IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Review On Polymer Properties,Classification And Application

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Abstract : Polymer is a long chain molecule that is composed of multiples of simpler units called monomers. Monomers are large number of repeating units of identical structure. Polymers can be natural or synthetic. Multiple biological, synthetic and hybrid polymers are used for multiple medical applications. A wide range of different polymers is available, and they have further the advantage to be tunable in physical, chemical and biological properties in a wide range to match the requirements of specific applications. This review gives a brief overview about the introduction, polymer classification, properties. There is subsequently an overview of the most frequently used polymer classes. The main body of the review then is structured according to the applications, where key requirements of the applications and the currently used polymer solutions are indicated.

Index Terms: Polymer, Properties,Classsification, Application, Review.

1. Introduction

The meaning of word “polymer” is “many parts”. Polymer is composed of multiples of simpler units called monomers. Polymers are classified into natural polymers and synthetic polymers. Natural polymers are derived from nature. Synthetic polymers are produced by synthetic routes. In vulcanization process, transformation of sticky latex of natural rubber to useful elastomer takes place for tyre use[1].

Polymers are used in many industrial applications. Polyamides such as nylon, Polyacrylonitriles are used in various industrial applications. Polyolefins such as polyethylene, poly vinyl chloride and polypropylene have industrial applications. Elastomers are capable of recovering their shape after being stretched to great extents. Butadiene based elastomers polyisoprene, polychloroprene are used in various industries. Cellulose is a natural polymer composed of glucose units. Cellulose is obtained from natural resources such as wood[2]. Starch is also referred as a polysaccharide, because it is a polymer of the monosaccharide glucose. Starch molecules include amylose and amylopectin are present in plants. Their consequently large molecular mass relative to small molecule compounds produces unique physical properties, including toughness, viscoelasticity, and a tendency to form glasses and semi crystalline structures rather than crystals.

The term was coined in 1833 by Jöns Jacob Berzelius, though with a definition distinct from the modern IUPAC definition[3]. The modern concept of polymers as covalently bonded macromolecular structures was proposed in 1920 by Hermann Staudinger, who spent the next decade finding experimental evidence for this hypothesis[4].

2. Polymer Composite

Polymers are large molecules that are buildup of a number of repeating units called monomers. The name of the polymers is often based on their repeating units as example from the monomer styrene which is consists of 7 backbones of Carbone atoms, 3 hydrogen atoms as in Figure (1).

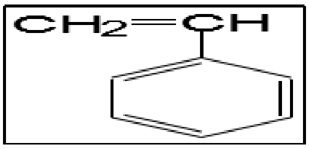

Figure 1: Shows the chemical structure of monomer styrene (M S) [5],[6]

Polystyrene are made up from the repeating unit each one consists of 4 monomer styrene unit and the structural formula of polystyrene is usually written as shows in Figure (2) or (3).

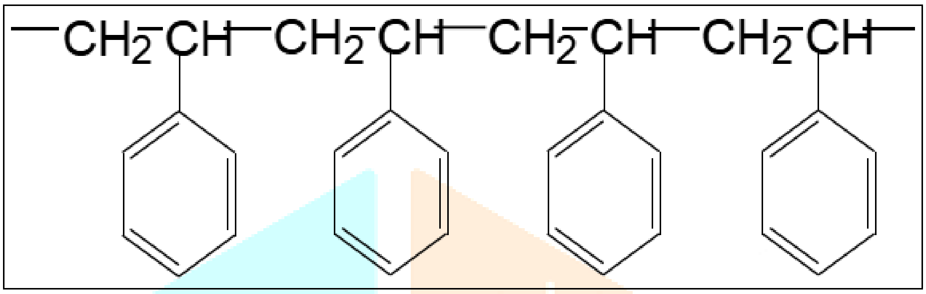

Figure 2: Shows the chemical structure of polystyrene (PS)[5],[6].

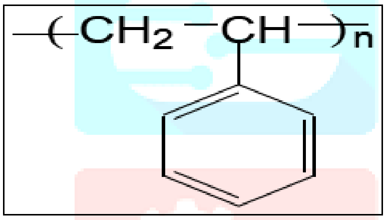

Figure3: Shows the structural formula of polystyrene where n is the number of repeating units in the polymer[5],[6].

The above polymers and many others are usually made by synthesis from their monomers.

3. PROPERTIES:

The most basic property of a polymer is the identity of its constituent monomers. A second set of properties, known as microstructure, essentially describe the arrangement of these monomers within the polymer at the scale of single chain[7]. how the bulk polymer interacts with other chemicals and solvents at macro scale[8],[9].

3.1 Chemical Property: The attractive forces between polymer chains play a large part in determining polymers Properties. The intermolecular forces in polymers can be affected by dipoles in the monomer units.

3.2 Mechanical properties: The tensile strength of a material maximum stress the material can bear before permanent deformation, when it is allowed to be stretched or pulled[10].

3.3 Elasticity: Polymer chains are stretched and then return to their original form when force is removed. All polymer except glassy or partially crystalline states show the property of high elasticity.

4. CLASSIFICATION[11]

4.1 Classification based on the source of origin, which is classified in three types:

4.1.1 **Natural polymers:** Polymers derived from plants or animal are called natural polymers. Examples are wool, cotton, silk etc.

4.1.2 **Synthetic Polymers:** Synthetic polymers are manmade polymers. Nylon, terylene, polyethene, polystyrene, nylon, pvc, backlite, Teflon etc.

4.1.3 **Semi-synthetic polymers:** The polymers obtained by simple chemical treatment of natural fibers to improve their physical properties like lastrus nature, tensile strength are called semisynthetic fibers. e g. Acetate rayon, cupra ammonium silk, viscous rayon.

4.2 The classifications based on the structure are three types of polymers as follows:

4.2.1 **Linear polymers**: Monomers are linked with each other and form a long straight chain. These chains have no any side chains. Examples are Polyethene, PVC, Nylons, polyesters etc.

4.2.2 **Branched polymers:** The polymers made up of linear chains with smaller chains as branches of main chain are called Branched polymers. Example is polypropylene.

4.2.3 **Network or Cross linked polymers**: A polymer in which long chain molecules are attached to each other forming a three dimensional network is called cross linked polymers. Examples are polyurethanes, epoxy resins.

4.3 The classifications based on polymerization process are two types as follows:

4.3.1 **Addition polymers:** The polymers formed by the addition of monomers without generation of by products are called addition polymers. These polymers contain all the atoms of monomers hence they are integral multiple of monomer unit. Addition polymers include polystyrene, polyethylene, polyacrylates, Teflon, polyethene, polypropylene, PVC etc.

4.3.2 **Condensation polymers:** They are formed by the combination of two monomers by release of small molecules like water, alcohol etc. Their molecular mass is not the integral multiple of monomer units. Examples are Nylons, polyesters, polyurethanes epoxies etc.

4.4 The classification based on molecular forces: tensile strength, toughness, elasticity are mechanical properties of polymers. These properties depend upon intermolecular forces like vander Waals forces and hydrogen bonding.

4.4.1 **Elastomers:** These are polymers with weak intermolecular forces. Elastomers are polymers that are very elastic. Examples are natural rubber, neoprene and polybutadiene .

4.4.2 **Fibers:** Fibres are thin, long flexible thread like structures. Natural fibres are obtained from nature. Examples are cotton, silk and wool etc. Synthetic fibres are manmade examples are rayon, nylon, acrylic etc.

4.4.3 **Thermoplastic polymers:** Thermoplastic is type of polymer that can be moulded or reshaped by heating. Examples of Thermoplastics include polyethylene, polypropylene, polyvinyl chloride, polystyrene and nylon etc.

4.4.4 **Thermosetting polymers:** Thermosetting polymers when moulded once cannot be softened by heating. . Examples are Bakelite and melamine.

4.5 The classification based on the homogeneity of Polymers:

4.5.1 **Homopolymers :** Homopolymers consists of only one type of repeating unit.

4.5.2 **Copolymers:** Copolymers are polymers consisting of more than one type of repeating unit.

4.6 The classification based on growth polymerization, implies two types:

4.6.1 **Chain growth polymers :** A chain growth polymer is formed when molecules of the same monomer or different monomers add together on a large scale to form the polymer. Example is Teflon.

4.6.2 **Step growth polymers :** Step growth polymerization is step wise reaction between bi functional and multifunctional monomers in which high molecular weight polymers are formed. Example is Dacron.

Table 1: Show some common addition polymers and their relevant monomers names and chemical structure

Name(s)	Formula	Monomer	Properties	Uses
Polyethylenelow density (LDPE)	–$(CH_2\text{-}CH_2)_n$–	ethylene $CH_2{=}CH_2$	soft, waxy solid	film wrap, plastic bags
Polyethylenehigh density (HDPE)	–$(CH_2\text{-}CH_2)_n$–	ethylene $CH_2{=}CH_2$	rigid, translucent solid	electrical insulationbottles, toys
Polypropylene(PP) different grades	–$[CH_2\text{-}CH(CH_3)]_n$–	propylene $CH_2{=}CHCH_3$	atactic: soft, elastic solid isotactic: hard, strong solid	similar to LDPEcarpet, upholstery
Poly(vinyl chloride)(PVC)	–$(CH_2\text{-}CHCl)_n$–	vinyl chloride $CH_2{=}CHCl$	strong rigid solid	pipes, siding, flooring
Poly(vinylidene chloride)(Saran A)	–$(CH_2\text{-}CCl_2)_n$–	vinylidene chloride $CH_2{=}CCl_2$	dense, high-melting solid	seat covers, films
Polystyrene(PS)	–$[CH_2\text{-}CH(C_6H_5)]_n$–	styrene $CH_2{=}CHC_6H_5$	hard, rigid, clear solid soluble in organic solvents	toys, cabinetspackaging (foamed)
Polyacrylonitrile(PAN, Orlon, Acrilan)	–$(CH_2\text{-}CHCN)_n$–	acrylonitrile $CH_2{=}CHCN$	high-melting solid soluble in organic solvents	rugs, blanketsclothing
Polytetrafluoroethylene(PTFE, Teflon)	–$(CF_2\text{-}CF_2)_n$–	etrafluoroethylene $CF_2{=}CF_2$	resistant, smooth solid	non-stick surfaces electrical insulation
Poly(methyl methacrylate) (PMMA, Lucite, Plexiglas)	–$[CH_2\text{-}C(CH_3)CO_2CH_3]_n$–	methyl methacrylate $CH_2{=}C(CH_3)CO_2CH_3$	hard, transparent solid	lighting covers, signsskylights
Poly(vinyl acetate)(PVAc)	–$(CH_2\text{-}CHOCOCH_3)_n$–	vinyl acetate $CH_2{=}CHOCOCH_3$	soft, sticky solid	latex paints, adhesives
cis-Polyisoprenenatural rubber	–$[CH_2\text{-}CH{=}C(CH_3)\text{-}CH_2]_n$–	isoprene $CH_2{=}CH\text{-}C(CH_3){=}CH_2$	soft, sticky solid	requires vulcanization for practical use
Polychloroprene (cis +	–$[CH_2\text{-}CH{=}CCl\text{-}CH_2]_n$–	chloroprene	tough, rubbery solid	synthetic rubber oil resistant

trans)(Neoprene)		CH_2=CH-CCl=CH_2		

5. APPLICATIONS OF POLYMERS:

5.1 Chitosan and methyl cellulose: Polymers are used in Drug Delivery. Natural-based polymers such as methyl cellulose and chitosan are used for controlled drug delivery[12].

5.2 Polyolefin: Polyolefin include polyethylene, Polyvinyl chloride, polyvinyl styrene etc. Polyethylene is most important petrochemical. Low density polyethylene is produced by free radical polymerization[13]. The principal commercial applications HDPE include blow moulded containers, crates, drums gas tanks and blow film.Polypropylene It is a light weight plastic. Main uses are pipe sheet and blow moulded containers .Polystyrene is is used in manufacture of form and bead for insulation and packaging materials.Polyvinylchloride is co polymer of polyvinyl chloride. It is the largest volume commodity plastics .Rigid grade PVC is used as sheet, pipe and window profiles.

5.3 Elastomers: Butadiene based elastomers Polybutadiene has good resilience, abrasion resistance. It has important properties for tire applications[14]. Nitrile rubber has improved oil and aromatic solvent resistance. It is used in the manufacture of gasket , tubing and gasoline hose etc. Polychloroprene shows good resistance to attack by oxygen and gas. It is used as material for gaskets, tubing seals and gasoline hose.

5.4 Polyamides: Polyamides have many industrial applications in carpets, apparel , tire reinforcement etc.

5.5 Polyvinyl chloride (PVC): PVC has an ethylene backbone with one covalently bound chlorine. Its fabrication and application requires stabilizers and plasticizers, which are the main reason for medical concerns against this polymer. Plasticizers, most frequently phthalates, turn the rigid PVC to a soft polymer, which is used for extra corporeal tubing or blood storage bags[15].

5.6 Silicone : Silicones consist of an –Si–O– backbone with different chain lengths and cross links, which determine mechanical properties from liquid oil via a gel structure to rubber elastomer.The biological response differs for various applications.There is high tolerance in ophthalmologic applications fibrous capsule formation at breastim plants[16].

5.7 Polyethers : Ether bondings are bio stable. Poly ether ether ketone (PEEK) as hard material for orthopedic applications and polyether sulfone(PES) for dialysis membranes are main representatives of this polymer class in biomedicine[17].

6. CONCLUSION :

Polymers have wide range of applications in medical field and other industries. Polymer-based pharmaceuticals are key elements to treat many lethal diseases that affect a great number of individuals such as cancer or hepatitis. Methyl cellulose and chitosan are being used in drug delivery system. Polymers are raw materials for the products we use everyday including fibreglass, plastic bags, polyethylene, cups etc. It is need of hour to train persons to carry out research and development in polymer science and engineering.

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