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Nanoparticles – An Overview of Classification and Applications

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Review Article

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ABSTRACT

The purpose of this review article is to reflect the emerging importance of Nanotechnology with emphasis on nanoparticles with a current research of scientific interest in biomedical, pharmaceutical, optical, biosensors, and electronic areas. In this article, a general overview of classification of nanoparticles such as 1D, 2D and 3D structures of organic and inorganic molecules exhibiting a wide range of applications in different fields of knowledge. Nanotechnology employing nanoparticles can be applied to any field of medicines, energy, electronics, manufacturing and materials, food agriculture, textiles, environment, renewable energy, quantum computers, UV protection and industrial catalysts.

INTRODUCTION

Nanotechnology is the field of science that includes different area of physics [1-3], chemistry, biology, materials science, health sciences [4], therapeutics and engineering [5,6] along with application of materials and devices at nanoscale [7]. The word ‘Nano’ derives from the Greek word "nanos", which means dwarf or extremely small, which is carried out by the fabrication of a nanostructure. ‘Nano’ has a wide range of approaches in different areas of Nanoscience, Nanotechnology, Nanomaterial or Nanochemistry. Nanotechnology defines small object as a whole unit with respect to its properties and termed as Nanoparticles. Nanoparticles are ultrafine molecules ranging between 1 to 100 nanometres [8] in size which refers to inorganic materials **(Table 1)**. Nanoparticles have at least one dimension smaller than 1 micron and potentially as small as atomic and molecular length scales (~0.2 nm).

Nanotechnology involves nanoparticles for the purpose of Nanomedicines which is a landscape for both biotechnology and therapeutics industries [9,10]. Some of the nanoparticles can be defined as Pharmaceutical nanoparticles [11], which are solid, submicron-sized employed as drug carrier. The review focuses on nanoparticles such as carbon nanotubes [12], fullerenes, dendrimers, quantum dots, buckyballs, nanobelts and nanoribbons [13] and their applications in different fields of research and innovation.

The nano-sized objects having customized surface, improved solubility with multi-functionality [14,15] has open many doors and create new biomedical applications to design and develop the devices that can target, diagnose and treat devastating diseases such as cancer [16,17] efficacy in treating solid tumors, for single dose vaccination and oral delivery of therapeutic [18,19] proteins. Nanotechnology has emerged with different types of nanoparticulate systems [20] for the development of different types of nanoparticles such as Metallic nanoparticles, silica nanoparticles, carbon nanoparticles and composite nanoparticles [21].

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Table 1: Definitions of nanoparticles and nanomaterials by various organizations

Organizations	Nanoparticle	Nanomaterial
ISO	A particle spanning 1–100 nm (diameter)	-
ASTM	An ultrafine particle whose length in 2 or 3 places is 1–100 nm	-
NIOSH	A particle with diameter between 1 and 100 nm or a fiber spanning the range 1–100 nm.	-
SCCP	At least one side is in the nanoscale range.	Material for which at least one side or internal structure is in the nanoscale
BSI	All the fields or diameters are in the nanoscale range.	Material for which at least one side or internal structure is in the nanoscale
BAuA	All the fields or diameters are in the nanoscale range	Material consisting of a nanostructure or a Nano-substances.

CLASSIFICATION OF NANOPARTICLES

Nanomaterials [22] can be classified by different approaches. Nanoparticles can be classified on the basis of dimensions as one, two and three dimensions.

One Dimension Nanoparticles (1D NP's)

The word "nano'' has been assigned to refer the number 10^{-9} [23] which means one billionth of any unit that results in development of 1D NP's like a thin film which has been used from decades in electronics, chemistry, pharmaceutics and engineering [24]. The thin films or monolayers ranges from 1-100 nm in size due to which NP's have increased their importance in research and developments and have a wide range of potential applications in field of fabricating electronic, optoelectronic, LEDs with nanoscale dimensions [25], storage system, chemical and biological sensors [26,27], fibre-optic system, magneto-optic system [28,29] and optical devices. 1D NP's has a profound impact for the construction of nanowires [30], nanorods, nanotubes, nanobelts, nanoribbons [31,32], and hierarchical nanostructures [33-35].

Two Dimension Nanoparticles (2D NP's)

2D nanostructures have two dimensions outside of the nanometric size range with unique shape-dependent characteristics and subsequent utilization as building blocks for the key components of nanodevices [36]. 2D nanostructures have been investigated and developed their potential applications in field of sensors, photocatalysts, nanocontainers, nanoreactors, and templates for 2D structures of other materials. Nanostructures which exhibit 2D structure include:

Carbon Nanotubes (CNTs)

CNTs [37] are seamless cylindrical hollow fibres that comprise a single sheet of pure graphite with hexagonal network of carbon atoms, 1nm in diameter and 100nm in length and being hollow they are extremely light weight. Carbon nanotubes [38] are strong and nanotubes can be bent easily and when released, they will spring back to their original shape but they didn't brittle. Nanotubes exhibits in different shapes and structures, differing in length, thickness, and number of layers [39] but the characteristics of nanotubes depend upon graphene sheet [40].

CNTs are of many types but normally categorised as either single walled [41] (SWNT) or multi-walled nanotubes (MWNT), where carbon nanotubes [42] combines with their remarkable properties. SWNT **(Figure 1)** can be structured by wrapping a one-atom-thick layer of graphite into a seamless cylinder whereas MWNT [43] consist of multiple rolled layers of graphite. MWNT [44] **(Figure 1)** are known for their unique mechanical properties, strength, optical and thermal properties.

Three Dimension Nanoparticles (3D NP's)

The behaviour of nanoparticles strongly depend on the sizes, shapes, dimensions and morphologies, which are key factors for the performance and applications of nanostructures [45] and the resemblance to this, 3D NP's [46] have gained their interest in research and medical science from past 10 years. 3D nanoparticles are an important material because of its wide range of applications in the field of catalysis, magnetic material, electrode material for batteries, transport of reactants and products. Nanostructures which exhibit 3D structure can be categorised as:

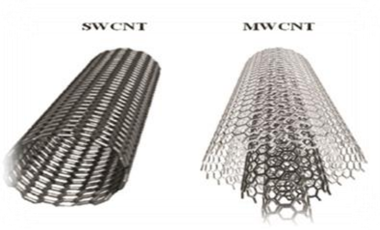

Figure 1: Single walled and multi walled carbon nanotubes.

Fullerenes

Fullerenes (**Figure 2**) are known by different names such as Carbon 60 [47] Buckminsterfullerene Buckytubes" and "Buckyonions and Buckyballs. Carbon 60 are hollow spherical cages consist of 20 hexagonal and 12 pentagonal rings with 28 to more than 100 carbon atoms resembling a soccer ball. Fullerenes [48] display unique physical properties as they can exposed to extreme pressure and regains their original shape when pressure is released. They have interesting application as lubricants, data storage and medical application [49,50] to carry biological active molecules.

Dendrimers

Dendrimers [51] are a new class of polymeric materials which are highly branched, star-shaped macromolecules with nanometric dimensions. They differ from one another due to different shapes and sizes of drimers [52] having shielded interior cores with a potential application [53] in both biological and materials sciences including drug delivery [54], gene transfection, catalysis, energy harvesting [55], photo activity, molecular weight and size determination, rheology modification, and nanoscale science and technology. Dendrimers [56] (**Figure 2**) can be synthesised by divergent or convergent methods.

Quantum Dots (QDs)

Quantum dots are small particles or nanocrystals of a semiconducting material ranging from 2 to 10 nm in diameters [57] that display unique electronic properties and optical applications [58] owing to their bright, pure colors along with their ability to emit rainbow of colors coupled with their high efficiencies, longer lifetimes and high extinction coefficient. QDs (Figure 2)can be prepared by different techniques via Colloidal synthesis, Fabrication method [59] or electrochemical techniques most commonly using cadmium selenide (CdSe), cadmium telluride [60] (CdTe), indium phosphide (InP) and indium arsenide (InAs). QDs composed of two main parts shell and core where the shell and core were made using zinc sulphide (ZnS) CdSe, CdTe, InP or InAs [61]. Thus, QDs is a small dots of (CdSe) ZnS. The tiny particles i.e. QDs can go anywhere in the body, making applicable for biomedical applications in different fields of medical imaging [62], biosensors, drug delivery, DNA testing and target specific protein or cells.

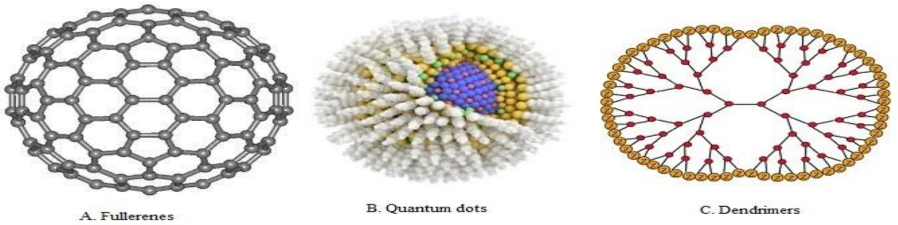

Figure 2: Three dimensional nanoparticles.

APPLICATIONS OF NANOPARTICLES

Nanoparticles are used, or being evaluated for use, in many fields and list below introduces several fields where nanoparticles can be potentially applied [62-64].

Nanoparticle Applications in Medicine

Nanotechnology by employing nanoparticles gains researchers and scientific interest in medicinal and medical field as nanoparticles are core form of nano-biomaterials. Nanoparticles in medical applications are used for cancer [65] therapy, multicolour optical coding for biological assays, Manipulation of cells and biomolecules, Protein detection, bio-pharmaceutical [66], surface disinfectant, nanobarcodes for bioanalysis, acticoat bandages [67] and etc.

Some common areas of medicinal application of nanoparticles includes: drug delivery [68], therapy techniques [69], diagnostic techniques [70], anti-microbial techniques [71], cell repair, tumor cell targeting, gene delivery [72], diagnosis and bioimaging [73]. Drug delivery is being carried out by polymeric nanoparticles [74,75] that can achieve both controlled drug release and disease-specific localization where the nanocarriers have been concentrated to tumors, inflammatory sites and at antigen sampling sites by virtue of the enhanced permeability and retention (EPR) [76].

The role of nanoparticles in therapy techniques [77] mostly includes Combination therapy [78] for cancer treatment, the effective drug delivery that has improved pharmacokinetics [79,80] and reduced side effects and several nanoparticle-based chemotherapeutics emerging with clinical or preclinical [81] development.

Nanoparticles are also known for their antimicrobial properties to treat the against almost all Gram-positive and Gram-negative bacteria, fungi and viruses [82,83]. Antimicrobial property [84] was investigated by different metal nanoparticles such as gold [85], silver, zinc oxide, copper oxide and iron oxide nanoparticles. The increase of microbial resistant organisms [86,87] to drug therapy reflects an urgent need to develop new antimicrobial agents thus, different types of metallic nanoparticles are well known for their antimicrobial applications.

Nanoparticle Applications in Energy, Electronics, Manufacturing and Materials

Nanoparticles are stronger, lighter, cleaner and “smarter” surfaces and systems because of which they are used for manufacture [88] of scratchproof eyeglasses, crack- resistant paints, anti-graffiti coatings for walls, transparent sunscreens, stain-repellent fabrics, self-cleaning windows, ceramic coatings for solar cells [89] and nanoparticles fillers in tyres can improve adhesion to the road, reducing the stopping distance in wet conditions [90].

Applications of nanoparticles in Energy reflects the use of Nanostructures [91], that are very promising for manufacturing of fuel cells, nanocollodial catalysts, nanoclusters [92,93] in hydrogen storage as Ti13-THF nanocluster, electrocatalysts in polymer electrolyte fuel cells, solar cells and solar roofing tiles [94,95]. Nanoparticles are impacting the field of food such as Nanotea [96] and Nanoceuticals Slim Shake Chocolate [97], bioprocessing industries, wearable electronics [98] and especially in the field of cosmetics.

CONCLUSION

Nanoparticles have a wide spectrum of application in different areas of science and technology, which represents a highly attractive platform for research and innovative studies [99]. The development of nanotechnology increased our awareness for new hope that would lead to a significant development in medial and clinical research . We focus a future with hopeful fabrication and manipulation of new nanomaterials to be engineered for individual and multimodal application s including therapeutic delivery biosensors and bioimaging for pharmaceutical use. Nanotechnology is also currently improving technologies in batteries, coal liquefaction, metal nanopowders [100], metal nanoparticles using simple and green methods for the preparation and synthesis of Nanoparticles.

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