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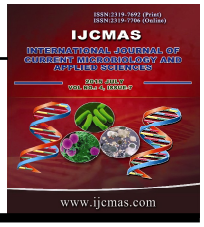

Review Article

Nanoparticle Characterization and Application: An Overview

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A B S T R A C T

For the past few decades there has been a considerable research interest in the area of nanotechnology using nanoparticles such as metals, semiconductors and metal oxides are of great interest for a wide of variety of applications in the field of information, energy, environmental and medical technologies due to their unique or improved properties determined primarily by size, composition and structure along with their self-organized film structures. Current review focus on nanoparticle synthesis, types, characterization and most advanced application related to nanotechnology.

Introduction

Nanotechnology is a modern field of science which plays a dominant role in day to day life aspects. Nanotechnology deals with production, manipulation and use of material ranging in nanometres (Kavitha *et al.*, 2013). Human life gets an impact role in all sphere mainly in the field of nanotechnology (Jannathul Firdhouse *et al.*, 2012). Nanotechnology mainly deals with the Nanoparticle having a size of 1-100nm in one dimension used significantly concerning medicinal chemistry, atomic physics, and all other known fields (Amudha Murugan *et al.*, 2014). Richard Feynman was the first person who gave a talk in the year of 1959 which many years later inspired the conceptual foundations of "nanotechnology".

Nanoparticles

Nanoparticles have been in use in pottery and medicine since ancient times. There are different ideal methods for nanoparticle to get synthesized. The following aspects involved for synthesizing nanoparticle are neutral pH, low cost and environmental friendly fashion. Nanoparticles get produced by plants are more stable and the rate of synthesis is faster than that in other case of organism (Siavash Iravani and Behzad Zolfaghari, 2013). Mainly these methods for synthesizing nanoparticle have been developed in different methods in upcoming days because of the cost efficient and require little or no maintenance (Naheed Ahmad and Seema Sharma, 2012). Nanoparticles get classified mainly into two groups they are organic nanoparticles and inorganic nanoparticles. Organic

nanoparticles are carbon nanoparticle and inorganic nanoparticles are magnetic nanoparticle, semiconductor nanoparticle (Sonali Pradhan, 2013).

Materials and Methods

The literature search for this review used the various databases like PubMed, web of science, etc., the search terms included nanotechnology, nanoparticles, nanomedicine, etc., as well as the additional keywords to capture preparation, types, SEM, XRD etc.,

Types of nanoparticles

Inorganic nanoparticles:

In the field of Modern material science Inorganic nanoparticle has been developed the role based upon their unique physical properties and particularly in biotechnology. Based upon these two factors of inorganic nanoparticles they have certain physical properties that mainly include size-dependent optical, magnetic, electronic, and catalytic properties. Bio related application are involved for the preparation of these interesting nanoparticles like iron oxides, gold, silver, silica, quantum dots etc (Ladj *et al.,* 2013). Novel physical properties mainly related because of their size approaches nanometer scale dimension (Mark Asta *et al.,* 2007).

Polymeric nanoparticles

Polymeric nanoparticle it is also a type of nanoparticle. In the recent year polymeric nanoparticle has a tremendous development in the field of research. The dispersion of preformed polymers and the polymerization of monomers are two strong strategies mainly involved for preparation (Prasad Rao and Kurt Geckeler, 2011). 10–1000nm it is the range of size involved with solid particles (Nagavarma *et al.,* 2012).

Solid lipid nanoparticles

For controlling the drug delivery in 1990's Solid lipid nanoparticles played a dominant role. There are certain alternate carrier systems to emulsions, liposomes and polymeric nanoparticles as a colloidal Carrier system (Abhilash, 2010).

Liposomes

Liposomes are one of the methods based upon the different types of nanoparticles. Structure of liposomes consists of one or more phospholipid bilayers and they are sphere-shaped vesicles to carry compound of interest. Today liposomes have been useful in the field of reagent and tool in various scientific disciplines. Since many features involved in liposome they made their own way in the market. Cosmetic and pharmaceutical industries numerous molecules act as a carrier, and in the field of Food and farming industries liposomes involved in encapsulation to grow delivery system that can entrap unstable compounds (Abolfazl Akbarzadeh *et al.,* 2013).

Nanocrystal

A nanocrystal is a type based upon material particle having at least one dimension smaller than 100 nanometres and mainly composed of atoms in either a single or poly-crystalline arrangement (Jens-Uwe *et al.,* 2008). Nanocrystals are aggregates of around hundreds or thousands of molecules that combine in a crystalline form, composed of pure drug with only a thin coating comprised of surfactant or combination of surfactants.

Nanotube

A nanotube is a nanometer scale tube like

structure. Nanotubes are members of the fullerene structural family. Their name is derived from their long, hollow structure with the walls formed by one-atom-thick sheets of carbon called graphene. These sheets are rolled at specific and discrete ("chiral") angles and the combination of the rolling angle and radius decides the nanotube properties; for example, whether the individual nanotube shell is a metal or semiconductor. Nanotubes are categorized as single-walled nanotubes (SWNTs) and multi-walled nanotubes.

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 and also Dendrimers are hyper-branched, globular, monodisperse, three dimensional nanoscales synthetic Polymers. Molecular chemistry and polymer chemistry both exhibit well-defined characteristics features of Dendrites (Anirudha Malik *et al.,* 2012).

Strategies used to synthesize nanoparticles

Traditionally nanoparticles were produced only by physical and chemical methods. Some of the commonly used physical and chemical methods are ion sputtering, solvothermal synthesis, and sol gel technique. Basically there are two approaches for nanoparticle synthesis namely the Bottom up approach and the Top down approach.

In the Top down approach, scientists try to formulate nanoparticles using larger ones to direct their assembly. The Bottom up approach is a process that builds towards larger and more complex systems by starting at the molecular level and maintaining precise control of

Molecular structure (Prathna *et al.,* 2010).

In Top down process bulk material is converted to fine particle in Bottom up process atom is processed to nuclei and finally to nanoparticles these are the process employed for the synthesis of nanoparticles.

Nanoparticle synthesis- Physical and chemical methods

Sol-gel technique: In Sol-gel technique discrete particles are integrated network precursor involved in chemical solution that mainly used for the fabrication of metal oxides hence it is a chemical technique. The precursor sol can be either deposited on the substrate to form a film or used to synthesize powders.

Solvothermal synthesis: In Solovothermal synthesis process the polar solvents are involved in different condition like at temperatures above their boiling points and in the condition of under pressure at versatile low temperature. Hence the reaction does not involve in lower temperature because the solubility of reaction get significantly increases in Solovothermal condition.

Chemical reduction: Sodium borohydride, hydrazine hydrate and sodium citrate are some of the commonly used reducing agents in which the ionic salts get involved in reduction process by an appropriate medium in the presence of surfactant were involved using reducing agents are used.

Laser ablation: The laser ablation laser beam is a technique that used for removing materials from a solid surface. Absorbed laser energy and evaporates mainly involves when the material is heated at low laser flux.

The material is converted to plasma in case of higher flux. For example Carbon nanotubes can be produced by this method.

Inert gas condensation: In inert gas condensation there is an ultra-high vacuum chamber filled with helium or argon gas at typical pressure of few 100 Pascal's where different metals are evaporated in separate crucibles inside. As a result of inter atomic collisions with gas atoms in chamber, the evaporated metal atoms lose their kinetic energy and condense in the form of small crystals which accumulate on liquid nitrogen filled cold finger. Example gold nanoparticles have been synthesized from gold wires**.** Synthesis using bio organisms is compatible with the green chemistry principles. Environmental friendly, non-toxic and safe reagents are mainly involved in green synthesis of nanoparticle.

Biosynthesis of nanoparticles

For the biosynthesis of nanoparticle - Preparation of botanical extracts, Bioreduction depends on reaction mixture and incubation time, Nanoparticles formation analysed by UV-Visible spectroscopy, Characterization of nanoparticles by – SEM, TEM, XRD, FTIR, EXD, Purification and its application. There are basic steps involved in the biosynthesis of nanoparticles (Kavitha *et al.,* 2013; Jitendra *et al.,* 2014).

Characterization of nanoparticle

UV-visible absorption spectroscopy:

Absorbance spectroscopy is used to determine the optical properties of a solution. A Light is send through the sample solution and the amount of absorbed light is measured. When the wavelength is varied and the absorbance is measured at each wavelength. The absorbance can be used to measure the concentration of a solution by using Beer-Lamberts Law. The optical measurement of UV-visible spectrophotometer has different absorbance peak like 410nm when treated with the Nerium Obander plant extract after addition of aqueous 1mM Silver nitrate solution (Subbaiya *et al.,* 2014). In case of Azadirachta indica get synthesized with Iron nanoparticles by the indication of suitable surface Plasmon resonance with high band intensities and peaks was found through UV-visible spectroscopy at the range of 216-265 nm (Monalisa Pattanayat and Nayak, 2013).

X-ray diffraction (XRD) analysis:

X-ray diffraction is a conventional technique for determination of crystallographic structure and morphology. There is increase or decrease in intensity with the amount of constituent.

This Technique is used to establish the metallic nature of particles gives information on translational symmetry size and shape of the unit cell from peak positions and information on electron density inside the unit cell, namely where the atoms are located from peak intensities.

XRD patterns were calculated using X'per Rota flex diffraction meter using Cu K radiation and λ =1.5406 Å. Crystallite size is calculated using Scherrer equation CS= Kλ /β cos θ Where CS is the crystallite size Constant [K] = 0.94 β is the full width at half maximum [FWHM] Full width at half maximum in radius [β] = FWHM x π/180 λ = 1.5406 x 10-10, Cos θ = Bragg angle. X-ray diffraction analysis with various nanoparticles has been studied by various research workers to find the high crystallinity of the prepared sample (Yelil Arasi *et al.,* 2012).

Fourier Transform Infrared [FTIR] spectroscopy

Measures infrared intensity *vs.* wavelength of light, it is used to determine the nature of associated functional groups and structural features of biological extracts with nanoparticles. The calculated spectra clearly reflect the well-known dependence of nanoparticle optical properties. The green synthesized silver nanoparticle by employing various leaf extract was analysed using Fourier Transform Infrared [FTIR] Spectroscopy showed characteristic peaks. (Amudha Murugan *et al.,* 2014).

Microscopic techniques

These techniques namely SEM and TEM Mainly used for morphological studies of nanoparticles. Many researchers used these techniques to show that the synthesized nanoparticles were more or less uniform in size and shape (Shobha *et al.,* 2014).

Transmission electron microscopy (**TEM**)

Transmission electron microscopy is a microscopy technique in which a beam of electrons is transmitted through an ultra-thin specimen, interacting with the specimen as it passes through. An image is formed from the interaction of the electrons transmitted through the specimen; the image is magnified and focused onto an imaging device, such as a fluorescent screen, on a layer of photographic film, or to be detected by a sensor such as a CCD camera.

TEM forms a major analysis method in a range of scientific fields, in both physical and biological sciences. TEMs find application in cancer research, virology, materials science as well as pollution, nanotechnology, and semiconductor research.

Scanning electron microscope:

The characterization of Scanning electron microscope analysis is employed to determine the size, shape & morphologies of formed nanoparticle SEM gives high-resolution images of the surface of a sample is desired. The scanning electron microscope works as same principle as an optical microscope, but it measures the electrons scattered from the sample rather than photon. Because electrons can be accelerated by an electric potential, the wavelength can be made shorter than the one of photons. This makes the SEM capable of magnifying images up to 200.000 times. Measures the particle size and characterization, Conductive or sputter coated sample involved and the sensitivity down to 1nm (Asim Umer *et al.,* 2012).

Applications of nanotechnology

The main application involved in use of nanoparticles for biomedical applications, such as drug and gene delivery, cancer treatment and diagnostic tools, food etc. has been extensively studied throughout the past decade and also nanoparticle created a huge interest due to their very small size and large surface-to-volume ratio, and they display absolutely novel uniqueness contrast to the large particles of bulk material (Jitendra Mittal *et al.,* 2014). Very recently, nanoparticles have gained significance in the field of Biomedicine (Varahalarao Vadlapudi *et al.,* 2013). Nanoparticles have potential application in medical field including diagnostics and therapeutics (Rajshri *et al.,* 2007).

Application of nanoparticle in drug delivery

Nanoparticle involved in drug delivery - The nanoparticle get entrapment of drugs are either enhanced delivery to, or uptake by,

target cells and/or a reduction in the toxicity of the free drug to non-target organs (Wim H De Jong and Paul JA Borm, 2008).

Applications of nanoparticles in food

Nanofood is a term used to describe foods that use nanotechnology techniques, tools or manufactured nanomaterials that have been added during cultivation, production, processing or packaging. There are several purposes for the development of nanofood. These include improvement of food safety, enhancement of nutrition and flavor, and cutting production and consumer costs. In addition, nanofood provides various benefits by which include health promoting additives, longer shelf lives and new flavor varieties The application of nanotechnology in food is rapidly emerging and is involving all areas of the food chain from agricultural applications to food processing and enhancing bioavailability of nutrients.

Application of nanoparticle in gene delivery

Gene delivery it is a technique that plays a vital role that can efficiently introduce a gene of interest in order to express its encoded protein in a suitable host or host cell. Now a day, there are different types of primary gene delivery systems that mainly employ viral vectors like retroviruses and adenoviruses, nucleic acid electroporation, and nucleic acid transfection (Daisuke Kami *et al.,* 2011)

Application of nanoparticle in cancer treatment

There are a variety of nanoparticle systems currently under investigation to be applied in biomedical with the emphasis on cancer therapeutics. There are a variety of nanoparticle systems currently investigated and explored for biomedical applications with some particular emphasis for cancer therapeutics; hence some precious metals (mainly gold and silver systems, Au, and Ag) and some magnetic oxides (in particular magnetite Fe_3O_4) received much interest including quantum dots and some of what is called "natural nanoparticles" (Bououdina *et al.,* 2013). The unique up conversion process of UCNPs may be utilized to activate photosensitive therapeutic agents for applications in cancer treatment (Liang Cheng *et al.*, 2013).

Other applications of nanoparticles

In recent years nanoparticles are involved with new applications in areas like information & communication technology, power engineering, industrial engineering, environmental engineering, chemical industry, medicine, in pharmaceuticals and cosmetics etc. For decades some nanoscale materials have been involved (for e.g. they are used in window glass, sunglasses, car bumpers, paints), whereas others are newly discovered are used as sunscreens and cosmetics, textiles, coatings, sports goods, explosives, propellants and pyrotechnics or their applications are currently under development (e.g. in batteries, solar cells, fuel cells, light sources, electronic storage media, display technologies, bioanalysis and bio detectors, drug delivery systems, medical implants and new organs). All in all, the number of nano products and methods of their use increase continually.

This paper has reviewed recent knowledge and built a data base of nanoparticles. This review provides an overview of nanoparticle based upon the characterization methods, types, protocols based upon Strategies used to synthesize nanoparticles and wide range of applications. Our study concludes that nanoparticle has a tremendous growth in

recent years. A wide range of opportunities or upcoming projects are available some of the nanoparticles get synthesized are cost effectiveness. For example nanoparticle synthesis using plant sources is largely adopted due to its eco-friendly nature and cost effectiveness etc.,

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