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A REVIEW ON NANOPARTICLES AND ITS APPLICATION

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ABSTRACT

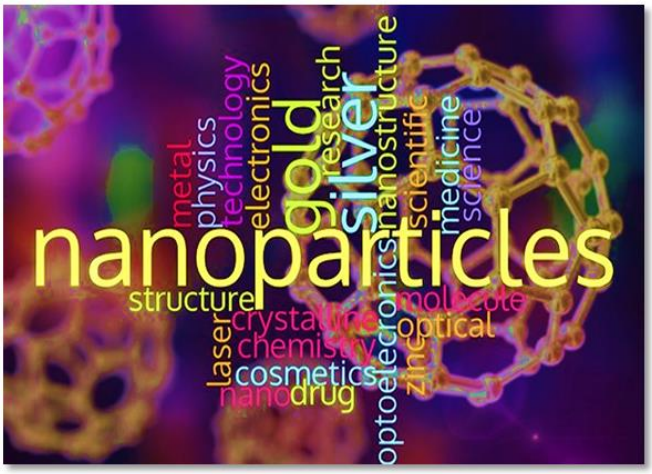
Nanoparticles, defined as particles with dimensions in the nanometer scale, have general significant attention across various scientific disciplines. Nanomaterials have unique physicochemical properties, such as ultrasmall size, large surface area to mass ratio, and high reactivity, which are different from bulk materials of the same composition. These properties can be used to overcome some of the limitations found in traditional therapeutic and diagnostic agents. Pharmaceutical nanotechnology is made up of nano-sized goods that can be altered in a variety of ways to improve their properties. Drugs that have been changed into the nano range have several distinct characteristics that can contribute to longer circulation and increased medicinal efficacy. This review provides a comprehensive overview of the classification, characterization, and applications of nanoparticles. The classification section involves various types of nanoparticles, including metallic, metal oxide, polymeric, lipid-based, and carbon-based nanoparticles, highlighting their distinctive properties. The applications section explores the wide-ranging uses of nanoparticles in diverse domains such as medicine, electronics, environmental science, and energy. In medicine, nanoparticles are revolutionizing drug delivery, imaging, and diagnostics, enhancing the efficacy and precision of treatments. In electronics, they contribute to the development of smaller, faster, and more efficient devices. Environmental applications focus on water purification, pollution control, and sustainable agricultural practices. In the energy sector, nanoparticles play a crucial role in improving the efficiency of energy storage and conversion systems.

KEYWORDS: Nanotechnology, Nanoparticles, Advantages of Nanoparticles, Disadvantages of Nanoparticles, Classification of Nanoparticles, Characterisation of Nanoparticles, Application of Nanoparticles.

INTRODUCTION

Nanoscience is the study of structures and molecules on the scales of nanometers ranging between 1 and 100 nm, and the technology that utilizes it in practical applications such as devices etc., is called nanotechnology. This technology was introduced by Richard Feynman who is known as Father of Nanotechnology. He laid foundation step of nanotechnology in his lecture on "There is a plenty of room at the bottom" in 1959 at the California Institute of Technology (Caltech). The term Nanotechnology was coined by Japanese Professor Norio Taniguchi.

Nanotechnology employs knowledge from the field of physics, chemistry, biology, materials science, health sciences, engineering.



Nanoparticles are the building blocks of nanotechnology. Nanotechnology defined as the design, characterization, production and applications of structures, devices and systems which involved in controlling shape and size at nanometer scale. According to International System of Units (SI) nanotechnology is typically measured in nanometers scale of 1 billionth of a meter (1nm corresponding to 10^{-9} m) referred as the 'tiny science'. At this small size, molecules and atoms work differently, and provide a variety of advantages. Nanotechnology is the study of materials which are altered into one billionth of a meter that is10^{-9} m which is about one hundred thousand times smaller than the diameter of a human hair, a thousand times smaller than a red blood cell. Nanotechnology is called as interdisciplinary subject which opens a new door of many applications. Nanotechnology can be used to design pharmaceuticals that can target specific organs or cells in the body such as cancer cells, and enhance the effectiveness of the therapy.

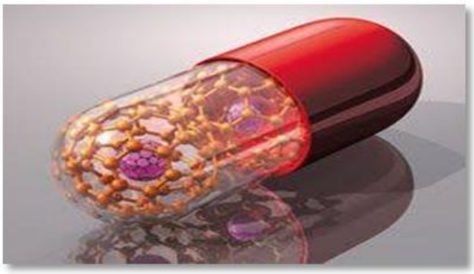
DEFINITION

The prefix “nano” comes from the ancient Greek vavoc through the Latin “nanus” meaning very small. “Technology” is the making, usage, knowledge of tools, machines, techniques, in order to solve a problem or perform a specific action. A nanoparticle is a microscopic particle whose size is measured in nanometres.

A Nanoparticles are sub-nanosized colloidal structures composed of synthetic or semisynthetic polymer. These polymers are able to changes the actual activity of drug via, delay or increases the drug release. The drug is dissolved, entrapped, encapsulated or attached to a nanoparticle matrix.

The nanoparticles are made up of carbon, metal, metal oxides or organic matter. Nanoparticles are basically a small object they are designed to improve the therapeutic and pharmacological effects of the drugs.

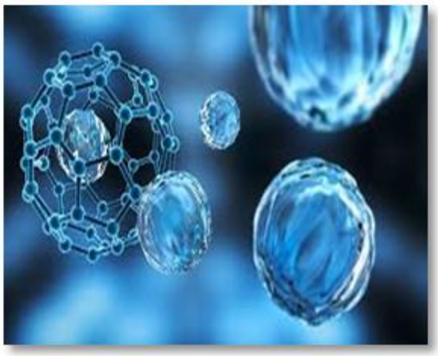
They also have a high surface area and they permit many functional groups to be adhered to them which in turn can bind to tumour cells. They provento be an excellent replacement for adiation and chemotherapy as they can easily assemble in the microenvironment of the tumour.



The term nanoparticle is a combined name for both nanosphere and nanocapsules. Drug is confined to a cavity surrounded by a unique polymer membrane called nanocapsules, while nanospheres are matrix systems in which the drug is physically and uniformly dispersed.

They are in different shape, size and structure. It maybe spherical, cylindrical, tubular, conical, hollow core, spiral, flat, etc. or irregular. Some nanoparticle may be crystalline, amorphous with single or multiple crystal solids either loose or agglomerated. Drug carriers which are solid, submicron-sized (less than 100 nm in diameter), and either biodegradable or not are referred to as pharmaceutical nanoparticles.

Nanoparticle formulation are more convenient formulation when compared to tablet, pellets, capsule. They have nanosize so they can be used in parenteral formulation and also have 100% bioavailability. Nanoparticle is formulated for BCS class Ⅱ and Ⅳ because these class of drugs have solubility problems. So by converting this type of molecules into nanoparticles we can remove this problem. The major goals in designing nanoparticles as a delivery system are to control the particle size, surface properties and release of pharmacologically active agents on the affected area to produce specific action at a therapeutically optimal rate.



Nanoparticles can be classified into as hard particles (titanic, silica) soft particles (liposomes, vesicles and Nano droplets). Nanoparticles can be created as the by-product of combustion reaction / through engineering technique.

On the other hand, polymeric nanoparticles offer some specific advantages of increasing the stability of drugs/proteins and possess useful controlled release properties. Other features of nanoparticles include low number of excipients used in their formulations, simple procedure for preparation, high physical stability, and the possibility of sustained drug release that may be suitable in the treatment of chronic diseases.

Nanoparticles are well known for targeted drug delivery due to its targeting nature nanoparticles used to deliver DNA, drug, protein. This is because of its nature, size and optical property. Nano formulation are easy to penetrate physiological barrier and reaches the target cell. Nanoparticles are the simplest form of structures with sizes in the nanometer range. In principle, any collection of atoms bonded together with a structural radius of < 100 nm can be considered a nanoparticle. Nanotechnology have various applications such as in agriculture (Grain spoilage detection sensor, Nanopesticides, Nanofertilizer and bioprocess engineering), Environmental chemistry (Nanoremediation and Ground Water Remediation), Food science, Veterinary medicine, Marine, Medicine detection (Cardiac therapy, Dental care, Diagnostic techniques, Skin therapy and Cancer therapy) and Tissue engineering, Industries (Cosmetics, Textiles and Nanoelectronics) and many others.

This review, aimed for definition, classification, advantages and its disadvantages, and various application of nanoparticles.

ADVANTAGES

It enhances the aqueous solubility of poorly soluble drugs
It increases bioavailability
Reduces side effects
Targeted drug carrier nanoparticles enhance efficient drug distribution.
Long storage stability
They have the ability to incorporate both hydrophilic and hydrophobic drug molecules.
They have higher carrier capacity and drugs can be incorporated without any chemical reaction and hence preserving the drug activity.
The system can be administered via different routes including oral, nasal, parenteral etc..
It increases drug resistance time
Polymer used in the preparation of nanoparticles are biodegradable so that, nanoparticles are less toxic.
Less amount of dose required.
Drug released in a sustained and controllable manner.
Good biocompatibility and biodegradability.
Protection from degradation

DISADVANTAGES

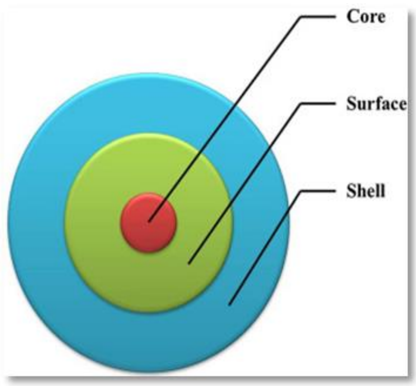
It may involve high manufacturing costs
They have low encapsulation efficiency
Requires skilled person to manufacture
Handling of nanoparticles are very difficult in their dry and liquid forms due to small size
High chances of contamination
More complex operational procedure
They may trigger immune response and allergic reactions

Small size and larger surface area can lead to particle-particle aggregation
Limited drug loading
Toxic metabolites may form in certain cases
Susceptible to bursting and leakage of contents
Productivity more difficult

IDEAL PROPERTIES OF NANOPARTICLES

It should be biochemical inert
It should be non-toxic
It should be physically and chemically stable in in-vitro and in-vivo conditions
Carriers must be biodegradable and easily eliminated from the body without any problems
It should be non-immunogenic
It should be non-thrombogenic
It should be non-inflammatory
Cost effective manufacturing process
It should be biocompatible
Avoidance of the reticulo-endothelial system
Applicable to various molecules, such as small molecules, proteins, peptides or nucleic acids.

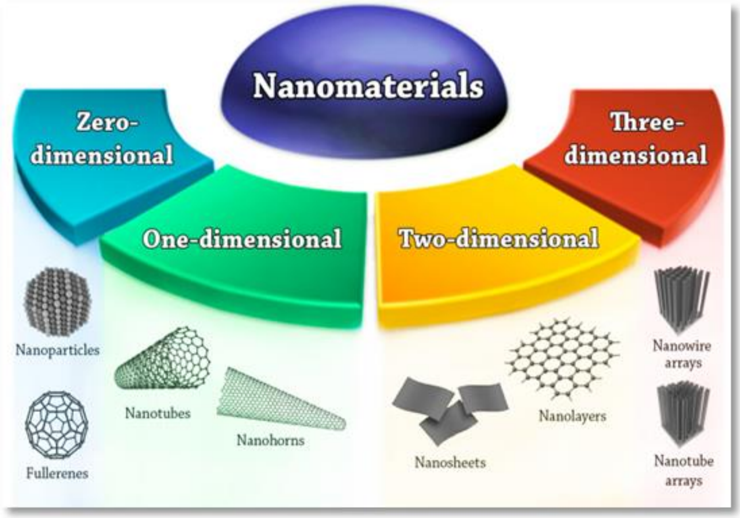
STRUCTURE OF NANOPARTICLES



Nanoparticles (NPs) have complex structure. They are comprised of two or three layers[17]

A surface layer: Functionalized by a variety of small molecules, metal ions, surfactants or polymers.
The shell layer: Can be purposely added and is chemically different from the core.
The core material: The central portion of NPs

CLASSIFICATION OF NANOPARTICLES



BASED ON DIMENSION

1) ZERO DIMENSIONAL

Materials where all the dimension are measured with in the nanoscale(no dimension are larger than 100nm).

Length, breadth, height are confined at single point.

EXAMPLE: Quantum dots, Nanodots, Nanoclusters.

2) ONE DIMENSIONAL

Materials having one dimension outside the nanoscale (one dimension are larger than 100nm). It has only one parameter length or breadth. EXAMPLE: Nanowires, Nanotubes, Nanorods, Nanopillars.

3) TWO DIMENSIONAL

Materials having two dimension outside the nanoscale (two dimension are larger than 100nm).

It has only two parameter either length or breadth or height.

EXAMPLE: Nanofilms, Nanoplates, Nanosheets.

4) THREE DIMENSIONAL

Materials that are not confined to the nanoscale in any dimensions.

It has all the parameters of length, breadth, and height.

EXAMPLE: Graphite, Diamond, Nanosponge, A bundle of nanowires.

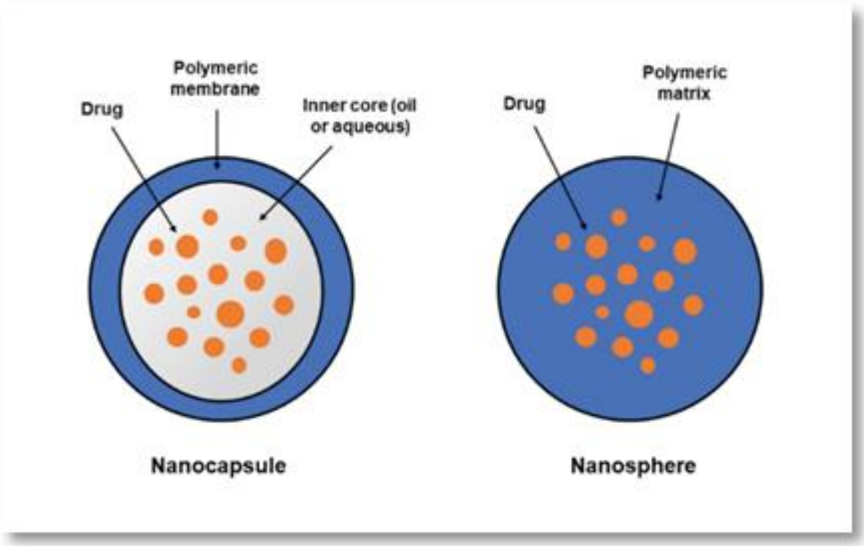
BASED ON STRUCTURE

1) NANOCAPSULE

A nanocapsule consists of central oily core containing the lipophillic drug surrounded by a shell composed of polymer.

2) NANOSPHERE

Nanospheres are solid core spherical particulates having a matrix consisting of a homogeneous distribution of the drug and polymer. The drug is either solubilized in the polymer matrix to form an amorphous particle or embedded in the polymer matrix as crystal.



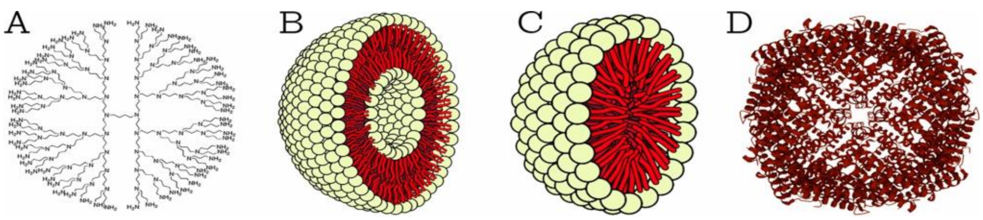
BASED ON COMPOSITION

1) ORGANIC NANOPARTICLES: 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.

Dendrimers, micelles, liposomes and ferritin are organic nanoparticles

These particles are biodegradable

Less toxic, Comparatively more biocompatible.



A Dendrimers B liposomes C micelles D ferritin

i) DENDRIMERS

Dendrimers arise from two Greek words: Dendron meaning tree and Meros meaning part. Structure of dendrimers has a well-defined size, shape and defined molecular weight.

Dendrimers are hyperbranched, globular, monodisperse, three dimensional nanoscales synthetic Polymers.

Dendrimers have been used in the pharmaceutical industry as non-steroidal anti-inflammatory drugs, antimicrobials, anticancer agents, pro-drugs, screening agents for high-throughput drug development, used in conventional applications such as coatings and inks, dendrimers can trap metal ions, which could then be filtered out of water with ultra-filtration techniques.

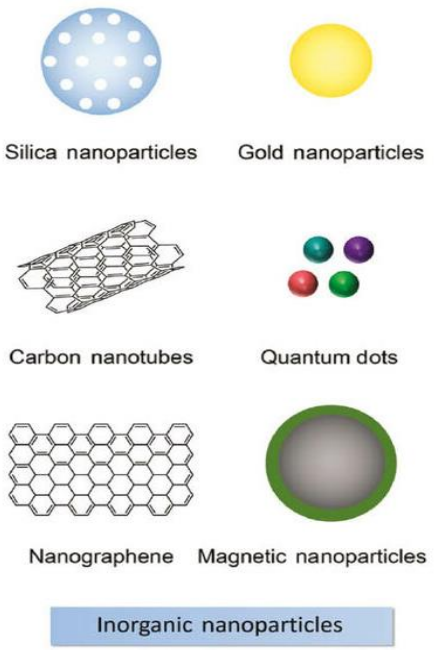
ii) LIPOSOMES

Liposomes is derived from Greek word “Lipo” means fat and “somes” means body.

Liposomes are concentric bilayered vesicles in which aqueous volume is entirely enclosed by a membranous lipid bilayer mainly composed of natural or synthetic phospholipids.

The use of liposomes as a DDS for chemotherapy is desirable due to their simple functionalization, effective drug encapsulation, biocompatible properties, and ability to control their size.

2) INORGANIC NANOPARTICLES



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

i) METAL OXIDE

Due to their smaller size, metal oxide NPs have a higher surface area, making them useful in a variety of applications, including biosensors, bionanotechnology, and nanomedicines. Some examples of metal oxidesbased NPs are Iron oxide ($Fe2O3$), Magnetite ($Fe3O4$), Aluminium oxide ($Al2O3$), Cerium oxide ($CeO2$), Silicon dioxide ($SiO2$), Titanium oxide ($TiO2$), Zinc oxide (ZnO).

a) Zinc oxide

ZnO is a suitable additive for textiles and surfaces that come into contact with the human body due to its safety and compatibility with human skin. Gram-positive and Gram-negative bacteria, as well as spores that can withstand high temperatures and pressure, are resistant to ZnO NPs.

b) Titanium dioxide

Titanium dioxide used in the reduction of toxic chemicals such as pollutants and dyes from water.

Titanium dioxide has received much attention for the application in the fields of photocatalytic activity and photocells due to its stability and low cost. $TiO2$ particles can also be used as energy storage devices, and in paints and coatings, sunscreens.

c) Aluminium oxide

Aluminium oxide nanoparticles have high surface area, inexpensive, well adsorption ability, thermal stability. There are many methods to prepare aluminium oxide nanoparticles hydrothermal, co-precipitation, pyrolysis, vapour phase reaction, combustion methods.

d) Iron oxide

Iron oxide nanoparticles are tiny particles of iron oxide that have magnetic properties and a large surface area. They are used in various applications such as metal-ion sensing and magnetic resonance imaging. They are also known for their low toxicity and biocompatibility.

ii) METAL BASED NANOPARTICLES

Metal based nanoparticles are only made up of metals. Almost all the metals can be synthesised into their nanoparticles. Thecommonly 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.

a) SILVER NANOPARTICLES

Silver nanoparticles (AgNPs) have been one of the most attractive nanomaterials in biomedicine due to their unique physicochemical properties. The biological action mechanisms of AgNPs, which mainly involve the release of silver ions (Ag^{+}), generation of reactive oxygen species (ROS), destruction of membrane structure. Despite these therapeutic benefits. The manufacturing of silver nanoparticles is relatively cheap, and the addition of these particles into goods (i.e., plastics, clothing, creams and soaps) increases their market value due to the consumer valued antimicrobial property. Silver nanoparticles in domestic products are becoming more common in washing machines, fridges and food containers to reduce surface mould growths.

b) GOLD NANOPARTICLES

Gold NPs, also known as colloidal gold or nano-gold is a colloidal suspension of sub-micron sized gold particles in an aqueous phase (water). They have well defined optical properties due to the collective oscillation of electrons on their surface. The preparation involves rapid stirring of chloroauric acid (HAuCl4) solution with appropriate reducing agents. This results in reduction of $Au3^{+}$ ions to neutral gold atoms. As the generation of neutral gold atoms increases, they tend to start precipitating as sub-nanometer particles. Vigorous stirring of the solution can facilitate to produce particles of uniform shape and size. They can absorb and scatter visible and nearinfrared light.

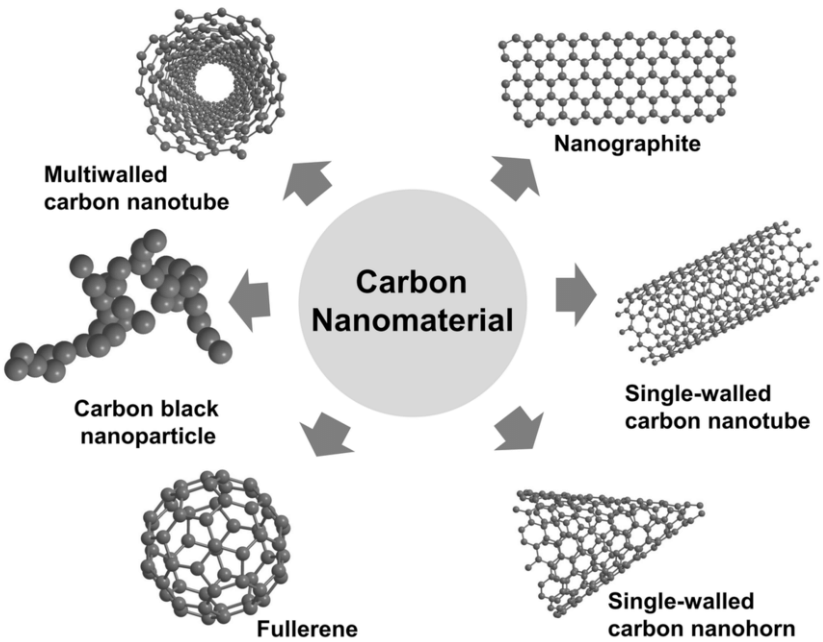
Gold nanoparticles are quite stable, inert and their electronic and optical properties can be adjusted.

c) COPPER NANOPARTICLES

The copper NPs can be prepared by the reduction of copper sulphate (CuSO4) under microwave irradiation by hydrazine in ethylene glycol. The reaction tends to produce well dispersed copper nano powders with a diameter of 15 nm. Further, the synthesis of pure copper NPs can be prepared by using reaction time of 8 h. In this case, use of ethylene glycol provides higher reaction rate and to facilitates reduction process. Also, the use of polyvinyl-pyrrolidone (PVP) provides a vital role in reducing the size and dimension of the particles. It primarily acts as a capping agent and tends to reduce and/or prevent particles agglomeration. Besides, use of water as the reaction medium facilities faster conversion of the $Cu2^{+}$ complex to Cu^{+} complex during formation of copper NPs.

iii) CARBON BASED

Carbon-based nanoparticles are made up of two major materials: carbon nanotubes (CNTs) and fullerenes.



a) CARBON NANOTUBES

CNTs are just graphene sheets folded into a tube. These materials are mostly utilised for structural reinforcement because they are 100 times stronger than steel. CNTs are cylindrical structures with a diameter of several nanometers, consisting of rolled graphene sheets. They may vary in length, diameter, symmetry and number of layers. The ends of CNTs can either be hollow or closed by a half fullerene molecule. Depending on their structure they can be broadly classified into two main groups.

(a) single- walled carbon nanotubes (SWCNTs) having a diameter of 1-3 nm and few micrometers in length and

(b) multi-walled carbon nanotubes (MWCNTs) with a diameter of 5-40 nm and a length of around 10 μm.

They are robust but flexible and have been used not only in the manufacturing industry (aircrafts, sports equipment, etc.,), but also as electron field emitters, nanoprobes in atomic force microscopy, supports for heterogeneous catalysis, microelectrodes in electrochemical reactions, and they are currently being investigated as potential hydrogen storage devices.

b) FULLERENES

Fullerenes (C60) is a carbon molecule that is spherical in shape, about 1nm in diameter, comprising 60 carbon atoms arranged as 20 hexagons and 12 pentagons and made up of carbon atoms held together by sp2 hybridization. Fullerenes and derivates are very insoluble in biofluids, which limits their application in the medical field. However, they have attracted the attention of many scientists for the variety of interesting applications in this field, and preliminary studies have investigated their role on HIV-Protease inhibition, DNA photocleavage, neuro-protection, apoptosis, among others biological effects.

c) GRAPHENE

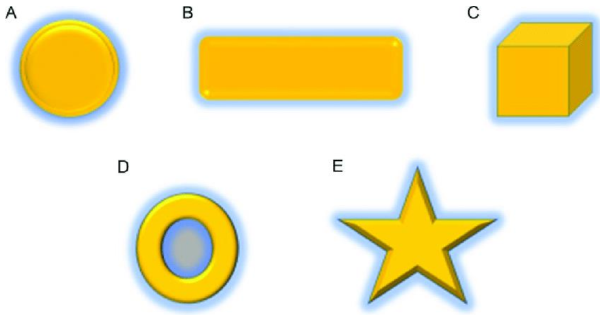
Graphene is an allotrope of carbon. Graphene is a hexagonal neighbourhood of honeycomb lattice made up of carbon atoms in a twodimensional planar surface. Generally the thickness of the graphene sheet is spherical 1 nm.

d) CARBON NANOFIBER

The same graphene nanofoils are used to produce carbon nanofiber as CNT alternatively wound into a cone or cup shape as an choice of a everyday cylindrical tubes. Carbon nanofibers (CNFs) are cylindrical or conical 1D nanostructures with diameters in the range of few to hundreds of nanometers and lengths varying from less than a micron to millimeters. CNFs areconductive materials with electronic structure similar to graphite. These nanofibers are also mesoporous and have high thermal stability in air, up to 900°C. CNF synthesis is easy and environmental friendly, and its process is cheaper than CNT.

e) CARBON BLACK

An amorphous material made up of carbon, commonly spherical in shape with diameters from 20 to 70 nm. The interaction between the particles are so immoderate that they positive in aggregates and spherical 5 hundred nm agglomerates are formed.



BASED ON SHAPE

a) Nanosphere
b) Nanorods
c) Nanocages
d) Nanoshell
e) Nanostar

NANORODS: Nanorods are a very important nanoscale systems usually obtained by metals or semiconducting materials. Their aspect ratios (length divided by width) are commonly 3–5 and the characteristic dimension ranges from 1 to 100 nm.

Nanorods are produced by direct chemical synthesis: ligands are combined to act as shape control agents and they bond to different faces of the nanorod with variable strengths. Nanorods, along with other noble metal nanoparticles, also function as theragnostic agents. Nanorods absorb in the near IR, and generate heat when excited with IR light. This property has led to the use of nanorods as cancer therapeutics. Nanorods can be conjugated with tumour targeting motives and ingested. When a patient is exposed to IR light (which passes through body tissue), nanorods selectively taken up by tumour cells are locally heated, destroying only the cancerous tissue while leaving healthy cells intact. EX: Carbon nanorods, zinc nanorods, magnetic nanorods.

NANOSHELL: Nanoshells have been a promising drug delivery systemin cancer treatment and diagnosis. A nanoshell is a spherical nanoparticle made up of a dielectric core and a thin metallic shell, typicallymade of gold.

Core particles of different morphologies such as rods, wires, tubes, rings, cubes, etc. can be coated with thin shell to get desired morphology in core shell structures. There are various methods to fabricate core shell structures e.g. precipitation, grafted polymerization, micro emulsion, reverse micelle, sol–gel condensation, layer-by-layer adsorption technique.

NANOSTAR

Nanostars are a form of anisotropic, star-shaped nanoparticle, of 1-100 nm in diameter. They possess a spherical core with multiple branches of adjustable length, width and sharpness.

Nanostars can be made from various metals, including gold, silver, platinum and palladium among others. Nanostars may also be grown from a mixture of these and other materials such as iron oxide or silica. Nanostars may be coated with a variety of ligands with the aim of providing protection from protein accumulation in a biological setting, providing the ability to selectively accumulate in a particular tissue or cell using targeting biomolecules such as antibodies, or as drug delivery vehicles.

BASED ON CHEMICAL STRUCTURE AND NATURE

1. NANOCRYSTALS: Nanocrystals are nanometer-sized crystals, which means they are nanoparticles having crystalline properties. Drug powder is dissolved in a surfactant solution to form nanocrystals.

2. NANOSUSPENSION: The term "nanosuspension" refers to a very tiny colloidal biphasic, dispersed and solid drug particle in an aqueous vehicle, size less than 1 micrometre without any matrix material, stabilised by surfactant and polymer, and prepared by proper drug delivery application by multiple routes of administration.

3. NANOBUBBLE: Nanoscale bubble-like formations called nanobubbles (NBs) are produced at the interface of hydrophobic surfaces in liquids. When heated to physiological temperature inside the body, these nanobubbles combine to produce microbubbles and are stable at normal temperature. The mechanism of NB creation is based on the nucleation of gas from a supersaturated solution at the hydrophobic surface, trapping ambient gases. There are four different kinds of nanobubbles: oscillating, interfacial, bulk, and plasmonic. These bubble-like nanoscale structures can contain cancer treatment medicines. Potential benefits of nanobubbles include their ability to target tumour tissue and deliver drugs under the influence of ultrasonic exposure, might demonstrate advantages in targeting the tumour tissue and administering the medicine selectively. This could improve the tumour cells' ability to absorb the medication intracellularly. Furthermore, these nanobubbles can be clearly seen in tumours using a variety of ultrasound techniques.

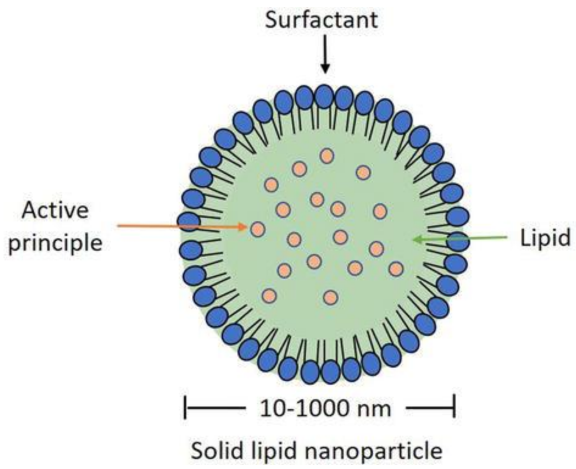
4. CERAMIC NANOPARTICLES: These are the Nanoparticles made up of inorganic compound silica, titanium and alumina. Exist in size less than 50nm, which help them in evading deeper part of body.

5. HYDROGEL NANOPARTICLE: Hydrogel Nanoparticle are formed in water by selfassembly and self-aggregation of nature polymer amphiphiles. Hydrogel nanoparticles also referred as polymeric nanogels. Hydrogels are polymeric networks with three dimensional configuration that absorbs large quantities of water or biological fluids. Their water affinity is attributed due to the presence of hydrophilic groups such as ether, amine, hydroxyl, sulfate and carboxyl in the polymer chains.

6. SOLID LIPID NANOPARTICLES (SLN): Solid Lipid Nanoparticles are nano-size colloidal carrier(50-1000nm),which are composed of lipid, surfactants and drugs in appropriate ratios. SLN are generation of submicron sized lipid emulsion where liquid-liquid has been substituted by solid-liquid.

These can be prepared using fatty acids, acylglycerols, waxes, triacylglycerols, and triglycerides as solid lipids. The SLNs have the ability to encapsulate the drug and it helps in the functionalization of small molecules, protein moieties by introducing desired functional groups to target specific cells in the body. Larger surface area and smaller size of the SLNs give rise to numerous potential applications in drug delivery.

SLNs are applied for some of their significant features such as enhancement of drug solubility, increased bioavailability, controlled drug release, better targeting of drug, and ease of administering through various routes such as parenteral, oral, pulmonary, and topical.

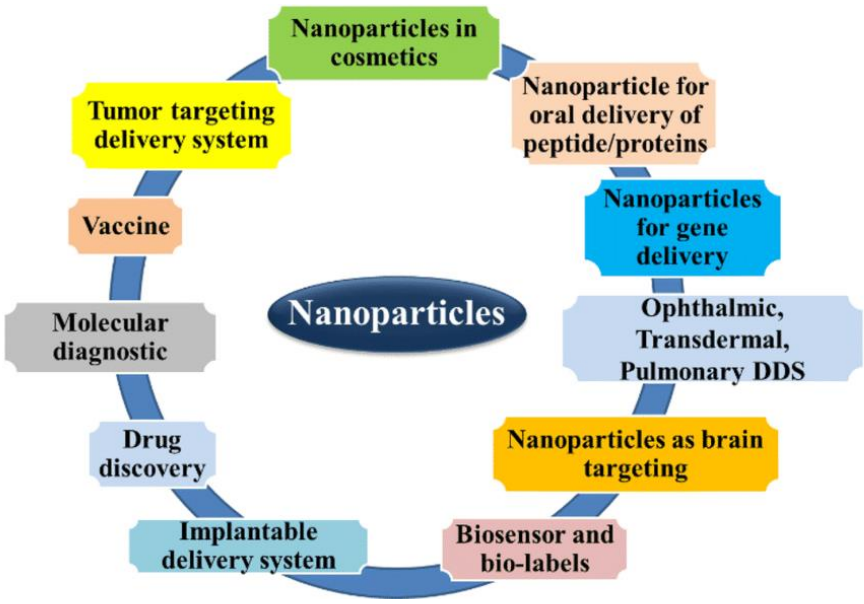


SLN, are nanoparticles composed of a mixture of a solid and a liquid lipid in which the lipid matrix is solid at room and body temperature. Various methods have been developed for the preparation of SLN, such as by high-pressure homogenization, cold and heat, microfluidization, supercritical method, and double emulsion.

SLNs have been reported to be useful as drug carriers to treat neoplasms. Tamoxifen, an anticancer drug incorporated in SLN to prolong release of drug after i.v. administration in breast cancer and to enhance the permeability and retention effect. Tumour targeting has been achieved with SLNs loaded with drugs like methotrexateand camptothecin.

The SLNs have been applied in the preparation of sunscreens and as an active carrier agent for molecular sunscreens and UV blockers.

APPLICATION OF NANOPARTICLES



1. IN AGRICULTURE

Nanotechnology helps for monitoring environmental conditions and delivering nutrients or pesticides and also this technique are used in crop development, food process engineering.

a) Grain spoilage detection sensor

Grain spoilage is the major problem arrived in crop production. This spoilage is due to the difference in the atmospheric climate and pathogens. Fabric sensor is a special sensor that helps the farmer which indicates the arrival of pathogens during crop development and sending alerts via mobile phone.

b) Nano pesticides

Nano pesticides are developed which are biosafety and has a molecular interaction with plant, soil and environment with very limited dosage. Silver nanoparticlesis, a kind of antimicrobial substance has been used as fungicides. They are used without causing damage to the environment. Nanopesticides are plant protection products where nanotechnology is employed to enhance the efficacy, make them environmentally safe and less toxic effects. These nanostructures have shown slow degradation and controlled release of active ingredients for longer time. **Eg:** Aqueous dispersion of nano-permethin, novaluron.

c) Nano fertilizers

Nanofertilizers comprise one or more plant nutrients within nanoparticles where at least 50% of the particles are smaller than 100 nanometers.

Carbon nanotubes, graphene, and quantum dots are some examples of the types of nanomaterials used in the production of nanofertilizers.

Nanofertilizers are a new generation of fertilizers that utilize advanced nanotechnology to provide an efficient and sustainable method of fertilizing crops. They are designed to deliver plant nutrients in a controlled manner, ensuring that the nutrients are gradually released over an extended period, thus providing a steady supply of essential elements to the plants.

Nanoparticles of Fe, Zn, Mn and Cu oxides may have the potential for increasing plant growth when they are applied to soils.

d) Nanotechnology in crop improvement

Nanotechnology are used to control the effective release of the right doses of plant nutrients which makes the fertilizer nutrients which makes the fertilizer nutrients more available to the nanoscale pores. The application of Tio_2 was reported to increase the yield by promoting growth, photosynthetic rate and by reducing disease severity.

2. IN ENVIRONMENTAL

Nanoparticles are the key players that give many benefits through their nano-enabled applications. Nanomaterials provides an increasing efforts to use nanotechnology in environmental engineering to protect the environment by pollution control, treatment of drinking water and contaminated waste sites. This technique has proved to be an effective substitute to the conventional practices for site remediation.

a. Nanoremediation

Nanoremediation methods involve application of reactive materials for the detoxification and transformation of pollutants. This eco-friendly technology was used to protect the environment from pollution.

b. Ground water remediation

Nanomaterials such as zero valent iron (nZVI) and carbon nanotubes (CNT) in environmental cleanup like ground water remediation for drinking and reuse.

c. Titanium di-oxide Nanoparticles

Titanium oxide nanoparticles (TiO_2 NPs) also proved to have a good antimicrobial effect, since its photocatalytic properties generate free radical oxides and peroxides with potent antimicrobial activity and broad reactivity against many microbial pathogens.

Semiconducting, photocatalytic, energy converting, electronic and gas sensing properties of TiO2 materials is responsible for the removal of various organic pollutants from the environment. Diazinon and Imidacloprid as N-heterocyclic aromatics are the two major agricultural pollutants were mineralized and degraded by immobilized TiO2 nanoparticles.

Photodegradation of direct azo dyes (Direct red 23 and Direct blue 53) can be done by using silver nanoparticles doped TiO2. This material can be used for the extraction of phenols and removal of heavy metal cations (zinc, cadmium, chromium, copper, lead, palladium and mercury) from the wastewater.

d. Bimetallic Nanoparticles

Bimetallic nanoparticles are synthesized when two different metals are mixed together in a reaction vessel under optimized conditions, resulting in various structural and morphological changes.

Bimetallic nanoparticle (Pd/Au) which are used to reduce the chlorinated compounds present in surface water and ground water.

Sodium carboxy methyl cellulose (CMC) was bimetallic with Fe-Pd as a stabilizer and used for the degradation of lindane and atrazine from the chlorinated herbicides.

Bimetallic Cu/Fe nanoparticle having ability to remove Nitrate compound Ground and surface waters were mainly contaminated by the increasing presence of nitrate in water.

e. Nanoclays

Nanoclays are nanoparticles of layered mineral silicates. Depending on chemical composition and nanoparticle morphology, nanoclays are organized into several classes such as montmorillonite, bentonite, kaolinite, hectorite, and halloysite.

f. Nanomembrane

(a) NM on the original substrate with a sacrificial layer in-between,

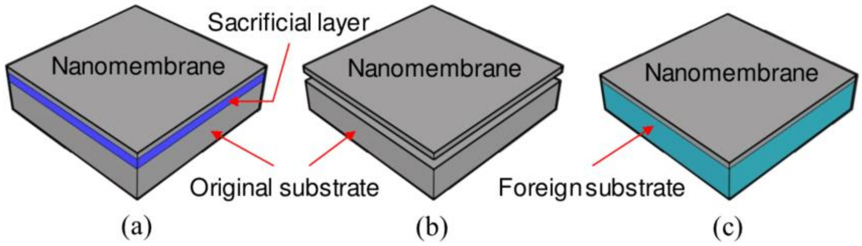
(b) NM released from the original substrate by selective removal ofthe sacrificial layer,

(c) NM transfer printed onto a foreign substrate.

Nanomembrane is a semi-permeable and selective barrier between retentive and permeate phases and used for filtration of dissolved solutes in a fluid or the separation of a gas mixture.

Natural Organic Matter (NOM) such as humic acid and fulvic acid are widely distributed in soil, natural water and sediments.

Nanofiltration (NF) is a process carried out with membrane permeability of nanomembrane used for the fractionation of Natural Organic Matter (NOM) from RO (desalination of seawater) and UF (ultrafiltration) process.



3. IN OPTHALMOLOGY

New eye nano-systems with different shapes and characteristics to optimize the bioavailability of drugs, prolong the contact time and reduce the eye removal process had been designed.

It includes the treatment of oxidative stress; measurement of intraocular pressure, theragnostics (use of nano particles for treatment of choroidal vessels), to prevent scars after glaucoma surgery, and for treatment of retinal degenerative disease using gene therapy (prosthetics) and regenerative nano medicine.

Nanomaterials are used to help in various unsolved problems such as sight-restoring therapy for patients with retinal degenerative disease.

Nano-sizedophthalmic drugshavethe advantages of good solubility, large dissolution area, fast dissolution speed, strong biological adhesion, and strong corneal penetration. It is suggested that the particle size should be less than 10 and reduce the tear and bleeding of the drip dose, so as to improve the effectiveness of eye treatment. Nano suspensionare colloidal dispersions in which the hydrophobic phase is uniformly dispersed in the aqueous medium with the help of surfactant.

For example, prednisone, dexamethasone, hydro-cortisone, and other corticosteroids have been administered through nanosuspensionsto treat anterior inflammation without the expected side effects of high-dose application, such as cataract and glaucomatous optic neuropathy.

4. IN VETERINARY MEDICINE

Nanotechnology provides improving pet health care and visualizes the quality of animals life. The variety of nanomaterials have been used for disease diagnosis, treatment, drug delivery, animal nutrition, animal breeding, reproduction, and value added products into animal products, including liposomes nanoparticles, micellar nanoparticles, polymeric nanoparticles, dendrimer nanoparticles, metallic nanoparticles, and carbon nanoparticles.

Nanobiosensors are very sensitive for environmental monitoring and clinical diagnostics and also it has been used for reproductive management, such as detection of oestrus, hormone levels, and metabolites profiles.

Nanomaterials could be used for the cryopreservation of gonadal tissues, sperm, oocytes, and embryos, which are very essential in animal reproduction. Finally, nanomaterials are being used in food technology including meat and meat products free from contaminations.

The nanomaterials would facilitate develop products and processes for animal health and production in line with economic, social, and environmental valuable materials to challenge the animal reproduction.

Nanosensors are miniature devices that can diagnose biological material or tissue samples. Nanosensors have been used as invasive measurement to monitor important physiological variables, such as blood gases, ions, metabolites, blood pressure, and blood flow.

Nanoparticles based sensors have been used in several biomedical applications in veterinary medicine, including animal health and other areas of animal production, particularly the delivery of controlled amounts of drugs into the beverage of breeding animals, prevention of bovine tuberculosis, the controlled release of injectable poorly water-soluble drugs, and as destroyer of pathogens.

5. IN MEDICINE

Nanoparticles can not only circulate widely throughout the body but also enter cells or be designed to bind to specific cells.

Nanoparticles help to cure people faster and without the side effects. Nanotechnology in medicine is now focusing on areas like tissue regeneration, bone repair, immunity and even cures for such ailments like cancer, diabetes and other life threatening diseases. Nanorobots (computational genes) introduce into the body to repair or detect damages and infections.

Nanoparticles can be used for the better deliver drugs to tiny areas within the body due to its particle size and surface properties. They control and maintain the release of the drug during drug targeting.

Nanoparticles can act as a physiological barrier in the body, because of its efficient characteristics in delivery of drug to various parts of the body. It provides more efficient drug distribution.

Nanoparticles enhance the stem cells ability to stimulate regeneration of damaged vascular tissue and reduce muscle degeneration in stem cell therapy.

a. Cancer therapy

Nanoparticles can be utilized to improve antigen presentation and T cells activation. They can also deliver pro-immune/pro-inflammatory agents to tumors and tumor microenvironments to enhance the cancer immunotherapy response.

There are many types of nanoparticles, including metallic, magnetic, polymeric, metal oxide, quantum dots, graphene, fullerene, liposomes, carbon nanotubes, and dendrimers, which are used in breast, colon, and cervical cancer diagnosis.

Nanoparticles deliver chemotherapy drugs directly to cancer cells to minimize damage to normal cells.

b. Drug delivery

Nanoparticles deliver chemotherapy drugs directly to cancer cells to minimize damage to normal cells.

Nanoparticles are used to deliver drugs, heat, light or other substances to specific types of cells (such as cancer cells). Particles are engineered so that they are attracted to diseased cells, which allow direct treatment of those cells. This technique reduces damage to healthy cells in the body and allows for earlier detection of disease.

c. Cardiac therapy

Nanotechnology is currently offering promising tools for the cellular level and treat challenging cardiovascular diseases. Nanocrystals and Nano barcodes are capable of monitoring complex immune signals in response to cardiac or inflammatory events.

d. Dental care

The benefit of nanodentistry in natural tooth maintenance could also be significant. Covalently bonded artificial materials like sapphire may replace upper enamel layer to boost the appearance and strength of teeth.

e. Diagnostics

NPs can assist in the visualization of particular body parts when used as imaging agents. For instance, iron oxide nanoparticles, or Fe3O4NPs, have been used as MRI contrast agents to improve the visibility of Quantum Dots (qdots) may used for locating cancer tumours in patients and in the near term for performing diagnostic tests in samples.

Quantum Dots are spherical, fluorescent nanocrystals are widely used for the development of biosensors to detect biomolecules such as proteins, neurotransmitters, enzymes and amino acids.

Nanomaterials exhibit higher properties that are very different than their bulk materials, so that it is mainly used in diagnostic techniques. Because of their small size, nanomaterials can easily interact with biomolecules and gaining access to so many areas of the human body system. Nanomaterials give the opportunity to interact with cells at the molecular scales in real time, and also during the earliest stages of an disease.

f. Skin therapy

Applications of nanotechnology in dermatology include sunscreens, moisturizers, anti-aging formulations, phototherapy, anti-sepsis, skin cancers, hair and nail care, etc.

6. COSMETICS AND SUNSCREENS

Cosmetic manufacturers employ nanosized ingredients to improve UV protection, skin penetration, color, the release of fragrance, finish quality, anti-aging effect, and a variety of other properties. They prolong the duration of action by either controlling the delivery of active ingredients, causing site-specificity, improving biocompatibility, or enhancing the drug-loading capacity.

Nanoparticles utilized in cosmetics or cosmeceuticals can be comprehensively classified into two categories: biodegradable nanoparticles (made up of lipids, chitosan, etc.) and non-biodegradable nanoparticles (ZnO, silica-based nanoparticles, etc.)

Sunscreens are useful for shielding the skin from the hazardous impacts of solar radiation, including UVB, UVA-1, and UVA-2. They usually consist of zinc oxide (ZnO) and titanium dioxide (TiO_2) as inorganic UV radiation filters, which prevent the harmful radiation of sunlight from reaching the skin. It has been established that ZnO is more effective for obstructing UVA, and TiO_2 is better for the UVB range.

Gold nanoparticles play a substantial role in fixing skin damage and improving skin surface, grace, and flexibility. The soothing properties of gold make it an exceptional agent for treating skin inflammation, sunburn, and hypersensitivity. Hence, it can be successfully used in face masks and other cosmetics.

Silver nanoparticles can be utilized as successful inhibitors of various microorganisms. Silver and silver-based mixtures can be utilized to control bacterial development in different formulations.

7. IN TEXTILES

Textiles Nanotechnology in the textile industry has become multifunctional and produces fabrics with special functions, including antibacterial, UV protection, easy-clean, water- and stain repellent and anti-odour, flexibility etc.

Clay nanoparticles are resistant to heat and ability to block UV light Chitosan and silver are used as antibacterial, Polybutylacrylate used for increase durability, Nanoporous hydrocarbon on nitrogen coating used for improved staining or reduce fade in clothes.

Nanotechnology has created antibacterial cotton used for antibacterial textile.

This technique has been advanced by a focus on inorganic nanostructured materials that acquire good antibacterial activity and application of these materials to the textiles.

8. IN NANOELECTRONICS

The term nanoelectronics refers to the use of nanotechnology in electronic components.

Nanomaterials are used to increasing the density of memory chips. It also reduces the size of transistors used in integrated circuits.

The higher necessity for large size and high brightness displays in recent days that are used in the computer monitors and television is encouraging the use of nanoparticles in the display technology. For example nanocrystalline lead telluride, cadmium sulphide, zinc selenide and sulphide, are used in the light emitting diodes (LED) of modern displays.

Nanoparticles are the ideal choice for separator plates in batteries.

The increase in electrical conductivity of nanoparticles is used to detect gases like NO_2 and NH_3

There are various applications such as computing and electronic devices. Devices such as Flash memory chips, antimicrobial and antibacterial coatings for mouse, keyboard. Also, mobile phone castings are good examples of nanoelectronics. Solar cell and supercapacitor are example of areas where nanoelectronics is playing a major role in enery generation and storage.

9. IN TISSUE ENGINEERING

Tissue engineering (TE) is the study of the growth of new tissues and organs, starting from a base of cells and scaffolds. The scaffolds are used as three-dimensional (3D) structures in which cells grow, proliferate and differentiate into various cell types.

Nanoparticles have been used to serve various functions in TE, ranging from enhancement of biological, electrical and mechanical properties to gene delivery, DNA transfection, viral transduction and patterning of cells, to facilitate the growth of various types of tissues to molecular detection and biosensing.

10. IN ANTIBIOTIC RESISTANCE

Zinc Oxide nanoparticles can decrease the antibiotic resistance and enhances the antibacterial activity of Ciprofloxacin against microorganism by interfering with various proteins that are interacting in the antibiotic resistance or pharmacologic mechanisms of drugs. Nanoparticles can penetrate the cell wall and membrane of bacteria and act by disrupting important molecular mechanism.

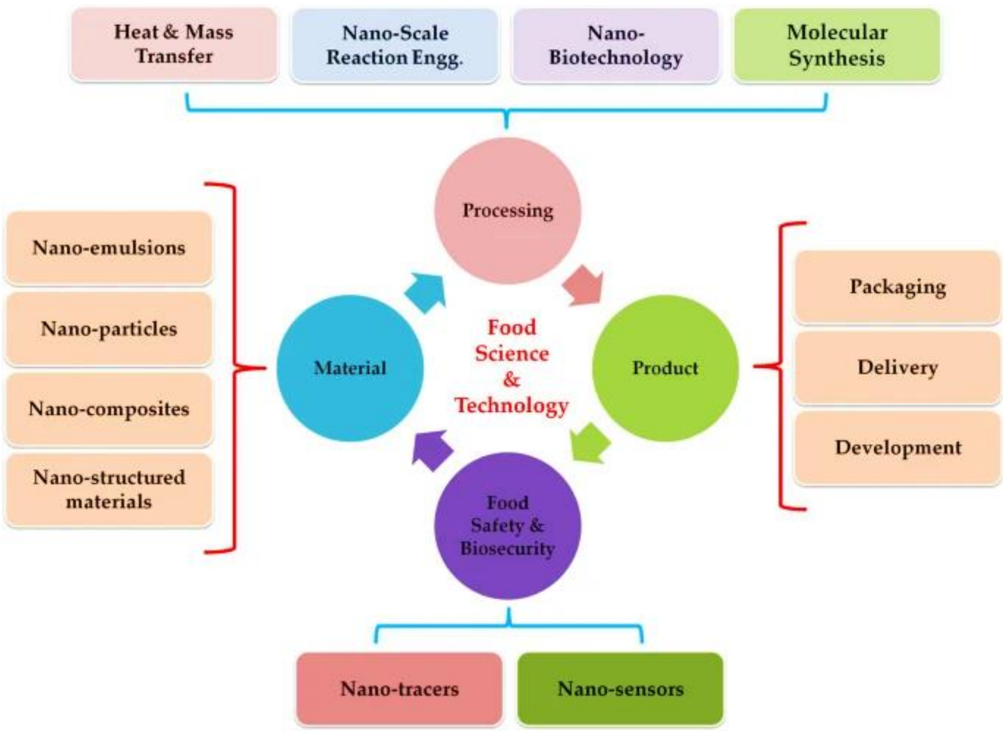
11. IN FOOD

Nanotechnology has introduced alternative techniques to food processing in terms of both improving physicochemical qualities and increasing nutrient stability and bioavailability.

Antimicrobial nanoparticles are used in active packaging to protectfood against detrimental and spoilage-causing bacteria to extend shelf-life and quality freshness. They are also included in the active packaging to make it stronger, lighter, and less O_2 accessible.

Nanosensors are another application for the food sector. Nanosensors convert physical quantities into signals, which can be easily detected and analyzed. This approach is used to detect foodborne pathogens, food spoilage, toxins, vitamins, pesticides, and any unwanted taste or smell, as well as to monitor time–temperature and oxygen indicators.

Nanotechnology is thus a novel technology that holds great promise in all aspects of the food industry, including food processing, food packaging, food safety, and functional food development.



Silicon dioxide and titanium dioxide are the most commonly used nanoparticles. Silicon dioxide is used as a food colorant, anticaking agent, and drying agent for food preservation and packaging. It also helps in absorbing the water molecules and therefore has hygroscopic application. Titanium dioxide nanoparticles are used as a food colorant and photocatalytic disinfecting agent. They can also be used as a whitener in dairy products such as milk and cheese. Generally, titanium dioxide provides a barrier for UV protection in food packaging.

Chitosan is a high molecular weight, polycationic heteropolysaccharide, and it is generally known for its biodegradability, biocompatibility, and metal complexation. Its polycationic nature is mainly responsible for its wide antimicrobial activity.

Chitosan-based films provide a better solution with regard to increasing the shelf life of the product without affecting its properties.

Nanomaterials (nanocomposites) in food packaging and preservation. The use of nanocomposites in packaging results in effective thermal and barrier properties at a lower cost.

For example: Zinc oxide nanocomposite has gained a great deal of attention from the food industry as it has antioxidant effects and is therefore widely used in the active packaging of food material. Nanocomposites are typically comprised of polymers in combination with nanoparticles, and their presence extends the properties of the polymer. Generally, nanocomposites help to maintain the freshness of food material and to delay microbial spoilage for a longer period of time.

Nanocomposites act as a gas barrier to prevent the leakage of carbon dioxide from carbonated beverage bottles and cans. Food industries that mainly produce carbonated beverages can use the nanocomposites layer on the cans or bottles of the beverage in order to minimize the leakage instead of using heavy glass bottles and expensive cans.

12. CONSTRUCTION

Nanotechnology has improved the construction processes by making them quicker, inexpensive and safer. For example when nanosilica (SiO2) is mixed with the normal concrete, the nanoparticles can improve its mechanical properties, and also improvements in durability.[36] The addition of haematite (Fe2O3) nanoparticles increases the strength of the concrete. Steel is the most widely available and used material in the construction industry. The properties of steel can be improved by using nanotechnology in steel for example in bridge construction the use of nano size steel offers stronger steel cables. The use of nanotechnology provides a better blocking of light and heat penetrating through the windows. The paints with self-healing abilities and corrosion resistance and insulation are obtained by adding nanoparticles to the paints. The addition of nanoparticles in paints also improves its performance by making them lighter with enhanced properties so when used for example on aircraft, it might reduce their overall weight and the amount of paint required, which is favourable to the environment as well the company to improve cost savings.

CONCLUSION

Nanoparticles are the novel drug delivery system, which can be of potential use in controlling and targeting drug delivery. It is a smaller substance which are different than its bigger form. Nanotechnology helps to understand the world around us, and will provide inspiration and drive for many generation of scientists. Thus the future generation is going to continue the fantastic voyage with Nanotechnology in advanced level making life easier.

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