A Review on Basics of Nanoparticles (Historical Background, Classification, Synthesis, Applications, Future Development)

Dushyant Singh[1], Astha Sharma[2]
[1, 2] Dept of Chemistry
[1, 2] Ramjas College, University of Delhi

Abstract- *Nanoparticles, nanoscience, nanotechnology are all interrelated terms. Nanoparticles are particles with extremely small sizes: 1-100 nm in diameter. They have been used for various applications such as in drug delivery, agriculture, display and many more. The article also throws light on the classification of nanoparticles, the synthesis, green methods and chemical methods, with the green method being more popularized. Further, future developments in nanotechnology have also been discussed.*

Keywords- Dichroism, Miniaturizing, Nanometer, Super capacitor.

I. INTRODUCTION

Nanoparticles are defined as particles that have at least one dimension in between 1–100 nm. Nanoparticles not only differ in their material but as well with their dimension, shape and size.[1]

These particles lead us the way to Nanoscience and Nanotechnology. Nanoscience is inclined towards the study of structures and properties of these ultra-small particles. Nanotechnology cares more about the design, production, characterization and applications of these particles. [2]

Nanoparticles have been used in the past since ancient times, are being used today for a variety of applications and will be an emerging field in the future.

II. HISTORY OF NANOPARTICLE

Nanotechnology is a legacy that Romans started in the fourth century A.D. with the invention of coloured glass (Lycurgus Cup), which shows the phenomenon of dichroism. A similar effect was seen in late medieval church windows due to the fusion of Au and Ag nanoparticles into the glass. Inthe 9th-17th century,"lustres" containing nanoparticles were developed in the Islamic world then followed by Europe with Cu and Ag nanoparticles. During the 16th century, Italians also experimented with nanoparticles in which they created Renaissance pottery inspired by the Ottoman technique. During the 13th–18th centuries, to produce "Damascus" sabre blades, cementite nanowires and carbon nanotubes were used to provide strength, resilience, and the ability to hold a keen edge. Then in 1857, Michael Faraday studied the properties of colloidal suspension of "Ruby" gold.[2]

In 1925, Richard Zsigmondy was chosen as the Noble Prize Laureate of Chemistry for proposing the concept of "nanometer", which was an industrial revolution. In 1965, Richard Feynman (The Nobel Prize Laureate of Physics) introduced the concept of manipulating matter at the atomic level. Almost 15 years after Feynman's lecture, a Japanese scientist, Norio Taniguchi, was the first to use "nanotechnology". The beginning of the 21st century saw an accelerated interest in the emerging fields of nanoscience and nanotechnology. [3]

III. CLASSIFICATION OF NANOPARTICLES

The nanoparticles are classified as:

A. Polymer nanoparticles

These are the organic-based polymeric nanoparticles. They are prepared from biocompatible and biodegradable polymers where the sizes lie between 10-1000 nm. As per the preparation methods, nanoparticles, nano-capsules or nanospheres are obtained. They are used extensively in targeted drug delivery and diagnosis. [4]

B. Metallic nanoparticles

These are prepared from metal precursors by chemical, electrochemical or by photochemical methods. They find their uses in research and analytical areas. Example include gold, silver nanoparticles. [5]

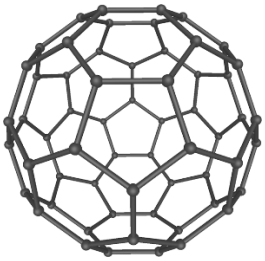
C. Metal oxide nanoparticles

Many metal elements can form a large number of oxide compounds. They can adopt a vast number of structural geometrics. They have used in fuel cells, microelectronic circuits etc. Examples include SnO_2, ZrO_2 etc. [6]

D. Carbon-based nanoparticles

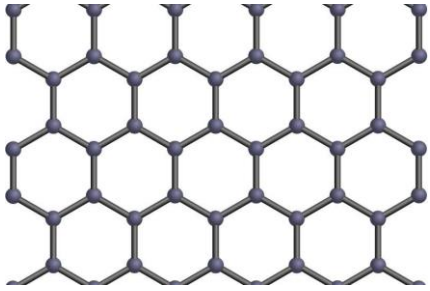
Carbon-based nanoparticles are entirely made of carbon and include materials such as:

1. **Carbon nanotubes** are perfectly straight tubules with diameters in nanometers, and they have excellent properties, close to ideal graphite fibre. They have used widely in flat panel displays, sensors, vacuum microelectronics etc. [7]
2. **Fullerenes** have total carbon composition. They find applications in antiviral activity and biological electron transfer. [8]



Fullerene [9]

3. **Graphene** is a single monolayer of graphite with carbon atoms arranged in a honeycomb-like structure. It has excellent electrical conductivity and is used in super capacitor. [10,11]

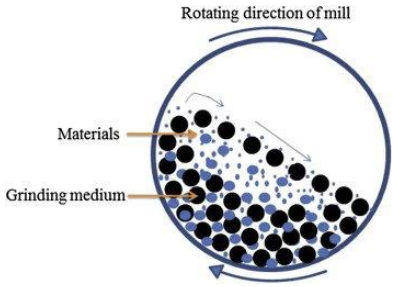


Graphene [12]

IV. APPROACHES FOR SYNTHESIS OF NANOPARTICLES

A. Top-down Approach

The top-down approach is based on bulk material miniaturizing. The solid material is broken down into smaller particles by applying external forces (thermal, chemical or physical processes). Though this approach cannot avoid imperfections, this technique is essentially helpful as per the cost considerations. This approach includes Ball Milling, Thermal Decomposition, Explosion Process, Lithography etc. [1]



Ball milling [13]

B. Bottom-Up Approach

The bottom-up approach involves the building of nanoparticles from smaller entities. Here, nanoclusters assemble up to form nanoparticles. Thus, this approach consists of moving up from the atomic scale to the nanoscale. This approach is essential when considerations are given to fewer defects and getter homogeneity. This approach includes Chemical Vapor Deposition, Pyrolysis, Sol-gel etc. [14,15]

V. METHODS FOR SYNTHESIS

A. Green Synthesis

Green synthesis of nanoparticles involves the use of non-hazardous and environmentally friendly reagents for synthesis. This method is advantageous to chemical synthesis as it eliminates the use of costly and toxic chemicals. The three main points in this synthesis regard to:

1. Selection of green solvent medium
2. Non-toxic Reducing agent
3. Non-toxic Stabilizing agent [15]

A classic example of this synthesis includes the synthesis of silver nanoparticles by Ocimum sanctum leaf extract. [16]

B. Chemical Synthesis

The chemical synthesis of nanoparticles involves inorganic or organic chemical solutions as reducing agents. Though it is a standard method for synthesis, it has various environmental and biological concerns.

A typical example of this synthesis includes the chemical reduction of silver nitrate solution by sodium citrate solution. [17]

VI. APPLICATIONS OF NANOPARTICLES

With their excellent potential, the nanoparticles find their uses in a variety of fields, with some discussed below:

1. An important application of nanotechnology is in medicine "Nano medicine". Nanoparticles can be used as biosensors, in genetic repair and targeted drug delivery. [18,19]

2. To meet fresh food demand, industries have utilized nanoparticles in food packaging. For example, Silver nanoparticles have been used to make AgNPs based antimicrobial food packaging. [20]

3. In agriculture, the addition of silicon nanoparticles improves plant growth and yield. [21]

4. Colloidal quantum dots have enabled QLEDs (Quantum dot Light Emitting Diode) to replace conventional Liquid Crystal Displays (LCD), providing greater performance. [22]

5. In the textile industry, the addition of nanoparticles increases the durability of the fabric and may add unique properties to the fabric. For example, addition of ZnO to fabric provides U.V. resistance. [23]

VII. FUTURE DEVELOPMENT

Nanotechnology has become a basis for industrial applications. For example, in pharmaceuticals, nanotechnology has had a profound impact on medical devices such as diagnostic biosensors, drug delivery systems etc. [3]

Nanotechnology is an emerging science that is expected to have rapid and strong future developments. Nanotechnology is predicted to have four distinct generations of advancement, and the world is currently experiencing the first or maybe the second generation of nanomaterial. [24]

The most effective future application of nanoparticles is in the medical field which can be a game-changer for the medical field. For example, Quantum dots are used in optical imaging, Super Magnetic Iron Oxide Nanoparticles are used in MRI for cancer detection and Polymer and Liposome based nanoparticles are used for drug and gene delivery used in cancer therapy and various diseases. [25]

Today, nanotechnology impacts human life every day and will continue to do that as nanotechnology has future potential way beyond than we can imagine.

VIII. CONCLUSION

Nanoparticles have fascinated the world with their remarkable properties. More work is being done to improve the efficiency and quality of these particles. In the current scenario, more focus is laid on the biosynthesis of nanoparticles to reduce cost and environmental impact. Nanotechnology has a much greater future to come.

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