

Topic 4 Polymers

Syllabus - Polymer, Polymerization reactions – Addition, Condensation and Co polymerization. Comparison of addition and condensation polymerization and polymers, Plastics and its types- Thermoplastic and thermosetting plastics, comparison Thermoplastic and thermosetting plastics, Properties and Uses of Poly Vinyl Chloride (PVC), Bakelite, Epoxy resin, Fiber Reinforced Plastic (FRP), Rubber and properties of Rubber, vulcanization of natural rubber.

4.1 Materials Chemistry is most significant branch with respect to synthesis and applications of new materials in fields of emerging technological developments.

Material – The term material is defined as any kind of matter from which something can be made.

Simplest kind of matter all around us is clay and is widely used for making earthen pots, white ware, bricks, roofing tiles, used as cementing material, ceramics etc. Materials are classified in several groups based purposes for which they are used. One of group is '**Engineering materials**'.

Engineering Materials- Any kind of material which is successfully used by an engineer or technologist towards his practice or profession.

Types of Engineering Material – As on today there are six groups of engineering materials according to historical development in field of technology, and certain type of materials used on each stage of development. See the chart below

Engineering Materials

Metallic	Ceramics	Organic	Composite	Electronic	Smart materials
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i) Metallic materials – These are materials bearing metallic properties. They include all pure metals and alloys obtained out of metals. An alloy is solid solution bearing metallic properties and consisting of two or more different elements.

Metallic materials are of two classes i) **ferrous metals**- These are metallic materials consisting Fe as main constituent. These are widely used in several technological applications since a) Fe is abundantly available b) Easily and economically extracted from ore and c) Show versatile mechanical properties e.g. Wrought iron, Cast iron, Steel, Stainless steel, Tungsten steel etc ii) **Non-ferrous metals** – These are metallic materials in which Fe is not main constituent. Examples – Cu and its alloys (Brasses, Bronzes) Al and its alloys (Duralumin) etc.

ii) Ceramic Materials – These are non-metallic inorganic solids with complex structure. Complex structure means exact structure of material is not predicted or difficult to predict. e.g. clay is ceramic and like NaCl its structure cannot be predicted as it consist several ingredients. Ceramics are classified in four types based on its structure like

a) Crystalline ceramics – All structural phases are crystalline – Emery stone, Marble.

b) Non crystalline ceramics - All structural phases are amorphous – Asbestos, Oxides.

c) Mixed ceramics- Consist both crystalline and amorphous phases – Clay

d) Glassy ceramics – Consist Glassy phase (Super cooled liquid)- All types of Glasses.

Based on applications these are classified as i) Corundum, ii) Clay iii) Oxides iv) Glass v) Mica vi) Asbestos vii) Stones and rocks viii) Refractory's (High thermal stability) ix) Cements (Binding and cementing properties).

iii) Organic Materials – These are organic high polymers with excellent plastic, elastic and adhesive properties. These are classified in four types – i) Plastics –Excellent plastic behavior. ii) Elastomers or Rubbers – Excellent elastic behavior iii) Fibers – Low plasticity iv) Adhesives- Excellent adhesive properties.

iv) Composite materials- These are physical compositions obtained by composing two or more different materials in specific manner in order to rectify drawbacks from parent material. Depending on manner in which these are composed, there are four main types of composites.

a) Agglomerated Composites – The two materials are composed in random manner. They do not show any geometry or symmetry. Example –Mosaic tiles – pieces of solid (rocks – different sizes, shapes, colors) are bonded in concrete matrix.

b) Laminating composites- The materials to be composed are arranged in layer wise manner. Example – Plywood.

c) Reinforced composites – A regularly arranged network of suitable material is trapped inside a matrix of parent material. This causes reinforcement of parent material. Example- RCC – Reinforced Cement Concrete. FRP- Fiber Reinforced Plastic.

d) Surface coating composites – A material with technological property is coated on suitable material providing support to parent material. Examples Thin and thick film materials used as – audio tapes, video tapes , compact discs, DVD, solar cell, integrated circuits etc.

e) Nano composites – Recent type – Materials are composed on atomic or molecular level.

v) Electronic Materials – These are silicon based semiconductors used for making electronic components.

vi) Smart materials – Materials of any type showing extraordinary behavior are called smart materials. Examples – Shape memory alloy –(Nitinol – Ni and Ti alloy) Material remember its original shape on regenerating conditions at the time of initial shaping.

4.2 Polymer and Polymerization reactions

A polymer is a large molecule or a macromolecule which essentially is a combination of many subunits. The term polymer in Greek means 'many parts'. Polymers can be found all around us. From the strand of our DNA which is a naturally occurring biopolymer to polypropylene which is used throughout the world as plastic. Polymers may be naturally found in plants and animals (**natural polymers**) or may be man-made (synthetic polymers). Different polymers have a number of unique physical and chemical properties due to which they find usage in everyday life.

Classification of Polymers

Polymers cannot be classified under one category because of their complex structures, different behaviors, and vast applications. We can, therefore, classify polymers based on the following considerations.

1 Classification of Polymers based on the Source of Availability

There are three types of classification under this category, namely, Natural, Synthetic, and Semi-synthetic Polymers.

a) **Natural Polymers:** They occur naturally and are found in plants and animals. For example proteins, starch, cellulose, and rubber. To add up, we also have biodegradable polymers which are called biopolymers.

b) **Semi-synthetic Polymers:** They are derived from naturally occurring polymers and undergo further chemical modification. For example, cellulose nitrate, cellulose acetate.

c) **Synthetic Polymers:** These are man-made polymers. Plastic is the most common and widely used synthetic polymer. It is used in industries and various dairy products. For example nylon-6, 6, polyether's etc.

2 Classification of Polymers based on the Structure of the Monomer Chain

This category has the following classifications:

a) Linear Polymers

The structure of polymers containing long and straight chains fall into this category. PVC, i.e. poly-vinyl chloride is largely used for making pipes and electric cables is an example of a linear polymer.

b) Branched-chain Polymers

When linear chains of a polymer form branches, then, such polymers are categorized as branched chain polymers. For example Low-density polythene.

c) Cross-linked Polymers

They are composed of bi functional and tri functional monomers. They have a stronger covalent bond in comparison to other linear polymers. Bakelite and Melamine are examples in this category.

Other Ways to Classify Polymers

3 Classification Based on Polymerization

a) **Addition Polymerization:** Example, poly ethane, Teflon, Polyvinyl chloride (PVC)

b) **Condensation Polymerization:** Example, Nylon -6, 6, perylene, polyesters.

4 Classification Based on Monomers

a) **Homo polymer:** In this type, a single type of monomer unit is present. For example, Polyethene

b) **Hetero polymer or co-polymer:** It consists of different type of monomer units. For example, nylon -6, 6

5 Classification Based on Molecular Forces

a) **Elastomers:** These are rubber-like solids weak interaction forces are present. For example, Rubber.

b) **Fibers:** Strong, tough, high tensile strength and strong forces of interaction are present. For example, nylon -6, 6.

c) **Thermoplastics:** These have intermediate forces of attraction. For example, polyvinyl chloride.

d) **Thermosetting polymers:** These polymers greatly improve the material's mechanical properties. It provides enhanced chemical and heat resistance. For example, phenolics, epoxies, and silicones.

Structure of Polymers

Most of the polymers around us are made up of a **hydrocarbon backbone**. A Hydrocarbon backbone being a long chain of linked carbon and hydrogen atoms, possible due to the tetravalent nature of carbon.

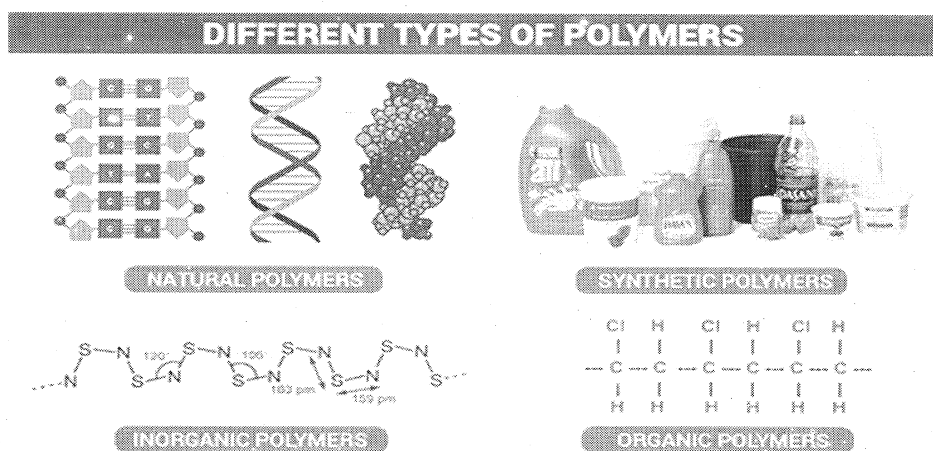
A few examples of a hydrocarbon backbone polymer are polypropylene, polybutylene, polystyrene. Also, there are polymers which instead of carbon have other elements in its backbone. For example, Nylon, which contains nitrogen atoms in the repeated unit backbone.

Types of Polymers

On the basis of the type of the backbone chain, polymers can be divided into:

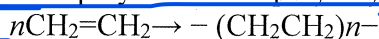
Organic Polymers: Carbon backbone.

Inorganic Polymers: Backbone constituted by elements other than carbon.

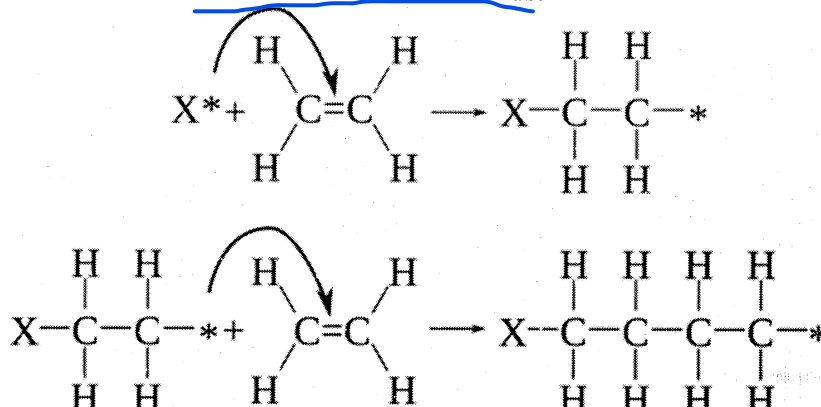


1. Addition Polymerization

An **addition polymer** is a polymer formed by simple addition between monomers that contain a double bond. (Unsaturated) The reaction is possible with same or different types of monomers. Molecules of ethene can polymerize with each other under the right conditions to form the polymer called polyethylene.



n stands for the number of monomers that are joined in repeated fashion to make the polymer and can have a value in the hundreds or even thousands.



The reaction can also be initiated by forming anion or cation of some monomers.

The reactions above show three steps to form an addition polymer.

1. Initiation – The reaction can be started by activating some of monomers from reaction mixture to active forms like carbo-cation, carbo-anion or free radical. In above reaction free

radical initiator (X^\bullet) attacks the carbon-carbon double bond (first step above). The initiator can be something like hydrogen peroxide. This material can easily split to form two species with a free electron attached to each: $H-O-O-H \rightarrow 2H-O^\bullet$. This free radical attacks a carbon-carbon double bond of normal monomers from reaction mixture. One of the pi electrons forms a single bond with the initiator while the other pi electron forms a new free radical on the carbon atom. Thus reaction started.

2. **Propagation** – This is stage of chain growth. the new free radical compound interacts with another monomer, continuing the process of chain growth (second step above). Monomers get added to growing chains. Number of chains grows in reaction mixture, it continues till all normal monomers are added to growing chains.

3. **Termination**– The reaction stops by approaching of two growing chains. Occurs whenever two free radicals come in contact with one another (not shown). The two free electrons form a covalent bond and the free radical on each molecule no longer exists.

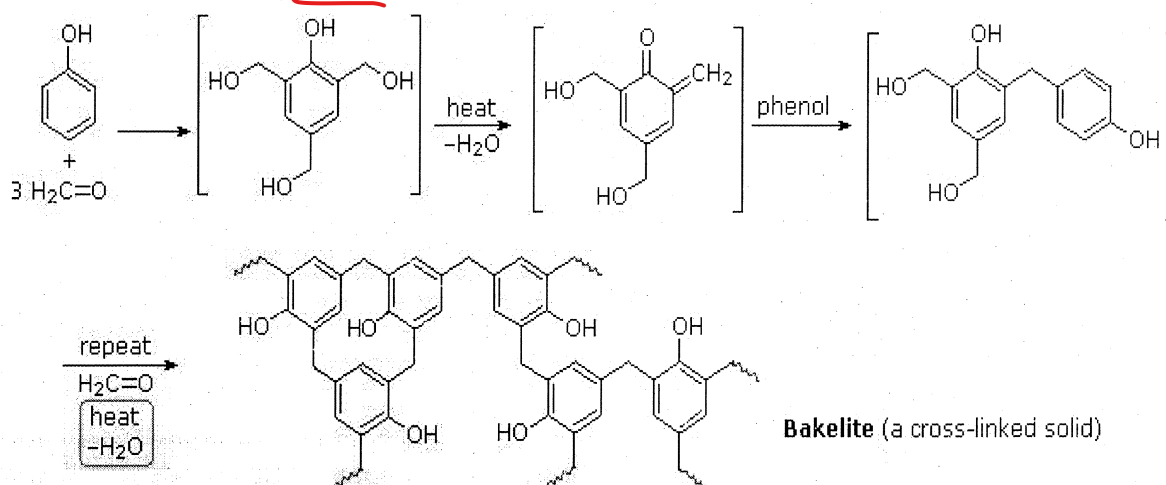
→ When addition polymerization is carried with two or more different monomers (for example say Ethene and propene) then it called as co-polymerization reaction

2. Condensation polymerization

A condensation polymerization is a form of step-growth polymerization. Small molecules react with each other to form larger structural units while releasing smaller molecules as a by-product, such as water or methanol. A well-known example of a condensation reaction is the *esterification* of carboxylic acids with alcohols. It is called condensation reaction since some part of monomers is missing in polymer and is eliminated as by-product. The reaction is single step reaction and need different monomers out of which one must have reactive functional group. When monomers approach each other they combine to give polymer.

The monomers are added in multiple directions to growing polymer hence these are non linear in structure.

A phenol and formaldehyde undergo condensation polymerization to give a polymer commercially called Bakelite, The reaction is as shown below.

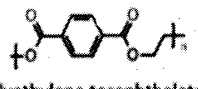
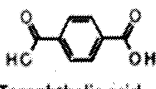
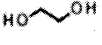
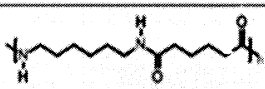
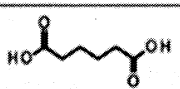

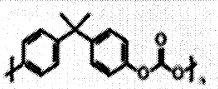
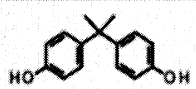

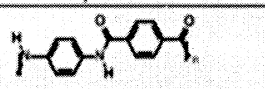
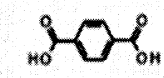

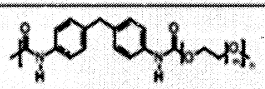
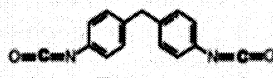



Some of the main characteristics of this type of polymerization are-

1. The molecules should have one or two functional groups (like alcohol, amine, or carboxylic acid groups).
2. The reaction occurs between two similar or different functional groups or monomers. It can take place between a dimer and oligomer, or between a chain and another chain of polymers.
3. Smaller molecules usually combine together to form larger molecules.

4. Mixed properties of both the molecules or functional groups are taken into consideration.
5. A linear polymer is obtained if the Condensation product when both functional groups are di- functional.
6. When one of the functional groups is tri- or tetra-functional, the polymer formed will be cross linked polymer having a **three-dimensional network**.
7. The average molecular weight decreases when monomers are added with one reactive group. Therefore, the functionality of each monomer determines the average molecular weight and crosslink density.

Important polymers prepared by condensation /step growth polymerization.

Polymer	Monomers	Uses
 Polyethylene terephthalate (PET)	  Terephthalic acid Ethylene glycol	Bottles, films (MYLAR), aluminized films for food packaging and insulation, yarn for clothing (Terylene), etc.
 Nylon 6,6	  Adipic acid 1,6-hexamethylene diamine	Fibre for carpets, bags (Cordura), molded parts for automobile applications, ropes and nets, etc.
 Polycarbonate	  Bisphenol A Phosgene	Tough transparent sheets used for green houses, airplane/train windows, safety goggles, spectacle lenses, electronic applications, CD's etc.
 Kevlar	  Terephthalic acid 1,4-phenylenediamine	One of the strongest synthetic fibres; used in the manufacture of bullet-proof vests; also used to make fibre-reinforced composites.
 Polyurethane	  Methylene diisocyanate (MDI) Polyethylene glycol	Representative structure; variety of diols (polyols) and diisocyanates are used to tailor the properties. Used as rigid foams for packaging, thermal insulation and for flexible foams in upholstery; coatings and finishes; and thermoplastic elastomers.

Addition Polymerization	Condensation Polymerization
Unsaturated monomers undergo addition polymerization.	Different monomers with reactive functional group
It is Kinetic chain reaction	It is intermolecular reaction
Reaction is very fast. Completes in few seconds after initiation	Reaction rate is slow and depending on monomers involved it took few hours or days to complete
Produces no by-products	By-products such as ammonia, water and HCl are produced
Approaching of two growing chains during reaction results in termination of reaction	Approaching of two growing chains during reaction results in propogation
The molecular weight of the resultant polymers is a multiple of monomer's molecular weight	The molecular weight of the resultant polymer is not a multiple of monomer's molecular weight
Forms straight chain / linear polymers	Forms non linear polymers with 3-D network structure
Common examples of addition polymerization are PVC, polyethene, Teflon etc.	Common examples of condensation polymerization are Nylon, Bakelite, Epoxy resins, etc.

Addition Polymer	Condensation Polymer
Formed by Addition polymerization.	Formed by condensation polymerization.
Soft and weak in appearance	Tough and strong in appearance
Linear/ st. chain structure , No cross links between chains	3-D network structure, cross links between chain
Produces no by-products	By-products such as ammonia, water and HCl are produced
Soften on heating , harden on cooling	Harden on heating, excessive heating leads charring.
Resistant to all chemicals except organic liquids	Resistant to all chemicals, even to organic liquids
Used as thermoplastics/thermo softening plastic	Used as thermo setting plastics.
Common examples of addition polymers are PVC, polyethene, Teflon, Polystyrene etc.	Common examples of condensation polymers are Nylon, Bakelite, Epoxy resins, etc.

4.3. Plastics – Plastic is commercial term used to designate organic high polymers with excellent plastic behavior. These became popular in last 40 years and its use is increased by many times in technological and domestic fields due its versatile properties, availability and economy.

Properties of plastic – i) Light nature ii) Precise moulding iii) Water repellent nature iv) Insect and termite proof v) Ability to take any colour vi) Bad conductors of heat and electricity vii) Excellent weathering stability, resist oxidation, corrosion viii) Resistant to almost all chemicals ix) Many plastics can be recycled, remoulded x) Economical, readily available.

From technological point of view, the main properties are listed below

Mechanical properties

Mechanical properties refer to displacement or breakage of plastic due to some mechanical change such as applying some load. Mechanical properties are dependent on the temperature, force (load), and the duration of time the load is applied. It may also be affected by ultra-violet radiation when used outside.

Thermal Properties

Thermal properties include heat resistance or combustibility. Thermoplastic has a larger coefficient of thermal expansion or combustibility and a smaller thermal conductivity or specific heat than other material such as metals.

Chemical properties

Chemical resistance, environmental stress crack resistance, or resistance to environmental change are referred as chemical properties. When a plastic contacts chemicals, there is some kind of change. After having a plastic in contacted with chemicals under no stress for about a week, changes in appearance, weight and size of the plastic are examined. Such changes are referred to as chemical properties.

Electric properties

Electric properties are also referred to as electromagnetic properties. Electric properties include insulation, conductivity and electro-static charges. Due to their good

insulation property, plastics are often used in electric fields. However, plastics do have a defect; they are easily electrified.

Physical properties

Specific gravity, index of refraction and moisture absorption are called physical properties. The specific gravity of the plastic is small, and it varies depending on the character of high polymer, or thermal and mechanical treatment of the plastic.

4.4. Thermo plastics and Thermosetting plastics

Plastics are classified in two main types based on conditions under which they are molded.

1. Thermoplastics/ thermo softening plastics- These are products of addition polymerization. When heated they become soft as polymer chains are lying one over other held together by weak Vander walls forces of attraction. Heating overcome these forces and polymer chains slide over each other causing softening. Softened state is plastic state and these are molded in required shape when they become soft on heating. Cooling will again harden them. So they can be softened and hardened for so many times and hence can be reshaped, remolded or reclaimed from waste. These are soft and weak and can swell/dissolve in organic solvents like benzene, toluene, acetone, carbon tetra chloride etc, Common examples are polyethene, polyvinylchloride, polystyrene, polybutene etc.

2. Thermosetting plastics - These are products of condensation polymerization. When heated they become slightly hard as polymer chains are lying one over are linked to each other by cross links. Heating cannot break these links and so there is no softening. Plastic state is the reaction mixture itself. Excessive heating leads to charring (Combustion leaving behind char a black residue). So they can molded only once before polymerization reaction complete and hence cannot be be reshaped, remolded or reclaimed from waste. These are tough and strong and stable towards organic solvents like benzene, toluene, acetone, carbon tetra chloride etc, Common examples are Nylon, Epoxy resin, Bakelite etc.

Thermoplastic	Thermosetting
Formed by addition polymerization	Condensation polymerization
Soft and weak appearance	Tough and strong
Linear structure	3-D Network
Soften on heating and acquire plasticity	No such Softening
Molded when become soft on heating	During polymerization reaction
Reshaped, recycled	Not possible
PE, PS, PVC	Bakelite, Nylon

4.5. Properties and Uses of

→ PVC- Properties: Polyvinyl chloride is colourless, odourless, non-inflammable inert powder. It is resistant to light, atmospheric oxygen, acids, alkalis. Soluble in hot chlorinated hydrocarbons. It softens at 148 °C and it is stiff and more rigid than polyethene.

Uses – Used for making sheets, tank linings, light fittings, safety helmets, refrigerator components, cycle and motorcycle mud guards, packing sheets, pipes, rain coats, curtains, toys, tool handles, conveyer belts etc.

→ Bakelite - Properties: It forms a hard, rigid, scratch resistant, high strength, durable material which is capable of being molded under a variety of conditions. It has high heat, electrical and water resistance, and may be produced in a wide range of colors.

Uses: It is used in the manufacture of coating materials. Laminated products, grinding wheels, and metal and glass bonding agents, and may be cast into many useful items.

Components made from molded cases, appliance plugs, bottle caps, knobs, dials, radio cabinets, knife handles, vacuum cleaner parts and numerous electrical parts.

→ **Epoxy Resin – Properties** – i) Good adhesive properties with metals, ceramics ii) Excellent water repellent nature. iii) Excellent chemical resistant iv) Excellent insulating nature v) High thermal stability

Uses- i) As an adhesive for glass, metals and ceramics. ii) Construction of super highways iii) For anti-skid surfaces iv) Crease resistance to fabric v) Water proofing of constructed surfaces vi) Insulating coating on wires and cables vii) Casting of electronic components.

Fiber reinforced Plastics (FRP)

FRP is composite material obtained by introducing regular network of fibers of different materials in to body of polymeric plastic. Thermoplastics are weak and soft, they possess poor load bearing capacity and poor strength. In order to rectify these drawbacks plastics are reinforced using fibers of different materials for composition. The use, properties and cost of FRP depend on type of fiber used for reinforcement. The important types of FRP are-

1. **Carbon Fiber reinforced plastics (CFRP)** – Obtained by composing carbon black as reinforcing material. Carbon black is light in nature but costly.

Properties - Light nature, High strength, shock resistant.

Uses – CFRP is used for making Lens hoods, camera bodies, optical devices, sportswear, aircraft parts, spectacle frames etc.

2. **Glass fiber reinforced plastics (GFRP)** – Here glass fibers are used for reinforcement. The strength depends on thickness/diameter of fiber used. Lesser the diameter higher is the strength also cost increases with decrease in diameter of fiber.

Properties – Heavy nature, good strength, high load bearing capacity.

Uses – Used for making all types of furniture like tables, chairs, cupboards, doors, cabinets for audio and video equipments, mud guards for vehicles, bodies of automobile vehicles etc

3. **Boron fiber reinforced plastic (BFRP)** - It uses boron fibers for reinforcement. Boron is ultra-light in nature but very costly.

Properties – Very high strength, Ultra-light nature, High cost.

Uses - For making air craft and space craft spares and components.

4. **Metal fiber reinforced plastics** – It uses thin metal wires/fibers for reinforcement. Generally metal wires are trapped between sheets of plastic and these sheets are used as conducting cords for all type of foldable electronic/ computing devices like laptops, PDA, Mobile phones, calculators etc.

4.6. Rubber and properties of Rubber

Rubber is a unique material that is both elastic and viscous. Rubber parts can therefore function as shock and vibration isolators and/or as dampers. In the raw state it is referred to as an elastomer – polymer with excellent elastic behavior. Vulcanization forms chemical bonds between adjacent elastomer chains and subsequently imparts dimensional stability, strength, and resilience. Rubber has a low modulus of elasticity and is capable of sustaining a deformation of as much as 1000 percent. After such deformation, it quickly and forcibly retracts to its original dimensions. It is resilient and yet exhibits internal damping. Rubber can be processed into a variety of shapes and can be adhered to metal inserts or

mounting plates. It can be compounded to have widely varying properties. Rubber will not corrode and normally requires no lubrication.

Rubber or elastomers are classified in two types i) Natural rubber – available from trees, herbs, shrubs and some type of grasses. ii) Synthetic rubber – synthesized in laboratory via polymerization reaction.

4.6.1. Properties of rubber

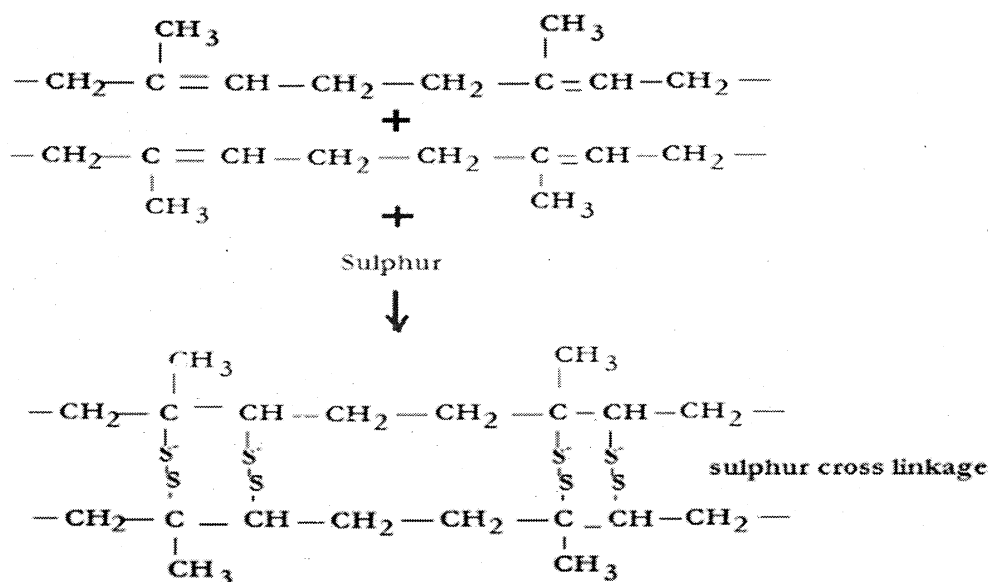
Besides normal properties rubbers are known for following special properties so they bear advantage in several technological applications.

- i) **Elasticity** – It is ability of material to undergo temporary deformation under conditions of load, tension, force or load etc. As soon as these conditions are withdrawn it regains its original dimensions. Rubbers are highly elastic and may show up to 100 times elongation.
- ii) **Resilience**- resilience is ability of material to regain original dimensions after elastic deformation quickly. In other words it is time taken to regain original dimensions after elastic deformation. Less is the time excellent is resilience while more is time poor is resilience. Rubbers possess excellent resilience.
- iii) **Tackiness** – It is ability of material to merge when two fresh surfaces of it are allowed in close contact. Rubber shows excellent tackiness.
- iv) **Abrasion resistance** – It is ability of material to withstand frictional conditions without considerable losses out of wear and tear. Rubber shows excellent abrasion resistance.
- v) **Re bounce** – Ability of material to absorb energy and move in opposite direction when impacts with some hard surface. Rubber shows excellent re bounce properties.

Based on above properties rubber is widely used for automobile tyre, conveyer belts, air tubes in tyre, sports balls etc.

For many applications associated with rubber mostly natural rubber is used. Natural rubber when extracted from trees is called crude rubber and possess many drawbacks like i) Very high elasticity ii) Soft and tacky nature, iii) tendency to absorb moisture is high, iv) Readily oxidize in air, v) Poor tensile strength vi) poor abrasion resistance and vii) Limited working temperature range (10 -45 °C). So that it cannot be directly employed in application without modifying its properties. The properties can be modified by converting linear structure of natural rubber (polyisoprene, $--(C_5H_8--)_n--$) to a three dimensional network structure by introducing cross links among polymer chains. Mostly sulphur crosslink's. **This process is called process of vulcanization of rubber.**

4.6.2. Vulcanization of Rubber. It is a curing reaction by which the rubber reacts with the setting reagents (chemicals). It was accidentally invented by scientist Goodyear in 1830. In process of vulcanization crude rubber is heated with elemental sulphur or some organo-sulphur compounds at 100 to 200 °C, depending on actual vulcanizing agent used. The unsaturation with rubber polymer is used to link two polymeric chains by means of sulphur cross links as shown below.



Sulphur can be added from 3 to 32%. As % S increases elasticity decreases, strength and hardness increases. **For 32% S a hard non elastic solid called ebonite is formed. Depending on use of rubber in desired application a required extent of Sulphur must be added.** E.g. Tyre rubber has 5 to 8% sulphur.

Vulcanization can be enhanced by the use of accelerators which are organic chemicals. When rubber is vulcanized with sulphur and reinforced with carbon black, tensile strength lies in the range of 25-32 N/mm² and elongation 550-650 %. Benefits of vulcanization are – i) Controlled elasticity ii) Good resilience iii) Non sticky appearance iv) Low water absorption and air oxidation v) High tensile strength vi) Good working temperature range (-10 to 140 °C) vii) Excellent abrasion resistance.

Property	Crude Rubber	Vulcanized Rubber
Appearance	Soft and tacky	Tough, strong and non tacky
Elasticity	Very high	Controlled as required by % sulphur
Resilience	Poor	Excellent
Tensile strength	Low 200 Kg/cm ²	Very high based on % sulphur, up to 2600kg/cm ²
Water absorption	High	Negligible
Air oxydation	Easy	Negligible
Abrasion resistance	Poor	Excellent
Re bounce	Poor	Improved according to % S
Working temp.	10 – 45 °C	-10 – 140 °C

Questions

Answer the following

- What is polymer? Give an account of addition/ condensation/copolymerisation.
- Distinguish between
 - Addition and Condensation polymerisation.
 - Addition and Condensation polymers.
 - Thermo and Thermosetting plastics.
 - Crude and Vulcanised rubber.
- Write a note on i) Thermoplastic ii) Thermosetting plastic iii) Vulcanisation of rubber

4. Discuss extraordinary properties of elastomers.
5. Explain process of vulcanisation of rubber.
6. What are polymers? How are they classified?
7. Give properties and uses of i) PVC ii) Bakelite iii) Epoxy resins
8. Define Engineering material and Give an account of its classification with examples.
9. Discuss properties of plastic.
10. Discuss different types of Fibre Reinforce Plastic (FRP's) with respect to properties and uses.

Define terms

Polymer, Ceramics, Composites, Monomer, Copolymer, addition polymer, Elastomer, Resilience, Thermoplastic, Thermosetting Plastic.

Give reason

1. Addition polymers bear linear structure.
2. Condensation polymers bear 3D structure.
3. Addition polymers become soft on heating.
5. Thermosetting plastics cannot be remoulded/reused/recycled.
6. Addition polymers can be remoulded/reused/recycled.
7. No heating required for moulding of thermosetting plastics.