ISSN: 0976-3031

Available Online at http://www.recentscientific.com

CODEN: IJRSFP (USA)

International Journal of Recent Scientific Research
Vol. 14, Issue, 04 (A), pp. 2980-2984, April, 2023

International Journal of Recent Scientific Research

DOI: 10.24327/IJRSR

Research Article

NANOPARTICLES-THEIR ADVANTAGES AND APPLICATIONS: A REVIEW

Mamta Sharma, Asha Rani, Ritu Saharan, RajRani, Kanchan Makker and Vivek Srivastava*

Department of Biotechnology, Dayanand College, Hisar-125001, Haryana, India

DOI: http://dx.doi.org/10.24327/ijrsr.2023.1404.0613

ARTICLE INFO

Article History:
Received 13th January, 2023
Received in revised form 11th February, 2023
Accepted 8th March, 2023
Published online 28th April, 2023

Keywords:

nanoparticles, application, technology, size, based.

ABSTRACT

Nanotechnology is an emerging technology, which have numerous applications in various fields. Nanoparticles are used in various enzyme catalysis to speed up the chemical reactions. These nanosized particles are used as drug delivery agents in medical nanotechnology. Their unique size based properties make them superior and helpful in different biological areas. These nanoparticles are categorized as carbon based, ceramic based, polymeric based and metal based. Different characterization techniques like TEM, SEM, FTIR help in understanding size and shape of these nanoparticles. Despites of its application, this review also cover the toxic effects of nanoparticles.

INTRODUCTION

Nanostructured materials are the nanoparticles of nanoscale range (<100 nm). These nanomaterials are made of a single or multiple materials. Therefore, nanomaterials are the formations of interlinked parts, which are in the nanoscale range [1]. Different types of simple materials like metal, carbon, polymer help in composition of nanoparticles and nanostructured materials [2].

Many interesting features, such as superior mechanical performance, the possibility of surface functionalization, large surface area, and tunable porosity are exhibit by different nanomaterials [3,4,5]. These properties makes nanomaterials the perfect candidates in the nanobiotechnology sector for their wide applications like production of tissue-engineered scaffolds (e.g., blood vessels, bone), drug delivery systems (gene therapy, cancer treatments, drugs for chronic respiratory infections), chemical sensors [6,7], biosensors [8,9] and wound dressings [10,11].

These nanostructured particles are found with many different shape, size and structure. It can be spherical, cylindrical, tubular, conical, hollow core, spiral, flat, etc. and the size of these nanoparticles ranges from 1 nm to 100 nm in size. These nanoparticles can be amorphous or crystalline. Surface variations like uniform and irregular are found in these nanostructured nanoparticles [2].

A recent growth in the instrumentation has led to an improved characterisation of different nanoparticle and its consequent application. Now a days, nanoparticles are now used in all stuff like from cooking vessel, electronics to renewable energy and aerospace industry. Nanotechnology is the key for a clean and sustainable future [12].

Many nanoparticles are engineered for production of useful products with enhanced performances, which make the nanoparticles an excellent example of emerging technology [13]. Currently, nanomaterials also have role in scratch-free paints, surface coatings, electronics, cosmetics, environmental remediation, sports equipment, sensors [14].

Due to a broad applications of nanoparticles in optical, electronic fields biomedical field, nanoparticle is currently an area of intense scientific interest for research purpose. Their unique and important features, such as their surface to mass ratio, which is much larger than that of other particles and materials, their ability to adsorb and carry other compounds such as drugs, probes and proteins as well as permitting the catalytic promotion of reactions makes nanoparticles an attractive field [15].

This review helps to provide information about the basic concepts, applications, advances relating to nanomaterials, covering the related information, its synthesis methods, properties, and achievable opportunities relating to the emerging area of nanomaterials.

Classification of Nanoparticles

Three major types of nanoparticles has been categorized under nanostructured material based on their properties.

Corresponding author:* **Vivek Srivastava
Department of Biotechnology, DayaNand College, Hisar-125001, Haryana, India

1. Organic
2. Inorganic
3. Carbon based

Organic Nanoparticles: Different knawn polymer cover under this category are micelles, dendrimers, ferritin and liposomes etc. properties like non-toxicity and biodegradablility, makes these kinds of nanoparticles attractive. Nanoparticles like liposomes and micelles also called nanocapsules, have a hollow core like structure and these structuse show sensitivity towards various thermal and electromagnetic radiation like heat and light [16].

These organic nanoparticles exhibit wide applications in the biomedical field for example lipsomes are efficient drug delivery system and can be injected on various parts of the body organ. Examples of organic nanoparticles include liposomes, dendrimers and micelles [17].

Inorganic nanoparticles: Theses are particles which are not made up of carbon. Inorganic nanoparticles categorized as metal and metal oxide based.

Metal NPs based

It include all those metals that can be synthesised into their nanoparticles [18]. The most commonly used metals for synthesis are aluminium (Al), cadmium (Cd), cobalt (Co), copper (Cu), gold (Au), iron (Fe), lead (Pb), silver (Ag) and zinc (Zn). These are prepared by chemical, photochemical or electrochemical methods [17]. The nanoparticles have numerous properties like their sizes as low as 10 to 100nm, pore size, surface charge and surface charge density, crystalline and amorphous structures, shapes like spherical and cylindrical, color reactivity and sensitivity to various environmental factors such as air, moisture, heat and sunlight etc.[12].

Metal oxides based

Their preparation involve the modification of the properties of their respective metal in to their oxide form. For example oxides of iron (Fe_2O_3) are prepared by oxidation process of iron (Fe) nanoparticles in the presence of oxygen at room temperature that increases its reactivity and efficiency when compared to its metal form [19]. The most commonly synthesised are Aluminium oxide (Al_2O_3), Cerium oxide (CeO_2), Iron oxide (Fe_2O_3), Magnetite (Fe_3O_4), Titanium oxide (TiO_2), Zinc oxide (ZnO), Silicon dioxide (SiO_2). These metal oxide nanoparticles have possess an outstanding properties when compared to their metal counterparts [12].

Carbon-based Nanoparticles

As the name indicate, these nanoparticles contain various forms of carbon like carbon nanotubes (CNTs) and fullerenes. CNTs are made of graphene sheets that are rolled into a tube like structure (fig.1). These materials are commonly knawn for structural strengthening as they are 100 times stronger than steel. CNTs are further classified into single-walled carbon nanotubes (SWCNTs) and multi-walled carbon nanotubes (MWCNTs). CNTs are considered as they are most thermally conductive along the length and non-conductive over the tube [20]. Major carbon based structures which come under this category are carbon nano fibers, graphene, carbon black and carbon anion. Various methods are designed for the production of carbon based materials include chemical vapor deposition (CVD), laser ablation and arc discharge (except carbon black) [21].

Nanoparticles Preparation

There are two ways for different nanoparticle synthesis:

1. Top down approach
2. Bottom up approach

Table 1 Approach used for synthesis of different nanoparticles

Approach	Method	Nanoparticle type
Top down approach	Nanolithography	Metal based
	Mechanical milling	Oxide and polymer based
	Laser ablation	Carbon based
	Sputtering	Metal based
	Thermal decomposition	Metal oxide based
Bottom up approach	Spinning	Organic polymer based
	Pyrolysis	Metal oxide and carbon based
	Sol gel	Metal oxide and carbon based
	Chemical decomposition	Carbon and metal based
	Biosynthesis	Organic polymer based

CHARACTERIZATION OF NANOSTRUCTURED PARTICLES

Size and shape are the two main parameters which is used for characterization studies. Size and ligands present on the surface of nanoparticles greatly affect the nanoparticles properties. Different techniques have been used for characterization of nanoparticles like scanning electron microscopy, transmission electron microscopy ,X-ray diffraction, some of which are summarized here.

Transmission electron microscopy

It is a microscopic technique in which image is formed by interaction of electrons which are transmitted by the specimen. This image is further magnified on screen or photographic film or detected by nanosensor [17]. This technique uses electrons instead of light to illuminate the surface of particles, for this reason, this microscopy give higher resolution than light based microscopy. Before imaging, sample preparation has been done by carbon coating on copper grid of nanoparticles. Those materials which have higher electron densities give good resolution than less electron dense materials. These include metals, metal oxides and polymeric nanoparticles like carbon nanotubes, quantum dots etc.

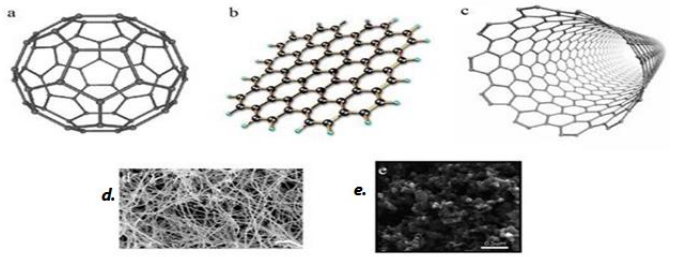

Fig 1 Different carbon based nanostructured particles.**a.**fullerene, **b**.graphene, **c**.carbon nanotubes, **d.** carbon nanofibers, **e.**carbon black [12]**.**

Scanning electron microscopy

Scanning electron microscopy uses the secondary electron for detection, which are emitted from sample upon electric beam interaction. SEM is used for charaterizarion of nanoparticles which are of thick morphology (>100nm),which is not possible to characterize with TEM. A conductive surface is prime requirement for better resolution however nonconductive surfaces are coated with thin metallic film for analysis of sample. The main difference between SEM and TEM image analysis is that SEM give information about surface morphology of sample whereas TEM interact with whole

volume of sample structure, hence give detailed information [22].

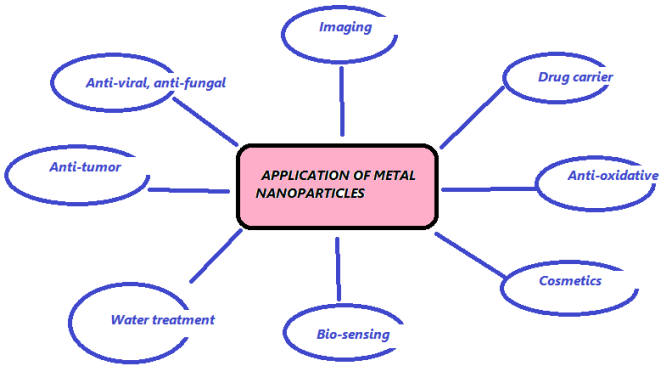

Fig 2 Wide Application of metallic nanoparticles

UV-visible spectroscopy

Studies of optical and spectral properties done by this spectroscopy technique. A light is pass through sample solution of nanostructured particles, some light is absorbed, some amount of light is transmitted. Amount of absorbed light is measured at various degree of wavelength. Using Beer-lambert law, the concentration of solution is determined. Absorbance peak is analysed at different wavelength(nm). Optical properties of nanoparticles which include size and shape makes UV-visible spectroscopy a good charactering tool.

X-ray diffraction(XRD)

It is an important technique to determine the crystal properties of nanoparticles. Arangment, size and shape of crystal are easily detected using X-ray diffraction studies. The information is analysed using Bragg,s reflection, since each bragg peak is indication of crysatallographic direction. This crystallgrapic direction is because of number of atoms involved in scattering events. Mean value of any crystal size is estimated using scherrer equation [22].

Fourier transform infrared spectroscopy (FTIR)

This spectroscopy helps to measure the nature of functional groups, which are the characterstics of knawn biological samples. FTIR measure the rotation of biological molecule and its vibration influenced by its infrared radiation at particular wavelength. Among all other spectroscopic methods, FTIR is the most famous one. One of the great advantage of using infrared spectral is its ability to bind to any type of sample in any state [23].

APPLICATIONS OF NANOPARTICLES

Some common applications of nanomaterial are listed here as:

- Fluorescent biological labels [24].
- Drug and gene delivery [25].
- Bio detection of pathogens [26].
- Detection of proteins [27].
- Probing of DNA structure [28].
- Tumour destruction via heating (hyperthermia) [29].
- Separation and purification of biological molecules and cells [30].
- MRI contrast enhancement [31].

Therapeutic applications of metallic nanoparticles

1. **As anti-Infective Agents**: Metallic nanoparticles are knawn for prevention of HIV. It is found in research that silver which acts as virucidal agent works directly by binding to glycoprotein GP120 present as coat on virus. This binding helps in decreasing the infection rate of HIV [32].Various metallic nanoparticles are found effective antiviral agents against different viruses like herpes simplex virus, influenza, respiratory viruses (fig.2).
2. **In Tumour Therapy:** It is found in studies that gold nanoparticles (AuNPs) involved in inhibition of proteins like VEGF165 and bFGF (heparin binding proteins) involve in induction of angiogenesis in vivo. Further it is also reported that, these proteins are adsorbed onto the surface of AuNPs and were later denatured [33]. The research showed that surface size plays a important role in the therapeutic effect of gold nanoparticles (AuNPs).

Therapeutic applications of polymeric nanoparticles

Polymeric nanoparticles involve in drug delivery system. They have application in treatment of neurodegenerative and brain associated diseases. Polymeric nanoparticles play a role in providing protection to the different drugs by entrapping inside a core or binding and adsorbing on to the surface of particle. Polymeric NPs undergo the process of endocytosis and transcytosis to deliver the cargo. Polymeric NPs also have been applied in gene therapy related to breast cancer by its anti-proliferative activity [17].

Therapeutic applications of lipid based nanoparticles

Lipid based NPs play a role in various types of cancer for example cancer related to GIT, lung, breast, pancreas, prostate. These lipid based NPs helps in transdermal penetration of phytomedicines inside skin. Lipid based NPs have role in inhibiting the growth of candida infection during oral candidiasis. It is also reported that these nanoparticles has superior antimicrobial activity [34].

Therapeutic applications of carbon based nanoparticles

The application of carbon based NPs specially graphene based nanoparticles in drug delivery is very common. Its structure is found as planar aromatic macromolecule because of six atom rings of carbon have π- conjugated system. These carbon based nanoparticles are of great capability for different probes and drugs. It is reported in research that graphene based NPs are good in delivering anti-cancer drugs to their target or specific tumor cells, and have non effective for normal healthy cells.

Carbon-based nanomaterials also have great role in bioimaging applications. For example magnetic resonance imaging (MRI), tomography (CT), fluorescence imaging (FL), photoacoustic imaging (PAI), computed positron emission tomography, Raman imaging/single photon emission computed tomography (PET/SPECT), multimodal imaging. One of the interesting and emerging carbon based nanoparticle is quantum dots which has found great application in bioimaging [35].

Application in nanoparticles in food sector

Nanotechnology also achieved a great potential in different food sector. Different nanomaterials are used in various food process of encapsulation and emulsion formation, nanosensor

development. Studies reported that production, packaging of food is named as nanofood [36]. FSAI reported various applications of these nanofood like sensory improvements (flavor/color enhancement and texture modification), targeted delivery of nutrition bioactive compounds, increased absorption, stabilization of active ingredients such as nutraceuticals in food sources, packaging and product upgrading to make longer shell life, sensors for food safety and to develop antimicrobials to eliminate pathogenic microbes from food, thus increasing its shelf life [37].

TOXIC EFFECTS OF NANOPARTICLES

Humans are continuously exposed to various forms of NPs because nanoparticles are produced by natural processes. Primary reasons for the environmental release of different nanoparticulates in their original or modified forms are its production, its use and disposal. Foreign particles are generally not acceptable by human skin and do the blockage of these foreign substances, whereas organs like lungs and GIT are susceptible to different foreign substances.

NPs are of the same size as of viruses as human immunodeficiency virus (HIV), whose diameter is found in the range of 100nm size [38]. Nanoparticles that are inhaled can reach the bloodstream easily and other organs in the human body like liver, heart or blood cells and specifically affect them. It is reported that toxic effects of these NPs depends on their origin [39].

Due to small size of these nanoparticles, they easily facilitates transfer of chemicals across different barriers like lungs, skin, body organs. Therefore, many defects have been associated with these transfer of nanoparticles both on molecular level or genetic level such as organelle damage, asthma, cancer, formation of reactive oxygen species, protein denaturation, mitochondrial defects. More common toxic effects of nanoparticles include the generation of neo antigens that causes enlargement of organs [40].

CONCLUSION

Nanotechnology is an emerging technology that makes many fields like environmental, medical, food sector, cosmetic, more useful. Nanostructured particles has strong potential to modify the current research scenario. Is has achieved wide success in drug delivery system. Despite of wide application of these nanoparticles, its toxicity also affect the human system.

Future prospective: Day by day, the increasing use of nanoparticles in research and development sector, it is expected to have strong future. Various innovations like nanofood, nanosensor, nanofertilizer, nanopackaging, nano-robotics etc. have achieved immense interest in nanoscience technology. Use of nanoparticles is also a good approach in environmental technology as these are used for pollution control.

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How to cite this article:

Mamta Sharma *et al*.2023, "Nanoparticles-Their Advantages And Applications: A Review". *Int J Recent Sci Res.* 14(04), pp. 2980-2984. DOI: http://dx.doi.org/10.24327/ijrsr.2023.1404.0613.

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