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The Shuffling of the Concept of Nanomaterials in Chemistry: A Critical Spectrum

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Abstract: ***Nanostructures science and technology is tremendous and multifaceted area of research in which nanomaterials are keystones. Anomalous properties of distinct types of nanomaterials including carbon nanotubes (CNT), quantum dots, nanowires, fullerenes, dendrimers provides them electrical, mechanical, thermal and catalytic characteristics which are highly prudential for the applications in various fields like commercial, medical, environmental, electronics etc. An eloquent property of nanomaterials which make them different from other materials is that they have an enormous surface area due to which nanomaterials are exceedingly reactive in comparison to their larger form. In nano level, quantum effect becomes more pronounced on the performance of particles. Nanotubes are one of the well known applications of nanomaterials in which carbon nanotubes (CNT) are one of the remarkable example. Nanomaterials possess applications in bio - medical sciences in which quantum dots have been used in cancer therapy, silicon based structures can act as an artificial growth. Detailed overviews of properties, classification and all - embracing applications of nanomaterials have been discussed in this paper.***

Keywords: Carbon nanotubes (CNT), Fullerenes, Nanomaterials, Nanotechnology, Nanowires, properties, quantum dots

1. Introduction

Nanotechnology is a cutting - edge field of study that utilises the ability to create, manipulate, and construct materials and devices at extremely small scales, referred to as nanoscales. These materials are commonly referred to as nanomaterials [1 - 2]. Nanomaterials refer to particles of inorganic or organic materials that are either crystalline or amorphous and have a size ranging from 1 to 100 nm [3]. Nanomaterials can exhibit dimensions of 0D, 1D, 2D, or 3D, which correspond to their respective forms. Upon discovering that size significantly affects the physiochemical properties of substances, researchers recognised the significance of nanomaterials. Nanomaterials have been categorised into different groups based on their form, size, and physical and chemical properties. Carbon - based nanoparticles (NPs), metal nanoparticles (NPs), ceramics nanoparticles (NPs), semiconductors nanoparticles (NPs), polymeric nanoparticles (NPs), and lipid - based nanoparticles (NPs) are well - known categories of nanomaterials [4]. Materials at the nano size exhibit distinctive features as a result of their vast surface area and the emergence of quantum phenomena. Nanomaterials are particles that possess at least one dimension inside the nanometric range [5]. Nanomaterials have generated significant interest due to their distinct optical, electrical, mechanical, and magnetic characteristics [6]. Nanomaterials have been utilised to create a range of products, such as paints, insulation, filters, and lubricating additives. These materials are utilised in several sectors including healthcare, air purification, commercial, electronics, and environmental industries. Nanomaterials with enzymatic characteristics are referred to as nanoenzymes, and they have diverse uses in biosensing, bioimaging, tumour diagnostics, and more [7, 8].

2. Classification of Nanomaterials

Nanomaterials can be classified on the basis of their origin, structural configuration as well as their dimensions. On the basis of their dimensions, nanomaterials are classified as follows:

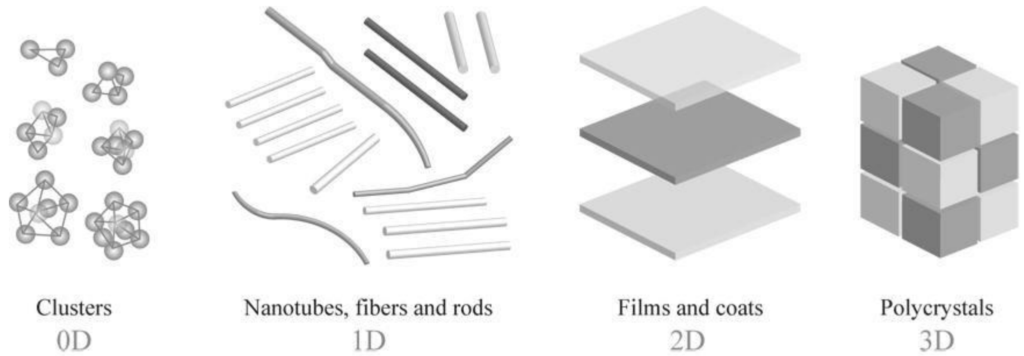

Figure 1: Nanomaterials of different dimensions

1) Zero Dimensional (O - D): Nanomaterials which possess nano - dimensions in all the directions are known as zero dimensional nanomaterials. Quantum dots, gold and silver nanomaterials are examples of 0 - D nanomaterials. Diameter of such nanomaterials lies in the range of 1 - 50

nm and has spherical size. Some of these materials also possess cubes and polygons.

2) One Dimensional (1 - D): Nanorods, nanowires and nanotubes are perfect example of 1 - D nanomaterials. These materials possess one dimension outside the nanometer range. In comparison to zero dimensional, they are long but has diameter of few nanometers.
3) Two dimensional (2 - D): These materials have two dimensions outside the nanometer range. Thin - film - multilayers, nano - sheets, nano - walls are the example of 2 - D nanomaterials. Area of such materials is of several square micrometers but has thickness in nano scale range.
4) Three Dimensional (3 - D): 3 - D nanomaterials have all the dimensions outside the nano meter range. Quantum dots, dendrimers, fullerenes are the example of 3 - D material [9 - 10].

On the basis of structural configuration, nanomaterials are classified as follows:

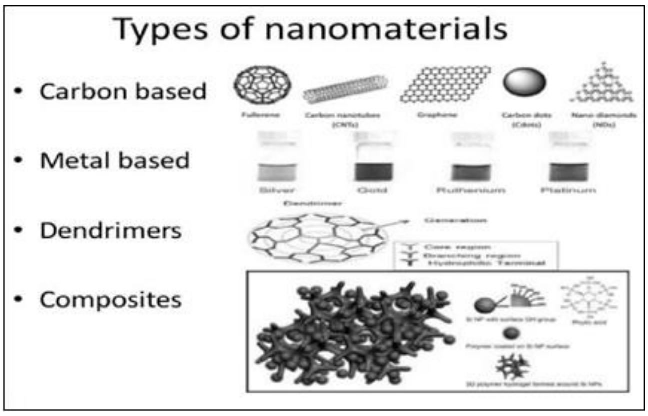

Figure 2: Nanomaterials on the basis of structural configuaration

1) Carbon based materials: Such kind of materials have hollow spheres, ellipsoids or tubes nature. Fullerenes come under the category of spherical and ellipsoidal configured carbo. However, nanotubes are cylindrical.
2) Metal based materials: Metal oxides such as titanium dioxide, nanogold, nanosilver are some of the metal based nanomaterials. Metal is the main constituent of these materials [9].
3) Dendrimers: New classes of polymeric materials which are hyper branched mono disperse macromolecules are knowns as dendrimers [10]. These macromolecules possess properties which are different from conventional polymers. Dendrimers have potential to act as carriers in gene therapy [11 - 12].
4) Composites: Colloids, copolymers and gels are the usual examples of nanocomposites. Multiphase solid materials which have atleast one of its phase with one, two or three dimensions in nanoscales [9, 13].

On the basis of their origin nanomaterials can be classified into two categories which are as follows:

1) Natural nanomaterials: Nanomaterials which belongs to resource of nature are called natural nanomaterials. Colloids like blood and milk, fog, gelatine minerals including clays are some of the perfect examples of natural nanomaterials [9, 14].

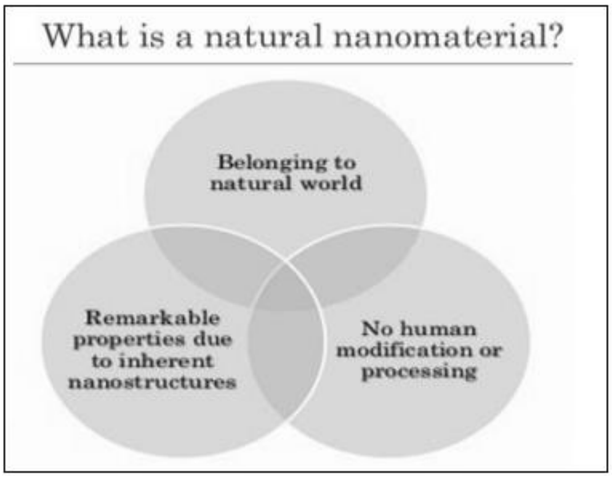

Figure 3: Natural Nanomaterials

2) Artificial nanomaterials: Materials which are formulated via rigorous mechanical and fabrication techniques are called artificial nanomaterials. Such materials include carbon nanotubes, quantumdots etc [9, 15].

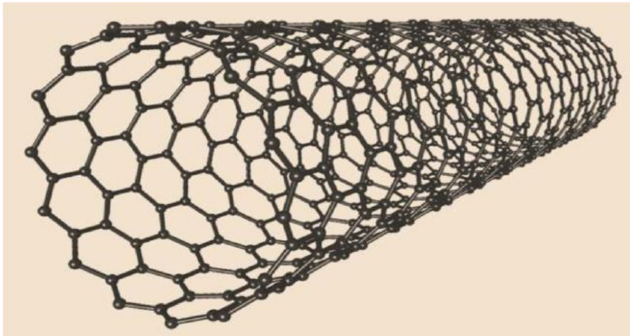

Figure 4: Carbon nanotubes

Properties of Nanomaterials:

Relatively large surface area and quantum effects are the main principle factors that make their properties remarkably different from other materials. Some of the unique properties of nanomaterials have been discussed below:

a) **Electrical Properties:** Due to minimum defects in the structures, nanomaterials have very high electrical conductivity. Electrical properties of nanomaterials depend upon the diameter and vary between metallic to semiconducting materials [16].
b) **Mechanical Properties:** Nanomaterials do not get fractured on bending as the other materials do because they are very hard and withstand extreme strain [16]. At nano scales, carbon cylinders are very flexible and 100 times stronger than steel, however bulk level steel is more stronger than carbon [17].
c) **Thermal Conductivity:** Due to vibrations of covalent bonds, nanomaterials possess high thermal conductivity. Thermal conductivity of nanomaterials is 10 times greater than metals [16].
d) **Optical Properties:** Optical properties includes color and transperancy, they are observed to be changed at nano

scales. Nanosize gold appears red in colour however bulk gold is yellow in colour. Electrons in the nanoparticles are not free to move due to small size of nanoparticles which makes them react differently with light in comparison to bulk material [17]. Due to their small size and quantum confinement effect; nanomaterials possess non linear optical properties as well as enhanced optical emission [18].

e) **Catalytic Properties:** Catalysts based on nanomaterials are generally heterogeneous catalysts which are broken up into metal nanoparticles and help in enhancing the rate of catalytic process. Metal nanoparticles possess large surface area due to which catalytic activity is increased as a greater number of catalytic reactions can take place at the same time. Seperation and recycling process of nanomaterials based catalyst is quite easy [19].

3. Applications

Nanomaterials possess a wide range of applications across numerous disciplines. In the field of engineering, nanomaterials are utilised in the fabrication of slender nanowires that have a wide range of uses. These materials have been used in nanocomposites, such as in the construction of bones. Magnetic nanoparticles possess the capability to function as medication carriers and biosensors within the realm of medicine [20]. Several essential nanomaterials, including carbon nanotubes, fullerenes, quantum dots, and nanowires, have a diverse variety of applications in numerous fields. These applications will be discussed in the following sections:

Fullerenes possess idiosyncratic electrical properties that make them promising contenders for diagnostic, theranostic, and therapeutic uses. Fullerene derivatives (FDs) that have been specifically designed and created have the ability to inhibit the release of proinflammatory mediators, therefore promoting the stability of human mast cells. Emptycage fullerenes exhibit distinctive electrochemical characteristics that offer significant advantages in biological applications [21]. Empty cage fullerenes have the potential to absorb electrons, which gives them antioxidant functionality. This ability opens up new possibilities for treating various ailments such as cancer, inflammation, osteoporosis, radiation exposure, and anti - HIV activity [22 - 24].

Nanowires have one unconstrained dimension and two quantum - constrained dimensions, resulting in distinct electronic conduction behaviour compared to their bulk counterparts. Semiconductor and superlattice nanowires have been employed in the production of diverse electronic devices, including logic gates, transistors, and junction diodes. The increased thermopower of nanowires has rendered them suitable for thermoelectric cooling systems and various energy conversion devices. The additional optical characteristics of nanowires have resulted in the creation of a pH sensor and a hydrogen gas sensor composed of Pb nanowire [25 - 26].

Quantum dots: Solar cells composed of semiconductors are costly to manufacture and have an efficiency of 33% in converting sunlight into power. Quantum dots have the capacity to both emit and absorb radiation, resulting in the efficient generation of electric current and voltage. Therefore, quantum dots are employed, offering a 60% efficiency at a significantly lower cost [27].

Carbon nanotubes exhibit unique characteristics in electronics, optics, transport, vibrations, and thermal properties, making them promising contenders in aerospace, energy, medical, and chemical industries. In these sectors, they are utilised as nanopipes, probes, chemical sensors, nano reactors, catalyst supports, and gas adsorbents. Carbon nanotubes have been utilised in various applications such as field emission devices, gas storage containers, and components of nanoelectronics devices [28].

4. Conclusion

This discussion provides a comprehensive examination of the characteristics, categorization, and uses of nanomaterials. The limitless potential of these materials has garnered considerable interest from individuals seeking to utilise nanotechnology and those studying nanoscience. These nanomaterials, such as carbon nanotubes (CNTs), fullerenes, quantum dots, and nanowires, possess unique characteristics that make them promising options for a wide range of applications in areas such as commerce, biomedicine, electronics, and the environment.

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