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Recent Review on Poly-methyl methacrylate (PMMA)-Polystyrene (PS) Blend Doped with Nanoparticles For Modern Applications

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Abstract

The [(poly-methyl methacrylate (PMMA)-polystyrene (PS)] blend doped with nanoparticles can be considered a quite promising material for different medical, environmental and industrial applications such as: antibacterial, biosensors, lens, electronics gates, transistors, and photovoltaic devices...etc. In this review, the discussion of polymer structure, polymer blend, composite materials and nanocomposites have been investigated. Also, the characterizations of poly-methyl methacrylate and polystyrene and their nanocomposites have been studied. The poly-methyl methacrylate and polystyrene and their nanocomposites have huge applications in an environmental applications.

Keywords: PMMA, nanoparticles, blend, PS, environmental, nanocomposites

INTRODUCTION

The nanotechnology field is one of the mainly popular areas for present researches and improvement in mostly all technical disciplines, this clearly includes polymer science and technology and even in this field, the investigations cover a broad range of topics [1]. It is a novel science which evolved as it was observed that substances displayed significantly different classification at sizes in a nanometer as compared to the characterization of the same substance at bigger particle sizes [2]. It will make possible the improvement of novel substances providing the basis for the design and development of new characterization and structures which will result in increased performance, reduced cost of maintenance and enhanced functionality [3]. Nowadays, studies on polymer nanocomposites have attracted much attention because of their wide range of applications in the field of polymer nanotechnology. The polymer nanocomposites heavily rely on geometry, size distribution, aggregation and surface chemistry of organic/inorganic nanoparticles as well as matrix-nanoparticle interactions. The properties of nanocomposites were found to depend on the type of nanoparticles, the content of nanofillers and nature to bridge chemically and physically with the polymer matrix [4]. Polymers are mostly used in electronic and electrical applications. In early works, polymers have been used as insulators because of their dielectric properties and high resistivity. Polymers have several advantages, such as low cost, secure processing, high strength, flexibility, and excellent mechanical properties. The applications of nanocomposites are quite promising in the fields of microelectronic packaging, optical integrated circuits, automobiles, drug delivery, sensors, injection moulded products, membranes, packaging materials, aerospace, coatings, adhesives, fire-retardants, medical devices, consumer goods, etc[5]. Many modern technologies require materials with unusual combinations of properties that cannot be met by conventional alloys, metal, ceramics and polymers. This is mainly true for materials that are needed for underwater, aerospace, and transportation applications [6]. The nanocomposites have huge applications for different fields in piezoelectric and pressure sensor [7-14], electronic and optoelectronic applications [15-17], bioenvironmental and radiation shielding [18-25], humidity sensors [26-35], antibacterial [36-47], thermal energy storage and release [48-51].

2. Polymer Structure

Polymers consist of large organic molecules (macromolecules) of repeating small structural units (monomers) linked together in a method called polymerization [52]. Each particle is composed of thousands of atoms connected by covalent chemical bonds. The polymer molecules attract each other by forces which are dependent on the kind of the polymer. The polymers consist of huge, combined molecules which are hard to control, limited crystal connections can be seen in polymers associated with its low temperature. It is only in limited regions that a linear chain of molecules can arrange themselves in an organized form. In the solid-state, polymers are comprised of crystalline and non-crystalline parts [53]

3. Polymer Blend

A polymer blend defines as a mixture of two or more polymers that have been blended to produce a new material with different physical properties. Generally, there are types of polymer blend: thermoplastic blends; thermoplastic-rubber blends; thermoplastic-thermosetting blends and rubber-thermosetting blends all of which have been extensively studied[54]. The major objective of polymer blending is to achieve cheap, readily available and commercially viable products with unique properties. Polymer blending is a vast and unlimited subject of interest that requires the highest attention theoretically and experimentally. From the literature, it was found that polymer blends have superior properties compared to its component polymers. The blending of different polymers is one of the most important industrial tools to get a more efficient and attractive product for various applications[55].

4. Composite Materials

It is a truism that technological development depends on advances in the field of materials. One does not have to be a professional to realize that the mainly advanced turbine or aircraft design is of no use if adequate substances to bear the service loads and conditions are not available. Whatever the field can be, the final limitation on advancement depends on substances. Composite materials in this regard represent nothing but a giant step in the ever-constant endeavour of optimization in substances.[56].

Broadly, four types of materials are used for making a structural element. These are metals, polymers, ceramics, and composites. In a general sense, a composite material is one that has two or more constituent materials in it. The component materials in a composite material are metals, polymers, ceramics, or a combination of these three. A definition of composites can be found by identifying the characteristics of the constituents and the process of combining them [57,58]. It checks them as follows:

a. The constituent materials differ in composition and form. Their combination results in two phases in a composite material: reinforcement—a discontinuous phase, which is usually hard and robust, and matrix—a continuous phase, which binds the reinforcements together.
b. The reinforcing material is embedded in the matrix material at a macroscopic level. Thus, the constituent elements do not dissolve or merge and they retain their individual properties.
c. The matrix binds the reinforcements in such a way as to form distinct interphase between them.
d. The reinforcements and the matrix, as original materials, may not be of any engineering use; it is the process of combining them that transforms them into a new article, which is a useful and efficient one. The interphase helps the reinforcement and the matrix act in unison and the resultant composite material often exhibits better properties than the constituent elements[59].

5. Nanocomposites

The composites technology is advanced through the last few decades, the component materials, particularly the reinforcement materials, steadily decreased in size. Most recently, there has been considerable interest in "nanocomposites" having nanometer-sized reinforcements [60]. Nanocomposites are a novel production of new materials, which are produced by mixing one or more dissimilar elements at the nanoscale in order to control and improved structures as well as properties[61]. Nanocomposites are materials in which at least one of the component shows dimensions in the nanometre range. As in the state of micro composites, the nanocomposite can be classified, according to their matrix, in three different categories [62].

- Ceramic Matrix Nanocomposites (CMNC)
- Metal Matrix Nanocomposites (MMNC)
- Polymer Matrix Nanocomposites (PMNC)

The advance of polymer nanocomposites is a fast increasing field because excellent properties can be gotten from such materials at low filler concentration. The incorporation of the semiconductor nanoparticles into apparent polar polymers matrix can induce essential changes in the final properties of polymers and improve their properties. The characteristics of these composite films can be manipulated by controlling the type, size and shape of the nanoparticles and the method used to prepare the nanocomposite [63].

6. Poly(methyl methacrylate) (PMMA):

Poly(methylmethacrylate) is an essential and interesting polymer because of attractive optical and physical characterizations decisive about its area applications. PMMA is the thermoplastic polymer with the excellent hardness and tensile strength, transparency, high rigidity, good insulation properties and thermal stability dependent on tactility. Poly(methylmethacrylate) has some disadvantages such as brittleness and low chemical resistance which can be eliminated by chemical or physical modification. It contains both hydrophobic (methylene) and hydrophilic (carbonyl) groups in each unit [64]. PMMA is often used as an alternative to glass and sold under a number tradenames including Lucite, Plexiglas, Acrylex, Acrylite, Oroglass, and Vitroflex. When completely burned the products are carbon dioxide and water making it an environmentally positive material in this regard. PMMA is often used as an alternative to glass. PMMA is used in the exterior lenses of automobiles and trucks. The spectator protection shield in ice hockey stadiums is made of PMMA. The windows of many aircraft and windows of police vehicles for riot control are PMMA as are many motorcycle helmet visors. PMMA is also used in medicine. PMMA has good compatibility with human tissue and has been used for replacement of intraocular lenses in eyes. Hard contact lenses are often composed of PMMA. Bone cement containing PMMA is used to connect bond implants and remodel lost bone. PMMA has Young's modulus near that of bone, so does a good job of load sharing with the native bone. Dentures are often PMMA [65]. A chemical structure of the repeating unit of PMMA polymer, as shown in figure (1) [66]. Table (1) illustrates the most important properties of PMMA polymer [67].

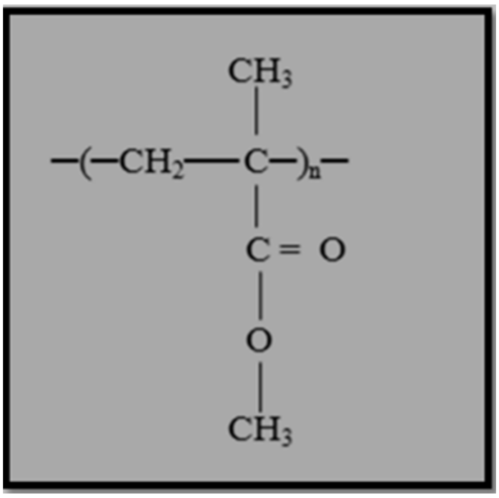

Figure 1: Chemical structure of the repeating unit of PMMA polymer [66]

Table 1: The most important properties of PMMA polymer [67]

Parameters	PMMA
Chemical formula	$(C_5O_2H_8)_n$
T_g	379K , 106 °C
Refractive index	1.49
Density (g/cm^3)	1.2
Melting point (°C)	160
Molecular weight Mw (g/mol)	Varies
Modulus of elasticity (G Pa)	3.2

7. Polystyrene

Polystyrene is a transparent glass-like substance which does not dissolve in acids, bases, or alcohol, but dissolve in aromatic hydrocarbons, benzene, and esters. Its melting point is 239^{o}C, density is 1.05 g/cm$^{3,\ the}$ glass transition temperature is 100^{o}C and its random crystallization [68]. Polystyrene is commercially manufactured from styrene which is prepared from benzene and ethylene by passing ethylene through benzene under pressure and the use of aluminium chloride as a catalyst. The resulting ethyl benzene undergoes a method by which a hydrogen atom is removed by passing ethylbenzene over a catalyst such as Iron oxide or magnesium oxide at 600^{o}C. The resultant of this method is styrene which is in turn refined before being polymerized. Polystyrene is fabricated under different polymerization conditions depending on the final application of the polymer. There are other industrial methods for the fabrication of polystyrenes such as emulsion polymerization, suspension polymerization, mass polymerization, and solution polymerization. As polystyrene does not stretch or shrink, it is used in the production of plates and cables because it is a good electrical insulator; it is also used in the manufacture of rubber and household articles [69].

8. Tungsten carbide nanoparticles (WC)

Transition metal carbides are essential materials because they possess some desired properties such as thermal stability, corrosion, and wear resistance, electronic, magnetic, and catalytic characteristics. Among them, titanium carbide (TiC), tungsten carbide (WC), and niobium carbide (NbC) are three kinds of important transition metal carbides, which are applied as cutting tools, ceramics, and wear resistance materials[70]. Tungsten carbide (WC) is very desirable material due to its attractive mechanical, physical and chemical properties such as high hardness, high melting point, good electrical and thermal conductivity, and high corrosion resistance[71]. G. Han et al. in (2014) [72] studied the effect of acid hydrolysis conditions on the properties of cellulose nanoparticle-reinforced poly(methyl methacrylate) composites. They found that the addition of CNPs in the PMMA matrix decreased the optical transparency of the nanocomposites. B. Hussien et al. in (2014) [73] studied the preparation of (PS-PMMA-ZnCl2) composites and their electrical and optical properties. They found that the absorbance is very large in the UV region and it increased with increasing the concentration of zinc chloride. The real and imaginary dielectric constant increase with increasing the incident photon energy. The optical constants increased with increasing zinc chloride concentration. H. Hakim. et al. in (2015) [74] investigated the preparation of (PMMA-Y2O3) nanocomposites and studying their optical properties. They found that the absorbance of PMMA increases with the increase of the concentrations of yttrium oxide nanoparticles. The optical constants (absorption coefficient, extinction coefficient, refractive index and real and imaginary dielectric constants) of PMMA are increasing with the increase of the concentrations of the yttrium oxide nanoparticles. The energy band gap of PMMA decreases with the increase of the concentrations of the yttrium oxide nanoparticles. Gyanesh Soni. et al. in (2018) [75] studied the optical, mechanical and structural properties of PMMA/SiO2 nanocomposite thin films. They found that the optical band gap decreases with an increase in the SiO_2 NP concentration.

9. Polymer Nanocomposites For X-ray shielding

Radiation protection materials and tools gained much interest due to the widespread of using ionizing radiations in several fields. Periodic exposure to ionizing radiation occurs for workers or patients in a severe radio environment caused by reactors facilities, X-ray tubes, accelerators and radioisotopic sources imposes safety regulations for protection from that radiation. Selection of suitable shielding materials depends on the type, intensity and energy of radiation source, as well as the shielding properties such as mechanical strength, economic preparation and resistance to radiation damage. The interaction probability of X-rays depends on the incident photon energy, the atomic number and the density (q) of the shielding materials[76]. Lead is usually used in medical radiology departments as a shielding material. Lead-based protective materials are also used by clinical personnel during X-ray image-guided interventional radiology (IVR) procedures. However, lead is extremely toxic and prolonged exposure to it can result in serious health concerns. Polymer composites, on the other hand, can be designed to be lead-free in addition to being lightweight, conformable, cost-effective, and potentially capable of significantly attenuating X-rays. Nanomaterials have exceptional material characterizations that can be exploited to extend novel lead-free radiation-protection materials. The selective development of radiation attenuation by the nanomaterials at the lower energies was attributed to the increased number of particles per gram and grain-size effects. Therefore, the use of nanomaterials for radiological protection purposes may have essential implications in terms of material durability and effective radiation shielding, all of which can be utilized to replace the toxic lead and lead composites[77]. The attenuation of radiation is characterized by $N = N_0 \exp(-\mu t)$, where $N_0$is the number of particles of radiation counted during a certain time, duration without any absorber, μ is the attenuation coefficient of X-ray and N is the number of counted during the same time, with a thickness of sample t [78].

10. CONCLUSION

The nanocomposites of (PMMA-PS) blend doped with nanoparticles have unique characterizations which make it can be used for different environmental, medical and industrial applications such as radiation shielding, antibacterial, biosensors, electronics gates, transistors, lens,...etc. This review showed that the poly-methyl methacrylate and polystyrene and their nanocomposites have different applications in environmental, industrial and medical fields.

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