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A Review On The Classification, Synthesis Of Nanoparticles And Their Application

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Abstract.

As per ISO and ASTM standards, nanoparticles are particles of sizes ranging from 1 to 100nm with one or more dimensions. The nanoparticles are generally classified into the organic, inorganic and carbon based particles in nanometric scale that has improved properties compared to larger sizes of respective materials. The nanoparticles show enhanced properties such as high reactivity, strength, surface area, sensitivity, stability, etc. because of their small size. The nanoparticles are synthesised by various methods for research and commercial uses that are classified into three main types namely physical, chemical and mechanical processes that has seen a vast improvement over time. This paper presents a review on nanoparticles, their types, properties, synthesis methods and its applications in the field of environment.

Keywords :- Types, Classification, Application and synthesis of nanoparticles.

Introduction

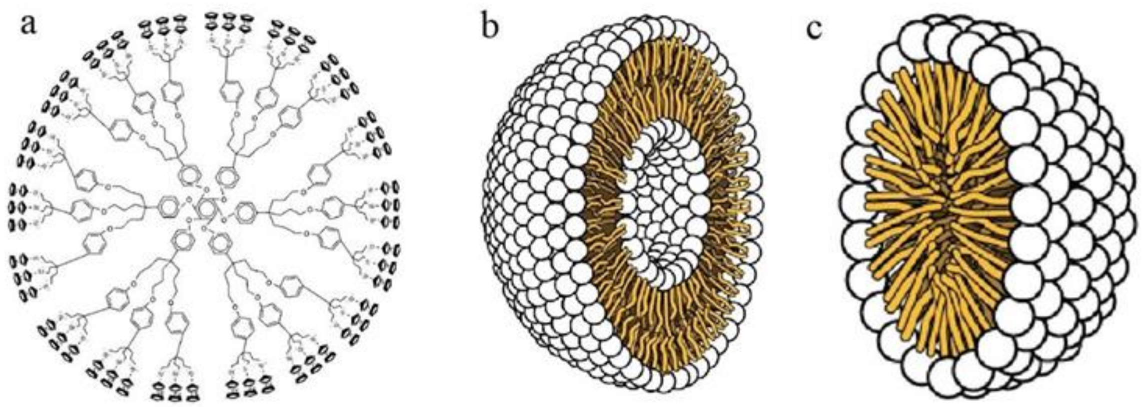
Nanotechnology has gained huge attention over time. The fundamental component of nanotechnology is the nanoparticles. Nanoparticles are particles between 1 and 100 nanometres in size and are made up of carbon, metal, metal oxides or organic matter [1]. The nanoparticles exhibit a unique physical, chemical 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 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 characterisation and subsequent application. The nanoparticles are now used in every objects like from cooking vessel, electronics to renewable energy and aerospace industry. Nanotechnology is the key for a clean and sustainable future.

Classification of Nanoparticles

The nanoparticles are generally classified into the organic, inorganic and carbon based.

Organic nanoparticles

Dendrimers, micelles, liposomes and ferritin, etc. are commonly knows the organic nanoparticles or polymers. These nanoparticles are biodegradable, non-toxic, and some particles such as micelles and liposomes has a hollow core (Figure1), also known as Nano capsules and are sensitive to thermal and electromagnetic radiation such as heat and light [5]. These unique characteristics makes them an ideal choice for drug delivery. The drug carrying capacity, its stability and delivery systems, either entrapped drug or adsorbed drug system determines their field of applications and their efficiency apart from their normal characteristics such as the size, composition, surface morphology, etc. The organic nanoparticles are most widely used in the biomedical field for example drug delivery system as they are efficient and also can be injected on specific parts of the body that is also known as targeted drug delivery. **fig no. 1**



Inorganic nanoparticles

Inorganic nanoparticles are particles that are not made up of carbon. Metal and metal oxide based nanoparticles are generally categorised as inorganic nanoparticles

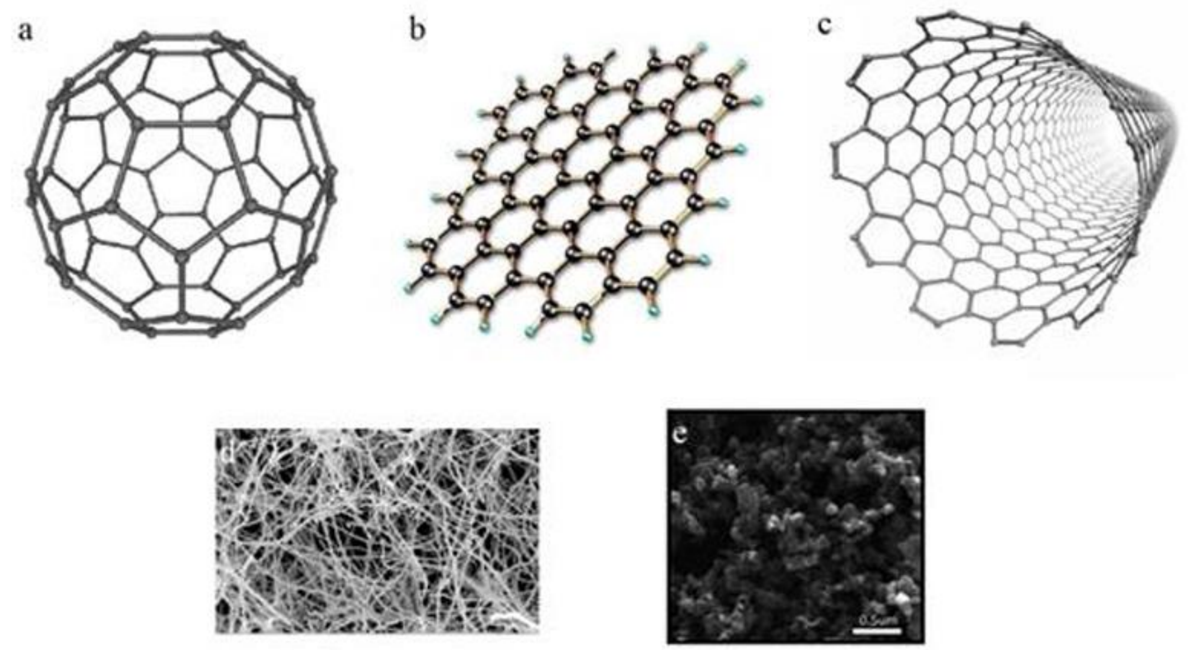
2.2.1 Metal based.

Nanoparticles that are synthesised from metals to nanometric sizes either by destructive or constructive methods are metal based nanoparticles. Almost all the metals can be synthesised into their nanoparticles [6]. The commonly used metals for nanoparticle synthesis are aluminium (Al), cadmium (Cd), cobalt (Co), copper (Cu), gold (Au), iron (Fe), lead (Pb), silver (Ag) and zinc (Zn). The nanoparticles have distinctive properties such sizes as low as 10 to 100nm, surface characteristics like high surface area to volume ratio, pore size, surface charge and surface charge density, crystalline and amorphous structures, shapes like spherical and cylindrical and colour, reactivity and sensitivity to environmental factors such as air, moisture, heat and sunlight etc.

2.2.2. Metal oxides based. The metal oxide based nanoparticles are synthesised to modify the properties of their respective metal based nanoparticles, for example nanoparticles of iron (Fe) instantly oxidises to iron oxide (Fe_2O_3) in the presence of oxygen at room temperature that increases its reactivity compared to iron nanoparticles. Metal oxide nanoparticles are synthesised mainly due to their increased reactivity and efficiency [7]. The commonly synthesised are Aluminium oxide (Al_2O_3), Cerium oxide (CeO_2), Iron oxide (Fe_2O_3), Magnetite (Fe_3O_4), Silicon dioxide (SiO_2), Titanium oxide (TiO_2), Zinc oxide (ZnO). These nanoparticles have possess an exceptional properties when compared to their metal counterparts.

2.2.3 Carbon based

The nanoparticles made completely of carbon are knows as carbon based [8]. They can be classified into fullerenes, graphene, carbon nano tubes (CNT), carbon nanofibers and carbon black and sometimes activated carbon in nano size and are presented in **Figure2.**



2.3.1. Fullerenes. Fullerenes (C60) is a carbon molecule that is spherical in shape and made up of carbon atoms held together by sp2 hybridization. About 28 to 1500 carbon atoms forms the spherical structure with diameters up to 8.2 nm for a single layer and 4 to 36 nm for multi-layered fullerenes.

2.3.2. Graphene. Graphene is an allotrope of carbon. Graphene is a hexagonal network of honeycomb lattice made up of carbon atoms in a two dimensional planar surface. Generally, the thickness of the graphene sheet is around 1 nm.

2.3.3. Carbon Nano Tubes (CNT). Carbon Nano Tubes (CNT), a graphene nano foil with a honeycomb lattice of carbon atoms is wound into hollow cylinders to form nanotubes of diameters as low as 0.7 nm for a single layered and 100 nm for multi-layered CNT and length varying from a few micrometres to several millimetres. The ends can either be hollow or closed by a half fullerene molecule.

2.3.4. Carbon Nanofiber. The same graphene nanofoils are used to produce carbon nanofiber as CNT but wound into a cone or cup shape instead of a regular cylindrical tube.

2.3.5. Carbon black. An amorphous material made up of carbon, generally spherical in shape with diameters from 20 to 70 nm. The interaction between the particles are so high that they bound in aggregates and around 500 nm agglomerates are formed.

Synthesis of Nanoparticles

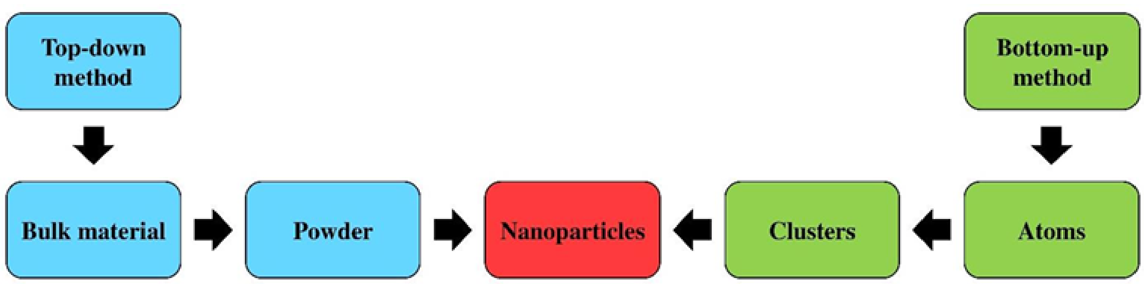


Fig.3 Synthesis Process

Nanoparticles can be synthesized chemically or biologically. Many adverse effects have been associated with chemical synthesis methods due to the presence of some toxic chemical absorbed on the surface. Eco friendly alternatives to Chemical and physical methods are Biological ways of nanoparticles synthesis using microorganisms, enzymes, fungus, and plants or plant [9,10,11,12] extracts [13,14]. The development of these eco friendly methods for the synthesis of nanoparticles is evolving into an important branch of nanotechnology especially silver nanoparticles, which have many applications[15-17].

Biosynthesis: Mechanism

Biosynthesis of nanoparticles by microorganisms is a green and eco-friendly technology. Diverse microorganisms, both prokaryotes and eukaryotes are used for synthesis of metallic nanoparticles viz. silver, gold, platinum, zirconium, palladium, iron, cadmium and metal oxides such as titanium oxide, zinc oxide, etc. These microorganisms include bacteria, actinomycetes, fungi and algae. The synthesis of nanoparticles may be intracellular or extracellular according to the location of nanoparticles[18,19]

Intracellular synthesis of nanoparticles by fungi:

This method involves transport of ions into microbial cells to form nanoparticles in the presence of enzymes. As compared to the size of extracellularly reduced nanoparticles, the nanoparticles formed inside the organism are smaller. The size limit is probably related to the particles nucleating inside the organisms[20].

Extracellular synthesis of nanoparticles by fungi:

Extracellular synthesis of nanoparticles has more applications as compared to intracellular synthesis since it is void of unnecessary adjoining cellular components from the cell. Mostly, fungi are known to produce nanoparticles extracellularly because of their enormous secretory components, which are involved in the reduction and capping of nanoparticles.

Microbes for production of nanoparticles: Both unicellular and multicellular organisms produce inorganic materials either intra- or extracellularly [21]. The ability of microorganisms like bacteria and fungi to control the synthesis of metallic nanoparticles is employed in the search for new materials. Because of their tolerance and metal bioaccumulation ability, fungi have occupied the center stage of studies on biological generation of metallic nanoparticles[22.]

Nanoparticles: Types

Silve: Silver nanoparticles have proved to be most effective because of it’s good antimicrobial efficacy against bacteria, viruses and other eukaryotic micro-organisms[23,24.] They are undoubtedly the most widely used nanomaterials among all, thereby being used as antimicrobial agents, in textile industries, for water treatment, sunscreen lotions etc[18,19.] Studies have already reported the successful biosynthesis of silver nanoparticles by plants such as Azadirachta indica Capsicum annuum and Carica papaya[25,26,27.]

Gold: Gold nanoparticles (AuNPs) are used in immunochemical studies for identification of protein interactions. They are used as lab tracer in DNA fingerprinting to detect presence of DNA in a sample. They are also used for detection of aminoglycoside antibiotics like streptomycin, gentamycin and neomycin. Gold nanorods are being used to detect cancer stem cells, beneficial for cancer diagnosis and for identification of different classes of bacteria[28,29.]

Alloy: Alloy nanoparticles exhibit structural properties that are different from their bulk samples[30]. Since Ag has the highest electrical conductivity among metal fillers and, unlike many other metals, their oxides have relatively better conductivity [31,] Ag flakes are most widely used . Bimetallic alloy nanoparticles properties are influenced by both metals and show more advantages over ordinary metallic NPs[32.]

Magnetic: Magnetic nanoparticles like Fe_3O_4 (magnetite) and Fe_2O_3 (maghemite) are known to be biocompatible. They have been actively investigated for targeted cancer treatment (magnetic hyperthermia), stem cell sorting and manipulation, guided drug delivery, gene therapy, DNA analysis, and magnetic resonance imaging (MRI) [33,34,35]

Applications

Nanomedicine has tremendous prospects for the improvement of the diagnosis and treatment of human diseases. Use of microbes in biosynthesis of nanoparticles is an environmentally acceptable procedure. Nanotechnology has potential to revolutionize a wide array of tools in biotechnology so that they are more personalized, portable, cheaper, safer, and easier to administer.

Conclusion

Due to their incredible properties, nanoparticles have become significant in many fields in recent years such as energy, health care, environment, agriculture etc. Nanoparticle technologies have great potentials, being able to convert poorly soluble, poorly absorbed and labile biologically active substance into promising deliverable substances.

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