- If cooled slowly, polymer becomes hard and brittle, and vice-versa.
- The time taken for cooling/heating also plays equally important role.

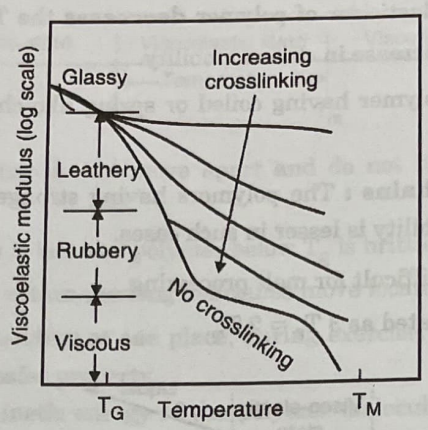


Fig. 5.10.1

- Thus with variation in temperature and time duration between the range of temperature, a polymeric material exhibits different range of viscocities.
- This behaviour of a polymer is known as "viscoelasticity".

5.11 Conducting Polymers

MU - May 13, Dec. 13, Dec. 14, May 17, Dec. 17

University Questions

Q. Write short notes on Conducting polymers. **(May 13, Dec. 14, May 17, Dec. 17, 5 Marks)**

Q. Define conducting polymers. Explain Intrinsic and Doped conducting polymer with appropriate examples. **(Dec. 13, 5 Marks)**

Polymers, generally with high crystallinity, more commonly develop conductivity. E.g. Cis-polyacetylene or poly para phenylene.

There are following types of conducting polymers :

1. Intrinsically Conducting Polymers (ICP)
2. Doped Conducting Polymers (DCP)
3. Extrinsically Conducting Polymers (ECP)
4. Co-ordination Conducting Polymers (CCP) (Inorganic polymers)

Characteristics of each type are discussed in brief.

5.11.1 Intrinsically Conducting Polymers (ICP)

- These possess conjugated π electrons backbone.

- When such polymer faces electric field, these electrons get excited, and hence move through polymeric material.
- The orbitals of conjugated π electrons get overlapped on the backbone and hence valence bands and conduction bands are developed which get distributed over entire surface of polymer.
- Appropriate proportion of conjugated π electrons makes polymer to conduct electricity very efficiently.

For example :

- Polyacetylenes
- Polyquinoline
- Poly-p-phenylene
- Poly-m-phenylene sulphides
- Aromatic : Polyaniline, polyanthrylene
- Aromatic heterocyclic : Polypyrrole, polythiophene, polybutadienylene.

5.11.2 Doped Conducting Polymers (DCP)

These are prepared by exposure of the polymer to a charged transfer agent either in gas phase or in liquid phase (i.e. solution).

- As compared to plain ICP, these have low I.P. but high E.A. Hence these can be easily oxidised or reduced.
- ICP can be made more conductive by creating positive or negative charge on its backbone by oxidation or reduction.
- This technique is called as "doping". There are two types of doping :

1. P-doping	2. N-doping

1. P-doping :

- P-doping is a technique in which an ICP is oxidized with lewis acid, creating the charge on backbone of polymer.
- The lewis acids used are known as p-dopant.
- E.g. I_2, Br_2, ASF_5, PF_6, Naphthylamine

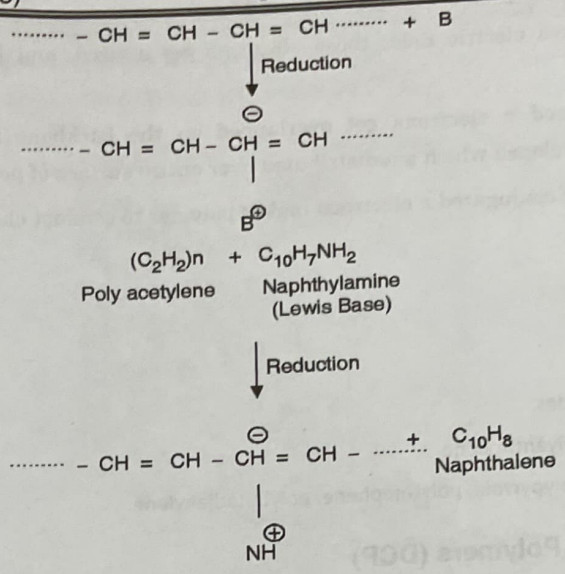
$$(C_2H_2)_n + 2\,Fecl_3 \rightarrow (C_2H_2^+)_n \cdot FeCl_4^- + FeCl_2$$

Poly Acetylene Lewis Acid + vely charged backbone

$$2\,(C_2H_2)_n + 3I_2 \rightarrow 2\left[(C_2H_2^+)_n I_3^-\right]$$

2. N-doping :

- This technique involves reduction of ICP with Lewis base to form negative charge on backbone of ICP.
- E.g. Li, Na, Cu, telra- butyl ammonium, Naphthyl amine



5.11.3 Extrinsically Conducting Polymers (ECP)

– These are the conducting polymers which possess conductivity due to externally added ingredient in them.

There are two types of ECPs :

1. Conducting Element Filled Polymer (CEFP)

– In this type, resin or polymer is filled up with conducting element. E.g. carbon black, metallic fibres, metal oxides etc.

– The polymer holds the metallic element, thus acting as a binder.

– Their conductivity is reasonably high.

Properties

(i) Cost is low (ii) They are light in weight

(iii) Strong (iv) Can be easily moulded

2. Blended conducting polymer (BCP)

– These are nothing but blend of normal polymer with conducting polymer.

– The blending is either only physical change or in certain cases chemical change.

– They possess good mechanical properties.

5.11.4 Co-ordination Conducting Polymers (CCP) - (Inorganic Polymers)

– These are inorganic in nature, in which a complex involved in transfer of charge is combined with polymer, and a metal atom is combined with polydentate ligands.

– They have very low degree of Polymerisation (≤ 18).

– They are corrosion resistant.

5.11.5 Applications of Conducting Polymers

Conducting polymers are used,

1. In rechargeable light weight batteries.
2. Optically display devices.
3. In wiring in aircrafts and aerospace components.
4. In telecommunication systems.
5. In electromagnetic screening material.
6. Solar cells, photovoltaic devices, transistors, diodes, molecular wires and switches etc.

5.12 Applications of Polymers

5.12.1 Applications of Industrial Polymers

Applications of Some industrial polymers are given below :

1. **Polycarbonate :** It is made from B is phenol A and diphenyl carbonate. It is transparent, tough and has very high impact strength. It is used as bullet-proof transparent material and also for crash helmets, cooking utensil covers, bodies of camera, apparatus, for telephone booths, lenses, electrically insulating materials.
2. **Teflon :** It is obtained from tetrafluoro ethylene. Teflon has high softening temperature of more than 350°C. It has smooth surface, chemically very innert, very low coefficient of friction. It is useful for coating on non-stick cookware, nonlubricated bearings, laboratory apparatus, tank linings, insulator in motors, cables.
3. **Bakelite :**

- Phenol and formaldehyde on reaction forms novolac resin, which on crosslinking in the moulds produces shaped Bakelite articles.
- Bakelite is rigid, strong, high voltage insulator fire and heat resistant material. It is used for electrical goods, automobile parts, telephone parts, ion exchange resins. Novolac is used of varnishes as binder on abrasives or grinding wheels, plywood.

4. **Polyurathanes (Perlon v) :** Possess excellent industry flexibility, toughness, abrasion resistance. It is used in defence / oceanographic research, for coir foam, thermocole, as rubber.
5. **Silicones :** Silicone liquid, silicone solid, silicone rubber possess excellent chemical resistance, heat and fire resistance, electrical insulation silicone solid and rubbers have high abrasion resistance. They are used for aeroplane tyres, in chemical reactors, as sealants, for insulation for artificial heart, valves, tubes, high temperature insulating foams.
6. **Polyamides :** They possess very high tensile strength useful in making ropes, fibres, fabrics, nets, reinforcement of tyres. A ramid or Kevlar polyamide possesses tensile strength close to steel and is thermally stable, chemically resistant. Aramid fibres are used for reinforced fibres plastics, very high T.S. ropes, and as optical fibres for telephone cables, engine parts.