

## Physical Properties and Applications of Conducting Polymers: An Overview

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### ABSTRACT

Polymer science was born in the great industrial laboratories of the world need to make and understand new kinds of plastics, rubber, adhesives, fibers and coatings. Polymer - nanoparticle composite materials have attracted the interest of a number of researchers, due to their synergistic and hybrid properties derived from several components. Whether in solution or in bulk, these materials offer unique mechanical, electrical, optical and thermal properties. Such enhancements are induced by the physical presence of the nanoparticle and by the interaction of the polymer with the particle and the state of dispersion. One advantage of nanoparticles, as polymer additives appear to have is that compared to traditional additives, loading requirements are quite low. Micro sized particles used as reinforcing agents scatter light, thus reducing light transmittance and optical clarity. Efficient nanoparticle dispersion combined with good polymer-particle interfacial adhesion eliminates scattering and allows the exciting possibility of developing strong yet transparent films, coatings and membranes. Polymer properties are broadly divided into several classes based on the scale at which the property is defined as well as upon its physical basis. The physical properties of a polymer are strongly dependent on the size. Polymers are different from other construction materials like ceramics and metals, because of their macromolecular nature. The covalently bonded, long chain structure makes them macromolecules and determines, via the weight averaged molecular weight, their processability, like spin, blow, deep draw, generally melt-formability. Nanostructured materials can be utilized in fabricating novel active devices with improved functionalities. The discipline of nanoscience and nanotechnology has recently become one of the most important areas of knowledge encompassing various scientific disciplines including physics, chemistry, biology and engineering. Semiconductor nanoparticles have been attracting widespread scientific and technological interest due to their unique size-tunable optical and electronic properties as well as their potential applications in solar cells, light-emitting diodes and bio-labels. This paper deals with the detailed explanation of polymer thin films, their properties and their applications.

**Keywords:** Polymers, Properties, Classification, Nanopolymers, Green polymers, Applications.

### 1. INTRODUCTION

Polymers are a large class of materials consisting of many small molecules called monomers, that can be linked together to form long chains, thus they are known as macromolecules. Polymers consist mainly of identical or similar units joined together. A small molecule which combines each other to form a giant molecule and the process itself is known as polymerization. A typical polymer may include tens of thousands of monomers. Because of their large size, polymers are classified as macromolecules. Humans have taken advantage of the versatility of

polymers for centuries in the form of oils, tars, resins and gums. However, it was not until the industrial revolution that the modern polymer industry began to develop. In the late 1830s, Charles Goodyear succeeded in producing a useful form of natural rubber through a process known as vulcanization. Some 40 years later, Celluloid was successfully commercialized. Despite these advances, progress in polymer science was slow until the 1930s, when materials such as vinyl, neoprene, polystyrene and nylon were developed. The introduction of these revolutionary materials began an explosion in

polymer research that is still going on today. Unmatched in the diversity of their properties, polymers such as cotton, wool, rubber, Teflon and all plastics are used in nearly every industry. Natural and synthetic polymers can be produced with a wide range of stiffness, strength, heat resistance, density and even price. With continued research into the science and applications of polymers, they are playing an ever increasing role in society. Polymer science was born in the great industrial laboratories of the world need to make and understand new kinds of plastics, rubber, adhesives, fibers and coatings<sup>1</sup>. Only much later did polymer science come to academic life. Perhaps because of its origins polymer science tends to be more interdisciplinary than most sciences combining chemistry, chemical engineering and material science<sup>2</sup>. The trade literature sometimes refers to polymers as resins, an old term that goes back before the chemical structure of the long chains was understood. The first polymers used are natural products, especially cotton, starch, proteins and wool. In the twentieth century synthetic polymers are made<sup>3,4</sup>. Fig.1 shows the representation of polymer chain.

Ex:  $n (\text{H}_2\text{C} = \text{CH}_2) \rightarrow -\text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 -$   
Ethene (Monomer)      Polythene (Polymer)

In recent years, polymer–nanoparticle composite materials have attracted the interest of a number of researchers, due to their synergistic and hybrid properties derived from several components. Whether in solution or in bulk, these materials offer unique mechanical, electrical, optical and thermal properties. Such enhancements are induced by the physical presence of the nanoparticle and by the interaction of the polymer with the particle and the state of dispersion. One advantage of nanoparticles, as polymer additives appear to have is that compared to traditional additives, loading requirements are quite low. Micro sized particles used as reinforcing agents scatter light, thus reducing light transmittance and optical clarity. Efficient nanoparticle dispersion combined with good polymer-particle interfacial adhesion eliminates scattering and allows the exciting possibility of developing strong yet transparent films, coatings and membranes<sup>5</sup>. Polymer composites are multi-phase materials produced by combining polymer resins such as polyester, vinyl ester and epoxy, with fillers and reinforcing fibres to produce a bulk material with properties better than those of the individual base materials. Fillers are often used to provide bulk to the material, reduce cost, lower bulk density or to produce aesthetic features. Fibres are used to reinforce the polymer and improve

mechanical properties such as stiffness and strength. High strength fibres of glass, aramid and carbon are used as the primary means of carrying load, while the polymer resin protects the fibres and binds them into a cohesive structural unit. These are commonly called fibre composite materials<sup>6</sup>.

Polymers such as proteins, polysaccharides and nucleic acids are present as basic components in living organic systems. Synthetic polymers, which are designed to mimic these biopolymers, have been developed into variety of functional forms to meet the industrial and scientific applications. The synthetic polymers can be classified into different categories based on their chemical properties. Out of these, some special types of polymers have emerged as a very useful class of polymers and have their own special chemical properties and applications in various areas. These polymers are coined with different names, based on their physical or chemical properties like, stimuli-responsive polymers or smart polymers (SP) or intelligent polymers or environmental-sensitive polymers<sup>7</sup>. We shall use further on the name smart polymers for such polymer systems in this review. The characteristic feature that actually makes them smart is their ability to respond to very slight changes in the surrounding environment. The uniqueness of these materials lies not only in the fast macroscopic changes occurring in their structure but also these transitions being reversible. The responses are manifested as changes in one or more of the following shape, surface characteristics, solubility, formation of an intricate molecular assembly, a sol-to-gel transition and others. The environmental trigger behind these transitions can be either change in temperature or pH shift, increase in ionic strength, presence of certain metabolic chemicals, addition of an oppositely charged polymer and polycation - polyanion complex formation<sup>8</sup>. More recently, changes in electric and magnetic field, light or radiation forces have also been reported as stimuli for these polymers. The physical stimuli, such as temperature, electric or magnetic fields and mechanical stress, will affect the level of various energy sources and alter molecular interactions at critical onset points. They undergo fast, reversible changes in microstructure from a hydrophilic to a hydrophobic state. These changes are apparent at the macroscopic level as precipitate formation from a solution or order-of-magnitude changes in the size and water content of stimuli-responsive hydro gels. An appropriate proportion of hydrophobicity and hydrophilicity in the molecular structure of the polymer is believed to be required for the phase transition to occur<sup>9-11</sup>.

Laser ablation of polymers was first reported in 1982<sup>12, 13</sup> and fast became an important research area<sup>14</sup>. Laser ablation was originally envisioned as a possible alternative or complementary technique to conventional photolithography, due to the lower number of processing steps; but up to now, this potential could not be exploited with commercially available polymers, such as polymethylmethacrylate (PMMA), polyimide (PI) and polycarbonate (PC), etc.<sup>15</sup>. These polymers have severe drawbacks, such as low sensitivity, carbonization upon irradiation, or ablation debris contaminating the surface and optics. Therefore, novel photopolymers were developed to overcome these limitations<sup>16</sup>. Photochemical considerations have been applied to the design of these polymers. They were designed for an irradiation wavelength of 308 nm, because not all photolithographic processes require a resolution in the sub-micrometer range and it is possible to decouple the absorption of the photochemically active groups from the absorption of other parts of the polymer structure. This concept can be used to test whether the incorporation of photochemically active groups into the polymer chain improves the ablation characteristics. The XeCl excimer laser (308 nm) is a technically interesting tool, due to the long lifetime of gas fills and laser optics. The most promising approach for the design of these 'laser ablation polymers' is the incorporation of the photochemically active chromophore into the main polymer chain<sup>17</sup>.

## 2. PROPERTIES OF POLYMERS

Polymer properties are broadly divided into several classes based on the scale at which the property is defined as well as upon its physical basis<sup>18</sup>. 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 a single chain. These basic structural properties play a major role in determining bulk physical properties of the polymer. The physical properties<sup>19</sup> of a polymer are strongly dependent on the size. Polymer's size may also be expressed in terms of molecular weight. The chemical properties of polymer chains play a large part in determining polymer's properties. Because polymer chains are so long, these interchange forces are amplified far beyond the attractions between conventional molecules. Different side groups on the polymer can lend the polymer to ionic bonding or hydrogen bonding between its own chains. These stronger forces typically result in higher tensile strength and higher crystalline melting points.

In recent years, polymer-nanoparticle composite materials have attracted the interest of a number of researchers, due to their synergistic and hybrid properties derived from several components. Whether in solution or in bulk, these materials offer unique mechanical, electrical, optical and thermal properties. Such enhancements are induced by the physical presence of the nanoparticle and by the interaction of the polymer with the particle and the state of dispersion. One advantage of nanoparticles, as polymer additives appear to have is that compared to traditional additives, loading requirements are quite low. Microsized particles used as reinforcing agents scatter light, thus reducing light transmittance and optical clarity. Efficient nanoparticle dispersion combined with good polymer-particle interfacial adhesion eliminates scattering and allows the exciting possibility of developing strong yet transparent films, coatings and membranes<sup>20</sup>.

### 2.1 Physical properties

**Density:** Optical glass types number in the hundreds. The glass types available from the catalogs cover a wide range of optical, physical, thermal and chemical properties. The density of these materials varies from about 2.3 g/cm<sup>3</sup> to about 6.3 g/cm<sup>3</sup>. The heaviest optically viable polymer possesses a density of only about 1.4 g/cm<sup>3</sup>, whereas the lightest of these materials will readily float in water, having a density of 0.83 g/cm<sup>3</sup>. All other things being equal, the total element count in an optical system may often be reduced by the inclusion of non spherical surfaces. All things considered, then, polymeric optical systems may be made much less massive than their glass counterparts, especially if aspheric technology is applied to the polymer optical trains<sup>21</sup>.

**Hardness:** Although cosmetic blemishes rarely impact final image quality, optical surfaces are customarily expected to be relatively free of scratches, pits and the like. Ordinary usage, especially cleaning procedures, is likely to result in some scratching with the passage of time. Most common optical glasses possess sufficient hardness that they are relatively immune to damage, if some modest amount of care is exercised. The polymeric optical materials, on the other hand, are often so soft that a determined thumbnail will permanently indent them. The hardness of polymeric optics is difficult to quantify, since this parameter is not only material-dependent, but also dependent upon the processing. Suffice it to say that handling procedures which would result in little or no damage to a glass element may produce considerable evidence of abrasion in a polymeric surface, particularly in a thermoplastic. In

fact, the compressibility of most thermoplastic polymers is such that the support for hard surface coatings is sufficiently low that protection provides immunity against only superficial abrasion. These deficiencies are of no particular consequence, however, if the questionable surfaces are internal and thereby inaccessible.

**Rigidity:** A property closely related to hardness is the elastic modulus, or Young's modulus. This quantity and the elongation factor at yield are determinants of the impact resistance, a performance parameter in which the polymers outshine the glasses. These properties are, again, dependent upon the specified polymeric alloy, any additives which may be present and processing history of the polymer and cannot be dependably quoted. Those properties which create good impact resistance become liabilities if an optical part is subjected to some torsion or compressive stress. Since optical surface profiles must often be maintained to sub wavelength accuracy, improper choice of the thickness / diameter ratio or excessive compression by retaining rings, may produce unacceptable optical figure deformations. Polymer chemistry is a complex subject probably best avoided in a discussion of polymer optics. Carbon-based polymers have been synthesized to include an extensive variety of chemical subgroups, however. Unfortunately, relatively few of these materials are actually in regular production and only a handful of those possess useful optical properties for imaging purposes<sup>22, 23</sup>.

**Additives:** Polymers are normally available in a variety of melt flow grades, each of which possesses viscosity properties best suited to use in parts having specific form factors. A number of additives are commonly present in these materials. Such additives may or may not be appropriate in an optical application. Additives for such things as flame retardancy, lubricants, lubrication and mold release are best avoided if not included to address a specific requirement. Frequently, colorants are added for the purpose of neutralizing the naturally occurring coloration of the material. These additives create an artificial, but clear, appearance. The colorants must, of course, absorb energy to accomplish this, resulting in a net reduction in total spectral transmission.

**Radiation Resistance:** Most of the optical polymers will be seen to exhibit some amount of fluorescence if irradiated by sufficiently intense high-energy radiation. High-energy radiation of the ultraviolet and ionizing varieties will, in addition, produce varying

amounts of polymer chain cross linking, depending upon the specific polymer chemistry. Cross linking typically results in discoloration of the material and some amount of non uniform energy absorption. Inhibitors may be added to the polymeric material to retard cross linking, although, oddly enough, the polymers most susceptible to UV-induced discoloration are generally the least likely to be affected by ionizing radiation and vice versa.

## 2.2 Optical properties

**Variations:** It is only a fortuitous accident that some of the polymers exhibit useful optical behavior, since most all of these materials were originally developed for other end uses. The possible exceptions are the materials used for eyeglass applications and the materials for optical information storage. Citation of optical properties for any polymeric material must be done with some caution and qualification, as different melt flow grades may exhibit slightly different refractive index properties. Additives to regulate lubricity, color and so on can also produce subtle alterations in the spectral transmission properties.

**Spectral Transmission:** In general, the carbon-based optical polymers are visible-wavelength materials, absorbing fairly strongly in the ultraviolet and throughout the infrared. This is not readily apparent from the absorption spectra published in numerous references though. Such data are normally generated by spectroscopists for the purpose of identifying chemical structure and are representative of very thin samples. One can easily develop the impression from this information that the polymers transmit well over a wide spectral range. Parenthetically, most of these polymers, while they have been characterized in the laboratory, are not commercially available. What is needed for optical design purposes is transmission data taken from samples having sufficient thickness to be useful for imaging purposes. Some specially formulated variants of poly-methylmethacrylate have useful transmission down to 300 nm. Most optical polymers, however, begin to absorb in the blue portion of the visible spectrum and have additional absorption regions at about 900 nm, 1150 nm, 1350 nm, finally becoming totally opaque at about 2100 nm. The chemical structure which results in these absorption regions is common to almost all carbon-based polymers, thus the internal transmittance characteristics of these materials are remarkably similar, with the possible exception of the blue and near-UV regions. A scant few polymers do exhibit some spotty narrowband transmission leakage in the far-infrared portion of the spectrum, but in

thicknesses suitable only for use in filter applications<sup>24-26</sup>.

**Homogeneity:** It must be kept constantly in mind that polymeric optics are molded and not mechanically shaped. The exact optical properties of a piece cannot, therefore, be quantified prior to manufacture of the element. In fact, the precise optical properties of the bulk material in an optical element are virtually certain to be a function of both the material itself and of the process which produced the part. Some materials, notably styrene and butyrate resins are crystalline to some degree and therefore inherently birefringent. Birefringence may develop in amorphous materials, though, if the injection mold and process parameters are not optimized to prevent this occurrence. Likewise, the bulk scatter properties of a molded optical element are a function of the inherent properties of the material, but are also strongly related to the cleanliness of the processing and the heat history of the finished part.

## 2.2 Electrical properties

The conventional method for preparing electrically conductive polymer composites (CPCs) is by admixing conductive solid fillers such as metal particles, carbon black, graphite or carbon nanotubes into the common polymer<sup>27</sup>. On the other hand, conductive polymers were also expected to yield numerous potential applications over the last decade. Conductive polymers are a suitable replacement for inorganic materials since they exhibit extraordinary electrical properties and a wide variation in colour due to their conjugated double-bond chain structure, which derives from both their conducting or neutral (non-conducting) forms. However, they are inherently insoluble, infusible and non processable due to their strong intermolecular interactions. Therefore, high-quality conducting blends with conventional polymers by melt mixing or by solution casting are still at the development stage<sup>28</sup>. Among the conjugated conducting polymers, polyaniline (PANI) and polypyrrole (PPy) have attracted much interest worldwide because of their high environmental, thermal and chemical stability and their high conductivities. The electrical conductivity of these polymers is between  $10^{-5}$  S/cm and  $10^2$  S/cm while being doped, whereas common insulators exhibit conductivities below  $10^{-12}$  S/cm. With a simple protonation process in PANI and PPy<sup>29</sup>, both solubility in common organic solvents and compatibility with various matrix polymers on the nanometer scale can be improved.

These conducting blends or composites have been developed with a wide range of exciting properties for applications in film, fibres and coatings. Conducting polymers may therefore find applications in electromagnetic interference (EMI) shielding, transparent packaging of electronic components, solar batteries, nonlinear optical display devices, 'smart' fabrics and recording and so on. Recently, electroluminescence from conjugated polymers was observed at Cambridge Display Technologies (CDT) and this extraordinary feature could open up potential markets for organic light-emitting diodes (OLED)<sup>30</sup>. This light-emitting polymer (LEP) technology is expected to provide an opportunity for the fabrication of flexible, full-colour displays with high luminescence, small power consumption and low-cost technology. On the other hand, the Clemson, Furman, and Ga. Tech. laboratories have begun to conduct research into chameleon fibres that change the substrate colour upon application of an electrical field. These intelligent textiles based on conductive materials have been prepared by direct surface coating or by in-situ polymerization on textile substrates<sup>31</sup>.

The ability of polymers to act as electrical insulators is the basis for their widespread use in the electrical and electronic fields. However, material designers have sought to combine the fabrication versatility of polymers with many of the electrical properties of metals. There are instances when an increased conductivity or permittivity of the polymer is warranted, such as in applications that require antistatic materials, low-temperature heaters, electromagnetic radiation shielding and electric field grading. The method most often employed to significantly alter the electrical properties of a polymer is an extrinsic approach whereby the insulating polymer is combined with a conductive additive. The conducting additive is incorporated into polymers at levels that allow the composite to maintain its electrically insulative qualities, as well as at higher levels, which allow the composite to become electrically (semi)conductive<sup>32</sup>. Polymer composites filled with metal are of interest for many fields of engineering. This interest arises from the fact that the electrical characteristics of such composites are close to the properties of metals, whereas the mechanical properties and processing methods are typical for plastics<sup>33</sup>. The achievement of metallic properties in such composites depends on many factors and it is just the possibility of controlling the electrical and physical characteristics which determines the variety of ranges of their application. The transfer conditions of the electric charge and heat flow determine the electrical and



thermal conductivity level in the heterogeneous polymer-filler system, in which the conductive phase is formed by dispersed metallic or carbon filler. The influence of the type of polymer matrix and filler on the electrical characteristics of the composite has been studied in many works<sup>34, 35</sup>.

### 2.3 Thermal conductivity

Thermal conductivity is a measure of the ease with which temperature is transmitted through a material and is a basic material property. Materials with high thermal conductivity are called conductors and those with low conductivity are called insulators. Solid conductors such as metals typically have thermal conductivities in the range of 10 to 400 W/°C m, while insulators such as polymers, glasses and ceramics have values in the range of 0.1 to 2 W/°C m. Furthermore, thermal conductivity changes as a weak function of temperature and rarely changes by a factor of ten within a general class of materials. Determination of a materials thermal conductivity is important in evaluating its utility for specific applications. In many of these applications, a textbook value or a single measurement near the temperature of use is sufficient to make a decision. In a few cases, however, the materials composition varies widely enough that regular measurement of thermal conductivity is required<sup>36</sup>.

## 3. CLASSIFICATION OF POLYMERS

Polymers are classified into different categories. Fig. 2 shows the classification of polymers.

### 3.1 Classification on the basis of source

(i) Natural Polymers: Natural Polymers are found in nature.

Ex: Starch, Cellulose, Proteins, Nucleic acids, Natural rubber

(ii) Synthetic Polymers: Synthetic Polymers are man-made polymers.

Ex: Polyethylene, Bakelite, Polyvinyl alcohol, Terylene

### 3.2 Classification on the basis of structure

(i) Linear Polymers: In Linear Polymers, monomeric units are joined in the form of long straight chains.

Ex: High Density Polythene (HDPE), Nylons, Polyester

(ii) Branched chain Polymers: Branched chain polymers are mainly linear in nature, but also possess some branches along the main chain.

Ex: Low Density Polythene (LDPE), Glycogen, Amylopectin

(iii) Three-dimensional network Polymers: Three-dimensional network polymers contain monomer molecules connected to each other by only covalent bonds. They are giant molecules in which movement of individual monomeric units is prevented by strong cross-links.

Ex: Bakelite, Urea-formaldehyde, Melamine formaldehyde

### 3.3 Classification on the basis of their methods of synthesis

Based on the modes of synthesis, the polymers have been classified into two groups.

(i) Addition Polymers: Addition Polymers are obtained by addition polymerization method, which involves the repeated addition of monomers to yield long chains.

Ex: Polyethylene, Polypropylene, Polystyrene, etc.

(ii) Condensation Polymers: Condensation Polymers are obtained by a series of condensation reaction, generally involving two monomers.

Ex: Nylon-6, Bakelite, Polyester, etc.

### 3.4 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 growing chain carrying reactive intermediate

Ex: Polyethene, Polypropylene, Polystyrene, etc...

(ii) Step-growth Polymers: Step-growth Polymers are formed through a series of independent reactions involving bond formation between two different monomers with loss of small molecules like H<sub>2</sub>O, HCl, and NH<sub>3</sub> etc.

### 3.5 Classification based on molecular forces

On the basis of magnitude of inter molecular forces present in polymers, they are classified into four categories.

**Thermoplastics:** Molecules in a thermoplastic are held together by relatively weak intermolecular forces, so that the material softens when exposed to heat and then returns to its original condition when cooled. Most linear and slightly branched polymers are thermoplastics. All the major thermoplastics are produced by chain polymerization. Some examples are food packaging, insulation, automobile bumpers and credit cards.

**Thermosets:** Thermosets cannot be reshaped by heating. Thermosets usually are three-dimensional networked polymers in which there is a high degree of cross-linking between polymer chains. The cross-

linking restricts the motion of the chains and leads to a rigid material, so thermosets are strong and durable. They are primarily used in automobiles and construction. They are also used to make toys, varnishes, boat hulls and glues.

**Elastomers:** Elastomers are rubbery polymers that can be stretched easily to several times their unstretched length and which rapidly return to their original dimensions when the applied stress is released. Elastomers are cross-linked, but have a low cross-link density. An elastomer must be above its glass transition temperature  $T_g$  and have a low degree of crystallinity. Rubber bands and other elastics are made of elastomers<sup>37</sup>.

**Fibers:** Many of the polymers used for synthetic fibers are identical to those used in plastics. A fiber is often defined as having an aspect ratio of at least 100. The thickness of the fiber is expressed in terms of denier. Denier is a unit of measure for the linear mass density of fibers. It is defined as the mass in grams per 9000m. Synthetic fibers include Kevlar, carbon, PE, PTFE and nylon while natural fibers include silk, cotton, wool and wood pulp<sup>38, 39</sup>.

#### 4. STRUCTURE OF POLYMERS

Polymers are different from other construction materials like ceramics and metals, because of their macromolecular nature. The covalently bonded, long chain structure makes them macromolecules and determines, via the weight averaged molecular weight, their processability, like spin, blow, deep draw, generally melt-formability. The number averaged molecular weight, determines the mechanical strength and high molecular weights are beneficial for properties like strain to break, impact resistance, wear, etc. Thus, natural limits are met, since too high molecular weights yield too high shear and elongational viscosities that make polymers inprocessable. Prime examples are the very useful poly-tetra-fluor-ethylenes (PTFE's)<sup>40</sup> and ultrahigh-molecular-weight-poly-ethylenes (UHMWPE's)<sup>41</sup> and not only garbage bags are made of polyethylene, but also high-performance fibers<sup>42</sup> that are even used for bullet proof vests. The resulting mechanical properties of these high performance fibers, with moduli of 150 GPa and strengths of up to 4 GPa, represent the optimal use of what the potential of the molecular structure of polymers yields, combined with their low density. Thinking about polymers, it becomes clear why living nature used the polymeric concept to build its structures, and not only in high strength applications like wood, silk or spider-webs<sup>43</sup>.

#### 5. NANO POLYMERS

Nano structured materials can be utilized in fabricating novel active devices with improved functionalities. The discipline of Nano science and nanotechnology has recently become one of the most important areas of knowledge encompassing various scientific disciplines including physics, chemistry, biology and engineering. The word nano is derived from the Greek word "dwarf". It is the prefix for units of  $10^{-9}$ . Nano science is concerned with the study of the unique properties of matter at its nano level and exploits them to create novel structures, devices and systems for different uses. Particles having size less than 100 nm are generally called nanoparticles. These have strikingly different properties due to their small size and thus are found useful in many applications. The ability to measure and manipulate matter on the nanometer level is making possible a new generation of materials with enhanced mechanical, optical, transport and magnetic properties. Polymer nanocomposites (PNC) are a polymer or copolymer having dispersed in its nanoparticles. These may be of different shape but at least one dimension must be in the range of 1 to 50 nm. These PNC's belong to the category of multi-phase systems that consume nearly 95% of plastics production. These systems require controlled mixing, stabilization of the achieved dispersion, orientation of the dispersed phase and the compounding strategies for all multi phase systems, including PNC are similar. The transition from micro to nano particles leads to change in its physical as well as chemical properties. Two of the major factors are increase in the ratio of surface area to volume and size of the particle. The increase in surface area-to-volume ratio, which increases as the particles get smaller, leads to an increasing dominance of the behavior of atoms on the surface area of particle over that of those interior of the particle. This affects the properties of particles when they are reacting with other particles. Because of higher surface area of nanoparticles the interaction with other particles within the mixture is more and this increases strength, heat resistance etc. and many factors do change for mixture<sup>44</sup>. Example of nanopolymer is silicon nanospheres which show quite different characteristics like its size is 40-100 nm and it is much harder than silicon and hardness of this nano-sphere lies between that of sapphire and diamond<sup>45</sup>.

##### 5.1 Semiconducting nanopolymers

Semiconductor nanoparticles (NPs) have been attracting widespread scientific and technological interest due to their unique size-tunable optical and electronic properties as well as their potential

applications in solar cells, light-emitting diodes (LEDs) and bio-labels<sup>46</sup>. The synthesis and characterization of these particles are quite important for betterment of optical devices. Zinc selenide (ZnSe) of II–VI group semiconductor is one of the most typical and important crystalline material for both application and research of quantum dots<sup>47</sup>. ZnSe is a wide band gap (2.69 eV) semiconductor with large binding energy and a small exciton with Bohr radius of 3.8 nm at room temperature. Better results are expected for ZnSe, which has a valence band-edge at higher energy with respect to ZnS<sup>48</sup>. So ZnSe has been regarded as an efficient host to dope different transition-metal ions to modify the properties. Doped semiconductor nanoparticles have been regarded as a new class of materials which have wide range of applications in sensors, displays, electronic devices, laser devices and nonlinear optical devices, etc.<sup>49</sup>. The properties of semiconductor nanoparticles depend mainly on their shape and size due to high surface-to-volume ratio. Polymers are used as stabilizers during the preparation of semiconductor nanoparticles. Poly vinyl alcohol (PVA) is a semi crystalline, water soluble and low electrical conductivity polymer<sup>50</sup>. PVA is an odorless and tasteless, translucent white or cream colored granular powder, it has excellent film forming, emulsifying and adhesive properties. It is nontoxic. It is used as a polymer to stabilize CdSe nanoparticles<sup>51</sup>. CdSe is an important II-VI, n-type direct band gap semiconductor has engrossed substantial consideration due to its applications in light-emitting diodes, photo detectors and full color display<sup>52</sup>. The wide band gap (bulk band gap of 2.6 eV) makes CdSe as inorganic passivation, in order to improve stability, and also an attractive host for the development of doped Nanoparticles<sup>53</sup>. Cadmium selenide is a semiconducting material, but has yet to find many applications in manufacturing. CdSe nanoparticles have received a lot of attention because of their unique optical and electronic properties<sup>54</sup>.

### 5.2 Green polymer

Materials are said to be green when they are biodegradable and renewable. The major attractions about green composites are that they are environmentally friendly, fully degradable and sustainable in every way. At the end of their service life they can be easily disposed of or composted without harming the environment. The challenge of green composite involves basically the challenge of obtaining green polymers that are used as matrix for the production of the composites. Polymer is said to be green when it possesses environmentally favorable properties such as renewability and degradability.

Biodegradation implies degradation of a polymer in natural environment that includes changes in the chemical structure, loss of mechanical and structural properties and changing into other compounds that are beneficial to the environment<sup>55</sup>. Polymers from natural sources such as starch, lignin, cellulose acetate, poly-lactic acid (PLA), polyhydroxylalkanoates (PHA), polyhydroxylbutyrate (PHB), etc. and some synthetic sources that are degradable are classified as biopolymers<sup>56</sup>. However, those from synthetic sources are not renewable and therefore do not conform wholly to the concept of renewability and degradability<sup>57</sup>. Fig. 3 shows the Schematic representation of PLA.

## 6. APPLICATIONS OF POLYMERS

**Agriculture and Agribusiness:** Polymeric materials are used in and on soil to improve aeration, provide much and promote plant growth and health.

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

**Consumer Science:** Plastic containers of all shapes and sizes are light weight and economically less expensive than the more traditional containers. Clothing, floor coverings, garbage disposal bags and packaging are other polymer applications.

**Industry:** Automobile parts, windshields for fighter planes, pipes, tanks, packing materials, insulation, wood substitutes, adhesives, matrix for composites and elastomers are all polymer applications used in the industrial market.

**Sports:** Playground equipment, various balls, golf clubs, swimming pools and protective helmets are often produced from polymers.

**Transparent and Optical Materials:** Polymers are used as windows, optical fibers, lenses, reflectors and transparent film package<sup>58</sup>.

Nanocomposites have been used in several applications such as mirror housings on various vehicle types, door handles, door panels, trunk liners, instrument panels, parcel shelves, head rests, roofs, upholstery and engine covers and intake manifolds and timing belt covers. Other applications currently being considered include impellers and blades for vacuum cleaners, power tool housings, mower hoods and covers for portable electronic equipment such as mobile phones, pagers etc. Its excellent barrier properties, chemical resistance and surface



appearance make it an excellent material for packaging applications such as in beer and carbonated drinks bottles and paperboard for fruit juice and dairy. Nanocomposites also have future in aerospace applications because of their light weight<sup>59</sup>.

### 7. CONCLUSIONS

In recent years, polymer–nanoparticle composite materials have attracted the interest of a number of researchers, due to their synergistic and hybrid properties derived from several components. Whether in solution or in bulk, these materials offer unique mechanical, electrical, optical and thermal properties. Such enhancements are induced by the physical presence of the nanoparticle and by the interaction of the polymer with the particle and the state of dispersion. One advantage of nanoparticles, as polymer additives appear to have is that compared to traditional additives, loading requirements are quite low. 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 a single chain. These basic structural properties play a major role in determining bulk physical properties of the polymer. Nano structured materials can be utilized in fabricating novel active devices with improved functionalities. The discipline of Nano science and nanotechnology has recently become one of the most important areas of knowledge encompassing various scientific disciplines including physics, chemistry, biology and engineering. Zinc selenide of II–VI group semiconductor is one of the most typical and important crystalline material for both application and research of quantum dots. ZnSe is a wide band gap semiconductor with large binding energy and a small exciton with Bohr radius of 3.8 nm at room temperature. Better results are expected for ZnSe, which has a valence band-edge at higher energy with respect to ZnS. So ZnSe has been regarded as an efficient host to dope different transition-metal ions to modify the properties. Nanocomposites have been used in several applications such as mirror housings on various vehicle types, door handles, door panels, trunk liners, instrument panels, parcel shelves, head rests, roofs, upholstery and engine covers and intake manifolds and timing belt covers. Other applications currently being considered include impellers and blades for vacuum cleaners, power tool housings, mower hoods and covers for portable electronic equipment such as mobile phones, pagers etc.

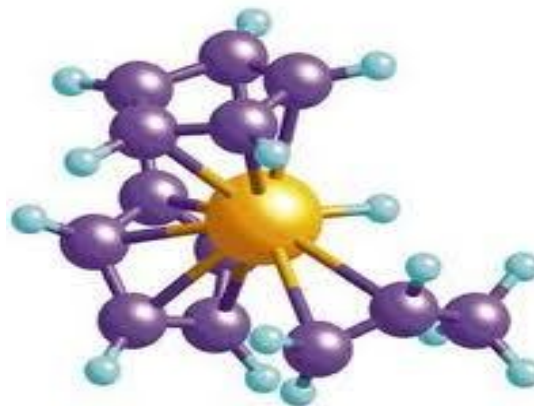


Fig. 1: Representation of polymer chain

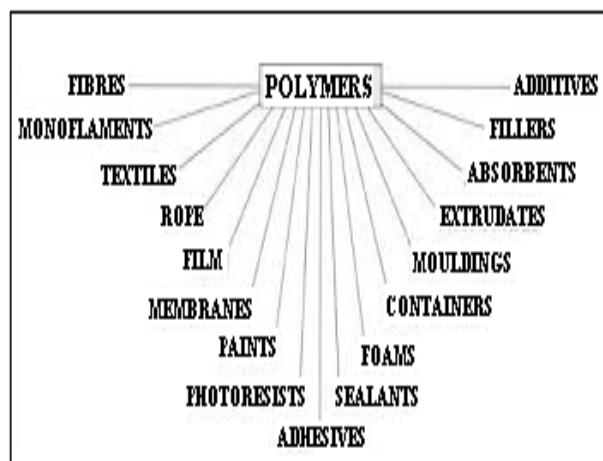


Fig. 2: Classification of polymers

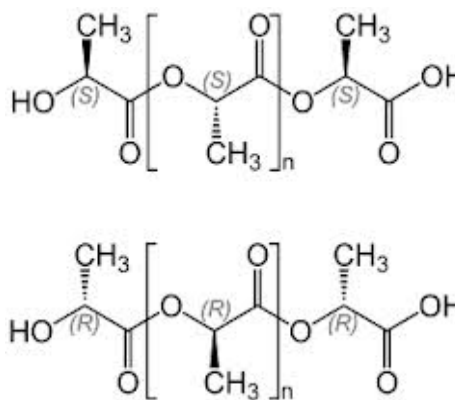


Fig. 3: Schematic representation of poly-lactic acid

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