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Recent Review on Metal-Oxide-Nanoparticles-Doped Polymethyl Methacrylate (PMMA) for Modern Fields

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The polymers like polymethyl methacrylate (PMMA) have unique characteristics, which made them to be considered as promising material for various biomedical, electronics and optics applications. Metal-oxide nanoparticles have huge applications in different approaches. This work includes a recent review on polymer like PMMA doped with metal-oxide nanoparticles such as SiO_2 and CeO_2. The previous studies showed that the nanocomposites of PMMA/metal-oxide nanoparticles have many applications in the biomedical, electronics, optical and optoelectronics fields.

Полімери, такі як поліметилметакрилат (ПММА), мають унікальні характеристики, що зробило їх перспективним матеріялом для різних біомедичних, електронних та оптичних застосувань. Металооксидні наночастинки мають величезне застосування в різних підходах. Ця робота включає недавній огляд полімерів, таких як ПММА, леґованих металооксидними наночастинками, такими як SiO_2 та CeO_2. Попередні дослідження показали, що нанокомпозити ПММА/металооксидні наночастинки мають багато застосувань у біомедичній, електронній, оптичній та оптоелектронній сферах.

Key words: polymethyl methacrylate, metal-oxide nanoparticles, biomedical nanotechnologies, optoelectronics.

Ключові слова: поліметилметакрилат, металооксидні наночастинки, біомедичні нанотехнології, оптоелектроніка.

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1. INTRODUCTION

Polymers are large molecules made up of many small molecules.

These macromolecules may be linear, slightly branched, or highly intertwined [1]. The small molecules used as the building blocks for these larger molecules are known as monomers. Monomers are small molecules can be joined together in a repetitive manner to form more complex molecules called polymers [2]. The polymerization process is the process that allows a simple low molecular weight compound to combine and form a high molecular weight complex. The polymerization processes can be classified into two types: gradual (condensation) polymerization and addition (chain growth) [3, 4].

As for nanomaterials, the nanoparticles (NPs) include particles having size between 1 and 100 nm, These particles have different properties at their atomic level due to their size [5].

Nanoparticles can be classified as metal nanoparticles, semiconductor nanoparticles, non-metal ceramic nanoparticles, and a well-known type is carbon nanoparticles [6]. The field of nanotechnology is one of the most popular areas of current research and development for basically all technical disciplines, and this obviously includes polymer science and technology [7]. Even before nanotechnology was recognized as a new scientific field, work on the manufacture and production of nanomaterials and nanostructures began a long time ago. However, research in this field has accelerated rapidly in the past decade, resulting in an influx of papers in a number of journals, and the field of nanotechnology is changing and expanding rapidly [8]. In general, most polymers were only used to make low-cost materials that were only used for a few applications. However, due to rapid technological advancements, some components currently used in manufacturing have had to be replaced with newer materials with improved specifications; as a result, studies of electrical and optical properties of polymers have gotten a lot of attention in recent years due to their usage in electronic and optical devices. In crystalline, semi-crystalline, and monocrystalline polymers [9, 10].

2. POLYMER STRUCTURE

The physical properties of polymer materials depend on the molecular weight and shape as well as on the molecular structure [11]. Polymers are classified according to their chemical composition into three main types (linear, branched and cross-linking polymers).

Linear polymers: these polymers have a linear structure and are generally thermoplastic polymers, and with the exception of materials with very high molecular weight, they are soluble in solvents. The basic of these polymers is a single molecular chain of a certain length connected to each other in a linear form.

As for the branched polymers, there are branches that arise from the original polymer chain. Branching may result in several physical properties in the polymer such as lower solubility in solvents, higher softening point and lower properties of thermoplastics.

In addition, the last type is cross-linked polymers. These polymers have a three-dimensional network structure where chemical bonds are intertwined with each other in a complex manner [4, 12].

Thermoplastic polymers: most thermoplastics have a high molecular weight. The polymer chains associate by intermolecular forces, which weaken rapidly with increased temperature, yielding a viscous liquid. In this state, thermoplastics may be reshaped and are typically used to produce parts by various polymer processing techniques such as injection moulding, compression moulding, extrusion and calendaring [13].

Thermosetting polymers: the molecules in this type of polymers are linked by strong covalent bonds within the cross-linking property, which leads to the formation of polymeric chains with a three-dimensional network structure. Branched while it is still soluble, but as the reaction continues for a longer period of time, the polymer begins to harden gradually [14].

Polymers are classified [14, 15] depending on the homogeneity of repeating units in to:

a) homopolymer: it is a polymer that consists of the same unit of basic building blocks (monomers), an example of which is polyethylene;

b) copolymers: where the building blocks of a polymer are more than one type, as in the polymer (styrene—butadiene);

c) composite polymers: it is the process of adding some material to homogeneous polymers in order to change in some of its characteristics and the entering of new recipes on it [14, 15]. Matrix (the base material) and additives are the two basic components of the compound. The additives coat the other ingredients and make them more viscous [16].

3. NANOCOMPOSITES

Nanocomposites are materials in which at least one of the phases has nanoscale dimensions [17] .These are high-performance materials with novel property combinations and design possibilities, and their capabilities are so promising that they may be used in a wide range of applications, from packaging to biomedicine. Materials can exhibit new properties such as electrical conductivity, dielectric behaviour, flexibility, greater strength, different colour, and greater activity properties with only a size reduction and no change in the material itself, which the same materials do not exhibit at the micro or micro scale [18]. Nanocomposites are made up of synthetic and natural polymers, as well as nanomaterials, which are materials with nanoscale dimensions or are made up of nanoscale building blocks [19]. Nanocomposites have mechanical, electrical, thermal, electronic, and electrochemical properties that differ significantly from their component constituents [20].

Nanotechnology is a new science that has developed, in which it has been observed that materials exhibit significantly different properties at nanometer sizes compared to properties of the same material at larger particle sizes [21]. Nanotechnology is an emerging multidisciplinary technology that has flourished in many fields during the last decade, including materials science, mechanics, electronics, optics, medicine, plastics, energy and aerospace [22]. Nanotechnology has opened new horizons in various fields of life, the most important of which is the field of medicine [23]. Nanomaterials are being developed as drug delivery mediums, contrast agents and diagnostic devices, and some are now being studied in clinical trials. Nanomaterials are now being designed to help transport diagnostic or therapeutic agents through biological barriers access to particles to mediate molecular interactions; and detect molecular changes in a sensitive and high-throughput manner [24]. The nanocomposites of nanomaterial-doped polymer (such as PMMA), composites' structures and ceramic matrix nanocomposites included huge applications in many fields like electronics and optoelectronics [25–44], sensors [45–50], optical fields [51–55], radiation shielding and bioenvironmental [56–62], antibacterial [63–65] and thermal energy storage [66–67].

3.1. Polymethyl Methacrylate (PMMA)

PMMA is one of the oldest and most popular polymers. Polymethacrylate has been seen as an alternative to glass in a variety of applications and is currently widely used in glazing applications. This material is one of the toughest polymers, a clear glassy with a glossy finish and good weather resistance. Polymethacrylate is naturally transparent and colourless. Visible light transmission is very high. Polymethacrylate polymeric compounds are well known for their importance in technical applications [68]. Methacrylate has attracted much attention for their use as optical components and in optoelectronic devices due to their low cost and scale. PMMA is an important and interesting polymer due to the attractive physical and optical properties crucial to its wide application. This is a thermoplastic material with good tensile strength and toughness, high toughness, transparency, good insulation properties and thermal stability dependent on texture. PMMA has some disadvantages such as embrittlement and low chemical resistance which can be eliminated by chemical or physical materials [69]. As for some properties of PMMA colourless polymer, this polymer dissolves at 130°C with water, One of the polymers that has a high resistance to sunlight, and is known to withstand temperatures up to 100°C and as low as 70°C. It also possesses good optical properties. It has low resistance to chlorinated and aromatic hydrocarbons. As for its solubility, PMMA shows little deviation as its solubility is somewhat complex, starting with swelling in the solvent and the subsequent formation of a very fine layer on its surface face. Then, it follows the diffusion of the solvent throughout the polymer before giving a homogeneous solution with the solvent, so PMMA takes a few minutes before it completely dissolves, even if it's inside the best solvent [70]. PMMA is widely used in engineering and decoration and in extensive applications in automobiles, home appliances, aircraft cockpits, dentures, laser disc manufacturing, manufacturing, and synthesis of semiconductor materials used in the manufacture of electronic devices [71].

3.2. Silicon Oxide (SiO_2)

Silicon dioxide, also known as silica, is a silicon oxide with the chemical formula SiO_2. The most common in nature as quartz and in various living things [72]. Silica is another name for the chemical compound composed of silicon and oxygen with the chemical formula SiO_2, or silicon dioxide. It has many forms, but all forms of silica are identical in chemical composition, but have different atomic arrangements. Silica compounds can be divided into two groups, crystalline (or *c*-silica) and amorphous silica (*a*-silica or non-crystalline silica). *c*-silica compounds have structures with repeating patterns of silicon and oxygen. The chemical structures of silica are randomly related when compared to silica. All forms of silica are odourless solids composed of silicon and oxygen atoms. Silica particles become suspended in the air and form non-explosive dust. Silica may combine with other metallic elements and oxides to form silicates [73].

3.3. Cerium Oxide (CeO_2)

Cerium oxide is an oxide of a rare earth mineral, for instance, a pale yellow powder with the chemical formula CeO_2. It is an important commercial product and an intermediate in the purification of elements from ores [74]. Cerium oxide (CeO_2), also known as ceria, is used in many technological applications [75], traditionally as a polisher in chemical mechanical polishing processes in the semiconductor industry and as a catalyst in solid oxide fuel cells. In the past ten years, there has been significant and growing research interest in cerium oxide nanoparticles for its distinctive catalytic properties, convertible redox reaction, and electronic configurations as well as use in a wide range of applications in biomedicine, biotechnology, and agriculture [76].

4. CONCLUSIONS

The present work includes a recent review on PMMA doped with metal-oxide NPs. The previous studies showed that the nanocomposites of PMMA/metal-oxide NPs have many applications in the biomedical, electronics, optical and optoelectronics fields.

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