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Various Developments of Nanoparticles: Behaviors, Characteristics and Applications over the Past Decades

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Abstract

By studying nanoparticles, the increased contribution of nanoparticles in modern science and its various fields has been reported. Its various applications and technologies have been analyzed and discussed about the area of demand for their ever-increasing production. Nanoparticles, which are small substances, ranging in size from one to 100 nm, can be classified into different classes on the basis of their properties and size. Nanoparticles themselves have unique physical properties. Due to their high surface area and nanoscale size, their chemical properties and their optical properties are reported to be dependent, in addition to absorption in the visible region that presents various colors, they have reactivity, durability and other properties. In this paper All these characteristics discussed which make nanotechnology suitable for a wide variety of technical, commercial, health related, energy-based research environments and domestic applications.

Keywords- Nanoparticles, Pollution, Nano materials

1. Introduction

Nobel laureate Richard P. Feynman, who brought nanotechnology to light, first presented the universality of nanotechnology in his famous lecture "There's Plenty of Room at the Bottom" (Feynman, 1960), followed by Various revolutionary developments have been made in the field of nanotechnology. Over the past few decades, nanotechnology has enabled the production of a variety of materials at the nanoscale level, with synthesized materials important in a wide variety of fields, including industry, environmental engineering, as well as medicine. In general, chemically synthesized nanoparticles within the size range of 1–100 nm are highly useful. Due to the systematically developed and predetermined chemical approaches employed for the production of nanoparticles, nanoparticles synthesized using these are referred to as engineered nanoparticles. (Quigg et al., 2013). Interesting, the behaviors of Engineered Nanoparticles differ noticeably from those of their bulk (non-Nanoparticles) counterparts (Auffan et al., 2009).

Since the late 1990s, a large number of articles dealing with the application of engineered nanoparticles in the fields of medicine, industry and electronics have been published (Grillo et al., 2015). For example, the synthesis of magnetic nanoparticles was achieved through various routes for application towards biomedical imaging over the past decade (Laurent et al., 2008). Similarly, nanomaterials were also actively employed in various fields of environmental applications (sorbents, antibacterial agent dye-degradation, and eco-friendly fertilizers).(Das et al., 2016).

Therefore, a detailed compilation of these reports would be helpful in identifying important areas for contemporary and future researchers. In a broad sense, engineered nanoparticles comprise a wide range of

synthesized materials such as carbon nano-tubes. (CNTs), carbon dots, epoxy resin-coated CNTs, polymer-coated Ag, super magnetic iron oxide nano-particles (SPION), mesoporous silica particles, catalytic metals, metal oxides, quantum dots, dendrimers, nanofilms, nanofibers and composite nanotechnology -particles (see Table 1 for classification). The properties of engineered nanoparticles are usually influenced by their particle size; For example, nano-sized ZnO has a different rate of reaction, adsorption capacity, and redox state compared to bulk ZnO particles. Similarly, the transition temperature of ferromagnetic particles ($MnFe_2O_4$, $MgFe_2O_4$, etc.) varies significantly according to size (Tang et al., 1991; Chen and Zhang, 1998). Therefore, much effort has been made to alter the physico-chemical properties of engineered nanoparticles such as size, shape and surface charge to enhance their reactivity, strength and electrical properties (Schekel et al., 2010).
In addition engineered nanoparticles are widely used in manufacturing industries such as pharmaceutical, electronics, cosmetics, diagnostic imaging, photothermal therapy, nucleic acid delivery, catalysis and materials science, environmental remediation, and clean energy generation (Guerrero et al., 2012; Naahidi et al., 2013). Many engineered nanoparticles based products such as implantable devices, antimicrobial commercial products, photo luminescent materials and semi-conductors are also available in abundance in the global market (Scheckel et al., 2010; Padmavathy et al., 2012). Over a period of the past few years, the global market value of engineered nanoparticles is expected to grow substantially, reaching approximately US$30 billion by the end of 2020 (Wang et al., 2013). A global market survey in 2013 also revealed that the production of various types of engineered nanoparticles would cross a margin of 350,000 tonnes in 2016, which turned out to be true.

2. Nature and Type

Engineered nanoparticles are derived from nano-materials that are designed and synthesized to enhance a variety of properties (Klein et al., 2008), including mechanical, catalytic, optical, and electrical conductivity. Different types of engineered nanoparticles have been described based on their morphology, as shown in Table 1. Based on synthesis precursors and processes, there are a large number of existing engineered nanoparticles derivatives:

I. Engineered inorganic nanoparticles i.e. zero-valent metals such as Fe, Ag, and Au and metal oxides.
II. Engineered organic nanoparticles, carbon nanotubes (CNTs) and Buckminster fullerenes.
III. Engineered polymer nanoparticles, polyvinyl pyrrolidone (coated Ag NPs, TiO_2, ZnO), PVP, and PEGcoated magnetic polymers.
IV. Various types of nanoparticles such as quantum dots, dendrimers, and graphene nano-foils, etc. (Novak and Bukeli, 2007).

2.1 Engineered Inorganic Nanoparticles

Engineered inorganic nanoparticles cover a wide range of substances, including elemental (zero-valent) metals, metal oxides and metal salts (Table 1). The initial techniques available for these nanoparticles include chemical reduction, irradiation, electrochemical reaction, hydrothermal, solvo-thermal reduction, and photochemical reduction (Li et al., 2015). Many of these engineered inorganic nanoparticles, including ZnO, FeO, SiO_2, CeO_2, and TiO_2, fall into frequently used materials because of their distinctive photocatalytic properties. Elemental metals of nano-metric dimensions such as Ag, Au, Fe, Cu, Pt, Pd, Ni, and Co are widely used for antimicrobial, optical, catalytic, electronic, and sensing purposes as well as doping agents. Different types of nano-metals such as Au, Cu, Si, and Co are commonly used as conductors and semiconductors. Metal oxide engineered inorganic nanoparticles are routinely used in various industries such as paints, cosmetics and plastic products as rubber additives, catalytic converters, biomedical imaging, photovoltaic cells, components of sensors and for environmental remediation (Mittal et al., 2013).

2.2 Engineered Organic Nanoparticles

The organic nanoparticles group includes carbonized nano-materials and nanosheets. One of the major members of this group is the fullerenes, a class of engineered nanoparticles with broad sp2 carbon atoms arranged in fused benzene rings. These engineered nanoparticles have exceptional electrical, chemical and physical properties (Mouter and Elimelek, 2008). Initially Kroto et al. (1985) synthesized a highly stable C60 structure from graphite sheets by laser irradiation. He named it fullerene by suggesting a truncated icosahedron shape of C 60. Subsequently, there have been reports of multi-layer structures containing the 28e1500 C atomic diameter was 8.2 nm (Sano et al., 2002). Fullerenes are mainly used as thin films in electro-optical devices and drug delivery systems (Bossi et al., 2003). Due to the pristine fullerenes showing low water solubility, a considerable number of C60 derivatives containing ionized capable or hydrophilic groups have been synthesized (Wudl, 2002). Generally, conventional C60 clusters are formed by dissolving pristine bulk C60 in various organic solvents (Fortner et al., 2005). When C60 is dissolved in water with a balanced pH via vigorous mixing, nano C60 aggregates are formed (Brent et al., 2005; Labile et al., 2006). A typical nanocrystal C60 carries a strong negative charge due to surface hydrolysis of electrons from organic solvent transfer and its apparent electron accepting properties (Fortner et al., 2005). Similarly CNTs are also another allotrope of carbon with a distinctive cylindrical shape that is classified structure-wise as single-, double-, or multi-walled CNTs. Based on the synthesis separation technique and the cleaning technique adopted, the various applications of CNTs (Nyogi et al., 2002) widely include electronics, optics and other fields of physics (Bianco and Prato, 2003). (Table 1).

2.3 Engineered Polymeric Nanoparticles

Engineered polymeric nanoparticles are synthesized by reacting multiple elements with organic polymers for general applications in the medical field especially drug delivery (Fare et al., 2011) (Table 1). Polymerization cascade synthesis, micro-emulsion, surfactant-free emulsion, interfacial emulsion, to synthesize specific types of engineered polymeric nanoparticles by modifying their size, surface charge, morphology and structure based on their intended use (Auffan et al., 2009) , can be achieved using sono-chemical, chemical reduction, oil in water emulsion or sol-gel synthesis. (Padrova et al., 2016). Among engineered polymeric nanoparticles, magnetic nanoparticles play an extremely important role in various biomedical applications. They are synthesized by reacting metal precursors as a reducing agent and monomer. Their properties and applications are mainly governed by their size and surface-to-volume ratio (Rao et al., 2015). Interestingly, most of the transition metals such as Fe, Co, Fe, Pt, Cu, Ni are used in this process as a synergistic nano-hybrid due to their magnetic properties and biocompatibility.

2.4 Miscellaneous nanoparticles

A group of semiconductor nanocrystals called quantum dots that have a reactive core to control their optical properties (Farrey et al., 2011). Graphene nano-foils are another carbon-based nanomaterial of interest that is composed of a series of superimposed layers of a hexagonal network of atoms. Modifications in the synthesis process and fabrication of graphene nano-foil structures have resulted in its wide application in anticorrosive electrodes and conductors used in modern electronic engineering (Vlassiouk et al., 2011). Dendrimers such as nano-polymers are efficient water-soluble chelators (Xu and Zhao, 2005, 2006).

Metals and non-metals used to make semiconductors exhibit properties between metals and non-metals and are therefore found in various applications in the literature due to this property (Khan et al., 2017). Semiconductor nanoparticles have wide bandgaps and their properties have been shown to change significantly with their tuning. Due to these properties, they are proven to be very superior to photo-catalysis, optics and electronic devices. A variety of semiconductor nanoparticles have been found to be exceptionally efficient in water splitting applications due to their suitable bandgap and bandage position (Hisatomi et al., 2014). She goes. Ceramic nanoparticles are inorganic nonmetallic solids synthesized through heat and gradual cooling and can be found in amorphous, polycrystalline, dense, porous or hollow forms (Sigmund et al., 2006). Therefore, such nanoparticles are receiving a lot of attention of researchers due to their use in various applications such as catalyst, photo catalysis, photo degradation of dye, and imaging applications. (Thomas et al., 2015).

2.5 Synthesis of Nanoparticles

A variety of methods have been used for the synthesis of nanoparticles, these methods are broadly divided into two categories: (1) bottom-up approach and (2) top-down approach (Wang and Xia, 2004).). These approaches are further divided into different subclasses depending on the operation, response status and protocol adopted.

3. Characterization of Nanoparticles

Various characterization techniques have been used to study and analyze various physico-chemical properties of nanoparticles. These include techniques such as X-ray diffraction, X-ray photoelectron spectroscopy, infrared, SEM, TEM, Brunauer–Emmett–Teller, and particle size analysis.

3.1 Morphological characterization

As morphology always influences most of the properties of nanoparticles, the morphological characteristics of nanoparticles are always of great interest. Different characterization techniques are used for morphological studies, the most important of which are microscopic techniques such as polarized optical microscopy, SEM and TEM.

3.2 Structural characterization

Structural characteristics are of utmost importance and primary for the study of the structure and nature of bonding materials, which provide a variety of information about the bulk properties of the subject material. XRD, energy dispersion X-ray, XPS, IR, Raman, BET, and zeta size analyzers are common techniques used to study the structural properties of nanoparticles.

3.3 Particle size and surface area characterization

Similarly various techniques like SEM, TEM, XRD, AFM, etc. can be used to estimate the size of nanoparticles, among which SEM, TEM, XRD and AFM are better known about particle size (Kestens et al., 2016). Thoughts can be given, but the zeta potential size analyzer can be used to find the size of nanoparticles at a very low level.

3.4 Optical characterization

Optical properties are of great importance in photocatalytic applications and, therefore, photochemists gain a good knowledge of this technique to reveal the mechanisms of their photochemical processes. These characterizations are based on the well-known Bierlambert law and basic light principles (Swinhardt, 1962). These techniques provide information on the absorption, reflectance, luminescence and phosphorescence properties of Nanoparticles.

4. Properties of Nanoparticles

The different properties of nanoparticles such as large surface area, mechanically strong, optically active and chemically reactive tendency make them unique and suitable applicators for a wide variety of applications. Some of their important qualities are discussed here –

4.1 Thermal properties

It is a well-known fact that metallic NPs have higher thermal conductivity than those in solid form. For example, the thermal conductivity of copper at room temperature is about 700 times higher than that of water and about 3000 times higher than that of engine oil. Oxides such as alumina (Al_2O_3) also have a higher thermal conductivity than water. Therefore, liquids containing suspended solid particles are expected to exhibit significantly enhanced thermal conductivity relative to conventional heat transfer fluids. Nanofluids are produced by dispersing nanometric scale solid particles in a liquid such as water, ethylene glycol or oil. Nanofluids are expected to exhibit superior properties relative to conventional heat transfer fluids and liquids containing micro-sized particles. Since heat transfer occurs at the surface of the particles, it is desirable to use particles with a large total surface area. The larger total surface area also enhances the suspension stability (Lee et al., 1999). Recently it has been demonstrated that nanofluids consisting of CuO or Al_2O_3 NPs in water or ethylene exhibit advance thermal conductivity (Cao, 2002).

4.2 Mechanical characteristics

The unique mechanical properties found in nanoparticles allow researchers to work in many important fields such as tribology, surface engineering, nanofabrication and nanofabrication. Various mechanical parameters such as elastic modulus, stiffness, stress and strain, adhesion and friction can be surveyed to know the precise mechanical nature of the nanoparticles. In addition to these parameters surface coating, coagulation and lubrication also play an important role in the mechanical properties of nanoparticles (Guo et al., 2014). Nanoparticles exhibit different mechanical properties as compared to microparticles and their bulk materials such that under a lubricating or enhanced contact, the stiffness between the nanoparticle and the contact outer surface deforms when the interaction pressure is large enough.

This important information can reveal how the nanoparticles perform in the contact state, which is important for proper control over the mechanical characteristics of the nanoparticles and their interaction with any type of surface to enhance the surface quality and remove the material. Useful results in these areas generally require a deep insight into the basics of the mechanical properties of nanoparticles, such as elastic modulus and stiffness, motion laws, friction and interfacial adhesion, and their size-dependent characteristics. (Guo et al., 2014).

4.3 Magnetic properties

A wide range of magnetic nanoparticles remains of great interest to investigators, including heterogeneous and homogeneous catalysis, biomedicine, magnetic fluids, data storage magnetic resonance imaging, and environmental treatments such as water purification. The literature has shown that nanoparticles have the best performance when the size is at the critical value i.e. 10–20 nm (Rees and Houten, 2005). Magnetic properties arise from uneven electronic distribution in nanoparticles that also depend on synthetic protocols and the use of various synthetic methods such as solvothermal (Qi et al., 2016), co-precipitation, micro-emulsion, thermal decomposition, and flame spray synthesis can be done for their preparation. At such a small scale the magnetic properties of nanoparticles effectively dominate, which makes these particles invaluable and can be used in a variety of applications (Favre and Bennett, 2016).

4.4 Electronic and Optical Properties

The optical and electronic properties of nanoparticles are interpreted in such a way that they are largely dependent on others. Noble metal nanoparticles have size-dependent optical properties and exhibit a strong UV-visible extinction band that is not present in the spectrum of the bulk metal.

This excitation band results when the incident photon frequency is stable with the collective excitation of the conduction electrons and is known as localized surface plasma resonance. Localized surface plasma resonance excitation results in wavelength selection absorption with extremely large molar excitation coefficient resonance ray light scattering efficiency equivalent to ten fluorophores and enhanced local electromagnetic fields near the nanoparticle surface that enhance spectroscopy.

5. Applications of Nanoparticles

Nanoparticles are currently used in various applications. Some of these important applications are given below**.**

5.1 Applications in mechanical industries

Through their excellent Young's modulus, stress and strain properties, and their mechanical properties, nanoparticles can be used in a variety of applications in the mechanical industries, particularly in coating, lubricants and adhesives. Furthermore, this special property may be useful for obtaining mechanically robust nano-devices for various purposes. Ethnic properties can be controlled at the nanoscale level by embedding the nanoparticle in a metal and polymer matrix to increase its mechanical strength because the rolling mode of the nanoparticle in the lubricated contact area provides very low friction and wear. In addition, nanoparticles provide good sliding and anti-polluting properties, which can also result in reduced friction and wear, and therefore increased lubrication effects (Guo et al., 2014). Coating of nanoparticles in materials can lead to various mechanically reinforcing characteristics, as it improves toughness and wear resistance. Alumina, titania and carbon based NPs successfully demonstrated to achieve desirable mechanical properties in coatings. (Kote et al., 2016)

5.2 Application in construction and materials

The properties of nanocrystalline materials deviate from related bulk materials in a size-dependent manner, providing very interesting materials for physics. The newly fabricated nanoparticles exhibit physico-chemical characteristics that possess unique electrical, mechanical, optical and imaging properties and are seen in some extremely important applications within the medical, commercial and ecological sectors (Todescato et al., 2016). Nanoparticles are based on the characterization, designing and engineering of organic as well as non-organic structures at 100 nm, which show unique and novel functional properties. Recognizing the potential benefits of nanotechnology, marketable products are already being mass-produced by many manufacturers, documented at high and low levels, important in the microelectronics, aerospace and pharmaceutical industries (Weiss et al., 2006).). Health fitness products by far the largest category in nanotechnology consumer products, followed by the electronic and computer category as well as the home and garden category.

Nanotechnology is currently seen as the next revolution in many industries including food processing and packaging. Recently resonant energy transfer systems consisting of organic dye molecules and nanoparticles of noble metals have attracted great interest in biophotonics as well as in physics (Lei et al., 2015). The presence of nanoparticles is becoming increasingly common in commercially available products and in various routine applications.

5.3 Applications in Energy Harvesting

As current studies warn of the limitations and scarcity in the coming years due to the non-renewable nature of fossil fuels, scientists are changing their research strategies to generate renewable energy from readily available resources at an affordable cost. Continuing in this area, they found that nanoparticles are best for this purpose due to their large surface area, optical behavior and catalytic nature. They are widely used to generate energy from photoelectron chemical and electrochemical water splitting, especially in photocatalytic applications (Avasare et al., 2015; Ning et al., 2016). In addition to the splitting of water, electrochemical CO2 reduction into fuel precursors, solar cells and piezoelectric generators also offered advance options for generating energy (Gavande et al., 2016). Nanoparticles are used to reserve energy in various forms at the nanoscale level in energy storage applications (Sagadevan, 2015). Also nanogenerators have been created using nanoparticles, which can convert mechanical energy into electricity using piezoelectricity, an unconventional approach to generate energy (Wang et al., 2015).

5.4 Applications in Electronics

Printed electronics offer attractive alternatives to traditional silicon technologies and low-cost efficiencies, large-area electronics for flexible displays, sensors. In the past years printed electronics with various functional inks containing nanoparticles such as metallic nanoparticles, organic electronic molecules, CNTs and ceramic nanoparticles has accelerated as a mass production process for new types of electronic device (Kosmala et al., 2011). The distinctive structural, optical and electrical properties of one-dimensional semiconductors and metals make them major structural blocks for the future of electronic, sensor and photonic materials (Shallen et al., 2016).

A good example of a synergy between scientific discovery and technological development is the electronics industry, in which the discovery of new semiconductor materials resulted in the manufacture of diodes, then transistors, and eventually miniature chips (Cushing et al., 2004) from vacuum tubes.

5.5 Application in medicines and drugs

Nanotechnology represents an increasingly important material in the development of devices that can be used in many physical, biological, biomedical and pharmaceutical applications (Nikalje, 2015). Every branch of pharmaceutical manufacturing has shown maximum interest in nanoparticles as their ability to deliver drugs across dosage ranges is found to often result in increased therapeutic efficiency of drugs with lesser side effects and better patient compliance (Alexis et al., 2008). The selection of nanoparticles is based on the optical properties of the nanoparticle to achieve efficient contrast for biological and cell imaging applications as well as for photo thermal therapeutic applications. The development of hydrophilic nanoparticles as drug carriers in the past few years has faced a significant challenge. Among various approaches, polyethylene oxide and polylactic acid nanoparticles have appeared as very promising systems for intravenous administration of drugs (Calvo et al., 1997).

5.6 Application in the automobile sector

Studies on metal-support interactions from the point of view of advanced synthesis and development of engine control technology may play a significant role in the further development of catalysts for automobile exhaust control because the interactions between metal and oxide supports, the so-called metal-support interactions, of particular importance in heterogeneous induction. Pd-based automotive exhaust control catalysts in this area, especially Pd-based three-way catalysts, have received considerable research attention due to the predominant oxidation activity of hydrocarbons and carbon monoxide, as well as excellent thermal stability. The dispersion, chemical state and thermal stability of Pd species, which are important for catalytic performance, are closely associated with the interactions between metal nanoparticles and their supporting matrix (Yidan Cao 2022).

Commercial lithium-ion batteries are unable to meet the fast charging requirement of electric vehicles due to the poor rate performance of anode materials (graphite and $Li_4Ti_5O_{12}$). Thus, it is highly desirable to develop novel anode materials in lithium-ion batteries to address the issue of long charging times. In this work, perovskite strontium vanadate nanoparticles as anode material for lithium-ion batteries are prepared by the gel-sol method and their fast charging performance is studied for the first time that exhibit a safe lithiation capability

(Yafeng Zhang, 2022). Special attention has been paid to nanoparticles of platinum group elements, bringing to light the nanoparticles of noble metals and their effects on plants and related microorganisms, which can be considered as neglected pollutants, as they are released from vehicular catalysts (Lenka Burketova, 2022).

The high NOx emissions from biodiesel fueled engines is a major challenge in the mass adoption of biodiesel and as a solution the production of second generation biodiesel, its characterization and biodiesel-diesel mixture in diesel engines using water and CeO2 nanoparticles. The application was studied. The addition of CeO2 nanoparticles with the emulsion fuel resulted in an improvement in the in-cylinder peak pressure, while decreasing the peak pressure rise rate compared to diesel. In essence the biodiesel-diesel mixture dispersed with water and CeO2 nanoparticles could be a promising alternative fuel for low-emission diesel engines (Neeraj Kumar, 2022).

In catalytic converters to control automobile exhaust pollution, a variety of catalysts have been investigated in catalytic converters, proving to be the most efficient, active, low cost, readily available, to oxidize CO to copper among non-noble metals (S. Dey, 2020). Full use of light energy combined with photo catalysis technology, for the purification of harmful pollutants from exhaust gases, including the preparation of cerium-bismuth solid solution materials. Where the optimum ratio of cerium-bismuth to solid slurry material was achieved through the use of exhaust gas purification. Furthermore, under ultraviolet light conditions, the purification efficiency of the cerium-bismuth solid solution material was found to be satisfactory for hydrocarbons, carbon oxides, and carbon monoxide and nitrogen oxides. (Shengchao Cuia, 2020). Nanomaterials have a unique property of adsorbing many contaminants present in the air. The same properties of nanoparticles are used in environmental applications of nanotechnology as air pollution prevention as Nano adsorbents, Nano catalysts, Nano filters and Nano sensors. Conversely, the existence and nano size of some nanomaterials can have harmful effects on the health of animals and humans as well as the environment (Haleema Saleem, 2022).

Ta2O5 nanoparticle which is a wet chemical-synthesized of ultrafine nature and suitable for NOx control. The catalytic performance of Ta2O5 nanoparticles under Ultra Violate –Vis irradiation at room temperature in the direction of photo degradation of nitrogen oxides showed that compared to commercial TiO2, it is traditionally highly suitable for NOx degradation, such as-synthesized The nanoparticle specific surface area of Ta2O5 provides NOx treatment with minimally toxic NO2 and excellent stability under Ultra Violate irradiation (Vijay Khanal, 2021).

The global environmental and energy crisis as a result of the automotive industry consuming large amounts of fossil fuels and fuel cell electric vehicles are promising alternatives in the continuing transition to clean energy. From the perspective of the automobile industry, recent developments in fuel cell technologies and existing barriers hindering the commercialization of fuel cell electric vehicles such as fuel cell stack production, high costs of maintenance, inadequate hydrogen supply facilities, inadequate reliability, slow cold start, safety concerns and Future technological developments and commercialization can be pursued by focusing on solving problems such as the immature energy management systems of fuel cell electric vehicles (Yang Luo, 2021).

The after-life waste from low-density polyethylene products is mostly solid waste in most dumpsites, which contributes to environmental impacts. The foul odor of eggshells is a threat to human and animal health. Composites were developed using recycled low-density polyethylene and eggshell nanoparticles. They were evaluated structurally and mechanically. The improvement in the load bearing capacity of low-density polyethylene was confirmed due to the incorporation of eggshell nanoparticles. Maximum tensile strength was noted at 10% eggshell nanoparticle additions in low-density polyethylene, which is comparable to the maximum enhancement. Therefore, the future use of the developed low-density polyethylene and 10% eggshell nanoparticle composites is established (Adekunle Bello).

6. Conclusion

This review paper presents a detailed description of nanoparticles, their types, synthesis, characterization, properties and applications, based on various studies conducted over the past decade. Through various characterization techniques such as SEM, TEM and XRD, it was revealed that the nanoparticle sizes range from a few nanometers to 100 nm. Due to their small size, nanoparticles have a large surface area, which makes them suitable for various applications, as they are used to control pollution of the environment. In addition, optical properties are also prominent in that shape, which further increases the importance of these materials in photocatalytic applications. Synthetic techniques can be useful to control the specific morphology, size and magnetic properties of nanoparticles. At present, the use of nanotechnology in the fertilizer sector will result in production benefits and pollution reduction due to the reduction of chemical fertilizers in the environment. Overall, the use of nanoparticles is being recorded rapidly in various areas with effectiveness, especially it can be said that the use of nanoparticles in environmental pollution will prove to be justified**.**

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