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A Review Article on Nanoparticle

Jatin Kumar*, Ankush Uppal, Neeraj Bhandari

Arni University

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ABSTRACT

Due to their small size and high surface-area-to-volume ratio, nanoparticles—which can range in size from 1 to 100 nanometers—display special physical and chemical characteristics. These characteristics, which frequently deviate greatly from bulk materials, allow for a wide range of applications in industries including as electronics, energy, environmental science, and medical. By delivering therapeutic substances directly to damaged cells, nanoparticles are being created in medicine for targeted drug delivery, which reduces adverse effects and increases treatment effectiveness. Because of their size, they can pass through biological barriers and even react to certain triggers by releasing medications. Furthermore, because nanoparticles can improve contrast in imaging methods and facilitate early illness detection, they are being investigated for imaging and diagnostic applications. Nanoparticles help electronics miniaturize, which makes it possible to create devices that are faster, smaller, and use less energy. For example, quantum dots are nanoscale semiconductors with tunable optical characteristics that find use in solar cells, displays, and medical imaging. Nanoparticles can be used in environmental applications such as remediation and pollution control. As scientists learn more about the behavior of nanoparticles and work to harness their potential while resolving safety and ethical issues pertaining to biological and environmental interactions, the area of nanotechnology is expanding.

INTRODUCTION

Nanotechnology has gained huge attention over time. The fundamental component of nanotechnology is the nanoparticles. Nanoparticles are particles between 1 and 100 nano-meter in size and are made up of carbon, metal, metal oxides or organic matter[1]. The nanoparticles exhibit a unique physical, chemical and biological properties at nanoscale compared to their respective particles at higher scales. This phenomenon is due to a relatively larger surface area to the volume, increased reactivity or stability

***Corresponding Author:** Jatin Kumar
Address: *Arni University.*
Email : Jatinbhagat890@gmail.com

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in a chemical process, enhanced mechanical strength, etc.[2] These properties of nanoparticles has led to its use various applications. The nanoparticles differ from various dimensions, to shapes and sizes apart from their material[3]. A nanoparticle can be either a zero dimensional where the length, breadth and height is fixed at a single point for example nano dots, one dimensional where it can possess only one parameter for example graphene, two dimensional where it has length and breadth for example carbon nanotubes or three dimensional where it has all the parameters such as length, breadth and height for example gold nanoparticles. The nanoparticles are of different shape, size and structure. It is spherical, cylindrical, tubular, conical, hollow core, spiral, flat, etc. or irregular and differ from 1 nm to 100 nm in size. The surface can be a uniform or irregular with surface variations. Some nanoparticles are crystalline or amorphous with single or multi crystal solids either loose or agglomerated[4]. Numerous synthesis methods are either being developed or improved to enhance the properties and reduce the production costs. Some methods are modified to achieve process specific nanoparticles to increase their optical, mechanical, physical and chemical properties. A vast development in the instrumentation has led to an improved nanoparticle characterization and subsequent application. The investment for nanotechnology research by the federal government in the United States will be approximately $1 billion, in Western Europe about $600 million, in Japan $800 million, in Korea $200 million, and other countries totaling about $800 million in 2005. This is a 7-fold increase in nanotechnology research and funding since 1999. Major emphasis is also being put on ensuring broader societal improvements and sustainable development[5].

Nanotechnology has great potential in improving air, water, and soil quality in the environment. It can improve detection and sensing of pollutants and help in the development of new technologies for remediation. Understanding the formation and growth dynamic processes of nanoparticles (e.g., in the combustion system) allows the development of efficient methodologies for minimizing the formation of pollutants in the first place and for reducing their emissions. Although nanotechnology has the potential to improve environmental quality, there are concerns that it can also lead to a new class of environmental hazards[6].Such concerns are associated with practically all new technologies, and they need to be addressed upfront. With proper attention, careful research, and incorporation of findings at an early stage, the safety of nanotechnology can be ensured[7].

Nanomaterials Classifications

- **Dimensionality**

From the point of view of their dimensionality, nanomaterials can be classified as nanomaterials with one, two, and three dimensions within the nanoscale[8].Materials with one dimension in the nanoscale are also called very thin filmsor surface coatings attached on a substrate usually made from a different material. Nanomaterials with two dimensions in the nanoscale are either nanoparticles attached onto a substrate, porous thin films with pores in the nanoscale, or free long aspect ratio nanoparticles, wires, or tubes. Finally, nanomaterials with three dimensions within the nanoscale can be fixed small nanostructures on a substrate, membranes with nanopores on a substrate, or nanoparticles. In this chapter one will focus mainly on nanoparticles[9].

- **Nanomaterials Composition**

According to their composition, nanoparticles can be made of a single material, compact or hollow. Nanomaterials can also be comprised of two or more materials that can be as coatings, encapsulated, barcode, or mixed[10].

- **Nanomaterials Uniformity and Agglomeration State**

According to their uniformity, nanoparticles can be classified as isometric and inhomogeneous. From the point of view of their agglomeration status, nanoparticles can be dispersed or agglomerate. Their agglomeration state depends on their electromagnetic properties, such as surface charge and magnetism. When in a liquid, their agglomeration depends on their surface morphology and functionalization which can confer it either hydrophobicity or hydrophilicity[11].

Physicochemical Properties of Nanoparticles

The most important physicochemical aspects of nanoparticles are:

- Composition and surface composition.
- Crystalline phase.
- Particle size distribution.
- Agglomeration/aggregation.
- Shape.
- Specific surface area.
- Roughness/Porosity.
- Water solubility/dispersibility or hydrophobicity/hydrophilicity.
- Zeta potential or surface charge.
- Surface chemistry.
- Catalytic/Photocatalytic activity.
- Magnetic properties.
- Optical properties

Polymerization method

In this method, monomers are polymerized to form nanoparticles in an aqueous solution. Drug is incorporated either by being dissolved in the polymerization medium or by adsorption onto the nanoparticles after polymerization completed. The nanoparticle suspension is then purified to remove various stabilizers and surfactants employed for polymerization by ultracentrifugation and re-suspending the particles in an isotonic surfactant-free medium. This technique has been reported for making polybutylcyanoacrylatenanoparticles[12,13]. Nano-capsule formation and their particle size depends on the concentration of the surfactants and stabilizers used[14].

Coacervation or ionic gelation method

Much research has been focused on the preparation of nanoparticles using biodegradable hydrophilic polymers such as chitosan, gelatin and sodium alginate. Calvo and co-workers developed a method for preparing hydrophilic chitosan nanoparticles by ionic gelation[15,16]. The method involves a mixture of two aqueous phases, of which one is the polymer chitosan, a di-block co-polymer ethylene oxide or propylene oxide (PEO-PPO) and the other is a polyanion sodium tripolyphosphate.In this method, positively charged amino group of chitosan interacts with negative charged tripolyphosphate to form coacervates with a size in the range of nanometer. Coacervates are formed as a result of electrostatic interaction between two aqueous phases, whereas, ionic gelation involves the material undergoing transition from liquid to geldue to ionic interaction conditions at room temperature[17].

Few Uses of Nanoparticles

1.Semiconductor Nanoparticles and Their Polymer Composites

During the past decade, tremendous progress has been made in the fabrication and understanding of three-dimensional confined semiconductor clusters (i.e., quantum dots,nanoclusters)[18].Our own efforts have evolved from work using a zeolite to template clusters of CdS[19],through a range of sol-gel encapsulated clusters[20],to free-standing, organically capped clusters[21]or layers[22]of a wide variety of semiconductors. Most of our own studies, and those of others, have focused on the spectroscopic, photochemical, photocatalytic, and nonlinear optical (NLO) properties of these materials[23].For example, single- and bi-layered perovskite materials derived from PbI_2 and alkylammonium ions were prepared and characterized in an attempt to generate isolated layers of the PbI_2 semiconductor as 2-dimensional nanosheets and to explore their remarkable excitonic properties and implied strong resonant third-order NLO behavior[24].

2.Other Polymer/Inorganic Nanocomposites

In addition to the optically and electronically active composites described above, another aspect of polymer/ inorganic composites is concerned with polymeric compositions where the polymer's mechanical properties are markedly altered by small quantities of the inorganic nanophase.

Two examples are

1. our work on polyamides with a fullerene component.
2. The introduction of exfoliated inorganic clay materials into polymers of various sorts, which improve the stiffness and barrier properties of the resultant films.

This latter aspect is dealt with in detail elsewhere in this issue.Since the isolation of fullerenes by Kratschmer [25]the chemistry surrounding fullerenes has been the focus of intense research. Fullerenes have been studied per se and in combination with other substances with the goal of modifying the properties of the resulting compositions. These molecules are beautiful examples of objects exhibiting Gaussian curvature[26](a topic to which we will return in the second part of this article), and the interaction of these objects with the surrounding matrix can lead to interesting property modification by essentially crosslinking the polymer to the molecule surface. We have described the use of fullerenes to provide improved photoconductive compositions from both photoconductive and non-photoconductive polymers[27].

3.Nanophase Materials as Catalysts

Bulk inorganic/organometallic catalyst materials can become nanophase materials by being [a]supported[o] onto what are typically oxide matrices. Often, the very act of supporting the active phase causes a large increase in surface area, which translates into higher activity. This is far from the only effect, however, and, in many cases, completely different reactivity begins to become manifest as the particles of the catalyst phase extend down to the nanoparticle regime. This has been well known in the noble metal catalysis arena where highly dispersed Ru, Pd, Pt, Rh, etc. can all perform catalytic transformations that the more bulklike metals cannot[28].AlF_3 is an important CFC-alternatives catalyst. We have explored alternate routes to AlF_3, starting from a number of organic cation salts of the AlF_4 ± anion, which were prepared as organic solvent soluble species[29]. A similar approach using discrete clusters of vanado phosphates has allowed us entry to highly desirablesupported butane oxidation catalysts such as vanadium pyrophosphate and vanadium phosphite[30].The idea of using discrete molecular precursors to complex catalyst or electronic materials phasesappear simple yet provides a powerful approach to generation of supported nanophase versions of those phases[31].

CONCLUSION

Nanoparticles' distinct physicochemical characteristics—such as their large surface area, adjustable size, and increased reactivity—represent a significant breakthrough in a number of sectors. Their growing use in electronics, energy storage, environmental cleanup, and medicine demonstrates the adaptability of nanoscale materials. Notwithstanding their enormous promise, issues like stability, toxicity, environmental effect, and large-scale production need to be resolved. Understanding long-term biological and ecological repercussions, creating sustainable production techniques, and guaranteeing safe handling procedures should be the top priorities of future research. Nanoparticles are positioned to play a revolutionary role in tackling some of the most important scientific and technology issues facing the globe as regulatory and technological environments change.

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