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3. Polymer Science and Engineering

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3.1 Polymers:

Polymers are very large molecules having high molecular mass. In the year 1833, Jons Jacob Berzelius; Swedish Chemist coined the word Polymer. In Greek language „poly" means "many" and „mer" means "units or parts". The combination (linking) of small units results in the formation of Polymer which is linked by Covalent bonds. The repeating unit in a polymer is called monomers. The process of conversion of monomers into Polymer is called Polymerization. The number of repeating units in a polymer chain is called degree of Polymerisation. Natural polymers are found in plants and animals. Synthetic polymers are man-made.

3.2 Classification of Polymers:

Natural Polymers	Synthetic Polymers
- Proteins - Polysaccharides - Polynucleotides	- Nylon - Teflon - Bakelite - Plastic - PVC - Dacron

Plastic:

Plastic is a polymer containing long carbon chains. Plastic was discovered by Christian Schonbein. Plasctics are strong and ductile, poor conductor of heat and electricity, resistant to corrosion and chemicals, can be moulded and coloured. There are two types of Plastics; Thermoplastics and Thermosetting plastics.

Thermoplastcis	Termosetting Plastics
▪ Linear or slightly branched long chain molecules	▪ Cross linked or heavily branched molecules
▪ Softens on heating and hardens on cooling	▪ On heating becomes infusible
▪ Can be reused	▪ Cannot be reused
▪ Formed by Addition Polymerisation	▪ Formed by Condensation

Thermoplastcis	Termosetting Plastics
	Polymerisation
▪ Soft, Weak and less brittle	▪ Hard, strong and more brittle
▪ Polythene, Polystyrene, PVC, Nylon	▪ Bakelite, Teflon, Urea-formaldehyde resins, Epoxy Resins

3.2.1 Polymerisation:

a. **Addition Polymerisation or Chain Growth Polymerisation**: Molecules of the same monomer or different monomers add together to form a polymer. . Examples are given in Table 1.

b. **Condensation Polymerisation or Step Growth Polymerisation:** Polymerisation involving a repetitive condensation reaction between two bi-functional or tri- functional monomeric units which result in the loss of some simple molecules like water, alcohol, hydrogen chloride. Examples are given in Table 3.1.

Sr. No.	Polymer	Monomer	Type Of Polymeri Sation	Uses
1	Polythene	Ethene	Addition	Bottles, Toys, Buckets, Dust-bins, Pipes
2	Polytetrafluoro ethene (Teflon)	Tetrafluoroethene	Addition	Oil seals, gaskets, non-stick utensils
3	Polyacrylonitrile	Acrylonitrile	Addition	Substitute for wool-Orlon or acrilan
4	Polystyrene	Styrene	Addition	Insulator,wrapping material, manufacture of radio and television cabinets
5	Polyvinyl Chloride (PVC)	Vinyl Chloride	Addition	Manufacture of Rain-coats, hand bags, vinyl flooring
6	Terylene (Dacron)-Polyesters	Ethylene glycol and Terephthalic acid	Condensation	Used in blending with cotton and wool, safety helmets
7	Nylon-6,6-Polyamides	Adipic acid and Hexamethylene diamine	Condensation	Making Sheets, bristles for brushes
8	Melamine-formaldehyde	Melamine-formaldehyde	Condensation	Unbreakable crockery
9	Nylon 6	Caprolactum	Condensation	Tyre cords, fabrics and ropes

Sr. No.	Polymer	Monomer	Type Of Polymeri Sation	Uses
10	Urea-formaldehyde Resin	Urea-formaldehyde	Condensation	Used for making unbreakable cup and laminated sheets
11	Glyptal	Ethylene glycol and Phthalic acid	Condensation	Manufacture of Paints
12	Bakelite	Phenol and Formaldehyde	Condensation	For making combs, electrical switches, computer discs, handles of utensils

3.2.2 Conducting Polymers:

In general Polymers are poor conductors of electricity because of the non- availability of large number of free electrons for the conduction process. So, most of the polymers are used as insulators.

Polymeric materials which possess electrical conductivities in comparison with metallic conductors are called Conducting Polymers. The conduction of polymers is due to unsaturation or due to presence of externally added substances to polymers.

Application of Conducting Polymers:

- Conducting Polymers are used for making electronic displays and optical fibres
- They are used for cancer treatment.
- Conducting polymers are used in rechargeable batteries.
- Conducting Polymers are used in photovoltaic devices, LED"s and Data Storage
- They are used for making analytical sensors for SO2, NH3, O2 and glucose.
- Used for making ion exchangers. These membranes made of conducting Polymers show selective permeability for ions and gases hence they are used for control release of drug.

3.2.3 Biodegradable Polymers:

Natural polymers are biodegradable, but synthetic polymers and plastics are non-bio-degradable and cause environmental pollution. In order to avoid this problem scientists and researchers started to focus their attention on crating biodegradable polymers.

Biodegradable Polymers are defined as the degradable polymers in which degradation is caused by the action of naturally occurring microorganisms such as bacteria, fungi and algae. They yield CO2, H2O, inorganic compounds and biomass while composting without leaving any toxic residual substances. Biodegradable polymers are of two kinds, naturally occurring and synthesized ones by Chemical methods.

A. Natural biodegradable Polymers:

The naturally occurring biodegradable polymers are classifying as four groups.

- Polysaccharides (Starch and cellulose)
- Proteins (Silk, wool, gelatin)
- Polyesters (Polyhydroxyalkanoids)
- Others (lignin, natural rubber)

B. Synthesized Biodegradable Polymers:

Many polymers derived from petrochemical or biological sources are biodegradable. These are the biodegradable synthetic resins:

a. Poly-lactic acid
b. Polyvinyl acetate
c. Polyvinyl alcohol
d. Polyamide esters

C. Polylactic acid or Polylactide (PLA):

Polylactic acid is biodegradable aliphatic polyester which is derived from renewable resources such as corn starch, tapioca roots or sugarcane. Lactic acid is obtained by the bacterial fermentation of sugarcane or from the starch obtained from corn. Oligomerisation and catalytic dimerization of lactic acid results in the formation of lactide monomer. Polylactic acid is obtained by the condensation polymerisation of lactic acid in presence of acid or base catalyst.

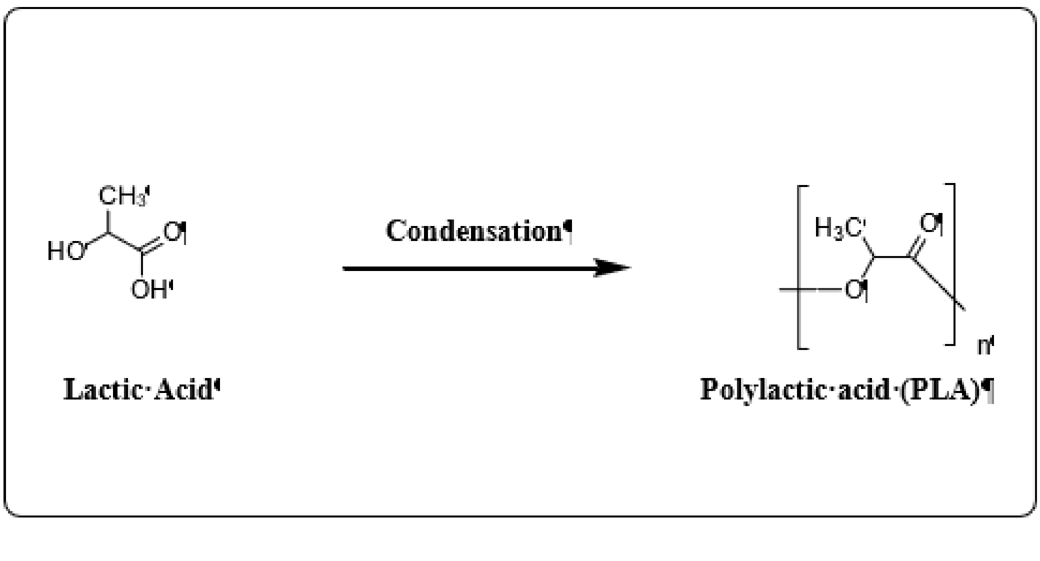

Figure 3.1: Polylactide (PLA)

Due to the chiral nature of lactic acid, several distinct forms of Polylactide exist: Poly-L-lactide (PLLA) is the product resulting from polymerisation of L- lactide. PLLA has crystallinity around 37%, a glass transition temperature between 60-65 oC, a melting temperature between 173-178 oC. Polylactic acid (PLA) can withstand temperatures of 110 oC. PLA is soluble in chlorinated solvents, hot benzene, tetrahydrofuran and dioxane.

PLA is used in biomedical applications such as drug delivery devices and dialysis media. It is used in making compost bags, food packaging, disposable tableware. PLA has many applications such as disposable garments, diapers etc. PLA is also used as a feedstock material in 3D printers such as Makerbot. Thus, the polymers finds applications in all fields of engineering and technology.

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