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Review Article

Nanoparticles at a Glance

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ABSTRACT

Nanoparticles (NPs) synthesis, properties, and application exist in different forms. A nanoparticle is a small particle that ranges between 1 to 100 nm in size. Nanoparticles (can be classified into different classes based on their properties, shapes or sizes. The different groups include fullerenes, metal NPs, ceramic NPs, and polymeric NPs. NPs possess unique physical and chemical properties due to their high surface area and nanoscale size. Their reactivity, toughness, and other properties are also dependent on their unique size, shape and structure. Due to these characteristics, they are suitable candidates for various commercial and domestic applications, which include catalysis, imaging, medical applications, energy-based research, and environmental applications. Heavy metal NPs of lead, mercury and tin are reported to be so rigid and stable that their degradation is not easily achievable, which can lead to many environmental toxicities.

Keywords: C*ontrol banding, Engineered nanoparticles,Eentry routes,Eenvironmental impact, Nanowaste disposal*

INTRODUCTION

Nanoparticles discovered by laureate Richard Feynman the American physicist and got Nobel Prize in 1959. We cannot see nanoparticles with naked eyes. We can see or detect nanoparticles with the help of microscope[1]. These particles have different types of physical and chemical properties. The first nanoparticle drug was Adagen which was the first nanomedicine to use synthetic nanoparticles (PEG) for severe combined immunodeficiency disease (SCID)[2]. The metals which are used in nanoparticles are (e.g., silver(Ag), copper(Cu), gold(Au), platinum(Pt), zinc(Zn), magnesium(Mg), iron(Fe), and alginate nanoparticles)[3]. NPs have characteristic wine red color, yellowish gray, black and dark black colors, respectively. The shape of a nanoparticles such as helices, zigzags, belts varies with length. Nanoparticles may be of oval, cubic, prism, helical, or pillar[4]. Nanoparticles are spherical, polymeric particles composed of natural or artificial polymers. They range in size between 10 and 500 nm[5].

LITERATURE REVIEW

NPs are complicated molecules itself hence composed of three layers (a) The surface layer, which is functionalized with a variety of small molecules, metal ions, surfactants and polymers.

(b) The shell layer, which has chemically different material from the core in all aspects.

(c) The core, which is essentially the central portion of the NP and usually refers the NP itself [6]. The NPs can be employed for drug delivery, chemical and biological sensing gas sensing, CO_2 capturing and other related applications.

Nanoparticles have antimicrobial activity, ROS-induced cytotoxicity, genotoxicity, plant growth promotion, etc[7].

Classification of NPs

NPs are divided into various categories depending on their morphology, size and chemical properties.

1. Carbon-based NPs

Fullerenes and carbon nanotubes (CNTs) represent two major classes of carbon-based NPs. Fullerenes contain nanomaterial that are made of globular hollow cage such as allotropic forms of carbon[8]. CNTs are elongated, tubular structure, 1–2 nm in diameter. These can be predicted as metallic or semiconducting reliant on their diameter telicity.[9] The rolled sheets can be single, double or many walls and therefore they named as single-walled (SWNTs), double-walled (DWNTs) or multi-walled carbon nanotubes (MWNTs), respectively.[10]

2. Metal NPs

Metal NPs are purely made of the metals precursors. Due to localized surface plasmon resonance (LSPR) characteristics, these NPs possess unique optoelectrical properties[11]. The facet, size, and shape-controlled synthesis of metal NPs is important in present-day cutting-edge materials.

3. Ceramics NPs

Ceramics NPs are inorganic nonmetallic solids, synthesized via heat and successive cooling. They can be found in amorphous, polycrystalline, dense, porous or hollow forms[12]. These can be used in photocatalysis, photodegradation of dyes etc.

4. Semiconductor NPs

Semiconductor materials possess properties between metals and nonmetals.Semiconductor NPs possess wide bandgaps[13]. Hence they are very important materials in photocatalysis, photo optics and electronic devices.

5. Polymeric NPs

These are normally organic based NPs and in the literature a special term polymer nanoparticle (PNP) collective used for it. They are mostly nanospheres or nanocapsular shaped.[14]

6. Lipid-based NPs

These NPs contain lipid moieties and effectively using in many biomedical applications. Generally, a lipid NP is characteristically spherical with diameter ranging from 10 to 1000 nm.[15] Lipid nanotechnology is a special field, which focus the designing and synthesis of lipid NPs for various applications such as drug carriers and delivery.[16]

The methods of preparation of nanoparticles

There are various methods used for the preparation of polymeric nanoparticles such as desolvation, dialysis, ionic gelation, nanoprecipitation, solvent evaporation, salting out, spray drying and supercritical fluid.[17]

Steps in the synthesis of nanoparticles

The synthesis of nanoparticles consists of three steps: (1)

nucleation, (2) seeding, and (3) growth.[18]

Characterization of NPs

Different characterization techniques can be used for the analysis of various physicochemical properties of NPs[19]. These include techniques such as X-ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS), infrared (IR), SEM, TEM, Brunauer–Emmett–Teller (BET), and particle size analysis[20].

Optical characterizations

These characterizations are based on the famous beer-lambert law and basic light principles. These techniques give information about the absorption, reflectance, luminescence and phosphorescence properties of NPs[21]. Ultraviolet–visible (UV–Vis), photoluminescence (PL) and the null ellipsometer are the well-known optical instruments, which can be used to study the optical properties of NPs materials[22].

The factors affecting formation of nanoparticles

1. pH
2. temperature
3. pressure
4. time
5. particle size
6. pore size
7. environment

Nanoparticles applications

Food Industry

Nanoparticles are added to packaging materials as antibacterial agents[23].

The popular nanoparticle used for this purpose is silver nanoparticle (AgNP). AgNP can be added to food products in form of an edible biodegradable casing for food products, such as fruits, meat, and poultry[24]. Due to the preservative effect of AgNP-containing packaging on asparagus, poultry meat, orange juice , and strawberries all of which improved shelf life by inhibiting the activities of pathogens such as E. coli, S. aureus, moulds, and yeasts[25].

Cosmetic Industry

Nanotechnology used in the cosmetic industry. In the sunscreen industry, nanoparticles of zinc oxide and titanium dioxide are added to sunscreen by virtue of their sizes, and they protect against UV radiation due to the reduction in particle size[26]. The use of these nanoparticles has increased the absorption rate of solar radiation and act as filter of UV[27].

Liposomes used in cosmetics such as ethosomes and transferosomes that are used to improve transdermal delivery of active cosmetic ingredients[28].

AgNPs are important ingredients in many cosmetic products as effective antibacterial agents such as in bathing products and because of AgNP activity against different yeast strains they are also present in different dental products such as mouthwash and toothpaste[29].

Nanomedicine

Nanotechnology has strongly influenced in the field of medicine in drug delivery systems from both natural and synthetic compounds.

Nanoparticles target cancer cells to deliver anticancer drugs without harming healthy cells in body[30]. Because nps has good penetration power for target cells or tumor cells and make it easy for drug delivery into target cells. It reduces the risk of side effects in patients because it uses in very low quantity. Due to its small size range its surface area is greater for absorption. Thus, nps increase the surface area for absorption of drugs and it is highly effective in patients[31].

Important physical and chemical properties of nanomaterials

- Size, shape, specific surface area, aspect ratio.
- Agglomeration/aggregation state.
- Size distribution.
- Surface morphology/topography.
- Structure, including crystallinity and defect structure.
- Solubility.

Role of Nanoparticle Drug Delivery Systems (DSSs) in Disease *Treatment*

Nanoparticles used in drug delivery system range from 10 to 1000 nm in size with at least one dimension being below 100 nm in size[31]. Smaller nanoparticles enter cells more effectively when compared with larger molecules. Systemic administration of cytotoxic drugs may cause the drugs to exert their cytotoxicity on tissues during the first pass before they reach the intended tissues[32]. As a solution to this, nanoparticle drug delivery systems (DSSs) have been developed to achieve targeted and more efficient delivery of the therapeutic substance, which would prevent damage to surrounding organs from the effect of administered drugs that will otherwise arise if the drugs were in the free form[33.]

Biological nanoparticles are used for drug delivery in target tissues

Nanoparticle drug delivery system minimize side-effects and reduce both dosage and dosage frequency in patients. Nanoparticles have specific surface properties that allow them to selectively target diseased cells and avoiding healthy cells which can increase efficacy and reduce the side effects of drugs[34]. Nanoparticles release their cargo in a controlled manner, allowing for sustained drug delivery over time. Nanoparticles can also be used for diagnostic purposes, such as contrast agents in medical imaging or the detection of specific biomolecules in biological samples. In regenerative medicine, nanomaterials can be used in tissue repair and regeneration[35]. While the popularity of nanoparticles in medicine will be explored, the imminent harmful effects due to the wide application of nanoparticles as well as the development of nanoparticle drug delivery systems (DSSs) in mitigating these effects will be explored[36].

CONCLUSIONS

In this review, we presented a detail overview about NPs, their types, synthesis, characterizations, physiochemical properties and applications. Due to their tiny size, NPs have large surface area, which make them suitable for targeted drug delivery system. Optical properties increase the importance of these materials in photocatalytic applications. Though NPs are useful for many applications such as cosmetics textiles, paints, food industry, wound healing, dressing, speech recognition, agriculture science etc. 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 NPs more convenient and environmental friendly.

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