Nanoparticles: A Review

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Abstract*- This review paper look into the present properties and applications of nanoparticles. It gives a description about nanoparticles and its application in different fields like in drugs and medication, manufacturing and materials, environment, electronics, energy harvesting, mechanical industries,etc. Nanoparticles are small materials having size ranges from 1 to 100 nm. Depending on their Properties They can be classified into different classes. A technology platform that provides a wide range of synthetic nanostructures that may be controlled as a function of size, shape and surface chemistry and scale to these nanotechnical dimensions will be a critical first step in developing appropriate tools and a scientific basis for understanding nanoparticles.*

I. INTRODUCTION

A nanoparticle also known as ultrafine particle and defined as a structure with at least 1 dimension less than 1 micrometer. Nanotechnology is the study of the controlling the matter on an atom and molecular scale. Nanotechnology involves modifying or developing materials within 1-100 nanometers size range. It makes the material lighter,stronger,faster,smaller and more durable. Nanoparticles can not be detected by human eyes and can exhibit significantly different physical and chemical properties to their larger material counterparts. The material properties change as their size approaches the atomic scale. This is due to the surface area to volume ratio increasing, resulting in the material's surface atoms dominating the material performance. Nanomaterials can occur naturally, be created as the by-products of combustion reactions or be produced purposefully through engineering to perform a specialized function. Nanoparticles can be used in industries, healthcare and cosmetics to environmental preservation and air purification. Nanotechnology is also used in herbal medicines. Herbal medicines have been widely used all over the world since ancient times and have been recognized by physicians and patients for their better therapeutic value as they have fewer adverse effects as compared with modern medicines. However, phytotherapeutics needs a scientific approach to deliver the components in a sustained manner to increase patient compliance and avoid repeated administration. This can be achieved by designing novel drug delivery systems for herbal constituents. Novel drug delivery systems not only reduce the repeated administration to overcome non-compliance, but also help to increase the therapeutic value by reducing toxicity and increasing the bioavailability.

II. NANOTECHNOLOGY

Nano a greek word means small. Nanotechnology is comprehension and control of matter at the nanoscale, at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications. By using nanotechnology we can increase energy consumption efficiency, helps to maintain environment clean and also helps to reduce health problems. Nanotechnology produce materials of various types at nanoscale level. The isolation of nanocellulose from natural sources is possible through nanotechnology, which requires combined methodologies including mechanical, chemical and other processes. The resulting cellulose nanofibers could have distinct morphologies such as a rod-like NPs (whiskers) or an entangled network (nanofibers).

BASIC PROPERTIES OF NANOPARTICLES

Their is a drastic change in properties of nanoparticles because of

- Surface to volume ratio:

$$\frac{surface}{volume} = \frac{r^2}{r^3} = \frac{1}{r}$$

As Size of material decreases,surface to volume ratio increases and more number of atoms reside on surface.

- 3 nm particle – 50% atoms on the surface
- 10 nm particle-20% atoms on the surface
- 30 nm particle-Only 5% on the surface

2)Quantum size effect:

As we decrease the size the degree of freedom goes on reducing so it puts limit on the motion of the electron.

PROPERTIES

- SIZE: Reactivity and agglomeration of NPs is mostly dependent on their particle size. It is well known that the process of agglomeration will happen at slower rates in smaller particles. After the synthesis of the NPs, it is impossible to retain their original size. Hence, encapsulation becomes highly inevitable in NP synthesis. The exceptional size-dependent chemistry of NPs is distinguished from classical colloid chemistry by categorizing NPs according to their particle size .
- AGGLOMERATION OR AGGREGATION: Weakly bound (agglomeration) and fused particles are significant risk criteria as they lead to poor corrosion resistance, high solubility and phase change of NMs. This further leads to deterioration and the structure maintenance becomes challenging.
- REACTIVITY OR CHARGE: NPs can be charged either by functionalization or spontaneous degradative reactions. Chemical species and their charge-related critical functional groups will be a significant factor for specific functionality and bioavailability of NMs.
- CONTAMINANT DISSOCIATION: The contamination of residual impurities in the NP is considered as a major risk factor. For example, sulfur impurities may present in iron oxide NPs depending on the precursor used for their production ($FeCl_3$ or $Fe_2(SO_4)_3$). Similarly, nickel, yttrium, or rubidium metal impurities may be present in the carbon nanotubes (CNTs) [285–286] that are adsorbed on the CNT surface.
- IMPURITY: Inherently, NPs interact with impurities due to their high reactivity. Due to this reason, encapsulation becomes a prime necessity for solution-based NP synthesis (chemical route). In the encapsulation process, the reactive nano-entities are encapsulated by nonreactive species to provide stability to the NPs.
- RECYCLING AND DISPOSAL: NMs are not bound to any hard-and-fast safe disposal policies. The experimental results of NP exposure are not available and their potential toxicity issues are still under question. Hence, the uncertainty of a nanomaterial's effect is yet to be developed for permanent disposal and recycling policies.

SYNTHESIS OF NANOPARTICLES

Nanostructure materials have attracted a great deal of attention because their physical, chemical, electronic and magnetic properties show dramatic change from higher dimensional counterparts and depends on their shape and size. • Many techniques have been developed to synthesize and fabricate nanostructure materials with controlled shape, size, dimensionality and structure. • The performance of materials depends on their properties. The properties in tern depend on the atomic structure, composition, microstructure, defects and interfaces which are controlled by thermodynamics and kinetics of the synthesis. Classification of Techniques for synthesis of Nanomaterials There are two general approaches for the synthesis of nanomaterials

a) Top- down approach
b) Bottom–up approach.

(a) Top-down approach

Top-down approach involves the breaking down of the bulk material into nanosized structures or particles. Top-down synthesis techniques are extension of those that have been used for producing micron sized particles. Top-down approaches are inherently simpler and depend either on removal or division of bulk material or on miniaturization of bulk fabrication processes to produce the desired structure with appropriate properties. The biggest problem with the top-down approach is the imperfection of surface structure. For example, nanowires made by lithography are not smooth and may contain a lot of impurities and structural defects on its surface. Examples of such techniques are high-energy wet ball milling, electron beam lithography, atomic force manipulation, gas-phase condensation, aerosol spray, etc.

(b) Bottom-up approach

✓ The alternative approach, which has the potential of creating less waste and hence the more economical, is the 'bottom- up'.
✓ Bottom-up approach refers to the build up of a material from the bottom: atom-by-atom, molecule-by-molecule, or cluster-by cluster.
✓ Many of these techniques are still under development or are just beginning to be used for commercial production of nanopowders.
✓Oraganometallic chemical route, revere-micelle route, sol-gel synthesis, colloidal precipitation, hydrothermal synthesis, template assisted sol-gel, electrodeposition etc, are some of the well- known bottom–up techniques reported for the preparation of luminescent nanoparticals.

III. APPLICATIONS OF NANOPARTICLES

Nanoparticles have applications in various fields like

- Textiles
- Biomedical
- Healthcare
- Food Agriculture
- Industrial
- Electronicsjnq
- Environments
- Renewable energy

TEXTILES

Nanotechnology is a growing interdisciplinary technology often seen as a new industrial revolution. The fundamentals of nanotechnology lie in the fact that the properties of materials drastically change when their dimensions are reduced to nanometer scale. Nanotechnology is used to develop desired textile characteristics, such as high tensile strength, unique surface structure, soft hand, durability, water repellency, fire retardancy, antimicrobial properties, and the like.

Nanotechnology has real commercial potential for the textile industry. This is mainly due to the fact that conventional methods used to impart different properties to fabrics often do not lead to permanent effects, and will lose their functions after laundering or wearing. A coating of nano-particles on fabrics will not affect their breath ability or hand feel.

The textile industry has already impacted by nanotechnology. Research involving nanotechnology to improve performances or to create unprecedented functions of textile materials is flourishing.

Nanoparticles also have application in properties of textile material. The properties imparted to textiles using nanotechnology include water repellence, soil resistance, wrinkle resistance, anti-bacteria, anti-static and UV-protection, flame retardation, improvement of dye ability, Self-cleaning fabrics and so on.

BIOMEDICAL

Nanoparticles have notable applications in nanobiotechnology, mostly in diagnosis, drug-controlled release, cancer therapy, drug delivery, imaging, prostheses and implants. Nanoscale materials combine well into biomedical devices because most biological systems are also nanosized. The commonly used materials to develop these nanotechnology products are inorganic and metal nanoparticles, carbon nanotubes and metallic surfaces.Applications of nanotechnology in biomedical has following fields:

- **Biocomposites**

Biocomposites are mixtures of different materials used for various tissue engineering and restorative applications mainly due to their biocompatibility, superior mechanical properties, and biodegradability. These composites used in medical practice use a significant variety of devices and apparatuses.Biocomposites in the form of implants such as sutures, bone and joint replacement, dental appliances, ligaments, cardiac grafts, heart valves, etc., are commonly used to restore damaged function and to replace organs or regenerated tissues, to aid in regeneration, to correct defects and to increase patient quality of life.

- **Biomarkers**

A biological molecule found in blood, other body fluids, or tissues that is a sign of a normal or abnormal process, or of a condition or disease. A biomarker may be used to see how well the body responds to a treatment for a disease or condition. Also called molecular marker and signature molecule. And is mainly used in cancer treatment.

- **Hyperthermic treatment**

Hyperthermia is defined as **greater than expected or usual**body temperatures. Research has shown that hyperthermia is able to damage and kill cancer cells. Localized hyperthermia treatment is a well-established cancer treatment method with a simple basic principle: If a temperature elevation to 40 ºC (104 ºF) can be maintained for one hour within a cancer tumor, the cancer cells will be destroyed. The heat is generated by using nanoparticles in hyperthermic treatment to kill cancer cells.

- **MRI contrast agents**

Magnetic resonance imaging (MRI) contrast agents are mostly used to increase the contrast difference between normal and abnormal tissues. The various contrast agents are capable of targeting specific tumors to treat cancer.

HEALTHCARE

Nanotechnology is currently working as a tool to investigate the darkest avenues of medical sciences in several ways like imaging,sensing, targeted drug delivery gene delivery systems, and artificial implants. Application of nanotechnology in treatment, diagnosis, monitoring and control of disease has been referred to as “nanomedicine.” Nanoparticles are used for bioimaging -two different type of nanoparticles have been widely used for imaging: luminescent nanoprobes for OI and magnetic nanoparticles for MRI. We are using nanoparticles for in vitro diagnostics such as nanotubes,nanowires, cantilevers or atomic forcemicroscopy.

- **Nanoparticles as Drug Delivery Systems (DDSs)**

Drug delivery system (DDS) has been used clinically and pre-clinically to deliver therapeutic substances for disease treatment.

Drug delivery sysyems can improve several crucial properties of “free” drugs, such as solubility, efficacy, in vivo stability, pharmacokinetics, and biodistribution, enhancing their efficacy.Chitosan nanoparticles have been mostly studied for their application in cancer therapies. Chitosan nanoparticles can target tumors on specific organs through passive targeting, active targeting, and physical targeting through stimuli-sensitive targeting. Silica xerogels haven been widely used as inorganic materials for drug delivery. It is biocompatible, highly porous and easy to modify for functionalization.

FOOD AGRICULTURE

Nanotechnology can boost agricultural production, and its applications include: 1) nanoformulations of agrochemicals for applying pesticides and fertilizers for crop improvement; 2) the application of nanosensors/nanobiosensors in crop protection for the identification of diseases and residues of agrochemicals; 3) nanodevices for the genetic manipulation of plants; 4) plant disease diagnostics; 5) animal health, animal breeding, poultry production; and 6) postharvest management. Nanotechnology improves current agriculture practices through the enhancement of management and preservation of inputs in crops, animal production, and fisheries.

- **Nanoagrochemicals**

Pesticides are mostly used in agriculture to upgrade crop yield and efficiency.Nanopesticides are one of a new master plans being used to address the problems of non-nanopesticides.Nanopesticides cover a wide variety of products, some of which are already on the market. They cannot be considered as a single entity; rather such nanoformulations combine several surfactants, polymers (organic), and metal nanoparticles (inorganic) in the nanometer size range.

- **Nanofertilizers**

Nanofertilizers for traditional methods of fertilizer application is a way to release nutrients into the soil gradually and in a controlled way, thus preventing autrification and pollution of water resources.The use of nanofertilizer leads to an increased efficiency of the elements, reduces the toxicity of the soil, to at least reach the negative effects caused by the consumption of excessive consumption of fertilizers, and reduces the frequency of application of fertilizers.

- **Nanobiotechnology in agri-food production**

Nanobiotechnology opportunities include food, agriculture and energy applications. In the food processing industries, a few of the most common uses of nanobiotechnology in quality monitoring of food products may be identify as nanosensors/nanobio sensors and bacteria identification.The nanosensors can be used to detect the presence of insects or fungus accurately inside the stored grain bulk in storage rooms.

INDUSTRIAL

Nanotechnology achieve a great height in industrial field also.Products made from nanoparticles with novel functions such as car bumpers are made lighter, sunscreen is more radiation resistant, synthetic bones are stronger, cell phone screens are lighter weight, glass packaging for drinksleads to a longer shelf-life, and balls for various sports are made more durable.

- **Industrial catalysts**

catalysis is an important field of nanoparticles application. Catalysis is defined as the acceleration of a chemical reaction by a catalyst.Catalytic technologies are used in Conversion of crude oil, coal and natural gas to fuels and chemical feedstock, production of a variety of petrochemical and chemical products, and emission control of CO, hydrocarbons, and NO. The advantages of catalysts include (i) production of high value products with inexpensive raw materials, (ii) energy-efficient and environmentally-benign chemical conversion processes, (iii) increasingly stringent environmental regulations, and (iv) low-cost catalysts such as with reduction or replacement of precious metals.

Some of the applications of nanocatalysts are as follows-

1. Carbon nanotubes-

CNTs have been used in many fields as field emission sources, electric nano-conductor, Li ion secondary batteries, electric double-layer capacitors, fuel cells and molecular sieves.

2. Water purification-

Shashikala et al. (2007) reported that the process of maintaining hydrogen economy by synthesizing nano-metallic particles of silver using novel electro-chemical deposition method over carbon covered alumina support. This method gives a silver catalyst, which is highly efficient in controlling microbes in wate

3. Bio diesel production
4. Fuel cell application

- **Super thermal-conductive liquid**

Nanoparticles are used for increasing thermal conductivity of fluids. Low thermal conductivity is a primary limitation in the development of energy-efficient heat transfer fluids that are required in many industrial applications.Thenanofluids are expected to exhibit high thermal conductivities compared to those of currently used heat transfer fluids, and they represent the best hope for enhancement of heat transfer. The results of the theoretical study of the thermal conductivity of nanofluids with copper nanophase material are presented, the potential benefits of the fluids are estimated, and it is shown that one of the benefits of the fluids are estimated, and it is shown that one of the benefits of nanofluids will be dramatic reductions in heat exchanger pumping power.

ELECTRONICS

Nanoelectronics is a term refers to the application of nanotechnology in electronic devices, especially transistors. Nanoelectronics offers you smaller faster, and more portable systems. It increases the capabilities of electronic devices, components, and integrated systems and enhances the density of memory chips to manage and store larger amounts of data and information.

Nanoelectronics can improve display screens on electronic devices and revolutionize a lot of electronic products, applications, and procedures and reduce their weight, power consumption and the size of transistors used in integrated circuits.

In addition to the use of nanomaterials in electronics, some nanomaterials are also being used as surface coatings in certain electrical goods, primarily because they have anti-microbial properties. Products already marketed as having ‘anti-microbial’ nanomaterial coatings include refrigerators, vacuum cleaners, washing machines, mobile phones and computer mice.

Some of the existing or emerging uses of nanomaterials in electronics include:

• the use of carbon nanotubes in semiconductor chips;
• research into the use of a variety of nanomaterials in lighting technologies (light emitting diodes or LEDs and organic light emitting diodes or OLEDs), with commercial use expected in the near future;
• use of ‘quantum dots’ in lasers, along with ongoing research into application of other nanomaterials in laser technology;
• a variety of nanomaterials used in lithium-ion batteries, or which are being researched for this use;
• potential use of carbon nanotubes and other nanomaterials in fuel cells and by the solar industry for use in photovoltaics.
• research into use of nanomaterials to produce lead-free solder, as well as the development of solder-free assembly technology.

ENVIRONMENT

Nanotechnology has a potential for providing innovative solutions to a different environmental issues. These include improved methods for reducing pollution, water treatment, environmental sensing, remediation and making alternative energy sources more cost-effective.

IV. CONCLUSION

In this review, we presented a detail overview about NPs, their synthesis, physiochemical properties and applications. Through different characterization techniques such as SEM, TEM and XRD, it was revealed that NPs have size ranges from few nanometer to 500 nm. While the morphology is also controllable. Due to their tiny size, Nanoparticles have large surface area, which make them suitable candidate for various applications. Beside this, the optical properties are also dominant at that size, which further increase the importance of these materials in photocatalytic applications. Synthetic techniques can be useful to control the specific morphology, size and magnetic properties of nanoparticles. Nanomaterials can be used in different applications such as in medicine, electronic device, sunscreens, military applications, photovoltaic cells, paints, catalysts, etc. Some of these do not have an effect on the environment, while others have an effect on it. Though nanoparticles are useful for many applications, but still there are some health hazard concerns due to their uncontrollable use and discharge to natural environment, which should be consider for make the use of nanoparticles more convenient and environmental friendly.

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