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History, Classification and Application of Polymers: A Review

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Abstract **Review Article**

A broad family of materials called polymers is made up of several tiny molecules. Nearly every industry uses polymers, including rubber, cotton, wool, Teflon(tm), and plastics of all kinds. The remarkable resemblance between the infrared absorption spectra of heavenly objects and cellulose indicates its existence. The uppermost layer of the film is composed of cellulose pellicle. Most materials, including the metal used in springs, are elastic because of bond distortions. Rubber's lengthy, tightly wrapped polymer chains are connected at a few locations when it is relaxed. The main goal of polymeric delivery systems is to produce regulated or prolonged pharmaceutical dispersion. It has also been possible to target medications to the colon after oral administration by utilizing polysaccharides. Future interesting new applications for polymeric materials have a huge promise. Uses for polymers are being developed in a wide range of fields.

Keywords: Polymer, Drug delivery system, Natural, cellulose.

INTRODUCTION

The word "polymer" (derived from the Greek words poly, meaning "many," andmero, meaning "parts") signifies "many parts." Massive molecules known as polymers have molar masses between thousands and millions. 80 percent or so of the organic chemical market is committed to the process of making synthetic polymers, including plastics, fibers for clothing, and rubber. The term "polymer" refers to a broad class of substances made up of numerous tiny molecules (known as monomers) that can be connected to form lengthy chains. Since ancient times, humans have utilized the versatility of polymers in the form of oils, tars, resins, and gums. The contemporary polymer business did not start to grow, nevertheless, until the industrial revolution. Charles Goodyear achieved success in creating a practical type of natural rubber through a procedure known as "vulcanization" [1] in the late 1830s. Firstly, cellulose is a naturally occurring biological photopolymer made up of glycosidically connected (1–4)-cellulose residues. Glucan chain bundles produce the microfibril, an insoluble ultra-fine thread, by forming hydrogen bonds with one another. These creatures are chordates, and since multicellular organisms at this stage of evolution are capable of synthesizing cellulose, it is plausible that mammals, including man, are also capable of doing so [2]. Cereal grains and potatoes both contain starch, a basic dietary grouping of carbs. Due to the fact that it is a polymer of the monosaccharide glucose, it is also known as a polysaccharide. Amylose and amylopectin are two different kinds of glucose polymers that make up starch molecules. Amylopectin is the primary source of starch in most plants and accounts for around three-fourths of the total amount of starch in wheat flour. Amylase is a straight chain polymer with a typical molecular weight of roughly 200 glucose units [3].

History

Henri Braconnot produced groundbreaking work on derivative cellulose compounds beginning in 1811, which is possibly the oldest significant study in polymer research. The first widely used semi-synthetic polymer, rubber, was made more durable by the advent of vulcanization later in the nineteenth century. By combining phenol and formaldehyde at a particular temperature and pressure, Leo Baekeland produced the first entirely synthetic polymer, Bakelite, in 1907. In 1909, Bakelite was subsequently made widely available [4].

The German chemist Karl Ziegler and the Italian chemist Giulio Natta, who shared the 1963 Nobel Prize in Chemistry for creating the Ziegler-Natta catalyst, made a significant contribution to the study of synthetic polymers. Paul Flory's receipt of the Chemistry

Nobel Prize in 1974 served as further confirmation of the significance of polymers.

Wax and shellac are examples of manmade organic polymers that have been used by humans for generations. Natural fibers and ropes are structurally strong thanks to a plant polymer called "cellulose," and by the early 19th century, granules of medicine and natural rubber, harvested from rubber trees, were widely used [5].

The polymer and its substance make Goodyear's vulcanized rubber stronger, more elastic, less sensitive to temperature, impermeable to gases, and highly resistant to chemicals and electric current than untreated natural rubber [6].

Properties

Based on the scale at which the property is specified as well as on its physical foundation, polymer properties are broadly categorized into a number of types. The identification of a polymer's component monomers is its most fundamental characteristic. The arrangement of these monomers within the polymer at the scale of a single chain is effectively described by a second set of characteristics, referred to as microstructure [7].

At the nanoscale, chemical characteristics characterize the interactions of the chains with different physical forces. They explain the interactions of the bulk polymer with various compounds and solvents at the macro-scale [8, 9].

1. Chemical Properties

The properties of a polymer are mostly governed by the attractive forces between its chains. These inter-chain forces are enhanced far beyond the attractions between regular molecules in polymer chains because they are so lengthy. Dipoles in the monomer units of polymers can influence the intermolecular forces. As the partially positively charged hydrogen atoms in N-H groups on one chain are strongly attracted to the partially negatively charged oxygen atoms in C=O groups on another chain, polymers having amide or carbonyl groups can establish hydrogen bonds between adjacent chains.

2. Mechanical properties

The bulk properties of a polymer are often those that are important for end uses. These are the characteristics that control the polymer's real macroscopic behaviour. A material's tensile strength measures how much stress it can withstand without permanently deforming [10].

3. Elasticity

The elastic characteristic is brought on by bond distortions in the majority of elastic materials, including metals utilized in springs. Bond lengths depart from the (least energy) equilibrium when force is applied, and strain energy is electrostatically stored.

4. Transport Property

Diffusivity is a transport property that describes how quickly molecules flow across the polymer matrix. These are crucial in a variety of polymer applications for films and membranes. When referring to polymers, the word "melting point" does not imply a solid-liquid phase but a change from a semi-crystalline or crystalline state to an amorphous solid section [11, 12].

Classification

Due to their complex structural makeup, vast range of functional applications and variety of features, polymers cannot be categorized into a single group. Depending on where they can be found, polymers are categorized into three categories. They are polymers that are natural, artificial, and semi-artificial. Natural polymers can be found in both plants and animals. Rubber, cellulose, starch, and proteins are a few examples. The term "biopolymers" also refers to biodegradable polymers. Semi-synthetic polymers are created by chemically altering naturally occurring polymers, such as cellulose nitrate and cellulose acetate. Synthetic polymers are created by humans. Plastic is the most abundant and often employed synthetic polymer. It is used in many different sectors and dairy products, like nylon-6 polyether.

Natural Polymer

They come in both organic and inorganic polymer varieties. Because they contribute to essential life processes and serve as basic structural elements, organic polymers are significant in living things. For instance, all plants' solid parts are made of polymers. Cellulose, lignin, and other resins are a few of them. A polysaccharide, or polymer comprised of sugar molecules, is cellulose. Lignin is a complicated three-dimensional network of polymers; wood resins are isoprene, a straightforward hydrocarbon, polymers. Another well-known isoprene polymer is rubber. Two additional important natural polymers are proteins, which are polymers of amino acids, and nucleic acids, which are polymers of nucleotides—complex compounds made up of nitrogen-containing bases, sugars, and phosphoric acid). Nucleic acids carry genetic information inside of cells. Starches, which are glucose-based natural polymers, are vital sources of dietary energy provided by plants. There are numerous inorganic polymers in nature as well, including graphite and diamond. Carbon makes up both. Diamonds' strength comes from the three-dimensional network of bonds between their carbon atoms. In graphite, which is used as a lubricant and in pencil leads, carbon atoms come together form planes that may glide over one another.

Starch

It is a glucose polymer and a source of sustenance for plants. Cellulose is a polymer found in plants. This is the hard substance that Paul's tree house, wood, and stems are composed of. Additionally, cellulose is what gives fibers like hemp and cotton their ability to be twisted into threads and woven into clothes. Additionally, many plants produce starch. There is a lot of starch in cereals, potatoes, corn, and rice [13].

Cellulose

It is a glucose polymer as well. It is the primary structural component of plants. From the glucose produced during photosynthesis, plants make both cellulose and starch. With the formula $(C_6H_{10}O_5)$ n, cellulose is an organic molecule that is a polysaccharide made up of a linear chain of several hundred to more than ten thousand β (1→4) connected D-glucose units [14]. Cellulosic ethanol is the fuel produced when some bacteria transform cellulose into ethanol.

Proteins

Proteins are composed of polymers of α-amino acids, typically containing 20 to 1000 α amino acids linked in a well-organized configuration. These are the fundamental components of an animal's body and are present in all of our diet [15].

Nucleic acids

These are different nucleotide polymers. For instance, common nucleotides are found in DNA and RNA. It should be mentioned that polymers that regulate different aspects of plant and animal life processes, such as proteins, nucleic acids, and polysaccharides (cellulose, starch), are also known as biopolymers. Linear polymers, or chains, of nucleotides, make up nucleic acids [16] A pentose sugar, a phosphate group, and a purine or pyrimidine nucleobase—also known as a nitrogenous base or just base make up each nucleotide.

Silk

Silk is another remarkable protein; it's a type of fabric produced by some caterpillars. For thousands of years, this material has been used to create exquisite textiles for garments. Furthermore, nothing compares to silk, even if people have created nylon, a substitute for silk.

Enzymes

Enzymes are a unique class of proteins that function within the body. Every enzyme in the body is a unique tiny glob of a protein that performs a specialized function really quickly. These processes either wouldn't occur at all or would proceed far too slowly to support life! Enzymes can even synthesize other enzymes [17].

Synthetic polymers

Several different processes can be used to create synthetic polymers. Many straightforward hydrocarbons, like ethylene and propylene, can be transformed into polymers by successively adding monomers to the growing chain. Repeated ethylene monomers make up the additive polymer known as polyethylene. It could include up to 10,000 monomers twisted into long strands and joined together. Crystalline, clear, and thermoplastic describe polyethylene, which softens when heated. It is utilized in the creation of packaging, bottles, containers, and molded components. While polypropylene is crystalline and thermoplastic like polyethylene, it is stronger. Its molecules can have anything between 50,000 and 200,000 monomers. Both the textile industry and the production of molded goods use this substance.

Application of Polymers [18]
Pharmaceutical uses of Natural Polymer
Using Polymers in Drug Delivery

The biocompatibility of natural-based polymers, biodegradable scaffolds for tissue regeneration, naturally derived hydrogels, biomimetic coatings, and sustained release systems.

Novel Colon Targeted Drug Delivery System Using Natural Polymers

Diltiazem HCl and Indomethacin were used as model drugs, while pectin was used as the carrier in the development of a novel colon targeted tablet formulation. Insulin was applied to the tablets first, then shellac, and their average weight, hardness, and coat thickness were assessed. The prepared tablets were subjected to two hours of in vitro release studies in a pH 1.2 HCl buffer, three hours in a pH 7.4 phosphate buffer, and six hours in a simulated colon fluid.

Use of cellulose

The primary goal of polymeric delivery systems is to accomplish sustained or regulated medication delivery. Time-controlled delivery systems can be produced using polysaccharides fabricated into hydrophilic matrices, which are still popular biomaterials for controlled-release dosage forms. Since cellulose is the most abundant naturally occurring biopolymer, hydroxy-propyl-methyl cellulose, hydroxypropyl cellulose, microcrystalline cellulose, and hydroxyethyl cellulose can all be utilized.

In addition, hydroxypropyl methyl cellulose, sodium carboxymethyl cellulose, and microcrystalline celluloseto coat tablets, cellulose, hydroxyethyl cellulose, and hydroxypropyl cellulose are utilized.

Use of Chitosan

- **Ophthalmic delivery**

Numerous investigations shown the potential of chitosan-based systems to enhance the biodistribution and retention of medications administered topically to the eye.

- **Nasal delivery**

Bio-adhesive drug delivery methods have the nasal mucosa as a perfect delivery site. It has been shown that chitosan drug delivery systems, including microspheres, liposomes, and gels, have high bio-adhesive properties and readily swell when in contact with the nasal mucosa.

- **Buccal delivery**

Chitosan is a great polymer to use for buccal administration since it can improve absorption and possesses muco-/bio-adhesive qualities. Three hours after intraoral (sublingual location of rabbits) medication administration, directly compressible bio-adhesive tablets of ketoprofen containing chitosan and sodium alginate in a weight ratio of 1:4 demonstrated sustained release.

- **Gastrointestinal drug delivery**

The density of floating systems is less than that of gastric fluid. This will increase the gastric residence duration and, in turn, the bioavailability of medications absorbed in the upper gastrointestinal system.

- **Intestinal drug delivery**

An effective substitute for injectable therapy appears to be sustained intestinal delivery of medications, such as insulin (for diabetes mellitus) and 5-fluorouracil (for colon cancers).

- **Colon delivery**

For oral medicinal formulations, chitosan was employed to offer a prolonged release of the medication. It was recently discovered that the bacteria present in the colon breaks down chitosan.

- **Vaginal delivery**

Clotrimazole, an imidazole derivative often used to treat mycotic infections of the genitourinary tract, is embedded in chitosan that has been modified by adding thioglycolic acid to the polymer's major amino groups.

- **Transdermal delivery**

Chitosan has a strong ability to create films. The thickness of the membrane and the film's cross-linking has an impact on the drug release from the devices. In situ preparation of chitosan-alginate poly electrolyte complex (PEC) in the form of beads and microspheres has been done in anticipation of future uses in wound dressings, controlled release systems, and packaging [19].

Pharmaceutical uses of Natural Polymer
Use of Guar Gum

- **Guar Gum for Pharmaceutical Industries**

The pharmaceutical industry uses guar gum powder for a variety of purposes, including pour control, process aid, water retention/phase control, binding, clouding/bodying, gelling/viscosifying/thickening, suspension, stabilization, emulsification, preservation, and the subsequent applications.

- **Guar Gum for Cosmetic Industries**

1. Used in skin care products, lotions, and creams as a protective colloid and thickening.
2. Also utilized in shaving cream and toothpaste to facilitate simple extrusion from the container tube.

- **Industrial Grade Guar Gum Powder**

Guar gum powder is a very adaptable product with a wide range of uses in the industrial sector, including thickening, sizing, wet-end strength addition, gelling agent, water barrier, flocculation aid, waste water treatment, emulsifier, and binder.

- **Guar Gum for Paper Industry**

1. When compared to replacements, guar gum offers superior qualities.
2. It gives denser surface to the paper used for printing.

- **Guar Gum for Textile Industry**

1. When used for textile sizing, finishing, and printing, guar gum has exceptional film-forming and thickening qualities.
2. It improves manufacturing efficiency and decreases dusting during sizing and warp breakage.

- **Guar Gum in Oil Field Applications**

1. Industrial-grade guar gum powder is used as a stabilizer, thickener, and suspending agent in mud drilling, oil well stimulation, and other industrial applications.
2. It is a naturally occurring, quickly hydrating, diesel-slurriable guar gum.
3. Within the oil field sector, guar gum finds application as a deformer, synthetic polymer, and surfactant, perfectly fitting the rheological demands of drilling fluids that are either water- or brine-based.

Fibers

Many of which come from the plastics and elastomer categories represent a significant application of polymeric materials. Humans have utilized natural fibers like cotton, wool, and silk for many generations. The patenting of artificial silk in 1885 marked the beginning of the modern textile business [21].

Textile Application

Furthermore, because to its exceptional elongation and recovery capabilities, rubber produced as a fiber, sometimes known as elastic, has substantial value for usage in the textile sector. For these uses, synthetic rubber fiber is produced as rectangular fibers that are cut into strips from extruded film or as an extruded round fiber.

Body Development

As the saying goes, "You are what you eat." We are made of protein, which is a natural polymer that we consume in large quantities.

Use of Rubber

Rubber is used extensively in a variety of items, from industrial to domestic, either as intermediate or final products in the production process. The two biggest uses of rubber are tires and tubes. The general rubber goods (GRG) industry, which encompasses all commodities other than tires and tubes, accounts for the remaining 44% [22].

Painting and Art

For artists, gum arabic powder is prepared by dissolving one part gum arabic in four parts distilled water to create a liquid that may be mixed with pigments.A variety of gum-containing gouaches Because it dissolves quickly in water, Arabic Acacia gum, often known as gum arabic, is used as a binder for watercolor painting. Watercolor paint is made from pigment suspended in acacia gum in different proportions.

Papermaking

The world's largest non-food use of starches is in the production of paper, which uses millions of metric tons of starches per year. For example, the starch level of a normal sheet of copy paper can reach 8%. Papermaking uses both unmodified and chemically modified starches.

Corrugated Board Adhesives

The next-largest worldwide application of non-food starches is in corrugated board adhesives. The primary ingredients of starch glues are unprocessed natural starches with a few additives like caustic soda and borax. To prevent sedimentation and transfer the slurry of raw starches, a portion of the starch is gelatinized.

Clothing Starch

Clothes or cleaning Starch is a liquid used in laundry that is made by combining vegetable starch with water (previous formulations also required boiling). During the 16th and 17th centuries, starch was frequently employed in Europe to stiffen the wide collars and ruffs of fine linen that encircled the necks of the wealthy [23].

CONCLUSION

Humanity will select polymeric materials as the preferred material, just as nature has done with biological polymers. From the Stone Age to the Age of Polymers, humans have advanced through the Bronze, Iron, and Steel Ages. an era where the preferred material is and will continue to be synthetic polymers. People with specialized training to conduct research and development in polymer science and engineering are greatly needed nationwide due to the numerous present and potential uses of polymeric materials. One might anticipate both financial gain and personal fulfilment from a profession in this area.

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