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A review of nanoparticle synthesis categorization and applications

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Abstract

The development and application of materials whose constituents reside at the nanoscale—typically up to 100 nm in size—is referred to as nanotechnology. At the molecular and sub-molecular level, nanotechnology investigates structural behavior in addition to electrical, optical, and magnetic activity. It has the potential to completely transform several biotechnology and medical instruments and processes, making them more affordable, portable, safe, and simple to use. Nanoparticles are employed in many different fields, including medicine, industry, and the creation of oxide fuel and solar energy batteries for energy storage, as well as widespread integration into a variety of commonplace materials like clothing or cosmetics, optical equipment, catalysis, antibacterial, electrical, sensor technologies, biological labeling, and the treatment of certain cancers. Nanoparticles have garnered a lot of interest lately because of their remarkable qualities, which include antimicrobial activity, strong oxidation resistance, and high thermal conductivity. Both chemical and biological methods can be used to create nanoparticles. Several distinct kinds of metallic nanoparticles have extensive industrial uses, including magnetic, alloy, silver, and gold. An overview of nanoparticles is intended to be provided in this work, with particular attention to their method of kinds and biosynthesis.

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INTRODUCTION

Nanotechnology is the study of incredibly tiny objects. It entails working with and manipulating matters. The Latin term nanus, which literally translates to "dwarf" and consequently "very small," is the source of the prefix from the Greek word vavoc. The fundamental building blocks of nanotechnology are called nanoparticles. [1] Nanotechnology has gained massive attention over time. Solid particles or particulate dispersions with sizes They are known as nanoparticles and are between 10 and 1000 nm in size. The proposed drug has been attached, encapsulated, entrapped, or dissolved using a nanoparticle matrix [2]. Atoms and molecules function differently at this size, leading to unique applications not found in other formulations. Undetectable by the human eye. [3] Nanoparticles can be found in many different sizes and shapes: one-dimensional graphemes, which can only have one parameter; two-dimensional carbon nanotubes, which have two dimensions; three-dimensional gold nanoparticles, which have three dimensions; and zero-dimensionalnanodots, which have one dimension fixed at a single point. The variety of sizes, shapes, and configurations, including those that are conical, hollow core, tubular, spherical, spiral, and flat, Nanotechnology includes the creation, production, and use of substances at the unaltered, molecular, and macromolecular shapes and sizes., which aims to produce new nanosized materials. Solid medication transporters known as pharmaceutical nanoparticles are micron-sized in size (less than a millimeter in diameter) and biodegradable or not. The term "nanoparticle" applies to both nanospheres and nanocapsules. NPs vary in size from 1 to 100 nm. The term "atom clumps" is usually used when NPs are less than 1 nm. NPs may contain one or more crystalline bodies and be unstructured or structured. NPs can aggregate or be loose [4]. NPs are made up of three distinct layers because they aren't simple molecules. The surface is the initial layer and may be functionalized using a variety of ions of metal, polymer compounds, surfactants, and tiny molecules. (b) The core typically refers to the NP itself, and (c) the protective layer, which is chemically completely different from the core. Researchers from many different fields are particularly interested in such substances due to these special characteristics [5]. Medications are uniformly distributed in nanoparticles, a grid system that can be categorized as either soft (liposomes, vesicles, and nanodroplets) orchard (silica,titanicash). In addition to being created artificially or because of combustion processes, nanoparticles can also be found in biological materials like viruses and in organic materials like dirt, fine particles of sand, ash from volcanoes, and marine foam. Considering that nanoparticles may transfer DNA, proteins, and medicines, they are well-known for targeted medication delivery. Their size, make-up, and optical characteristics make it simple to pass through physical obstacles and eventually reach their intended cell. These are the advantages of nanoparticles. Nanoparticles, especially those from biodegradable polymers, are less toxic since they are broken down naturally in the body. Their small size can be passed through narrower capillaries, thus possibly facilitating the effective accumulation of drugs at target sites. Moreover, changing the surface characteristics and particle size of these nanoparticles makes it relatively easy to either passively or actively target medications following parenteral administration. Polymer-based nanoparticles and liposomes do not tend to accumulate in human tissues, and as they are usually biodegradable, there is minimal risk. They can be delivered via various routes, including oral, parenteral, or intraocular delivery. Nanotechnology has applications in almost every industrial sector, and its use is also skyrocketing in aquaculture. Aquaculture applications of nanotechnology include disease control, nutrition, reproduction, water purification, fishing, and reducing toxicity and side effects. These are the limitations of the given nanoparticles. The formation of aggregates or agglomerates results from the high free energy of nanoparticles, which causes Ostwald ripening. Nanoparticles' smaller size and greater surface area make handling them in both liquid and dry forms extremely challenging. Minimal medication loading and exploding release are caused by small particle size. Prior to the therapeutic or commercial usage of nanoparticles, many practical problems must be resolved [6]. Amoreintricate operational process. Increased likelihood of contamination. The cost of nanotechnology is high, and its development can be even more expensive.

NANOPARTICLE CLASSIFICATION

They are separated into three groups: based on carbon, inorganic, and organic nanoparticles.

ORGANIC NANOPARTICLE

The minimum size of the organic molecules used to make this type of organic nanoparticle is 100 nm. Ferritin, dendrimers, liposomes, and micelles are typical labels for organic matter or polymeric nanoparticles. Several are nanoparticles, such as liposomes and micelles; some, like micelles and liposomes, possess an elongated center and are susceptible to various electrical radiations, including light and warmth. In addition, they are reusable and harmless. Due to these unique characteristics, they are the ideal choice for medication release. Apart from the usual factors such as size, content, surface shape, and so forth, The medication's carrying capacity, strength, and mode of shipment (both adsorbed or encapsulated) impact the effectiveness and field of use. Because of their efficacy and injectable capacity into specific body areas, nanoparticles of organic material are most frequently employed in the biomedical industry, such as in medication systems for delivery (also known as tailored product distribution [7].

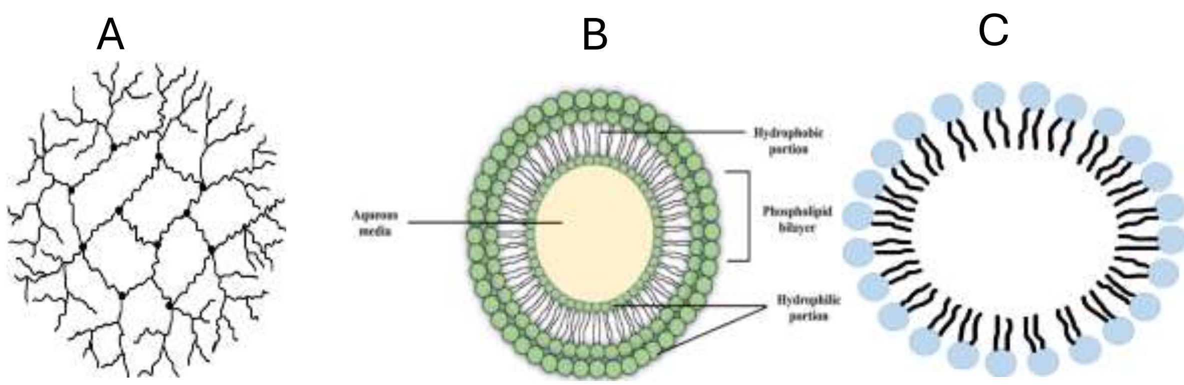

Figure 1 A) Dendrimers B) Liposomes C) Micelles

A. DENDRIMERS

The dendrimer is a novel group of nanometric-sized controlled-structure polymer compounds. Dendrimers have been utilized in imaging and the distribution of medications. Typically, they have several functional groups on their surface and are between 10 and 100 nm in size [8]. The pharmaceutical industry has employed dendrimers as pro-drugs, antimicrobials, anticancer agents, and non-steroidal anti-inflammatory medications, as well as testing tools for comprehensive drug discovery. However, due to their capacity to disrupt cell membranes due to the positive charge on their surfaces, dendrimers may be toxic

B. LIPOSOMES

These NPs' lipid moieties are beneficial for a range of natural uses. Lipid nanoparticles are usually spherical and have dimensions between 10 and a thousand mm. Liposomes are supramolecular aggregates made up of polar lipids and other amphiphilic substances that are distributed throughout an aqueous solution. Nanoparticles are safe to consume and renewable. Sure of them, such as liposomes, are highly susceptible to Heat and magnetic exposure to radiation, comprising Heat and light, and include an inner hollow known as a nanocapsule [9]. Liposomes are one technique that relies on various kinds of nanoparticles. Liposomes are sphere-shaped vesicles that carry compounds of interest and comprise one or more phospholipid bilayers. These days, liposomes are valued as reagents and tools in many scientific fields. Because liposomes have so many features, they have established themselves in the market. The food and agricultural industries use liposomes in encapsulation to develop delivery systems that can entrap unstable compounds. In contrast, the cosmetic and pharmaceutical industries use a variety of molecules as carriers. Liposomes that load two medications (hydrophobic and hydrophilic) simultaneously; facile surface functionalization; biocompatible; Low toxicity; Biodegradable.

INORGANIC NANOPARTICLE

Inorganic atoms joined by covalent or metallic bonds make inorganic nanoparticles (SNPs). They are created by non-carbon substances such as metals, metal salts, and metal oxides. Depending on the arrangement of atoms, they are shaped like cubes, elliptic shapes, oblate, globes, cylindrical objects, and stars, but they still have the clarity of substances based on metals [10]. Moreover, the characteristics of the base material itself give inorganic nanoparticles their distinct optical, magnetic, electrical, and physical characteristics. AuNPs, for instance, have photothermal properties because of their free electrons, which continually cycle at a rate that varies according to the dimension and form of their surface. Inorganic nanoparticles are helpful, particularly in biotechnology, because of their distinct physical characteristics. Inorganic NPs are among the most popular NP types on a commercial scale because of their effectiveness as therapeutic agents [11].

METAL-BASED NANOPARTICLE

Numerous metals, including aluminum (Al), gold (Au), silver (Ag), cadmium (Cd), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), and zinc (Zn), can be used to create metal-based nanoparticles. Notably, commonly used elements are Ag, Au, Cu, Fe, and ZincCe. Specific metal nanoparticles also have unique biological, magnetic, and thermal characteristics. These metal nanoparticles are made in a variety of ways by researchers. One tactic is to use natural assistance, like using animals to assist simultaneously. Various methods include microwaves or the aqueous strategy, which involves high temperatures and pressures to create robust nanoparticles or particles suspended in fluid (colloidal liquids). The characteristics of these nanoparticles of metal are remarkable. Oxides of metal nanoparticles are employed as catalysts and in manufacturing fuel cells and fuel cell piezoelectric devices. These Metal oxides are utilized as pigments in sunscreen, paint (TiO_2), cosmetics (TiO_2, ZnO), SnO_2, and Fe_2O_3 due to their photo-catalytic properties [12].

GOLD NANOPARTICLE

Due to its therapeutic properties, doctors have utilized soluble gold since antiquity to cure a wide range of illnesses, including syphilis, heart disease, epilepsy, and dysentery. Faraday created the first gold nanoparticle, which is still at the Royal Society of London after Francis Anthony published a book on colloidal gold in 1618. The distinct physical and chemical characteristics of gold nanoparticles improve drug loading, efficiency, and accessibility to the target cell. They area lso biocompatible, non-cytotoxic, and maybe produced using any techniques, such as for tumor treatment. Gold nanoparticles are particularly useful for medication, gene, and protein delivery in addition to biosensing pharmaceuticals [13]. The diameters of gold particles range the greatest effectiveness between two and one hundred nanometers.

Nevertheless, cell uptake is shown in the particle size range of Between 20- and 50-mm. Particles with sizes from 40 to 50 nm. Exhibit Particular cell contamination. These 40–50nm particles readily recover from tumors after diffusing into them. However, the greater particulates, which range from 80 to 100 nm in size, stay around the circulatory vessels instead of spreading throughout the cancer. As a result, gold nanoparticles are crucial for HIV treatment, cancer treatment, and the detection of malignant cells [14].

SILVER NANOPARTICLE

Silver nanoparticles, which are highly researched nanostructures with dimensions between 1 and 100 nm, are mostly employed in novel and improved biomedical applications, including tissue scaffolding, drug administration, wound dressings, and protective coatings. Silver nanoparticle surfacefunctionalizationismadepossiblebytheremarkablyaccessiblesurfaceofnano silver, which also permits the coordination of several ligands. For its antibacterial properties, silver is frequently utilized as silver nitrate [15]. Silver nanoparticles are also more advantageous than free silver because of their larger surface area, which exposes more microorganisms. Moreover, given their remarkable capacity to fight a wide variety of bacteria and their resistance to widely used antibiotics, silver nanoparticles have become an exciting area for researchers. Silver nanoparticles are crucial in nanomedicine because of their desirable physical, chemical, and biological capabilities, including their strong antibacterial efficacy and a comparatively not toxic, broad assortment of bactericidal capabilities [16].

METALOXIDE BASED NANOPARTICLE

In the recent past, researchers have been more interested in oxides of metals. Positively, Ionic compounds called metallic oxides are created when metallic ions and oxygen's unfavorable ions mix. Due to the positive electrostatic interactions of metal ions and the fact that the ions are composed of harmful oxygen, ionic connections are robust and stable[20]. When exposed to oxygen at ambient temperature, for example, iron (Fe) nanoparticles quickly transform into iron oxide (Fe_2O_3). Nanoparticles significantly increase their reactivity compared to iron nanoparticles. The goal of these oxide-based nanoparticles is to alter the characteristics of their metal-based equivalents. In order to benefit from their increased efficiency and reactivity, metal oxide nanoparticles are commonly synthesized. Silicon dioxide (SiO2), the oxide of titanium (TiO2), zinc oxide(ZnO), and aluminum oxide (Al2O3) are some of the most frequently created oxides. These nanoparticles are strikingly different from their metal cousins [17].

LIPID-BASED NANOPARTICLE

Lipid-based nanoparticles typically have a circumference of 10–100 nm and an elliptical form. It is composed of an inert lipids center and a covering of liquid, which is a lipophilic particle. Lipid-based nanoparticles are employed in RNA-release therapy for the treatment of cancer and as drug carriers [18].

CERAMIC BASED NANOPARTICLE

A different term for nanoparticles of ceramics is nonmetallic solids. The process of repeatedly heating or cooling is utilized to produce the ceramic particles. The ceramic nanoparticles might remain hollow, dense, porous, hazy, or polycrystalline. These nanoparticles are the focus of the research because of their many uses, including dye photodegradation, photocatalysis, catalysis, and imaging applications [19].

SEMI CONDUCTOR-BASED NANOPARTICLE

The result of their characteristics dropped somewhere, Comparing the properties of semiconductors to those of both metals and nonmetals in a wide range of literary contexts. Due to the vast bandgaps of semiconductor nanoparticles, bandgap tuning significantly changed their characteristics. They are, therefore, essential components for electronic devices, photocatalysis, and photo optics. In water-splitting applications, for example, it is found that a variety of semiconductor nanoparticles are highly efficient due to their proper gap size and band border positions [20].

CARBON-BASED NANOPARTICLE

"Carbon-based" describes nanoparticles that are made entirely of graphite. Substances such as graphene, fullerenes, carbon nanotubes (CNT), carbon nanofibers, carbon black, and even activated carbon are used in the nanoscale. Are among its classifications. Significant commercial interest has also been sparked by nanocomposites having a variety of uses, including support materials for various inorganic and organic catalysts, fillers, and adequate gas adsorbents for environmental cleanup [21].

FULLERENE

One of the most popular and extensively used fullers is Buckminsterfullerene (C60). Its 60 carbon atoms are arranged like an enclosure, each of which has three bonds and givesitafootball-likeshape. The C60 structure makes use of twenty hexagons and twelve pentagons. Two well-established characteristics of this structure are icosahedral symmetry and resonance stabilization. Its distinct combination of physicochemical features makes it useful in material research. Recently, C60 tiny structures have been utilized, such as applications of nanorods, nanotubes, and nanosheets. The versatility of the C sixty allows it to be utilized in a multitude of ways to accelerate a variety of responses of substances [22].

GRAPHENEAND OXIDE GRAPHENE

Graphite has been discovered to be a beneficial addition to polymers in the process of creating polymer-based nanocomposites. The remarkable electrical, mechanical, and molecular barrier qualities are the source of this. Pure graphene does have certain drawbacks, though, such as its complex bottom-up production, poor solubility, and agglomeration problems. Thus, a basic top-down approach may be employed to create graphene oxide and other structurally similar molecules from carbon sources. They are good alternatives to graphite while they are readily synthesized. The spread of functionalized oxygen groups on their structure allows for effective surface modification and high solubility.

Furthermore, GO works effectively as a filler in polymers used in nanocomposite materials. Its outstanding qualities and good dispersion in polymer matrices are the reasons behind this. Sp2 carbon atoms are used to prevent gas molecules from passing through a tight lattice.

It is, therefore, frequently utilized as container material, an impermeable substance, and a protective covering for delicate electronics. GO creates materials that react to stimuli because of their unique hydrophilic, electrical, and thermal properties [23].

SYNTHESIS OF NANOPARTICLE

The many methods employed to produce the nanoparticles can be separated into two types: bottom-up and top-down. A simplified representation of the process is given by the method of synthesis.

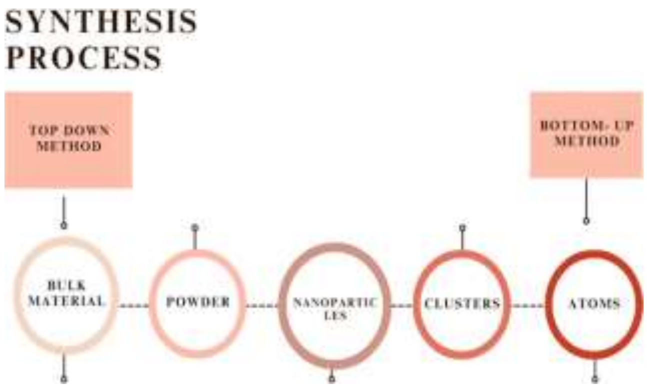

Figure 2 Synthesis Process

BOTTOM-UP METHOD

The substance is accumulated utilizing atoms, clusters, and nanoparticles. The positive or based on the bottom- method. Spin, pyrolysis, Vapor deposition of chemicals (CVD), sol-gel, and production are the most widely used based on bottom-up methods for creating nanoparticles.

SOL-GEL METHOD

A sol-gel is defined as a heterogeneous combination of particles in a liquid phase that remain suspended. An inert macromolecule immersed in a liquid is called a gel. Because of its simplicity of usage and ability to synthesize most nanoparticles, the more popular bottom-up method is sol-gel formation. This wet-chemical method uses a chemical solution as a starting point for a cohesive system of separate particles. Oxides of metals and chloride compounds are among the most often used intermediates in the Sol-gel technique. Organometallic inorganic salts or metal alkoxides are common precursors for the sol-gel technique. A colloidal suspension or a sol is produced from the precursor through a series of processes involving hydrolyzed and polycondensation. The sol-gel process, which takes place at ambient temperature and pressure, can change the components of a technique from a homogeneous fluid (or "sol") to a solid (or "gel") state. Following preparation, the gel is dried and made to varying degrees to make metal oxide nanopowder. The sol-gel technique allows for customization of the final materials' morphology, form, and textural characteristics [24]. The humidity sensitivity of the metallic alkoxide-based sol-gel technique and the absence of suitable commercial precursors are disadvantages, particularly for mixed-metal oxides. Due to the different hydrolysis vulnerabilities of the parts, the sol-gel synthesis of mixed oxides from alkoxide combinations commonly runs into problems. Furthermore, the benefits of enhanced homogeneity may be lost when the alkoxides are hydrolyzed, which could ultimately lead to component segregation and mixed phases in the final product.

SPINNING METHOD

A rotating disc reactor (SDR) spins to create nanoparticles. It has a revolving disc inside an oven or compartment that allows you to manage the temperature and other physical factors. Nitrogen or other inert gases are frequently injected into the combustion chamber to eliminate internal oxygen and prevent chemical reactions. The fluid, like water and its predecessor, is injected into the lens, which rotates at varying speeds. When atoms or molecules spin, they merge. And precipitate, gather, and dry. The properties of the nanoparticles synthesized from The fluid flow velocity, plate rotating speed, liquid/precursor ratio, feed position, disc surface, and other operating parameters all affect SDR [25].

CHEMICAL VAPOUR DEPOSITION

Applying a thin layer of gaseous reactants on an object is chemical vapor deposition. Deposition is accomplished by mixing gas molecules in a reaction chamber at room temperature. A chemical reaction takes place. When a mixed vapor and a heated substrate come into contact [26]. This reaction produces a small layer of product on the substrate's surface, which can be gathered and used.

There acting system need store receive energy activation. Because most CVD processes are endothermic, the primary disadvantage of chemical vapor deposition is the possibility of chemical hazards brought on by the corrosive, toxic, and explosive precursor gases. Another difficulty of this approach is the disadvantage of depositing materials with several components.

Depending on the energy generator utilized to start the method, the chemical vapor deposition (CVD) method is separated into smaller groups, encompassing thermally activated CVD, photo-initiated CVD, and plasma-enhanced CVD.

PYROLYSIS

Pyrolysis is an exceptionally widely utilized technique for industrial nanoparticle production. Flame is used to ignite an early stage. A small opening allows the precursors to enter the boiler at high pressure as a gas or fluid., where it ignites. Air is then utilized to extract the nanoparticles from the gases produced during combustion or bioproducts.

Somefurnacesuselaserlighttogenerate extreme temperatures that promote evaporation rather than burning. Its benefits are its ongoing nature, excellent yield, usability, and affordability.

BIOSYNTHESIS

An eco-friendly and sustainable technique for producing harmless, biodegradable Nanoparticles is produced by biosynthesis. Biosynthesis uses microbes, plant extracts, fungi, etc., for bioreduction and capping. Instead of traditional chemicals. In conjunction with the precursors to create nanoparticles. The unique and improved qualities of the biosynthesized nanoparticles are beneficial for biological uses.

TOP-DOWN METHOD

The top-down or destructive technique is the process of reducing a bulk material to nanometric-scale particles. Among the most widely used nanoparticle creation methods are mechanical milling, thermal breakdown, sputtering, laser ablation, and Nanolithography. This technique can break down significant materials into smaller nanoscale fragments. Although more accessible, top-down approaches are less effective when creating particles with intricate sizes or forms. Producing particles with the proper size and shape is a significant issue with this technology. Typical methods of thermal treatment are used to create nanoparticles. Nanolithography, mechanical milling, laser ablation, sputtering, and breakdown [27].

MECHANICAL MILLING METHOD

Mechanical grinding is a widespread top-down technique for creating different kinds of nanoparticles. Mechanical milling is used to perform both milling and after annealing of nanoparticles while milling Various components within an inert atmosphere during synthesis. In mechanical milling, plastic distortion determines the shape of the particles, fracture reduces their size, and cold welding increases their dimension.

NANOLITHOGRAPHY

Nanolithography creates objects at the nanometric scale, with at least a single dimension between 1 and 100 nm. Nanolithography comes in various forms: visible, electron-beam, multi-photon, scanning probe, and nanoimprint lithography. In general, lithography is the process of selectively eliminating material to create the appropriate shape and structure to print a desired form or arrangement of light-sensitive material. Generating a group of nanoparticles. The ability to make the required size and shape in a single nanoparticle is one of the primary benefits of Nanolithography. The disadvantages are the expense and need for advanced equipment [28].

LASER ABLATION

Making nanoparticles from different solvents is a standard method for producing Laser Ablation Synthesis in Solution. When a laser beam condenses plasma plumes on a metal surface submerged in a liquid solution, nanoparticles are produced. This reliable top-down method provides an alternative to the conventional metal reduction in chemicals for producing metal-based nanoparticles. Since it produces sustained nanoparticle synthesis in organic and aqueous solvents without chemicals or stabilizing agents, (LASIS) is a "green" technique.

SPUTTERING

The technique of releasing granules from an area by clashing with ions is known as sputtering. Therefore, nanoparticles are on it. After a thin layer of nanoparticles has been laid down, annealing is usually required for sputtering. The substrate type, annealing temperature and time, layer thickness, etc., all affect the nanoparticles' sizes and structure.

THERMAL DECOMPOSITION

When Heat breaks a compound's chemical bonds, an endothermic chemical breakdown known as thermal decomposition takes place, and the breakdown rate is the precise temperature at which a given element undergoes chemical degradation. The metal goes through a chemical process that creates additional compounds at specific temperatures to create the nanoparticles.

APPLICATIONS

Because of their distinct size, form, and organization, in addition to their unique biological, physical, and chemical characteristics, nanoparticles have significant opportunities for them. Several uses in a variety of backgrounds The several disciplines of nanotechnologies and the uses of nanoparticles.

BEAUTY PRODUCTS AND SUNSCREEN

The traditional sunscreen with UV protection is unstable when in use. There are many advantages to using sunscreen that contains nanoparticles like titanium dioxide. Nanoparticles of zinc oxide and titanium oxide have been used as sunscreens due to their capacity to retain their transparency to visible light while simultaneously reflecting and absorbing UV rays. Iron oxide nanoparticles are utilized as a coloring for certain lipsticks.

ELECTRONICS

The development of printed electronics has attracted increasing focus in the last few years because of its attractiveness to conventional silicon processes and the possibility of inexpensive wide-area electronics for adaptable sensors and screens. Electronics are manufactured with a range of functioning inks that contain nanoparticles (NPs), such as carbon nanotubes, ceramics, metallic NPs, and organic electronic molecules. It has been expected that NPs will flow rapidly when used in mass production for new types of electrical devices. The main characteristics of NPs are their reversible composition and simple manipulation that allow them to be included in optical, electrical, and electronic devices. In nanotechnology, "bottom-up" or "self-assembly" methods are the norm.

MEDICINE

Utilizing nanoparticles in medication administration has enhanced the medical profession thanks to nanotechnology. Nanoparticles can deliver the medication to targeted cells. The adverse reactions and cumulative consumption of drugs are significantly decreased when the medication is taken in the correct dosage and position. This method reduces expenses and unfavorable consequences. The field of nanotechnology can help repair tissue that is injured [29][30]. It can be replicated and repaired (a process known as tissue engineering). Conventional treatments like transplanting organs and artificial devices may eventually be replaced by tissue engineering. One instance is the development of carbon nanotube scaffolds for bones [31][32]. Gold has long been used in medicine. The Ayurveda, the Indian medicinal system, employs gold in various treatments. One such drug used to enhance memory is gold. Certain medications include gold to enhance a baby's mental well-being [33][34][35].

FOOD

The application of nanotechnology improves food production, wrapping, safeguarding, and manufacturing. For instance, a nanocomposite covering can be used to apply antimicrobial chemicals to the covered sheet face during the food packaging process. One example of the application of an ingredient used in the canola oil industry is nano drops that transfer the vitamins and minerals in meals.

CONSTRUCTION

Faster, cheaper, and safer construction procedures are the results of nanotechnology. Nanoparticles, for instance, can enhance regular concrete's mechanical characteristics and durability when mixed with nano silica ($SiO2$). The application of nanotechnology improves the ability to stop Heat and light from entering via windows. Adding nanoparticles to paints allows them to repair themselves, resist corrosion, and provide insulation. Because these paints' hydrophobic qualities repel water, they can be applied to metal pipes to defend against saltwater damage. Paints perform better when nanoparticles are included because they become lighter and have better qualities.

CATALYSIS

The nanoparticles' high surface area provides more excellent catalytic activity [36][37]. The nanoparticles are a powerful catalyst for chemical synthesis due to their substantial surface volume ratio) [38][39]. One noteworthy application of platinum nanoparticles is in automotive catalytic converters [40][41]. These nanoparticles' huge surface area reduces the amount of platinum required, improving performance and significantly lowering costs [42][43]. For example, in some chemical reactions, nanoparticles reduce nickeloxide to metal nickel (Ni) [44][45].

CONCLUSION

Future studies should also focus on biocompatibility, sustainable production techniques, and long-term safety evaluations to guarantee the broad use of technology based on nanoparticles. To sum up, nanoparticles have enormous potential to help solve some of the most significant issues that the world is currently experiencing. They have the potential to influence the development of a sustainable and technologically sophisticated future with sustained innovation and prudent management significantly. Nanoparticles' special qualities and extensive range of uses have made them a fundamental component of contemporary science and technology. Metal, polymeric, lipid-based, and silica based nanoparticles are among the many varieties that offer specialized answers to problems in a variety of fields. Particle size, shape, and surface properties may now be precisely controlled thanks to advancements in synthesis processes, including chemical, physical, and biological methods. This allows for customization for particular purposes. Nanoparticles are utilized throughout numerous industries, encompassing energy, agriculture, environmental cleanup, and medicine, where they are transforming drug delivery and diagnostics. Notwithstanding their potential, there are still obstacles to overcome, mainly related to large-scale manufacturing, stability in practical settings, possible risks to human wellness as the surroundings, and regulatory barriers. Scholars, businesses, and legislators must work together and use interdisciplinary techniques to address these problems.

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Author Contribution

All authors made substantial contributions to the conception, design, acquisition, analysis, or interpretation of data for the work. They were involved in drafting the manuscript or revising it critically for important intellectual content. All authors gave final approval of the version to be published and agreed to be accountable for all aspects of the work, ensuring its accuracy and integrity.

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REFERENCES

[1] Sarika Jha, Arti Kori, and Shivanand M Patil. A review on nanoparticles. International Journal of Pharmaceutical Sciences, 2(3):2023.

[2] S Anu Mary Ealia and M P Saravanakumar. A review on nanoparticle classification, characterization, synthesis, and application. IOP Conference Series: Materials Science and Engineering, 263(3):032019, 2017.

[3] Aishwarya Prakash*, Praveen Raj R, Daisy P A, and Abeena P B. A review on nanoparticles. International Journal of Pharmaceutical Sciences Review and Research, 64(1):12, 2020.

[4] Joudeh N, Linke D. Nanoparticle classification, physicochemical properties, characterization, and applications: A comprehensive review for biologists. J Nanobiotechnol. 2022; 20:262. Available from: https://doi.org/10.1186/s12951-022-01477-8.

[5] Konwar Ranjit, and Abdul Baquee Ahamed. Nanoparticle: An overview of preparation, characterization, and application. International Research Journal of Pharmacy, 12(4):32-36, 2021.

[6] Savita Kumari, and Leena Sarkar. A review on nanoparticles: Structure, classification, synthesis & applications.

Journal of Scientific Research, 65(8):1129-1142, 2021.

[7] Khadijah A Altammar. A review on nanoparticles: Characteristics, synthesis, applications, and challenges. Frontiers in Microbiology, 14:1155622, 2023.

[8] M Mohan Varma, K T Sunil Kumar and I Durga Srivalli. Nanoparticles in medicine: An overview. World Journal of Pharmaceutical and Medical Research, 7(8):9-13, 2021.

[9] Prerna, Anubhav Dubey, and Ratan Gupta. Nanoparticles: An overview. J Nanomater Chem Sci, 10(1):25-30, 2021.

[10] Ana Figueiras, Cátia Domingues, Ivana Jarak, Ana Isabel Santos, Ana Parra, Alberto Pais, Carmen Alvarez-Lorenzo, Angel Concheiro, Alexander Kabanov, Horacio Cabral, Francisco Veiga. New advances in the biomedical application of polymeric micelles. Pharmaceutics, 22(5):1-12, 2021.

[11] Furkan Eker, Hatice Duman, Emir Akda, Ecem Bolat, Sumeyye Sarıta, Sercan Karav, and Anna Maria Witkowska. A Comprehensive Review of Nanoparticles: From Classification to Application and Toxicity. Molecules, 29:3482, 2024.

[12] Priya B. Falke, Prashant G. Shelke, Pooja R. Hatwar, Ravindra Kumar L. Bakal, and Nitin B. Kohala. A comprehensive review on nanoparticles: Characterization, classification, synthesis method, silver nanoparticles and their applications. GSC Biological and Pharmaceutical Sciences, 28(1):26-35, 2024.

[13] Barhoum A, García-Betancourt ML, Jeevanandam J, Hussien EA, Mekkawy SA, Mostafa M, Omran MM, Abdalla MS, Bechelany M. Review on natural, incidental, bioinspired, and engineered nanomaterials: History, definitions, classifications, synthesis, properties, market, toxicities, risks, and regulations. Nanomaterials. 2021;11(5):1103. Available from: https://doi.org/10.3390/.

[14] V J Mohanraj, and Y Chen. Tropical journal of pharmaceutical research. Tropical Journal of Pharmaceutical Research, 5(2):59-65, 2006.

[15] Avnika Tomar and Garima Garg. A short review of the application of gold nanoparticles. Global Journal of Pharmacology, 7(1):25-29, 2013.

[16] Abhishek Singh, Tarun Parashar, Arbaaz Khan, and Vikash Jakhmola. Synthesis and method of nanoparticles and their applications: An exhaustive review. International Journal of Drug Delivery and Technology, 14(2):71-78, 2021.

[17] Almatroudi A. Silver nanoparticles: Synthesis, characterization, and biomedical applications. Biol Met Biol Appl, 16(4):1-11, 2020.

[18] Clifford Y. Tai, Chia-Te Tai, Ming-Hui Chang, and Hwai-Shen Liu. Synthesis of magnesium hydroxide and oxide nanoparticles using a spinning. Industrial & Engineering Chemistry Research, 45(23):8050-8056, 2006.

[19] Hongtao Cui, Marcos Zayat, and David Levy. Sol-gel synthesis of nanoscaledspinels using propylene oxide as a gelation agent. Journal of Sol-Gel Science and Technology, 35(2):175-181, 2005.

[20] Khan Y, Sadia H, Shah SZ, Khan MN, Shah AA, Ullah N, Ullah MF, Bibi H, Bafakeeh OT, Khedher NB, Eldin SM, Fadhl BM, Khan MI. Classification, synthetic, and characterization approaches to nanoparticles, and their applications in various fields of nanotechnology: A review.

[21] Alongkorn Pimpin, and Werayut Srituravanich. Review on micro- and nanolithography techniques and their applications. Engineering Journal, 16(1):37-47, 2012.

[22] Christy L. Haynes and Richard P. Van Duyne. Nanosphere lithography: A versatile nanofabrication tool for studies of size-dependent nanoparticle optics. The Journal of Physical Chemistry B, 105(14):1-12, 2001.

[23] Masoud Salavati-Niasari, Fatemeh Davar, and Noshin Mir. Synthesis and characterization of metallic copper nanoparticles via thermal decomposition. Polyhedron, 27(16):3514-3518, 2008.

[24] Tyagi A, Walia R, Murtaza Q. Tribological behavior of temperature-dependent environment-friendly thermal CVD diamond coating. DiamRelat Mater. 2019;96:148-159. doi:10.1016/j.diamond.2019.02.007.

[25] Aakanksha Arvind Patil. Nanoparticles: Properties, applications, and toxicities. - International Journal of Innovative Science, Engineering & Technology, 8(5):2348-7968, 2021.

[26] Kuppusamy P, Yusoff MM, Govindan N. Biosynthesis of metallic nanoparticles using plant derivatives and their new avenues in pharmacological applications: An updated report. Saudi Pharm J. 2014;22(5):443-450.

[27] Hasan S. A review on nanoparticles: Their synthesis and types biosynthesis: Mechanism. J Nanotechnol. 2015;4(1):9-11.

[28] Yadav TP, Yadav RM, Singh DP. Mechanical milling: A top-down approach for the synthesis of nanomaterial and nanocomposites. Nanoscience Nanotechnology. 2012;2(3):22-48. doi:10.5923/j.nn.20120203.01.

[29] S Machado, J G Pacheco, H P A Nouws, and J T Albergaria. Characterization of green zero-valent iron nanoparticles produced with tree leaf extracts. The Science of the Total Environment, 533:76-81, 2015.

[30] Yuan Li, Junchi Wu, and Nitin Chopra. Nano-carbon-based hybrids and heterostructures: Progress in growth and application for lithium-ion batteries. Journal of Materials Science, 50(23):7843-7865, 2015.

[31] Amendola V, Meneghetti M. Laser ablation synthesis in solution and size manipulation of noble metal nanoparticles. Phys Chem Chem Phys. 2009;11(31):5908-5918. doi:10.1039/b900654k.

[32] Shah P, Gavrin A. Synthesis of nanoparticles using high-pressure sputtering for magnetic domain imaging. J Appl Phys. 2006;99(3):118-123.

[33] Lugscheider E, Bärwulf S, Barimani C, Riester M, Hilgers H. Magnetron-sputtered hard material coatings on thermoplastic polymers for clean room applications. Surf Coat Technol. 1998;108-109:398-402.

[34] Salavati-Niasari M, Davar F, Mir N. Synthesis and characterization of metallic copper nanoparticles via thermal decomposition. Polyhedron. 2008;27(16):3514-3518.

[35] Wiechers JW, Musee N. Engineered inorganic nanoparticles and cosmetics: Facts, issues, knowledge gaps, and challenges. J Cosmet Dermatol. 2010;6(4):145-150.

[36] Patil AA. Nanoparticles: Properties, applications, and toxicities. Int J Innov Sci Eng Technol. 2021;8(5):2348-7968.

[37] Ganesh K, Archana D. Review article on targeted polymeric nanoparticles: An overview. J *Drug Target*. 2013;10(3):132-140.

[38] Mudshinge SR, Deore AB, Patil S, Bhalgat CM. Nanoparticles: Emerging carriers for drug delivery. Saudi Pharm J. 2011;19(3):129-141.

[39] Shinde NC, Keskar NJ, Argade PD. Nanoparticles: Advances in drug delivery systems. Res J Pharm Biol Chem Sci. 2011;3(4):922-929.

[40] Laad M, Jatti VKS. Titanium oxide nanoparticles as additives in engine oil. J King Saud Univ Eng Sci. 2016;28(4):234-242.

[41] Nazari A, Riahi S. The effects of SiO_2 nanoparticles on physical and mechanical properties of high-strength compacting concrete. Compos Part B Eng. 2011;42(6):570-578.

[42] Machado S, Pacheco JG, Nouws HPA, Albergaria JT. Characterization of green zero-valent iron nanoparticles produced with tree leaf extracts. Sci Total Environ. 2015;533:76-81.

[43] Mayegowda BS, et al. Green-synthesized nanoparticles and their therapeutic application: A review. Green Process Synth. 2023;12(1):1-9. doi:10.1515/gps-2023-0001.

[44] Ijaz I, Gilani E, Nazir A, Bukhari A. Detail review on chemical, physical and green synthesis, classification, characterizations, and applications of nanoparticles. Green Chem Lett Rev. 2020;13(3):223-245. doi:10.1080/17518253.2020.1802517.

[45] Li Y, Wu J, Chopra N. Nano-carbon-based hybrids and heterostructures: Progress in growth and application for lithium-ion batteries. J Mater Sci. 2015;50(23):7843-7865. doi:10.1007/s10853-015-9447-1.