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A Review on Properties, Classification and Applications of Polymer

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Abstract – Polymer engineering was born in the world's great research labs needing to make and understand new types of plastics, rubber, adhesives, fabrics and coatings. Due to their synergistic and hybrid properties derived from several components, polymer nano particle composite materials have attracted the interest of a number of researchers. Such materials have different mechanical, electrical, optical and thermal properties, whether in solution or in bulk. These changes were caused by the nano particle's physical presence and the polymer's contact with the particle and the dispersion state. One advantage of nano particles, as it tends to have polymer additives, is that charging requirements are quite small compared to traditional additives. Particles of micro size used as reinforcing agents scatter light, thus increasing light propagation and optical clarity. Efficient dispersion of nano particles combined with good interfacial adhesion of polymer particles prevents scattering and enables the exciting possibility of developing strong yet transparent films, coatings and membranes. Based on the scale at which the property is described as well as on its physical basis, polymer properties are commonly classified into several groups.

Keywords: Polymer, Molecules, Properties, Classification and Applications.

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I. INTRODUCTION

The term polymer originates from Greece. That means a lot of units (parts). Polymer is characterized by the combination of a large number of simple molecules, called monomers, as a chemical substance of a high molecular weight. The method of mixing and converting the monomers into polymers. It's called polymerization.

N[Monomer] Polymer

Polymers make up a very important material category without which life seems to be very difficult. For daily use, they are all around us; for rubber, glass, resins, and tapes of adhesives and adhesives. The term polymer is derived from Greek terms, poly= many, and mers= high molecular mass sections or units of each molecule consisting of a very large number of single structural units that are frequently joined together. In other words, polymers are massive high molecular weight molecules, called macromolecules, built up by connecting a large number of small molecules, called monomers. The reaction that combines the monomers to form polymer is called polymerization. Polymerization is a chemical reaction in which two or more substances combine to form a molecule of high molecular weight together with or without the creation of anything like water, heat or other solvents. The product is called polymer and is called monomer as the starting material.

Because of their large size, polymers are also called macromolecules, but conversation is not always accurate. A macromolecule mayor may not contain monomer units, e.g. chlorophyll is a macromolecule but not a polymer as there are no monomer units present so we can assume that all polymers are macromolecules while all macromolecules may not be polymers in nature. Polymers form a very important class of materials without which the life seems very difficult. For daily use, they are all around us; for rubber, glass, resins, and tapes of adhesives and adhesives. The term polymer is derived from Greek terms, poly= many, and mers= high molecular mass parts or units per molecule consisting of a very large number of single structural units that are regularly joined together. In other words, polymers are giant high molecular weight molecules, called macromolecules, which are formed by connecting a large number of small molecules, called monomers. The reaction that combines the monomers to form polymer is called polymerization. Polymerization is a chemical reaction in which two or more substances combine to form a molecule of high molecular weight together with or without the creation of anything like water, heat or other solvents. The product is called polymer and is called monomer as the starting material. [1]

II. HISTORICAL DEVELOPMENT OF POLYMERS

Since life began, polymers have existed in a natural form, and those like DNA, RNA, proteins and polysaccharides play vital roles in plant and animal life. Man has been using natural polymers as materials from the earliest times to provide clothes, furniture, shelter, tools, weapons, writing materials and other requirements. Nevertheless, the root of today's polymer industry is commonly accepted as the nineteenth century when major discoveries about the alteration of some natural polymers were made. Thomas Hancock provided an idea in the eighteenth century of manipulating natural rubber by combining it with ceatrain additives. Earlier, by vulcanization with sulfur, Charles Goodyear improved the properties of natural rubber. The Bakelite was the first synthetic polymer created in 1909 and was soon followed by the 1911 established synthetic fiber, rayon. The systematic polymer science research also started on a back with Herman Staudinger's pioneering work. Staudinger has identified polymer in a new century. He first published this concept in 1919 that composed of long covalently bonded molecules, high molecular mass compounds. [2]

III. PROPERTIES OF POLYMERS

Based on the scale at which the property is defined as well as its physical basis, the polymer properties are generally divided into several groups. A polymer's most basic property is the identity of its constituent monomers. A second set of properties, known as microstructure, basically explains how these monomers are organized within the polymer at a single chain level. These fundamental structural properties play a major role in assessing the polymer's bulk physical properties. A polymer's physical properties are highly dependent on the size. In terms of molecular weight, the volume of polymer can also be expressed. Polymer chains ' chemical properties play a major role in deciding the properties of polymer. Since polymer chains are so long, they are multiplied far beyond traditional molecules ' attractions. Various side groups on the polymer can provide ionic bonding or hydrogen bonding between their own chains to the polymer.

Higher tensile strength and higher crystalline melting points typically result from these stronger forces. Due to their synergistic and hybrid properties derived from multiple components, polymer-nanoparticle composite materials have attracted the interest of a number of researchers in recent years. Such materials have different mechanical, electrical, optical and thermal properties, whether in solution or in bulk. These changes were caused by the nanoparticle's physical presence and the polymer's interaction with the particle and the dispersion condition. As polymer additives seem to have, one advantage of nanoparticles is that charging requirements are quite small compared to traditional additives. Microsized particles used as reinforcing agents scatter light, increasing the transmission of light and optical clarity. Efficient dispersion of nanoparticles combined with good polymer-particle interfacial adhesion prevents scattering and provides an exciting opportunity to develop solid yet transparent films, coatings and membranes. [3]

- **Physical properties**

Density: The number of optical glass forms in the hundreds. Catalog types of glass cover a wide range of mechanical, physical, thermal and chemical properties. The density ranges from about 2.3 g / cm3 to about 6.3 g / cm3. The heaviest optically viable polymer has a density of only about 1.4 g / cm3, whereas the lightest of these materials can float with a density of 0.83 g / cm3 readily in air. All other things being equal, the total number of elements in an optical system can often be decreased through the use of non-spherical surfaces. All things considered, then, can be made much less massive in polymer optical systems than their glass counterparts, especially if aspheric technology is applied to optical polymer trains.

Hardness: While cosmetic blemishes rarely affect the final image quality, it is usually expected that optical surfaces will be relatively free of scratches, pits and the like. With the passage of time, ordinary use, particularly cleaning procedures, would likely result in some scratching. Many typical optical glasses have enough durability that if some modest amount of care is exercised, they are relatively immune to injury. On the other hand, the polymeric optical materials are often fragile that they are permanently indented by a determined thumbnail. Polymer optics hardness is hard to quantify, as this parameter is not only material-dependent, but also process-dependent. It is enough to say that in a polymer layer, particularly in a thermoplastic, handling procedures that would result in little or no damage to a glass component may produce considerable evidence of abrasion. Indeed, most thermoplastic polymers' compressibility is such that support for hard surface coatings is sufficiently low to provide protection from only superficial abrasion. Nevertheless, if the problematic surfaces are internal and thus unavailable, these defects are of no particular consequence.

Rigidity: The elastic module, or Young's unit, is a property closely related to hardness. This quantity and the yield elongation factor are determinants of impact resistance, a metric of quality in which the polymers outshine the lenses. Again, these properties are dependent on the polymer alloy specified, any additives that may be present and the polymer's processing history and cannot be quoted reliably If an optical component is exposed to some torsion or compressive stress, certain properties that create good impact resistance become liabilities. Since optical surface profiles are often required to maintain the accuracy of subwavelengths, inappropriate choice of the thickness / diameter ratio or excessive compression by retaining rings may result in unacceptable optical figure deformations. Polymer chemistry is likely a complex topic best avoided in a polymer optics article. [4]

- **Optical properties**

Variations: It is just a fortuitous coincidence that some of the polymers show useful optical behaviour, as most of these products were originally developed for other end uses. Products used for eyeglass applications and optical information storage products are the likely exceptions. Citation of optical properties for any polymeric material must be performed with some care and qualification, as there may be slightly different refractive index properties for different melt flow levels. Additives for controlling lubricity, colour, etc. can also create subtle changes in the properties of spectral transmission.

Spectral Transmission: Generally, optical carbon-based polymers are materials of visible wavelength that absorb fairly strongly in the ultraviolet and throughout the infrarot. Nevertheless, this is not readily apparent from the absorption spectrum described in many sources. These data are usually produced by spectroscopists for chemical structure identification purposes and represent very thin samples. The impression that the polymers transmit well over a wide spectral range can be easily established from this data. Parenthetically, although described in the laboratory, most of these polymers are not commercially available. The transmission data from samples with enough thickness to be usable for imaging purposes is what is required for optical design purposes. [5]

- **Electrical properties**

Through mixing conductive solid fillers such as metal particles, carbon black, graphite and carbon nanotubes into the typical polymer, the conventional method for preparing electrically conductive polymer composites (CPCs) is. Conductive polymers, on the other hand, have also been predicted to produce various potential applications over the past decade. Conductive polymers are a suitable replacement for inorganic materials because they exhibit exceptional electrical properties and wide color variability due to their conjugated double-bond chain structure, which stems from both their conductive and neutral (non-conductive) forms. However, because of their strong intermolecular interactions, they are inherently insoluble, infusible and unprocessable. High-quality mixing with traditional polymers by melt mixing or solution casting is therefore still being developed. Polyaniline (PANI) and polypyrrole (PPy) have attracted a great deal of worldwide interest among the conjugated conducting polymers due to their high physical, thermal and chemical stability and high conductivity.

The attainment of metallic properties in these composites depends on many factors and it is only possible to control the electrical and physical characteristics which determine the variety of ranges of their application. Electric charge and heat flow transfer conditions determine the level of electrical and thermal conductivity in the heterogeneous polymer filler process, in which the conductive layer is created by dispersed metal or carbon filler. Several studies have studied the effect of the form of polymer matrix and filler on the composite's electrical characteristics. [6]

IV. CLASSIFICATION OF POLYMERS

Polymer is a generic name given to a large number of high molecular weight materials. Due to the very large number and type of atoms found in their molecule, these materials exist in countless shape and numbers. Polymer may have different chemical structures, physical properties, mechanical behaviour, thermal characteristics, etc., and polymer may be categorized in different ways on the basis of these properties, as summarized in Table 1, while essential and specific polymer classification is defined in the next paragraph. [7]

Table 1: Classification of Polymers

Basis of Classification		Polymer Type
Origin	-	Natural, Semi synthetic, Synthetic
Thermal Response	-	Thermoplastic, Thermosetting
Mode of formation	-	Addition, Condensation
Line structure	-	Linear, Branched, Cross-linked
Application and Physical Properties	-	Rubber, Plastic, Fibers
Tacticity	-	Isotactic, Syndiotactic, Atactic
Crystallinity	-	Non crystalline(amorphous), Semi-crystalline, Crystalline
Polarity	-	Polar, Non polar
Chain	-	Hetro, Homo-chain

Polymers are classified into different categories.

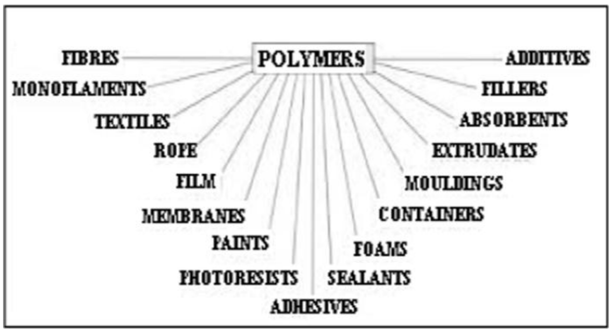

Fig. 1. Shows the classification of polymers.

- **Classification on the basis of source**

(i) Natural polymers: nature contains natural polymers. Ex: Starch, fats, cellulose, nucleic acids, organic rubber.

(ii) Synthetic Polymers: Man-made polymers are synthetic polymers. Ex: Bakelite, Polyvinyl alcohol, Terylene, Polyethylene.

- **Classification on the basis of structure**

(i) Linear Polymers: Monomeric units in the form of long straight chains are joined in Linear Polymers. Ex: polythene of high density (HDPE), nylon, polyester.

(ii) Polymers branched chain: branched polymers are mainly linear in nature, but they also have branches along the main chain. Ex: Polythene of low density (LDPE), glycogen, amylopectin.

(iii) Three-dimensional Polymers network: Three-dimensional polymers network comprise monomer molecules bound by covalent bonds only. These are giant molecules where heavy cross-links prevent the movement of individual monomeric units. Ex: bakelite, formaldehyde of urea, formaldehyde of melamine.

- **Classification on the basis of their methods of synthesis**

The polymers are divided into two groups based on the synthesis modes.

(i) Addition Polymers: Addition Polymers are obtained by an alternative process of polymerization involving the repeated addition of monomers to long chains. Ex: Polyethylene, Polypropylene, Polystyrene, etc.

(ii) Condensation Polymers: Condensation Polymers are obtained through a sequence of condensation reactions involving typically two monomers. Ex: Bakelite, Nylon-6, Polyester, etc. [8]

- **Classification on the basis of their growth polymer chain**

(i) Chain growth polymers: chain growth polymers are formed by the successive addition of monomer units to the reactive intermediate growing chain. Ex: polyethene, polypropylene, polystyrene, etc.

(ii) Step-growth polymers: Step-growth polymers are formed by a series of independent reactions involving the formation of bonds between two separate monomers with loss of small molecules such as H2O, HCl and NH3etc.

- **Classification based on molecular forces**

These were divided into four categories based on the strength of intermolecular forces present in polymers.

Thermoplastics: The relatively weak intermolecular forces hold the molecules in a thermoplastic together, so that the material softens when exposed to heat and then returns when cooled to its original condition. Thermoplastics are the bulk of linear and slightly branched polymers. Chain polymerization produces all the major thermoplastics. Food packaging, insulation, vehicle bumpers and credit cards are some examples.

Thermosets: Heating cannot reshape the thermosets. Thermosets are usually three-dimensional networked polymers in which polymer chains have a high degree of cross-linking. The cross linking limits the chains ' movement and contributes to a solid material that makes thermosets strong and robust. They are predominantly used in the automotive and construction industries. They are also used for making toys, varnishes, hulls of boats and glues.

Elastomers: Elastomers are rubbery polymers that can be extended easily to their unstretched length many times and that quickly return to their original dimensions when the pressure is released. Elastomers are cross-linked but have a low density of cross-link. An elastomer must have a glass transition temperature above Tg and a low crystallinity. Elastomers are composed from rubber bands and other elastics.

Fibers: Many of the polymers used in synthetic fibers are the same as in plastics. A fiber is often referred to as having at least 100 aspect ratio. The fiber thickness is represented in denier terms. Denier is a measurement unit of fiber linear mass density. It is known as the weight per 9000 m in grams. Kevlar, carbon, PE, PTFE and nylon are synthetic fibers, while silk, cotton, wool and wood pulp are natural fibers. [9]

V. APPLICATIONS OF POLYMERS

Agriculture and Agri-business: polymeric materials are used to boost aeration, provide much and encourage plant growth and health in and on soil.

Medicine: Many biomaterials are made of polymers such as Dacron, Teflon and Polyurethane, especially heart valve replacements and blood vessels.

Consumer Science: All shapes and sizes of plastic containers are light weight and economically less costly than conventional bottles. Certain polymer uses include clothes, floor coverings, garbage disposal bags and packaging.

Industry: Automotive components, fighter aircraft windshields, tubing, tanks, packaging materials, insulation, wood substitutes, adhesives, composite matrix and elastomers are all plastic products used in the automotive industry.

Sports: Playground equipment, balls, golf clubs, swimming pools and helmets are often made from polymers.

Clear or reflective materials: polymers are used as screens, optical fibres, mirrors, reflectors and clear film sets. [10]

VI. CHARACTERISTICS OF POLYMERS

Most of the polymers created are thermoplastic, which means that it can be heated and recycled over and over again once the polymer is formed. This property allows fast sorting and makes recycling easier. It is not possible to rewind the other band, the thermosets. Upon the formation of these polymers, reheating can ultimately cause the product to degrade but not melt. The characteristics of each polymer are very different, but most polymers have the following general attributes.

1. **Polymers can be very resistant to chemicals.** Remember all the plastic-packed cleaning fluids in your house. Reading the warning labels about what happens when the chemicals come into contact with skin or eyes or are swallowed can demonstrate the need for chemical resistance in the plastic packaging. While some plastics are easily dissolved by solvents, others provide durable, non-breakable packaging for aggressive solvents.

2. **Polymers can be both thermal and electrical insulators.** That idea will be strengthened by a walk through your house when you find all appliances, cables, electrical outlets and wiring made and coated with polymeric materials. Thermal resistance is visible in the kitchen with silicone pot and pan handles, coffee pot handles, refrigerator and freezer foam base, separated cups, coolers, and microwave cooking utensils. The thermal clothing most skiers wear is made of polypropylene or acrylic and polyester is the fiberfill in winter jackets.

3. **Generally, polymers are very light in weight with significant degrees of strength.** Note the range of applications, ranging from toys to space station frame construction, or from delicate pantyhose nylon fiber to Kevlar used in bulletproof jackets. Several polymers are floating in water while others are sinking. But all plastics are lightweight materials relative to the strength of rock, cement, steel, copper, and aluminum.

4. **Polymers can be processed in various ways.** Extrusion allows thin fibers or large tubes or films or bottles of water. Molding by injection can create very complex parts or large sections of the car body. For adhesives and paints, plastics can be formed into drums and blended with solvents. Elastomers are elastic and some plastics are very flexible. Many plastics, like soft drink bottles, are stretched in storage to maintain their form. Compared to polystyrene (StyrofoamTM), polyurethane and polyethylene, other polymers can be foamed.

5. **Polymers are materials with a seemingly limitless range of characteristics and colors.** Polymers have many intrinsic properties that can be further improved to expand their uses and applications by a wide range of additives. Polymers can be made to imitate fabrics of cotton, silk and wool; marble and porcelain; and aluminum and zinc. Polymers can also make possible things, such as transparent sheets and elastic films, that do not easily come from the natural world. [11]

VII. LITERATURE SURVEY

Junjie Chen et.al. [2018] This paper provides an overview of recent progress in work on carbon nanotube–polymer nanocomposites ' interfacial characteristics. There is a description of the state of knowledge on the chemical functionalization of carbon nanotubes as well as the relationship between the carbon nanotube and the polymer matrix. This paper focuses primarily on defining the fundamental relationship between properties of nanocomposite and interfacial characteristics. Development is addressed, ongoing issues and future research directions. Finally, in the hopes of encouraging the growth of this new field, the current challenges and opportunities to effectively translate the remarkable properties of carbon nanotubes into polymer matrices are summarized. Potential oncoming focus areas are outlined and a variety of recommendations are also given regarding future research needs. [12]

Abhishek Kumar Mishra [2018] Developments in the field of electrically conductive polymers have evolved very rapidly since the discovery and when intrinsically isolating organic conjugated polymers are doped with oxidizing and reducing agents, there is a very sharp increase in conductivity. An overview of technological developments involving polymers shows clearly that the field is expanding at unprecedented rates. Next, the paper presents the conducting polymers (CPs), conducting processes, doping principles, and briefly discusses key applications. Different types of CPs are discussed, their unique characteristics and synthesis. This analysis will help to effectively implement polymers in different fields, which depends directly on the degree to which their behavior and properties are understood. [13]

M. Diantoro et.al. [2018] Polyaniline (PANI) was intensively studied as one of the conductive polymers. The PANI has used electronic devices and gas detectors in training. Nevertheless, at high temperature and in an acidic environment, the PANI centered on the electronic device has weaknesses such as fragile and unstable conductivity. Through inducing other better thermal properties products, this problem can be overcome. TiO2 is one type of material that meets the criteria. Nonetheless, due to low conductivity relative to PANI conductivity, TiO2 has limitations. Theoretically, increasing the particle size of TiO2 to nanometric scale can solve this problem. In this test, we prepared a composite film with different amounts of nano TiO2 to obtain microstructure-related information, electrical conductivity, and thermal stability. However, through growing the TiO2 nanoparticles, the conductivity of PANI-TiO2 composite films decreased. On the other hand, by increasing the TiO2 nanoparticles, the thermal stability of the PANI composite films improved. [14]

Dong Uk Lee et. al. [2018] There are many applications in electronics, optical devices, sensors, and so on to conduct polymer; however, there is still a massive scope for improvement in this field. The ILs of the imidazolium and ammonium group have been used with the ability to interact with the newly synthesized conductive polymer. The results of interaction studies showed that IL-polymer mixtures and IL-polymer ammonium family mixtures in the imidazolium family have nearly identical conductivity at low IL concentration. This study provides insight into a polymer and IL's combined effect and can generate several conceptual and experimental opportunities. [15]

Thanh-Hai Le et.al. [2017] Because they have electrical and electrochemical properties similar to those of both traditional semiconductors and metals, conducting polymers (CPs) have received much attention in both fundamental and practical studies. CPs have excellent features such as mild conditions of synthesis and processing, chemical and structural variety, flexible conductivity, and structural stability. Advances in nanotechnology have allowed the manufacture of flexible CP nanomaterials with enhanced performance for different applications including electronics, optoelectronics, sensors and energy devices. The aim of this review is to examine the mechanisms of conductivity and the electrical and electrochemical properties of CPs and to address the factors that affect these properties significantly. Often discussed are the size and morphology of the materials as primary parameters influencing their main properties. Finally, through an in-depth discussion of the most outstanding studies published since 2003, the new developments in research on electrochemical capacitors and sensors are presented. [16]

Elsayed M. Elnaggar et.al. [2017] This study reported polyaniline (PANI) doping by in situ polymerization using graphene (G) and multi-walled carbon nanotubes (MWCNTs). FTIR has studied theemolecular structure of PANI and its composites, which indicates that the composite peak strength is higher than pure PANI due to the transfer of charges between PANI and graphic allotropes. It is possible to deduce from X-ray diffraction the structural details and crystallinity of PANI and its composites. The morphological characterization was observed by transmission electron microscope, which elucidated the physical adsorption and polymerization of aniline molecules on the graphene and MWCNT surfaces as a result of p–p* electron interaction. PANI is an external layer of multi-diameter composites depending on the degree of PANI deposition, where the core is GandMWCNT. The conductivity calculation explained the 0.1 wt percent G conductivity value in the PANI matrix is 17 times higher than without PANI. [17]

Dr. Santosh Kumar [2016] Polymer is a large molecule that consists of repeated linking of small molecules called monomers. Society's technological development depends largely on the resources. The search for new material led to conductive polymers being prepared. For more than 40 years, research in the field of conducting polymers has drawn significant interest. Doped conductive polymers–particularly polypyrrole and polyaniline, due to their better environmental stability, good electrical conductivity and economic importance, have shown considerable interest. [18]

CONCLUSION

Polymers initially tended to be viewed as a chemist specialty, but they are now strongly associated as plastics, fibers and elastomers with engineering as well, through design, fabrication and testing of products. The last decades have shown an increasing important requirement in the polymer industry; it is the rapid development and introduction of new and improved products. In the growth of this family of engineering materials during the last century, plastics are the leader, followed by fibers and elastomers. The new devices made of conducting polymers are going to be used in every phase of life on earth, as well as in space Compared to other existing technologies, conducting polymers are lightweight, take up less space, and are less expensive to manufacture.

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