its backbone. Overlapping of orbitals over the entire backbone results in the formation of valence bands as well as conduction bands.**
- **In an electric field, conjugated π electron of the polymer get excited & hence can be transported through the solid polymeric material. E.g**
- **Polyacetylene, polyaniline, polypyrrole etc.**

- **Extrinsically conducting polymers**
- **These polymer conductivity is due to externally added ingredients in them.**
- **They are of two types :**
- **a) Conductive elements filled polymers : polymers are filled with conducting elements like carbon black or metal oxides. Along with conductivity these polymers are low in cost, light in weight, mechanically strong & durable.**

b) Blended conducting polymer

It is a polymer obtained by blending a conventional polymer with conducting polymers. Such polymer possess better physical, chemical & mechanical properties.

- **Doped conducting polymers:**
- **The conductivity of intrinsically conducting polymers can be increased by creating positive or negative charge on them by oxidation or reduction reactions known as doping.**
- **a) p-doping**
- **+ ve charge is generated in ICP by using dopants I_2, Br_2, AsF_5, PF_6, naphthylamine etc.**
- **$2(C2H2)n + 3I_2 \rightarrow 2[(C2H2)n^+]I_3^-$**

- **N-doping**
- **In this intrinsically conducting polymer is treated with Lewis base where reduction takes place & negative charges are created on the polymer backbone.**
- **Commonly used n-dopants are Lithium(Li), Sodium(Na), Calcium(Ca) etc.**

$$(-CH=CH-CH=CH-)_n + B \rightarrow -CH=CH-\underset{\underset{\displaystyle B^+}{|}}{\overset{-}{CH}}=CH-$$

- **Coordination conducting polymers**
- **It is a charge transfer complex containing polymer obtained by combining a metal atom with a poly dentate ligand.**

- **Applications of conducting polymers**

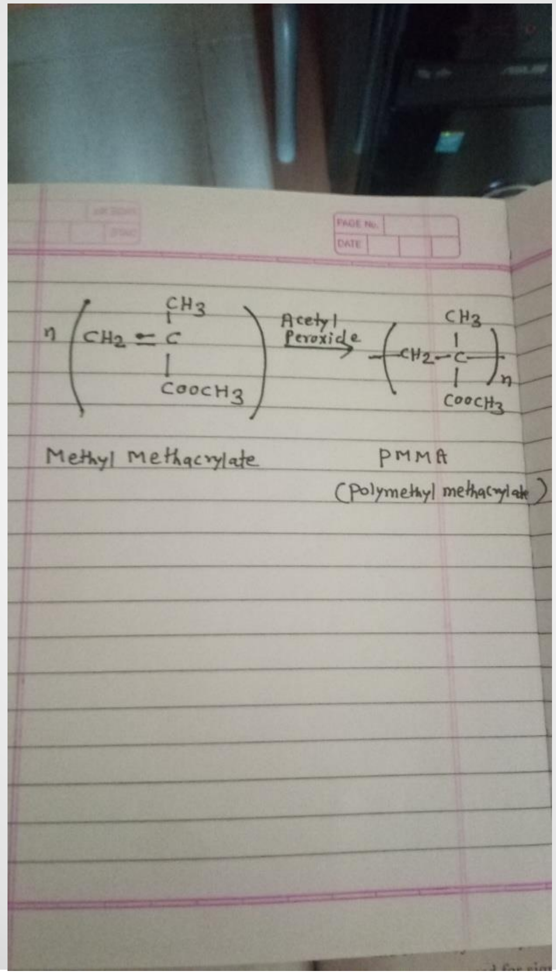
- **1) In rechargeable light weight batteries.**
- **2) In wiring in aircrafts & aerospace components.**
- **3)In electronic devices such as transistors & diodes & in telecommunication systems.**
- **4) In photovoltaic devices .**
- **5) In antistatic clothing**
- **6) In molecular switches & wires**

- **Polymers in medicines & surgery**
- **Characteristics of biomedical polymers :**
- **1) It should be bio compatible**
- **2) It should be fabricated into the desired shape without being degraded.**
- **3) It should be easily sterlized with no alteration in properties.**
- **4) They should have optimum physical & chemical properties**
- **5) They should not destroy cellular elements of blood, enzyme or produce toxic or allergic reactions.**

- **Applications of biomedical polymers**

Polymer	Applications
Polyethylene	Disposable syringe
Polypropylene	Heart walls, blood filters
Polyvinyl chloride	Disposable syringe
PMMA	Contact lenses
Polyalkyl sulphone	Membrane oxygenator
Silicone Rubber	Heart walls, drain tubes
polyurethane	Heart wall, blood filters, artificial heart

Synthesis of polymethyl methacrylate

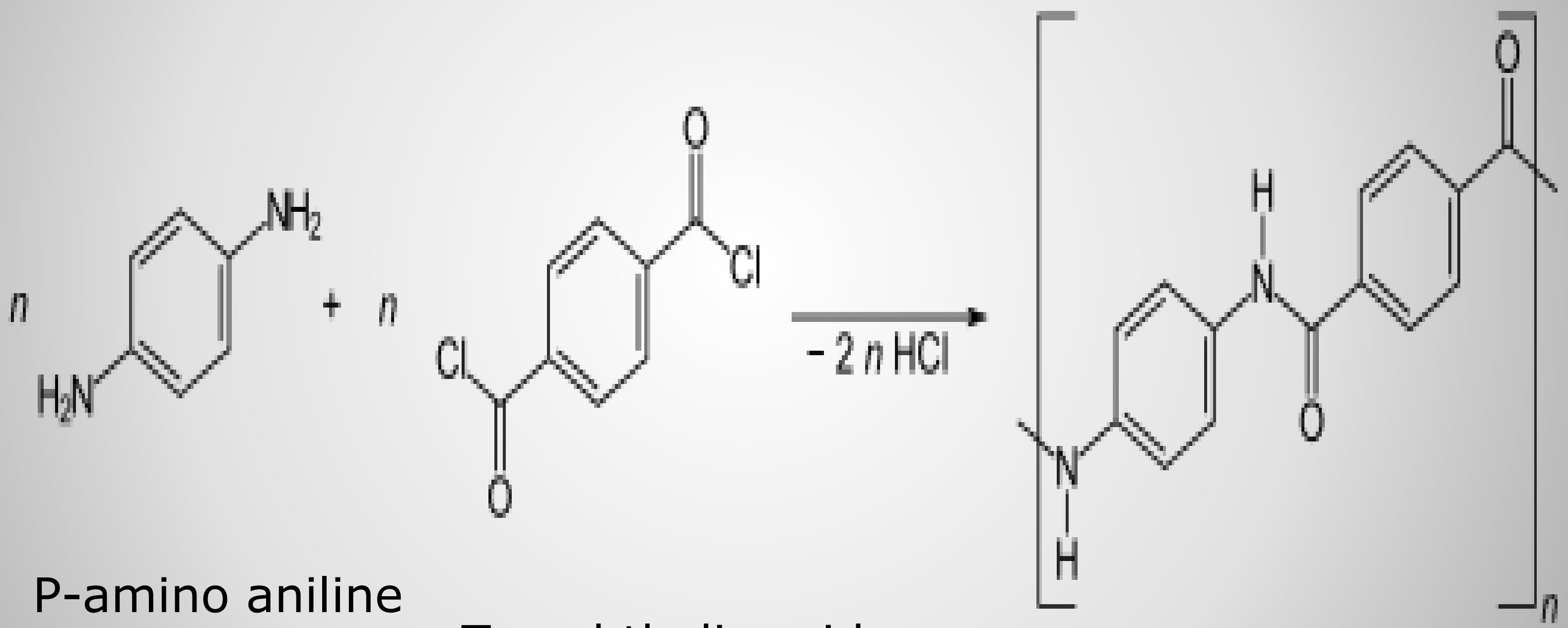


- **Properties of PMMA:**
- 1) It is colourless, transparent, hard & fairly rigid material.
- 2) It has high optical transparency
- 3) It has high resistance to sunlight & ability of transmitting light accurately.
- 4) It has low chemical resistance to acids & alkalies.

Uses:

1) **It is used for making contact lenses, artificial eyes, dentures, wind screens, TV screens etc.**
2) **2) For making aircraft light fixtures, cockpit canopies etc.**

- **Synthesis of Kevlar**



P-amino aniline

Terephthalic acid dichloride

Kevlar

- **Properties of Kevlar**
- **1) It is exceptionally strong (Five times stronger than steel.)**
- **2) It has high heat stability & flexibility.**
- **3) It is more rigid than nylon.**

Uses:

1) **It is used in the aerospace & aircraft industries.**
2) **It is used in car parts(tyres & brakes etc.)**
3) **It is used in ropes, cables, bullet proof vests, motor cycle helmets etc.**