International Journal of Engineering Research & Management Technology
ISSN: 2348-4039
Volume 9, Issue-1 Jan-Feb 2022
Email: editor@ijermt.org
www.ijermt.org

Nanomaterials: An Overview of Synthesis and Applications

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ABSTRACT

Nanomaterials comprise of a collection of particles with at least one dimension in the 1-100 nm range. The properties of bulk materials are unaffected by particle size and shape, whereas the properties of nanomaterials can be altered by modifying particle size and shape. Zero-dimensional, one-dimensional, or two-dimensional nanomaterials exist. 2D materials with a single dimension in the nano range appear as sheets, 1D materials with two dimensions in the nano range appear as filaments, and 0D materials with all three dimensions in the nano range appear as dots. Nanomaterials are characterized by high surface area, so that more number of atoms and molecules are exposed at the surface to enable rapid interaction between adjacent atoms and molecules, high flexibility and simplicity in functionalisation of the surface. This expands the applications of nanomaterials to include catalysis, sensing, additives, microelectronics, drug delivery, and cosmetics. Significant research employing nanomaterials has been conducted in the field of nanotechnology over the past few years. Due to the significant advancements made in a number of industries, including electronics, energy, medical, cosmetics, food engineering, telecommunications, and agriculture, nanotechnology is advancing quickly. As a result, nanomaterials are the foundation of nanotechnology. Due to their small size, nanomaterials have special optical, magnetic, electrical, and physical, reactivity, strength, surface area, sensitivity, and stability features. Surprisingly, the phase change occurs when bulk materials are converted into nanomaterials, which means that materials that were previously non-magnetic become magnetic at the nanoscale.

Key words : *Nanomaterials, microelectronics, nanotechnology*

INTRODUCTION

The meaning of the word 'nano' is nanos, which indicates a person of very low height or a very small object that is a dwarf. Consider that in an international system of units, the prefix nano is used to indicate part of a unit. For instance, a nanometer is a billionth of a meter or a millionth of a millimeter; a nano liter is a billionth of a liter or a millionth of a milliliter; and a nano is a billionth of a Kelvin. The prefix "nano" has found in the last decade an ever-increasing application to different fields of knowledge and is now a popular label for much of modern science; therefore, it is becoming increasingly common in the scientific literature.Size, which refers to the length scale from 1 to 100 nm, is the fundamental defining attribute of all nanoparticles, in which materials have at least a nanoscale dimension. Thus, according to refs. nanomaterials are substances that are between 1 and 100 nm in size, at least in one of the three dimensions and must be greater than 60 mm in terms of spherical surface area by volume.

Based on size, origin, structural configuration, pore diameters, and potential toxicity, nanomaterials can be divided into five major categories.Due to its unique properties, nanoparticle matter exhibits unique chemical, physical, and biological properties at the nanoscale compared to their respective particles at higher scales. Nano particulate matter is a distinct state of matter from the solid state, liquid state, gaseous state, and plasma state. In this dimension, their nanomaterials have distinctive optical, magnetic, and electrical properties. There are other ways to make nanomaterials, but the two basic approaches are bottom-up and top-down methods. Examples of top-down techniques include lithography, mechanical milling or ball milling, laser ablation, sputtering, electron explosion arc discharge, and thermal decomposition. Examples of bottom-up techniques include chemical vapor deposition

(CVD), sol-gel, spinning, pyrolysis, and biological synthesis. The field of study known as nanoscience is concerned with the characteristics of matter at the nanoscale, with a focus on the special, size-dependent characteristics of solid-state materials.

The field of study known as nanotechnology includes the synthesis, engineering, and application of nanomaterials. Due to the innovative and intriguing applications of nanomaterials for the next industrial generation, nanotechnology has attracted a lot of interest over time. Agriculture, biomedicine, electronics, energy, pollution abatement, food engineering, transportation, telecommunication, cosmetics, coatings, materials, and mechanical engineering are just a few of the industries that use nanomaterials.

Nanomaterials are now becoming important for the overall development of mankind. For example, to reduce the risk of global climate change and global warming in the first place, the only solution is to use green technology that works only using nanomaterials. Because it has been confirmed that the technology that uses nanomaterials is more effective than the technology that uses bulk materials. Secondly, nanomaterials are used to develop tools to diagnose and control the epidemic diseases that are happening all over the world. For example, in 2019, Covid-19, a disease that was killing many people in the world, was able to be diagnosed and controlled using nanomaterials. Also, it was possible to diagnose and treat the monkey pox disease that is currently happening in the world by using nanomaterials.[] In the future, it is expected that nano materials, nano science and nano technology will play a leading role in the development of the world. Therefore, it is necessary for everyone to have adequate knowledge and understanding about nanomaterials.

In the last 20 years, many studies have been done on nanoparticles and materials. However, many recent studies indicate that they focus on the classification, preparation method, properties, and uses of each nanomaterial. There is no more research that articulates all nanomaterials classification, preparation and properties that work for all careers. To solve this problem, we have studied clearly all classifications of nanomaterials and the reason for their classification, preparation, and classification of their preparation, which are useful for all classes, properties, and all practiced fields.

MATERIALS AROUND US

Everything in and around the human race is comprised of and surrounded by a vast array of materials. A material is a substance or combination of constituents that composes an object. The classification of materials is based on their physical and chemical properties, geological origin, or biological function. Raw materials can be processed in a variety of ways to alter their properties, including purification, shaping, and the addition of other substances. Synthesis can produce new materials from basic materials. In industry, materials serve as inputs for manufacturing processes that generate products or more complex materials. Materials are classified based on the diameters of their crystallites, and this classification determines their applications. Materials having minimum one external dimension measuring between 1-100 nm are termed as Nanomaterials. Typically, the optical, electronic, and mechanical properties of materials with a nanoscale dimension are unique. Due to their enthralling properties, nanomaterials, whether naturally occurring or man-made, have garnered considerable interest. Specifically for nanotechnology, the properties, applications, and uses of these substances are investigated in depth.

Nanomaterials research affords the opportunity to observe the evolution of material properties with crystal structure, size, and shape. Changing the particle size modifies the degree of electron confinement, thereby affecting the solid's electronic structure, particularly the band gap. As the size of particles decreases from microns to nanometers, their optical properties change drastically. Nanomaterials have attracted considerable interest due to their size-dependent optical, electronic, magnetic, thermal, mechanical, chemical, and physical properties, which are distinct not only from their bulk counterparts but also from the atomic or molecular precursors from which they are derived. The utilization of these substances as photocatalysts holds tremendous promise. For the efficient utilization of solar radiation, a photocatalyst that operates in the visible spectrum is essential, as solar light contains approximately 45 percent visible radiation.

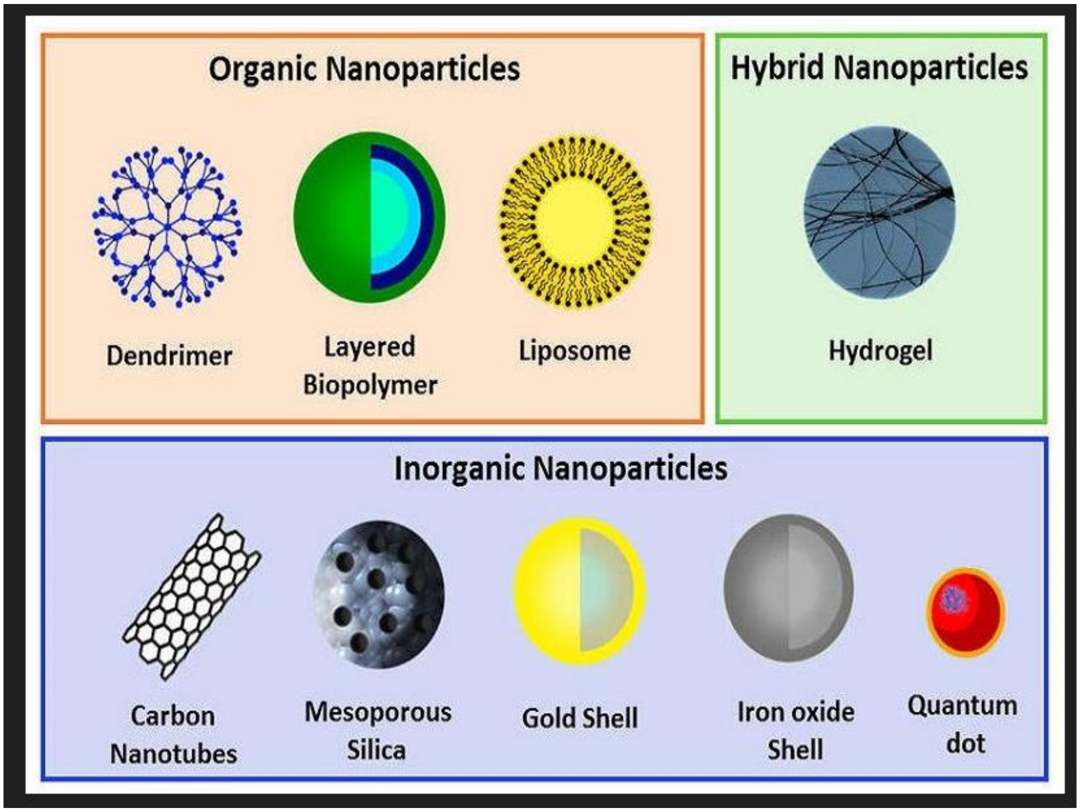

Figure: 1 - Nanomaterials

Consequently, the development of a visible-light active photocatalyst has become an essential topic in contemporary photocatalysis research. Various varieties of visible-light-driven photocatalysts for photodegradation and hydrogen production have been reported recently. However, the number of photocatalysts that operate in the visible spectrum is restricted. The stability and effectiveness of these catalysts are insufficient and require improvement presently. Since metal sulfides, such as CdS, are notoriously unstable during photocatalytic reactions, enhancing their stability is a formidable challenge. The incorporation of metal sulfides into the interlayer of sulfide compounds can solve this issue.

NANO MATERIALS

Particles, nanotubes, nanowires, quantum dots, fullerenes (buckyballs), and other materials with at least one dimension that influences their functional behavior at a size of 100 nm or less.

In plain English, a material created employing nanoparticles is referred to as a "nanomaterial." The Organization for Economic Co-operation and Development (OECD), the Scientific Committee on Emerging and Newly Identified Health Risks of the European Union (EU), the EU Cosmetic Products Regulation, among others, as well as definitions found in local legislation were all taken into account by the European Commission in its report on Considerations on a Definition of Nanomaterial for Regulatory Purposes (USA). Nanomaterials, according to the European Commission (EC), are "materials with internal structures and/or exterior dimensions within the size range measured in nanometers (nm), where 100 nm is usually considered as a delimiting size between the nanoscale and the micro and macroscopic scales."

Although the EU's initiative has been praised, there are some issues with this definition. According to the European Chemical Industry Council (Cefic), based in Brussels, the definition is "too broad in scope" and will be challenging to meaningfully incorporate into the current legislation because it will place an unnecessary burden on businesses, increasing costs and resulting in a less efficient use of resources. In addition, some decades-old substances, such as mineral pigments used in paints and other commonplace products, will be referred to as nanomaterials. 57 The definition is crucial from a regulatory perspective because without a clear definition, legal consequences and characteristics cannot be applied to a thing. Because nanoparticles may provide unexpected environmental and health risks, the defining issue warrants more study. The European Parliament placed a strong emphasis on creating a thorough, science-based definition of nanomaterials after realizing the significance of a definition. The definition is also essential for determining the degree of culpability of various parties involved in nanotechnology research and commerce. The definition of "one size fits all" may not be appropriate for nanomaterials, thus it is preferable to define them on a case-by-case basis, according to Andrew Maynard, one of the foremost authorities in favor of the definition of nano.

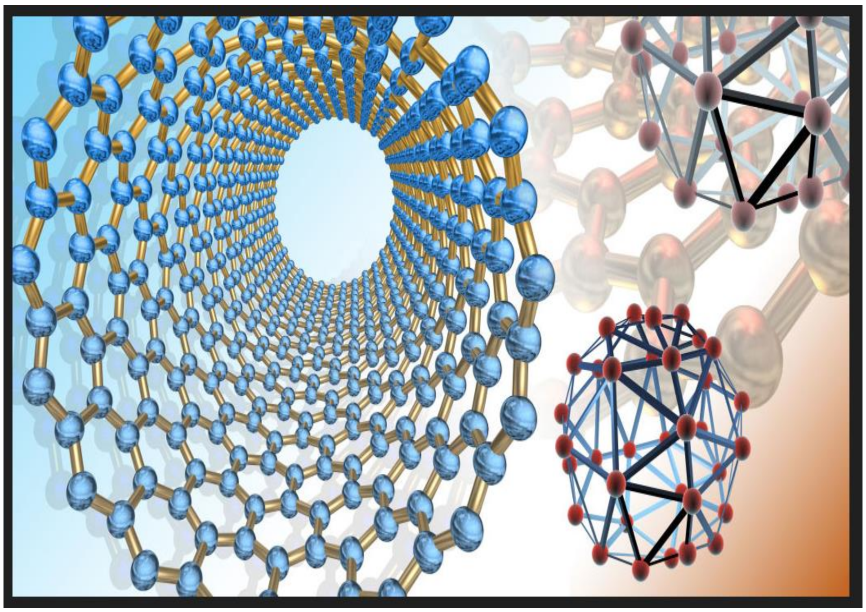

Figure: 2 - Types of carbon-based nanomaterials

The nanoscale is the spectrum of dimensions between 1 and 100 nanometers. When particle size is reduced to the nanoscale, the ratio of surface area to volume dramatically increases. Since many crucial chemical reactions, such as those involving catalysts, occur at surfaces, it is not surprising that extremely small particles are incredibly reactive. This is one of the reasons why chemists are so enthusiastic about nanoscience: if they can increase the surface area, they can increase the catalytic action, which has the potential to speed up nearly all physical and manufacturing processes, while also increasing the resource and energy efficiency of those processes and products. Quantum properties also manifested at the nanoscale level. Classical physics cannot explain why materials change color as their dimensions change. Consequently, we need quantum mechanics to comprehend it. Thus, nanoparticles are sometimes referred to as "Quantum Dots."

Currently, molecular manufacturing or nanotechnology are being used to create four different kinds of nanomaterials:

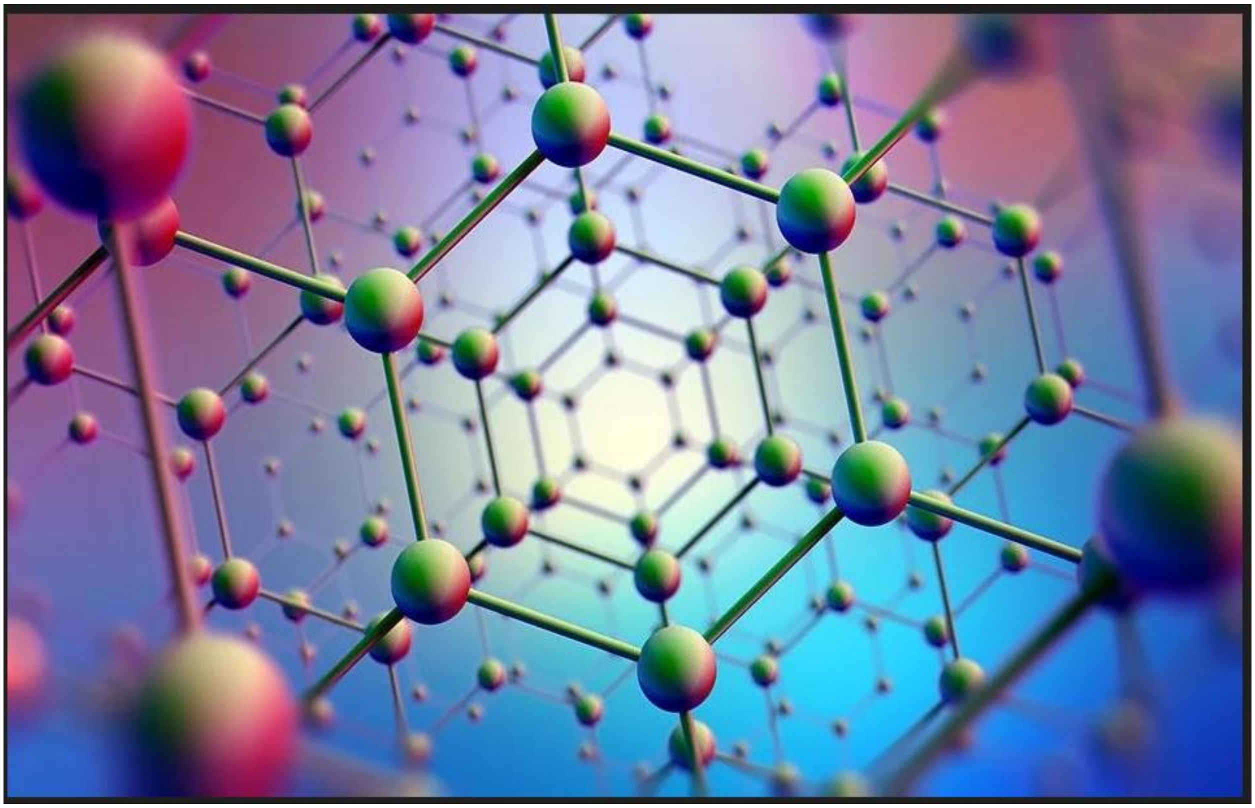

Figure: 3 - Classification of nanomaterials according to dimension

CARBON-BASED MATERIALS: These nanomaterials, which are primarily made of carbon, are most frequently found as hollow spheres, ellipses, or tubes. Carbon nanomaterials that are spherical, elliptical, or cylindrical are referred to as fullerenes. These particles can be used in electronics, stronger and lighter materials, better films and coatings, and other applications.

(II) METAL-BASED NANOMATERIALS: These include metal oxides like titanium dioxide, quantum dots, nanogold, and nanosilver. A quantum dot is an extremely densely packed semi-conductor crystal with a size of a few nanometers to a few hundred nanometers and a composition of hundreds of thousands of atoms. Quantum dots' optical characteristics alter depending on their size.

(III) DENDRIMERS: Made up of branching units, these nanomaterials are nanozized polymers. A dendrimer's surface is covered in multiple chain ends that can be configured to carry out particular chemical tasks. This characteristic might be helpful in catalysis. Additionally, three-dimensional dendrimers may be helpful for drug delivery since they have internal spaces that can accommodate additional molecules.

(IV) COMPOSITES: blend nanoparticles with larger, bulkier materials or with other nanoparticles. To improve the mechanical, thermal, barrier, and flame-retardant qualities of items ranging from auto components to packaging materials, nanoparticles, such as nanozized clays, are already being used.

Nanomaterials are further divided into two categories: loose nanomaterials and those embedded in composites, where they are less readily available for inhalation, cutaneous absorption, or ingestion. These categories may be used in a regulatory framework to address any concerns associated with human exposures.

Nanomaterials may be created purposefully or accidentally, for instance, during the production of nano- or non-nano-materials. Nanomaterials can occur naturally in the environment as well as in the bodies of humans and animals. They could be swallowed, breathed, or absorbed topically. The use of technology has the potential to significantly benefit humans, but it also carries considerable risks. These risks and benefits must be balanced through regulation.

Nanomaterials can be broadly divided into two types: naturally occurring nanomaterials and nanomaterials produced artificially.

Nanotechnologically-based applications, materials, and products that are truly revolutionary are years away (some say only a few years; some say many years). Basic research and development taking on in labs around the world today is what is classified as "nanotechnology."

The majority of "nanotech" products available on the market today are incrementally improved items (using evolutionary nanotechnology) made with some type of nano-enabled component (such as carbon nanotubes, nanocomposite structures, or nanoparticles of a specific substance) or nanotech manufacturing technique (such as nanopatterning or quantum dots for medical imaging).

The number of businesses that produce "nanoproducts" (by this definition) will increase quickly and soon make up the majority of businesses across many industries as they continue their quest to enhance existing products by developing smaller components and better performance materials, all at a lower cost. Therefore, it is important to think of evolutionary nanotechnology as a process that will gradually change most businesses and industries.

The ambiguity surrounding this technology's definition is one of its issues. The majority of definitions center on the investigation and management of events and substances at length scales below 100 nm, and they frequently draw comparisons to a human hair, which has a width of 80,000 nm. Some definitions mention molecular nanotechnology systems and gadgets, and "purists" contend that any definition must mention "functional systems." 13 researchers from various fields were asked to describe what nanotechnology meant to them for the first edition of Nature Nanotechnology. The comments, which ranged from excited to skeptical, reflect a variety of viewpoints.

CONCLUSION

This paper introduced nanomaterials and reviewed their type of classification based on different characteristics, varying synthesis methods in relation to their applications and properties, and the application of nanotechnology in different fields by manufacturing nanomaterials. In general, the physical, chemical, electrical, optical, magnetic, and mechanical properties of bulk materials are independent of their size, but the physical, chemical, electrical, optical, magnetic, and mechanical properties of nanomaterials are dependent on their size. The properties of nanometer-scale materials differ significantly from those of atoms and bulk materials because of the surface charge/interaction, crystallography, composition, surface area, and nanoscale size effects that can be seen in the magnetic, optical, electrical, mechanical, chemical, and physical properties of nanomaterials. Nanomaterials have a big role for societies due to their fantastic and power-full applications in many fields like agriculture, electrical engineering, medicine, etc.

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