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Studies on Ceramic-Nanoparticles-Doped Polymer for Modern Applications: Recent Review

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Polymer matrix nanocomposites mostly have unique characteristics include lightweight, flexibility, high corrosion resistance, few cost, and good chemical and physical properties. Ceramic nanoparticles (NPs) like carbides may be utilized as additive to the polymers such as polycarbonate (PC) that leads to formation of new nanomaterial, which can be employed in different biomedical and industrial fields. So, this work includes recent review on nanocomposites of ceramic-nanoparticles-doped polymers and their applications. The previous studies indicated that the nanostructures of ceramic-NPs-doped polymer have many applications in different fields.

Полімерні матричні нанокомпозити в основному мають унікальні характеристики, включаючи легкість, гнучкість, високу корозійну стійкість, невелику вартість і хороші хемічні та фізичні властивості. Керамічні наночастинки (НЧ), такі як карбіди, можуть бути використані як добавка до полімерів, таких як полікарбонат, що приводить до утворення нового наноматеріялу, який може бути використаний у різних біомедичних і промислових областях. Отже, ця робота включає нещодавній огляд нанокомпозитів полімерів, леґованих керамічними наночастинками, та їх застосування. Попередні дослідження показали, що наноструктури полімеру, леґованого керамічними НЧ, мають багато застосувань у різних областях.

Key words: polycarbonate, ceramic nanoparticles, carbides, nanocomposites.

Ключові слова: полікарбонат, керамічні наночастинки, карбіди, нанокомпозити.

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1. INTRODUCTION

Nanotechnology is one of the most popular topics for current research and development across a wide range of technological fields. This encompasses polymer science and technology, and research in this. include a wide range of fields [1]. Nanotechnology will enable the development of novel materials providing the basis for the design and development of new properties and structures, which will result in increased performance, reduced cost of maintenance and enhanced functionality [2].

There is a significant feature of nanotechnology which is the reduction instruments, sensors, and computers, both old and modern, that will have a significant effect on the planet computers of exponentially great strength that generate algorithms to mimic human brains, examples of future miniaturization include biosensors that warn us at the earliest stage of disease initiation, preferably at the molecular level, and medicines that target particular diseases. Nanorobots capable of repairing internal damage and removing toxic pollutants from human bodies, as well as nanoscale sensors capable of continuously monitoring our local world, are both possibilities. Nanotechnology has a broad variety of possible uses, ranging from nanoscale circuitry and optics to nanobiological structures and nanomedicine. As a result, it necessitates the production of experimental materials as well as multidisciplinary teams of physicists, chemists, and engineers, materials scientists, evolutionary biologists, pharmacologists, and others to cooperate on (i) nanomaterial synthesis and processing and nanostructures, (ii) a better understanding of the physical properties of the nanometer scale, (iii) nanodevices or devices that use nanomaterials as building blocks are designed and constructed, and work on the fabrication and production of nanomaterials and nanostructures started a long time ago, even before nanotechnology was recognized as a new scientific field, research in this field has accelerated rapidly in the last decade, resulting in a flood of literature in a number of journals. Nanotechnology science is increasingly evolving and expanding [3]. The polymers can be divided into two denominations: natural and industrial. The natural polymers include proteins, cellulose, starches and rubber, either the industrial include poly(vinyl chloride), nylons polyethylene, polypropylene , polyesters polycarbonate , and polycarbonate, *etc.* [4].

2. POLYMER STRUCTURE

A polymer consists of organic molecules (macromolecules) of small repeating structural units (monomers) connected to each other by a special process of polymerization, and each negative polymer molecule consists of thousands of atoms connected by covalent chemical bonds.

Polymer molecules are attracted to each other by forces that depend on the type of polymer [5, 6]. Polymers can be classified into two groups according to the effect of temperature on them. They are as follow.

(i) Thermoplastic polymers. These polymers change their properties depending on the temperature change. When the temperature is increased, they become flexible and viscous; by decreasing the temperature, these polymers return to the original (solid) state. This is because the molecules in the thermoplastic polymer are bound by relatively weak molecular (van der Waals) forces. When heated, these molecules can slide over each other as in polystyrene, polyethylene, polypropylene, polyvinyl alcohol [7].

(ii) Thermosetting polymers. These polymers change chemically when heated. Thermosetting materials are usually three-dimensional lattice polymers, in which there is a high degree of cross-linking between the polymer chains. After being heated, these polymers become insoluble, non-conductive, and hard, because the molecules of these polymers are connected by strong covalent chemical bonds. Phenol-formaldehyde resin and urea-formaldehyde resin are examples of this type of polymer [5, 8, 9, 10].

Materials that have a polymer matrix with a conductive filler are known as conductive polymer composites [11, 12]. These compounds are known for their high dielectric constants and for being highly conductive. This is achieved by conductive padding that forms a mesh throughout the compound allowing current to flow through the compound. The conductivity of these compounds can increase by several orders of magnitude. Since the matrix is composed of a polymer, these compounds have the potential to increase flexibility, if the polymer used in the matrix is flexible. The compound can be brittle and weak due to the amount of filler needed to produce a highly conductive material. The main advantage of conductive polymer composites is that they display the properties of both metal and polymer [12, 13]. Conductive polymer compounds can consist of two types of microstructures. A system can contain either a random microstructure or a discrete microstructure. The random microstructure consists of a polymer matrix with filler particles placed intermittently throughout the matrix. These compounds have isotropic properties and the filler does not show any bias to its location. The separate microstructure consists of filler particles showing a bias for their location. These compounds contain filler-rich regions along with polymer-rich regions [12, 14].

3. NANOCOMPOSITES

Nanocomposites consist of polymers that may be natural or synthetic, and they are nanomaterials, which refer to materials with nanosize topography or composed of nanosize building components [14]. Although the terms nanomaterials and nanocomposite represent new and exciting areas in materials science, they have been used for centuries when they exist in nature. However, methods for characterizing and controlling the structure at the nanoscale have only stimulated much later [15].

A nanocomposite is a conventional compound consisting of two parts, filler and a matrix. In a conventional composite usually, a fibre such as glass fibre or carbon fibre is used as filler, in a nanocomposite, the filler is a nanomaterial. Examples of nanomaterials are carbon nanotubes, carbon fibre tubs, and nanoparticles such as gold, diamond, silver, silicon and copper. Carbon nanocomposites are of particular interest due to their high strength and high hardness compounds that they produce at relatively low concentrations of carbon nanotubes [16].

The dispersion of inorganic nanocomposites into an organic polymer to form polymer nanocomposites has gained increasing attention in recent years. The new properties of nanocomposites can be obtained through the successful transfer of the properties of the original components into a single material [17]. An important and significant challenge in developing nanocomposites is to find ways to create macroscopic components that take advantage of the unique physical and mechanical properties of the very small objects within them. On the other hand, the fracture toughness of such biocomposites depends on the ultimate tensile strength, T, of the reinforcement. Crucially, the use of nanomaterials allows the maximum theoretical strength of the material to be reached, because the mechanical properties become increasingly insensitive to defects at the nanoscale [18]. Mechanical, electrical, thermal and electronic properties and the electrochemical properties of nanocomposites can differ significantly from those of their constituents [19].

The basic theory of nanocomposites is based on the principle that there is a very wide interface between the nanosize building blocks, and the polymer matrix that is under our study is based on this principle for the nanocomposite [20].

4. APPLICATIONS OF POLYMER NANOCOMPOSITES

The applications of polymer nanocomposites are based on the matrix and the nanocomposites [21]. Among its many applications are:

cars (gasoline tanks, fenders, interior and exterior panels, *etc.*);

construction (pull out the shape, panels);
electronics and electricity (printed circuits and electrical components);
food packaging (packaging, films);
cosmetics (controlled release of 'active ingredients');
dentistry (filling materials);
environment (biodegradable materials);
gas barrier (tennis balls, food and beverage packaging);
flame retardants, military, aerospace and commercial applications.

It can be noted that there are many industrial and medical applications of nanomaterials related to many fields, including engineering, biology, chemistry, computing, materials science, military applications, and communications, but their effects are difficult to enumerate. Benefits of nanotechnology include improved manufacturing methods, water purification systems, improved food production methods and energy networks, physical health promotion, nanomedicine. Products made with nanotechnology may require little labour, earth, or maintenance, are high in productivity, low in cost, and have modest material and energy requirements [22]. There are many applications of ceramic-doped polymer matrix and nanocomposites including: electronics and optoelectronics [23–42], sensors [43–48], antibacterial [49–51], optical fields [52–56], thermal energy storage [57–58], radiation shielding and bioenvironmental [59–65].

5. CARBIDES

In chemistry, carbide is a compound composed of carbon and a less electronegative element. Carbides can be generally classified by the type of chemical bonds as follow [66]:
(a) salts;
(b) interstitial compounds;
(c) covalent compounds;
(d) transition metal carbide.

Examples include calcium carbide, tungsten carbide, silicon carbide and tantalum carbide [66].

6. TANTALUM CARBIDE (TaC)

Tantalum carbide (TaC) is a ceramic material that has the ability to withstand very high temperatures. It is also used industrially in the manufacture of cutting tools because of its hardness that exceeds that of diamond [67]. It can also be added to the crystal structure of tungsten carbide alloy. Tantalum carbide (TaC) nanomaterial is strikingly interesting, because it contains some. Characteristics such as high hardness, high melting point (max 3880°C) [68]. This material is considered resistant to chemical attack and oxidation, and has good and excellent catalytic and thermal properties and limits of electronic conductivity [69, 70]. The chemical properties of this substance are attributed to the mixed metal covalent bond [71]. One of the main uses of TaC is a phase hardening in composites to increase strength and wear resistance [72]. Tantalum carbide (TaC) is difficult to produce by sintering to a high melting point of 3880°C. TaC is difficult to sinter in conventional or hot pressing furnaces. Furnaces designed for these higher temperatures are usually very expensive [73].

7. SILICON CARBIDE (SiC)

Silicon carbide is also known as carborundum and is found in nature in the form of the extremely rare mineral moissanite. Silicon carbide is a compound of silicon and carbon with the chemical formula (SiC). Silicon carbide powder has been produced since 1893 for use as abrasives. Granules of silicon carbide can be bonded together by roasting to form very hard ceramics, so it is widely used in applications that require high tolerances, such as automobile brakes, ceramic plates, in bulletproof vests, high speed steel polishing processes, deep drawing dies and carbide inserts [74].

SiC particles in the particles may behave as abrasives at the interface of the workpiece during machining and affect the mechanical properties of the composites, *i.e.*, hardness and tensile strength The silicon carbide material in the workpiece plays an important role in it as machinability; so, it represents abrasive areas in the metal that cause excessive wear of the tool, increases the cutting force, and has a significant impact on the quality of the machined surface [75].

8. POLYCARBONATES (PC)

Polycarbonates are a group of thermoplastic polymers that contain aggregates of carbonates in their chemical structures. They are strong, rigid, and sometimes optically transparent materials. Polycarbonate is easily fabricated and thermoformed. Because of these properties, polycarbonate finds in many applications. Polycarbonates got their name because they are polymers containing carbonate. A balance of beneficial features, including temperature resistance, shock resistance, and optical properties, places polycarbonate between commodity plastics and engineering plastics [76]. Polycarbonate is mainly used in electronic applications that take advantage of security features. Being a good electrical insulator with heat-resistant and flame-retardant properties, it is used in many products associated with telecommunication devices and electrical appliances and can also act as an electrical insulation in highly stable capacitors [77].

9. CONCLUSIONS

In this work, recent review on nanocomposites of ceramic-nanoparticles-doped polymers is presented with their applications analysed. The previous studies indicated that the nanostructure of ceramic-NPs-doped polymer have many applications in different fields.

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