Biogenic Green Synthesis of Nanoparticles from Living sources with Special Emphasis on Their Biomedical Applications

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Review Article

Keywords: Green synthesis, Nanoparticle Preparation, Biomedical Applications

Posted Date: February 1st, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-178316/v1>

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Abstract

Nanobiotechnology has been achieved great significance in terms of nanomedicine & many others. But the first challenge in nanobiotechnology science is the preparation of stable nanoparticles. Presently, many preparation methods have been developed like different chemical & physical processes, but the main drawbacks of these processes are required hazardous chemicals, environmental impact, and ultimately expenses a lot. To overcome these challenges another advanced technology has been developed, which is termed green or biogenic synthesis. This review is discussing the modern approaches of the eco-friendly and cost-effective methodology of green synthesis of nanoparticles by using different eukaryotic & prokaryotic agents like plants, human cell lines, diatoms, algae, fungi, bacteria, viruses, and other organisms. Also, this review gives a clear idea of the different applications of those nanoparticles in drug delivery, dentistry, labeling, diagnostics & sensors.

1. Introduction

From the recent times, nanotechnology emerged as a re- search ground where various materials are being created at nanoscale dimensions. Nanoparticles (NPs) are large groups of substances containing at least one dimension of particulate matter less than 100 nm and these NPs can obtain shape as three dimensional (3D), two dimensional (2D), one dimensional (1D), zero dimensional (0D) (1–3). It has been found that physiochemical properties of a substance like the optical properties can be manipulated by using different sized material to incorporate into NPs. Gold NPs (Au) is of distinctive wine red color; platinum (Pt) of yellowish grays color; silver (Ag) of black color and palladium (Pp) of dark black color. NPs are the complex molecules consist of three surface layers as given below:

1. The Surface layer that can interact with a number of small molecules, ions of carbon, surfactants and polymers.
2. The layer of shell that is chemical and non-core material, all things, and
3. The kernel that is basically the main part of the NP that is commonly referred to as the NP itself (4); such technologies also had tremendous appeal in multidisciplinary areas, due to these extraordinary characteristics.

To order to create modern man-sized products, nanotechnology reflects architecture, development and application of products at chemical, molecular and macromolecular scales (5).

For thousands of years, NPs have been used without any prior knowledge like the gold NPs which have been used to dye drinking glasses and also to even cure other health ailments. Through utilizing sophisticated methods, researchers have slowly been able to examine the form-and size-dependent physical and chemical properties of NPs. Metal NPs have recently been investigated for numerous applications in biomedical, biological, economic, and physiochemical fields (6, 7). In the past times gold NPs has been widely used in specific drug delivery like doxorubicin, methotrexate and paclitaxe (8). In various diagnostic functions gold NPs have been utilized via photo thermal therapy and photo imaging in order to detect diseases and disorders. Through the imaging technology and drug-gene delivery therapy as the iron (Fe) NPs were used to detect various health ailments like tumor, hyperthermia, targeting and immunoassays, cell labeling and in detoxification of biological fluids (9, 10). Similarly in multiple biomedical purposes like anticancer, antimicrobial, wound healing, and anti-inflammatory and applications Ag Nps reported to be used (11). Likewise Zinc and titanium NPs have been used for numerous cutting-edge processing applications owing to their non toxic, biocompatible, self-cleaning, skin care, antimicrobial actions in biomedicine, cosmetic, ultraviolet (UV) rays protecting agents (12, 13). Nasrollahzadeh et al., (2015) (14) and Momeni et al., (2015) (15) reported that in polymers, energy storage devices, optical restricting systems, and, plasmonic wave guides various NPs of palladium and copper is being used. Waki et al. (2015) (16) reported that in the spatial analysis of several biomolecules which includes fatty acids, metabolites, peptides, lipids, glycosphingolipids, nucleic acids, and drug molecules, metal nanoparticles have been incorporated to get the highest spatial resolution. Furthermore, the special features of NPs made them ideal for different kinds of sensors like biosensors and electrochemical sensors (17). So far to identify mercury, algal contaminants, and mycobacterium in drinking water a nano-sensor is built (18) as well as the nanosensors were used to identify plant bugs, pathogens, soil nutrient rates and stress factors while they have been created for the sensing of oxygen and auxin delivery. According to Simões (2017) (19), many substances and processes in nature vary functionally from macroscale to nanoscale which can lead us to initiate the formation of NPs and nano-devices via to mimic and manufacture them. The word

"biomimetics", a term invented by Otto Schmitt in 1957, is biologically based creation, modification or created from nature. The concept bio-mimetics is somewhat recent, but the design and creation of different materials and equipment was pursued by our ancestors several centuries ago (20). Knowing the roles of various artifacts and processes like microbes, spider webs, seashells etc will direct us through nanoparticles and nanodevices such as the biological molecular motor which is an example of bacterial flagella which rotates around 10,000 rpm (21). The bearing diameter is about 20–30 nm, with a clearance measured at 1.5 nm and motion in the biological motor is due to the variations in electrochemical potential crossways the membrane. Molecules started to assemble into intricate life-supporting systems more than few billion years ago as for the sustenance solar energy is being harness by plants via the cells which ranges from nanometer to the micrometer scales and this natural phenomenon is being utilized in the production of solar energy using semi-conductor photovoltaic plates in order to convert light energy to electricity. Many natural surfaces are considered to be super hydrophobic, the appearance of wax coating and self-cleaning owing to symmetrical roughness (micro bumps superimposed with nanostructure) (22). Various application processes needs to reduce the drag like in exterior paints for buildings, roof tiles, textiles, self-cleaning windows, and navigation ships so super hydrophobic and self-cleaning surfaces are of interest to be applied through in micro/nanofluids (23).

2. Classification Of Nanoparticles

From the recent times On the basis of size, physic-chemical properties and morphology, NPs are divided into the organic, inorganic and carbon based categories, hence some classes of NPs are discussed below:

2.1. Organic Nanoparticles

The organic NPs or polymers are generally classified as dendrimers, micelles, liposomes, and ferritin and so on due to their various properties like non-toxicity, biodegradability as due to hollow core structure of some liposomes and micelles which makes them susceptible to thermal and electromagnetic radiation (24), hence such special characteristics allow them an excellent alternative for supplying medicines. The organic NPS are effective and can often be inserted into different areas of the body which is often known as targeted drug delivery due to the fact of their properties like stability, drug carrying capacity along with some common characteristics like composition, size and morphology.

2.2. Metal based Nanoparticles

Salavati-niasari et al. (2008) (25) reported that both constructive and destructive methods are used to synthesize metal based NPs in the nanometric size variations, by using some common metals like Gold, silver, copper, lead, iron, zinc, cadmium and cobalt because of their unique low size (10-100nm) characteristics as well as due to large surface area to volume ratio, pore depth, intensity of surface and surface charge, crystalline and amorphous structures, shapes like spherical and cylindrical and color, reactivity and sensitivity to various environmental factors.

2.3. Carbon-based Nanoparticles

The two major groups of carbon-based nanoparticles include carbon nanotubes (CNTs) and fullerenes. As allotropic forms of carbon laid the foundation of fullerenes which are having structures like globular hollow cage. Saeed and Khan (2016; 2014) (26, 27) reported the creation of nano composites for many commercial applications like fillers which are of marketable interest and they are the having remediation capability to adsorb gaseous pollutants by serving as a medium support for both organic and inorganic (28, 29).

2.4. Metal Nanoparticles

The sole precursors of metal NPs are metals as they exhibit distinctive optoelectrical properties owing to the well-known "Localized Surface Plasmon resonance (LSPR)" characteristics. Due to broad absorption band of copper, gold and silver in "the visible zone of the electromagnetic spectrum" NPs of metals and alkalis have been created with controlled metal NPs synthesis of facet, thickness, and form is essential in cutting-edge materials today (30). Metal NPs find uses in many research fields, owing to their sophisticated optical properties. Gold NPs coating is commonly used for SEM sampling to improve the electronic stream which helps to get high-quality SEM images. Given below is the list of other NPs.

2.5. Ceramics Nanoparticles

The process of heat and subsequent refrigeration are used to manufacture ceramic nanoparticles which are non-metallic inorganic solids and can be achieved as amorphous, thick, porous shaped (31). Thus, owing to their usage in applications like catalysis, photo degradation of dyes, photo catalysis, and imaging applications; these NPs attract considerable interest from researchers (32). As reported by Sun (2000) (33) significant alteration in the properties with extensive and gap tuning in the NPs of semiconductors and proved significant supplies in the photo catalysis and electronic devices and also found various water splitting applications (34). Semiconductor material possesses properties between non metallic and metallic materials and execute to this characteristic features (35, 36).

2.6. Polymeric Nanoparticles

The term polymer nanoparticle (PNP) refers to organic based NPs in the form of nanocapsules or nanospheres (37). These matrix molecules are formed due to adsorption of spherical surfaces on superficial boundary while for the solid mass particles encapsulation is being processed. Hence polymeric nanoparticles find huge applications which are readily functionalized (38).

3. Physical Preparation Of Nps

The Size, shape and morphological structures serve as important principal parameters for the preparation of NPs which can be used to laid down the formation of various types of NPs like “an emulsion (two liquid phases); a suspension (mostly solid in liquids) or an aerosol (mostly solid or liquid phase in air)” and so on and so forth (39). Many different agents are prone to condensation on cooling of particles and are exposed to diverse ambient atmosphere as have been seen from past history regarding combustion of nanoparticles; hence NPs of various complexity mixtures are going to be formed on being observations from the growth in this sector. While for the small number of particulate model systems complex surface chemical processes have been recognized till yet. Poly electrolytes were used at the nanoparticle-liquid interface to alter surface properties and the interactions between particles and their surroundings. Liufu et al., (2005) (40) reported that for preparation of NPs have gone through extensive techniques like colloidal dispersion adhesion, lubrication, stabilization and guided flocculation. Atomic and molecular are both used to produce NPs of different physic-chemical properties and size varies for such particles in between angstrom and micrometer.

The use of volume or comprehensive surfaces for the preparation of NPs leads to development of various NPs in order to achieve the minute clusters with optical, chemical reactivity and electronic properties. To anticipate the evolution of these properties with particle size, complex quantum mechanics are necessary and usually well-defined conditions are important to compare observations and theoretical forecasts (41, 42).

4. Different Methodology For Nps Preparation

The principal mechanized methods of NPs from preformed polymer are based upon the physicochemical character the product being prepared. Therefore the key processing methods of preformed polymer NPs includes the following:

4.1. Evaporation Method

It is the most widely used method of preparation involving two phased emulsifying solvent evaporation processes. The first step allows the polymer solution to be emulsified in aqueous phases. Polymer solvent is evaporated and induces accumulation of polymers as nanospheres during the second step. Ultra centric NPs are gathered and cleaned with purified water for the elimination of stabilizer contaminants or free drugs and for storage freeze (43). Changing this method is referred to as high-pressure emulsification and solvent evaporation (44). This technique entails preparation of an emulsion subjected to homogenization under high pressure and eventual agitation of organic disinfectant removal (45). The size can be regulated by changing the rate, form and volume of the dispersing agent, the viscosity and temperature of organic and aqueous phases (46). This approach can therefore be generalized to liposoluble drugs and the scale-issue imposes restriction. Polymers used in

this method are PLGA (47), EC (Bodmeier et al., 1990), PLA (48), -εcellulose acetate phthalate (49), Poly (caprolactone)\ (PCL) (50, 51), Poly (β-hydroxybutyrate) (PHB) (52).

4.2. Double Emulsion and Evaporation Method

The hydrophilic material encapsulates double emulsion process, including applying aqueous product solutions to the organic polymer solution in intense agitation to create W/O emulsion. The emulsion and evaporation system suffer from the limitation of the weak entanglement of hydrophilic drugs. This W/O emulsion is applied with a persistent agitation to form the W/O / W emulsion in the second aqueous phases. The emulsion will then be separated by high-speed centrifugation by evaporating solvents and nano-particles. Before lyophilization, the shaped NPs need to be fully washed (53). The amounts of the hydrophilic material to be added, stabilizer concentration used, polymer density, and aqueous phase volume are the variables which influence the characterization of NPs (54).

4.3. Salting Out Method

Salting-out effect is used to separate the water-miscible solvent from aqueous solution (55). The method of Salting-out is relying upon the separation of water miscible liquid from the aquatic solution. Many salting out agents like electrolytes (MgCl, CaCl); and non-electrolytes (i.e., sucrose) and a colloidal stabilizer (polyvinylpyrrolidone or hydroxyethylcellulose) are used to dissolve polymer and drug in order to achieve process of emulsification. The method of the formation of nanospheres involves the process of emulsification of oil and water which can be enhanced by diffusion for the solvent into the aqueous phase. Allemann et al. (1993) (49) reported that various parameters (stirring rate, internal/external phase ratio, type of electrolyte concentration, concentration of polymers in the organic phase and type of stabilizer) varies for the aqueous phase can be manipulated in order to achieve highest quality of nanospheres. The most important merit of the Salting out method is that it can be useful for heat sensitive substances because it does not involve increase in temperature but it is also associated with demerit is the lipophilic drug exclusion involving wide-ranging nanoparticles washing procedure (56). Hence this practice is useful in preparation of Poly (methacrylic) acids (PLA); Ethyl cellulose nanospheres (EAN) with high competence and precision scale-up processing (57).

4.4. Emulsions- Diffusion Method

The emulsion-diffusion method is the one more technique to set up NPs production in which partial emulsification can be achieved by using polymer encapsulation to make sure the preliminary thermodynamic equilibrium by using water-miscible solvent like propylene carbonate, benzyl alcohol etc. Instead, in an aqueous solution with a stabilizer, the polymer-water saturated solvent level becomes emulsified, contributing to additional solvent diffusion and the development of oil-to-polymer nanospheres or nanocapsules. Finally, the solution according to its boiling point is removed by evaporation or filtration. Eventually, the solution is removed according to its saturation point by evaporation or filtration. The properties like encapsulation near about seventy percent with high excellence is the recompense of this method along with other achievable benefits like strong reproductively from batch to fight, simple scaling up, versatility and small release range and there is no need for homogenization. The drawbacks are the large amount of water which is lost during emulsification, decreasing encapsulation capacity, through the deferral and the leakage of water-soluble drugs into a saturated-aqueous surface process (58–60). Several nano particles which are loaded with drugs were produced by the technique, including doxorubicin-loaded PLGA nano particles (61), loaded sodium glycolate nanoparticles (62, 63) and “mesotetra (hydroxyphenyl) porphyrin-loaded PLGA (p-THPP) nanoparticles” (64, 65)

4.5. Solvent Displacement/Precipitation Method

Whether in the presence and absence of surfactant a polymer precipitation can be achieved using organic solution followed by diffusion in aqueous medium in the very technique called Solvent displacement. In a semi polar water miscible solvent including acetone or ethanol, polymers, drugs and other lipophilic surfactants are distributed. The fluid is either drained or pumped under a mechanical mixing into aqueous water with a stabilizer. The fast diffusion of solvents automatically shapes the NPs. And the liquid is extracted under decreased strain from the suspensions. The concentrations at which the organic layer is applied to the water process influence the particle size. The mixing rate for the two processes has improved (66) and a

reduction in all particles and product interposition was reported. For several of the poorly soluble drugs, nano-precipitation is fine. The scale, release and yield of the nanospheres were effectively tracked by modification of preparation parameters. In the development of smaller nanospheres, the modulation of polymer concentrations in the organic phase was considered useful by limiting the polymer-drug connection to a restricted range (67).

4.5. Laser-ablation Method

Recently, laser-ablation method was introduced to prepare metal NPs in a solution (68, 69). This physical technique allows us to start preparing NPs with convenience even without spoilage by a reduction agent; however the size distribution of NPs appears to be expanded because atom coagulation processes can hardly be controlled. On the other hand, a "laser-induced size reduction" technique was considered to be a effective method for modifying the size and geometric structure of gold NPs by using the fact that gold NPs have an extreme surface plasmon peak centering at 520 nm (70–72). The technique of laser ablation has been developed has been developed to practice metal NPs in a solution (68, 69) as well as this physical method allows us to simple and non-contaminate NPs with a diminishing agent. Nevertheless, the NPs are typically more widely distributed because the coagulation mechanisms of atoms are difficult to control. Nonetheless, a technique of the "laser-induced size reduction" became well known as a effective method for altering the scale and geometrical structure of gold nanoparticles in the shape of an extreme plasma surface of 520 nm (73, 74). Mafuné et al (2001) (75) reported that gold NP is measured "to absorb consecutively more than one thousand photons" in the procedure of single laser pulse with outcome of fragmentation of gold NPs which gets disperse in solutions. When the internal energy of irradiated NPs decreases (76); this fragmentation intensity will rise with an improvement in laser fluence. On the other side, by collecting such tiny fragments, the NPs in the solution expand. With the enhanced accumulation of the tiny fragments, the risk of coagulation rises. Such phases of fragmentation and clotting are equilibrated under 532-nm laser irradiation (70, 77). The Laser ablation of gold metal plate in aqueous SDS solution formed gold NPs of a specific average diameter (10.0, 7.5 and 6.0 nm) and were subject to the SDS concentration of 0.05 M induced by laser size reduction. A typical dependency of the surface plasma peak in the spectral optical absorption is provided in gold nanoscales with an average gap in diameters before laser irradiation. However, the distribution of the gold NPs after laser irradiation is the same regardless of the original NPs with average diameter (77).

Gold NPs of all diameters are broken into tiny NPs with equal diameters under irradiation of a 532-nm laser because nanoparticle diameters rely on the laser fluence alone and the rate of coagulation based upon the concentration of the SDS, through dynamic equilibrium. These results lead us to infer by determining the surfactant concentration and the laser fluence in a regulated way, irrespective of the initial average size and initial size distribution for the gold NPs, which are of the target average diameter. Such findings contribute to the assumption that the "laser fluence and surfactant concentration, regardless of the initial average size and initial size distribution of the gold nanoparticles" used, may be correctly chosen for gold, with the required average diameter from the larger nanoparticles. Laser ablation in conjunction with laser-induced size regulation gives a robust total physical preparedness of gold nanoparticles in size chosen without contamination with a reducing agent, which is unavoidably found in wet chemicals (78, 79).

5. Chemical Aspects Of Green Synthesis

The chemical aspects of NPs green synthesis include the following:

5.1. Microwave Irradiation

The Microwave (MW) warming of particles was found in 1940s and has become fruitful in the nourishment business with applications in science (80). It is an electromagnetic radiation; usually in between frequencies of 0.3–300 GHz. Microwave science depends on the rule of dielectric warming (81). There are two fundamental instruments for microwave illumination, to be specific dipolar polarization and ionic conduction systems. The light of issue, thus, causes the arrangement of dipoles or particles in the electric field. Since electromagnetic radiations (EMR) produce a wavering field, these dipoles or particles endeavor to realign themselves inside this field and produce heat through atomic grinding (82). Utilizing microwaves to warm the examples is a green technique for the blend of NPs, while it likewise yields attractive highlights, including shorter response

periods and better item yields (83). Microwave light includes a few focal points inside the domain of substance amalgamation. For example, in the arrangement of inorganic NPs, conductive warming is completed by utilizing an outside warmth source; be that as it may, this technique is moderate what's more, generally wasteful. Conversely, microwave light delivers productive interior warming, while consistently raising the temperature of the whole response blend. Moreover, microwave warming expands the response rate; for example, Au nanowires have been blended under the microwave illumination strategy within 2–3 min (84). Additionally, the warmth source doesn't come into direct contact with reactants, permitting the exact control of response parameters and the decrease of concoction squanders. There are additionally restrictions to the utilization of light systems, counting the short infiltration profundity (85). MW-helped warming has been utilized for the readiness of nanostructures, including Ag, Au, Pt, and Au–Pd. Notwithstanding circular nanoparticles, crystalline polygonal plates, sheets, poles, and wires have likewise been set up inside just a couple of moments under MW illumination conditions (86). Other than requiring less vitality, microwave illumination ought to be more condition well-disposed than regular warming strategies (87).

5.2. Tollens Process

The tollens process is a one-advance strategy that, for instance, can yield Ag NPs with a controlled size (88). Through an investigation directed on the saccharide reduction of Ag⁺ particles by the tollens procedure (89), it was discovered that little particles of 57 nm in size are shaped with glucose at low concentrations of ammonia (0.005 M). Diverse molecule sizes can be accomplished by changing the ammonia concentrations though the higher centralization of ammonia would prompt a bigger molecule size (90). Le et al. likewise brought up a changed tollens method, in which oleic acid is included as a stabilizer and an UV radiation is all the while utilized with treatment by glucose during the reduction procedure, to accomplish controlled size silver NPs (91). Yin et al., analyzed the capability of the tollens strategy in getting ready silver NPs (92). In another technique portrayed by Le et al. and associates, there is a deferent period more noteworthy than 5 min, which permits the total blending of reactants. Most have presumed that the combination by the tollens technique is earth green, because of the utilization of non-dangerous synthetic compounds (91).

5.3. Polyoxometals Mediated Synthesis

Polyoxometalates (POMs) are anionic structures made out of early progress metal components in their most noteworthy oxidation state. Since POMs are dissolvable in water and have the ability of experiencing stepwise, multielectron redox responses without upsetting their structure have the potential for orchestrating Ag nanoparticles (93, 94). Zhang et al. depicted an amalgamation technique for metal nanoparticles. They found that for the proficient amalgamation of Pd and Pt nanoparticles, diminished POMs were useful, as both lessening and topping specialists at room temperature in water (95). Georgakilas et al. concentrated on the way toward enriching carbon nanotubes (CNTs) with nanoparticles so as to deliver novel nanohybrid materials for a more extensive scope of utilizations. The connection of Au NPs to CNTs' sidewalls has demonstrated to be promising for exceptionally efficient electrochemical cells and photoelectronicsensor gadgets. POMs fill in as lessening, exemplifying and connecting particles furthermore, maintain a strategic distance from the presentation of other natural lethal particles. The nanohybrids delivered utilizing the POMs upgrade photocatalytic exercises under noticeable light irradiations (96).

6. Biological Aspects Of Green Synthesis

The Green science is step by step fused into state-of-the-art advancements in support with an overall endeavor to diminish the creation of hazardous squanders and to create vitality productive union strategies. To do as such, any manufactured methods or compound methodology need to manage the fundamental gauges of green science, by utilizing earth kind solvents and nontoxic synthetics (97, 98). The biological green synthesis of NPs should envelop fundamental advances, which are predictable with green science viewpoints concerning the decision of: biocompatible and nontoxic solvents, naturally decreasing materials, and nontoxic specialists for balancing out the delivered NPs. Applying the previously mentioned choices into Nanoscience will help the preparing of naturally more secure NPs and nanostructure gadgets. Therefore, green nanotechnology means to apply green science hypotheses in creating nanoscale materials, and to structure creation procedures with diminished risky waste age and more secure applications (99, 100).

In addition, biochemical procedures can happen at low temperatures, thus of the high particularity of biocatalysts. Subsequently, an engineered strategy containing one or progressively natural advances would cause the vitality sparing and lesser ecological impacts, contrasted with ordinary procedures. So as to streamline more secure nanoparticle manufacture, it is famous to utilize bio-based procedures limiting the risky types of material creation. Utilizing models from nature, the way that living beings make inorganic materials during bio-guided courses ought to be received as a propelled way to deal with NPs get together (101–104). Normally, biomineralization strategies create bimolecular models, which identify with nano-scaled inorganic materials, prompting skilled and controlled amalgamations. The structures of these materials are all around controlled at both nano-and full scale levels, permitting the structure of multifunctional practices. Less complex life forms including microscopic organisms, green growth, furthermore, parasites have created plans for bio-minerals creation all through 100 millions of long periods of progression. The target of templating biomolecules in the mineralization process is to introduce a counterfeit microenvironment where the inorganic stage morphology is solidly constrained by a scope of low-go connections. Nature has conceived an assortment of movements for the formation of nano and microscaled inorganic materials, adding to the improvement of genuinely imaginative furthermore, generally unexplored research zones as to the biogenic green synthesis NPs (105–107). Biosynthesis of NPs is a classification of base up techniques in which the chief compound response is decrease and oxidation. Cancer prevention agent and decreasing specialists in microbial proteins or plant phytochemicals are commonly considered for decreasing metal constituents into NPs (108, 109).

7. Applications In Drug Delivery

Nanoparticles have a suitable possibility as medication treatments (110). A powerful portion of medications could be reached to an unequivocal focused on tissue yet built to convey in an arranged timeframe so as to guarantee the most elevated productivity just as the patient's wellbeing. Because of the nontoxicity and non-immunogenicity and fictionalization properties, Au nanoparticles are superlative for the readiness of frameworks and vehicles for tranquilize conveyance (110, 111). Aubin-Tam et al. planned a medication conveyance framework with Au NPs and infrared light which discharged numerous tranquilizes in a controlled manner, since the various states of NPs react to different infrared frequencies. For instance, nanobones and nanocapsules are dissolved at light frequencies comparing to 1,100 and 800 nm, individually. In this manner, excitation at a specific frequency can dissolve specific sorts of Au nanorods and discharge a specific sort of DNA strand (112).

"Brown et al. additionally directed research on Au NPs for an improved anticancer property of the dynamic part of oxaliplatin. To do as such, exposed Au NPs were functionalized with a thiolatedpoly (ethylene glycol) (PEG) monolayer topped with a carboxylate gathering, and afterward $[Pt(1R, 2R\text{-diaminocyclohexane})(H_2O)_2]_2NO_3$ was added to the PEG surface to make a supramolecular complex with tranquilize atoms. The cytocompatibility, sedate take-up, and limitation in lung epithelial malignancy cell line (A549) and colon disease cell lines (HCT116, HCT15, HT29, and RKO) were read for platinum-fastened nanoparticles. The platinum-fastened nanoparticles introduced a signify cannot improvement in biocompatibility, contrasted with oxaliplatin in the entirety of the referenced cell lines, and a phenomenal capacity to infiltrate the core in the lung malignant growth cells. The light engrossing conduct of Au nanoparticles detail it suitable as warmth intervening objects, where the assimilated light vitality is dissipated into the earth of the molecule, creating a high temperature in their encompassing region. This outcome might be used to open polymer microcapsules for tranquilize conveyance applications and even decimate dangerous cells. Besides, NPs are functionalized with antibodies comparing to malignant cells. These NPs explicitly connect to focusing on cells, which are then murdered by hyperthermal treatment (113). It is significant that, for such in vivo purposes, the cell similarity of the NPs may be considered as an issue and ought to be concentrated with care. Due to biocompatibility of Au NPs and their hyperthermal action, this material has discovered a broad application for treating dangerous malignant cells (114). Melancon et al. indicated the photothermal influence of empty Au nanoshells with the width of around 30 nm bound to monoclonal neutralizer on the devastation of destructive cells. Au nanoshells coordinated to the epidermal development factor receptor (EGFR) and the subsequent enemy of EGFR-Au showed a decent colloidal dependability and proficient photothermal influence in the close infrared locale. The light of A431 tumor cells treated with against EGFR-Au with close infrared laser drove to cell passing. Au NPs have likewise been utilized to expand the bio recognition of anticancer medications. Dacarbazine [5-(3,3-dimethyl-1-triazeno)imidazole-4-carboxamide; DTIC] is generally used as an anticancer medication. Au nanoparticles are contrarily charged by PPh₃ and the oxidized DTIC is certain charged. Along these lines, DTIC could be basically collected onto

the outside of Au NPs, what's more, the specific communications between anticancer medication DTIC and DNA or DNA bases are encouraged by Au NPs (115).

8. Uses In Labelling

Metal NPs are utilized to create differentiate because of their electron engrossing properties. Au NPs are reasonable as a differentiating specialist in transmission electron microscopy, since they exceptionally ingest electrons. Likewise, because of a similar size of NPs with proteins, they are used for bio labeling or marking (116). Au NPs give an extremely high spatial goals thus have been applied in some of naming applications, because of their little size and characteristic features, i.e., with antibodies (immune staining) (117). Besides, optical recognition techniques are broad in the organic field, because of the adjustment in the optical or fluorescence properties of NPs. Correspondingly, the optical properties of particles including solid retention, dispersing also, especially Plasmon reverberation, make them important for light-based strategies for example, photothermal or photograph acoustic imaging. In addition, radioactive Au NPs make it appropriate for touchy discovery and as an X-beam differentiate specialist (105).

9. Applications As Sensor

Metal NPs can be used as sensors. The electronic and optical detecting properties of biomaterial surfaces are a standard practice in diagnostic organic chemistry. Hence, the immobilization of bimolecular–nanoparticle conjugates on a superficial level gives a wide way to deal with the improvement of optical or electronic biosensors. Metal NPs like Au or Ag show plasmon absorbance groups in the obvious ghastly district, which are constrained by the particles size. Their optical conduct can be adjusted by authoritative to unique atoms, permitting the particle discovery and measurement of analytes. The assimilation properties of Au NPs change impressively when agglomeration happens. Numerous looks into have been reported on bioassay marking and tissue recoloring, utilizing metal particles as a way to deal with watching organic procedures. Spectral shifts which originate from agglomerated metal NPs, similar to Au, are considered in the improvement of biosensors, in light of a cross breed framework being made out of biomolecules and NPs. For instance, NPs that were functionalized with two sorts of nucleic corrosive, which were coordinating to two pieces of a dissected DNA, were hybridized with examined DNA, bringing about agglomeration of the NPs and in the discovery of a red moved interparticle plasmon absorbance of the agglomerated NP (118–120).

10. Applications In Dentistry

In bone implantation surgery, if the surface is left smooth, the body will attempt to dismiss it. This is because of the way that the smooth surface will probably cause the creation of a fibrous tissue, covering the outside of the embed material. This fibrous layer thusly diminishes the contact zone between the embed material and bone, which may prompt slackening of the embed material and aggravation around there. It was demonstrated that having nano-sized highlights on the outside of the prosthesis could diminish the odds of dismissal, notwithstanding invigorating the creation of osteoblasts (117, 121).

Moreover, in the domain of dentistry, titanium is widely utilized; on account of its high break opposition, and malleability. In any case, it needs bioactivity, so it doesn't bolster cell bond and development. Apatite coatings have been utilized in the past because of their bioactivity and capacity to cling deep down. In any case, the thickness what's more, non-uniformity of apatite coatings on titanium is considered as restrictions. Additionally, permeable structures are expected to help supplement transport. Earthenware nanoparticles are utilized to set up an artificial half breed material which could be put on the tooth surface to improve scratch opposition (122–124).

Nanoparticles have been likewise appeared to have antibacterial and antifungal characteristics, due to their enormous surface territory. Metallic NPs can be utilized to adequately restrain development in various organisms and along these lines have various applications in medication furthermore, dentistry. In particular, in dental materials, NPs can be utilized as dynamic antibacterial operators. Optional caries are seen as the fundamental purpose behind rebuilding disappointment and are principally brought about by the intrusion of plaque microorganisms for example, "*Streptococcus mutans* and *Lactobacillus*

spp.” within the sight of fermentable sugars. So as to guarantee an enduring reclamation and the conceivable manage of oral diseases, the utilization of NPs to construct antimicrobial resources ought to be investigated (125, 126).

11. Different Nanoparticles And Their Applications

Sl. No.	Type of nanoparticles	Source of preparation	Size of NPs	Biomedical applications like	Reference
01.	silver Nanoparticles	g leaves extract of <i>Artemisia vulgaris</i>	420 nm	antimicrobial, antioxidant, and antiproliferative activities	(127)
02.	Iron Oxide (Fe_3O_4)	Seaweed (<i>Sargassum muticum</i>)	20nm	Antimicrobial, fabricate of industrially important metal oxides	(128)
03.	Silver Nanoparticles	<i>Annona squamosa</i> leaf extract	20 to 100 nm	cytotoxicity against human breast cancer cell	(129)
04.	Supper Magnetic Magnetite Fe_3O_4	plant extract and other biological materials	50 nm	anticancer drug delivery system	(130)
05.	AgNPs	plant extract and other biological materials	20 to 100 nm	Blood contacting implants, endodontic filling materials, dental instruments, and coating of contact lenses.	(131)
06.	CeO ₂ -NPs	plant extract and other biological materials	20-50nm	Therapy for neurodegenerative diseases	(132)
07.	Silver Nanoparticles	<i>Curcuma longa</i> tuber powder	6.30 ± 2.64 nm	Biolabeling, nonlinear optics	(133)
08.	Silver Nanoparticles	<i>Streptomyces</i> sp.	100-200nm	Wound infection and drug resistant clinical pathogens	(134)
09.	Silver nanoparticles	<i>Brevibacterium frigoritolerans</i> DC2	97 nm	Commercial antibiotics	(135)
10.	Fe_3O_4 -NPs	Plant Cai Soya bean sprouts	~8 nm	37.1 at 300 K 44.7 at 1.7 K	(136)
11.	Palladium	<i>Algae</i> Tobacco mosaic virus (TMV)	2.9-3.7nm	Catalyst in Suzuki reaction and recyclable	(137)
12.	Nanoassemblies	<i>Algae</i>	~29nm	Anticancer drug	(138)

		Cucumber mosaic virus		delivery	
13.	Nanoconjugates	<i>Algae</i> Potato virus X	12nm	Herceptin drug delivery in breast cancer therapy	(139)
14.	Titanium dioxide	<i>Algae</i> (M13 virus)	20–40nm	Photo-electrochemical properties	(140)
15.	Gold Nanoparticles	<i>Algae</i> Tobacco mosaic virus (TMV)	5nm	Building block for chiral meta-molecules	(141)
16.	Nanoconjugates	<i>Algae</i>	27–34nm	Cancer therapy	(142)
17.	Nanocarriers	<i>Algae</i>	13nm	Doxorubicin delivery in cancer therapy	(143)
18.	Silver Nanoparticles	<i>Gelidiummamsii</i> (Algae)	27–54 nm	Antibacterial and antibiofilm activity	(144)
19.	Zinc oxide Nanoparticles	<i>Sargassummuticum</i> (Algae)	30–57 nm	Anti-angiogenesis and anti-apoptotic activity	(145)
20.	Silver Nanoparticles	<i>Caulerparacemosa</i> (Algae)	05–25 nm	Antimicrobial activity	(146)

12. Conclusion

Nanoparticles with ordinary measurements in the scope of 1–100 nm are at the main edge of nanotechnology (103, 147). As of late, NPs, especially metal NPs, have been pulled in uncommon enthusiasm for the various field of technology extending from nanotechnology to biological science. In addition, mounting developing consideration has been seen in the natural amalgamation of NPs. The information increment towards green science and natural methodologies has brought about the utilization of eco-accommodating methods for assembling biocompatible and nontoxic NPs. The improvement of condition agreeable courses in the creation of material is of important worth to grow their organic purposes. As of late, a scope of green NPs with distinct compound structures and sizes have been delivered by different strategies, in addition to utilizes in lots of bleeding-edge mechanical territories have been analyzed. Diverse natural bodies have been created in the green synthesis strategies for metallic NPs what's more; the utilization of life forms or constituents that encourage the combination of monodisperse metal NPs.

13. Future Prospects

The oversimplified green synthesis of NPs with restricted measurements and shapes by utilizing sub-atomic cloning furthermore, hereditary designing methodologies, and other photobiological procedures will be a grand development in the field of nanobiotechnology. Speeding up explores on such living beings, bio components, or parameters will discharge such preservationist perilous forms. Earthly and oceanic phototrophic eukaryotes, heterotrophic eukaryotes, what are more, biocompatible operators have a gigantic ability to make metal NPs. Phototrophic eukaryotes, for example, plants, green

growth, and diatoms are considered as possibly reasonable and inexhaustible bio-factories for the creation of NPs. NPs by inexhaustible bio-resources and biocompatible operators with excellent “physicochemical, optoelectronics, and electronic properties” are of enormous implication for more extensive purposes in the zones of science, medication, hardware, what's more, farming. Even the green synthesized NPs may open up a branch with nano-cosmetology, while nanotechnology already has been introduced to cosmetic products. In addition to all of these prospects, the proper technology direction and leadership may play a major role to take care of the post-COVID-19 global economy.

Declarations

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

ACKNOWLEDGEMENT

The Authors are thankful to Dr. R Vimala and Prof. Andrews Nirmala Grace for their knowledge sharing.

References

1. Laurent S, Forge D, Port M, Roch A, Robic C, Vander Elst L et al. Magnetic iron oxide nanoparticles: synthesis, stabilization, vectorization, physicochemical characterizations, and biological applications. 2008;108(6):2064–110
2. Tiwari JN, Tiwari RN, Kim KSJPiMS. Zero-dimensional, one-dimensional, two-dimensional and three-dimensional nanostructured materials for advanced electrochemical energy devices. 2012;57(4):724–803
3. Chakravorty A, Rather GA, Ali A, Bhat BA, Sana SS, Abhishek N et al. Nano Approach: Indian Spices as Antimicrobial Agents. *Ethnopharmacological Investigation of Indian Spices*: IGI Global; 2020. p. 205 – 41
4. Shin W-K, Cho J, Kannan AG, Lee Y-S, Kim D-WJSr. Cross-linked composite gel polymer electrolyte using mesoporous methacrylate-functionalized SiO₂ nanoparticles for lithium-ion polymer batteries. 2016;6(1):1–10
5. Hagens WI, Oomen AG, de Jong WH, Cassee FR, Sips AJJRt, pharmacology. What do we (need to) know about the kinetic properties of nanoparticles in the body? 2007;49(3):217–29
6. Pereira L, Mehboob F, Stams AJ, Mota MM, Rijnaarts HH (2015) Alves MMJCrib. Metallic nanoparticles: microbial synthesis and unique properties for biotechnological applications. *bioavailability biotransformation* 35(1):114–128
7. Giljohann DA, Seferos DS, Daniel WL, Massich MD, Patel PC, Mirkin CAJACIE (2010) Gold nanoparticles for biology medicine 49(19):3280–3294
8. Khlebtsov N, Dykman LJCSR. Biodistribution and toxicity of engineered gold nanoparticles: a review of in vitro and in vivo studies. 2011;40(3):1647–71
9. Huang X, Jain PK, El-Sayed IH, El-Sayed MA. Gold nanoparticles: interesting optical properties and recent applications in cancer diagnostics and therapy. 2007
10. Iv M, Telischak N, Feng D, Holdsworth SJ, Yeom KW, Daldrup-Link HEJN. Clinical applications of iron oxide nanoparticles for magnetic resonance imaging of brain tumors. 2015;10(6):993–1018
11. Ahamed M, AlSalhi MS, Siddiqui MJCa (2010) Silver nanoparticle applications human health 411(23–24):1841–1848
12. Ambika S, Sundrarajan MJJoP, Biology PB. Green biosynthesis of ZnO nanoparticles using *Vitex negundo* L. extract: spectroscopic investigation of interaction between ZnO nanoparticles and human serum albumin. 2015;149:143–8
13. Zahir AA, Chauhan IS, Bagavan A, Kamaraj C, Elango G, Shankar J et al. Green synthesis of silver and titanium dioxide nanoparticles using *Euphorbia prostrata* extract shows shift from apoptosis to G0/G1 arrest followed by necrotic cell death in *Leishmania donovani*. 2015;59(8):4782–99

14. Nasrollahzadeh M, Sajadi SMJJoc, science i. Green synthesis of copper nanoparticles using Ginkgo biloba L. leaf extract and their catalytic activity for the Huisgen [3 + 2] cycloaddition of azides and alkynes at room temperature. 2015;457:141-7
15. Momeni S, Nabipour IJAb, biotechnology. A simple green synthesis of palladium nanoparticles with Sargassum alga and their electrocatalytic activities towards hydrogen peroxide. 2015;176(7):1937–49
16. Waki M, Sugiyama E, Kondo T, Sano K, Setou M. Nanoparticle-assisted laser desorption/ionization for metabolite imaging. Mass Spectrometry Imaging of Small Molecules: Springer; 2015. p. 159 – 73
17. Peng H-I, Miller BLJA. Recent advancements in optical DNA biosensors: exploiting the plasmonic effects of metal nanoparticles. 2011;136(3):436–47
18. Selid PD, Xu H, Collins EM, Striped Face-Collins M, Zhao JXJS (2009) Sensing mercury for biomedical environmental monitoring 9(7):5446–5459
19. Park H, Cannizzaro C, Vunjak-Novakovic G, Langer R, Vacanti CA (2007) Farokhzad OCJTe. Nanofabrication microfabrication of functional materials for tissue engineering 13(8):1867–1877
20. Bar-Cohen Y. Biomimetics: biologically inspired technologies: CRC Press; 2005
21. Jones CJ, Aizawa S-IJAimp. The bacterial flagellum and flagellar motor: structure, assembly and function. 1991;32:109–72
22. Bhushan B, Jung YCJJoPCM. Wetting, adhesion and friction of superhydrophobic and hydrophilic leaves and fabricated micro/nanopatterned surfaces. 2008;20(22):225010
23. Dhar P, Gaur SS, Ghosh T, Katiyar VJCN. 9 Nanocellulose: material development, characterization, and testing protocols. 2020:279
24. Bethi B, Sonawane SH, Bhanvase BA, Gumfekar SPJCE, Intensification P-P (2016) Nanomaterials-based advanced oxidation processes for wastewater treatment. A review 109:178–189
25. Salavati-Niasari M, Davar F, Mir NJP. Synthesis and characterization of metallic copper nanoparticles via thermal decomposition. 2008;27(17):3514–8
26. Azhar El, El-Kafrawy SA, Farraj SA, Hassan AM, Al-Saeed MS, Hashem AM et al (2014) Evidence for camel-to-human transmission of. MERS coronavirus 370(26):2499–2505
27. Saeed K, Khan IJIS, Technology. Preparation and characterization of single-walled carbon nanotube/nylon 6, 6 nanocomposites. 2016;44(4):435–44
28. Ngoy JM, Wagner N, Riboldi L, Bolland OJEP. A CO₂ capture technology using multi-walled carbon nanotubes with polyaspartamide surfactant. 2014;63:2230–48
29. Mabena LF, Ray SS, Mhlanga SD, Coville NJJAN. Nitrogen-doped carbon nanotubes as a metal catalyst support. 2011;1(2):67–77
30. Dreaden EC, Alkilany AM, Huang X, Murphy CJ, El-Sayed MAJCSR. The golden age: gold nanoparticles for biomedicine. 2012;41(7):2740–79
31. Sigmund W, Yuh J, Park H, Maneeratana V, Pyrgiotakis G, Daga A et al. Processing and structure relationships in electrospinning of ceramic fiber systems. 2006;89(2):395–407
32. Thomas C, Kumar Mishra S, Talegaonkar P SJCpd. Ceramic nanoparticles: fabrication methods and applications in drug delivery. 2015;21(42):6165–88
33. Sun S, Murray CB, Weller D, Folks L, Moser AJs (2000) Monodisperse FePt nanoparticles and ferromagnetic FePt. nanocrystal superlattices 287(5460):1989–1992
34. Hisatomi T, Kubota J, Domen KJCSR. Recent advances in semiconductors for photocatalytic and photoelectrochemical water splitting. 2014;43(22):7520–35
35. Ali S, Khan I, Khan SA, Sohail M, Ahmed R, ur Rehman A et al. Electrocatalytic performance of Ni@ Pt core–shell nanoparticles supported on carbon nanotubes for methanol oxidation reaction. 2017;795:17–25

36. Khan I, Abdalla A, Qurashi AJJohe. Synthesis of hierarchical WO₃ and Bi₂O₃/WO₃ nanocomposite for solar-driven water splitting applications. 2017;42(5):3431–9
37. Khan I, Saeed K, Khan IJAjoc. Nanoparticles: Properties, applications and toxicities. 2019;12(7):908 – 31
38. Abd Ellah NH, Abouelmagd SAJEoodd. Surface functionalization of polymeric nanoparticles for tumor drug delivery: approaches and challenges. 2017;14(2):201–14
39. El-Wahab H, Attia M, Hassan W, Nasser AJIJNN. Preparation, characterization and evaluation of some acrylate polymers nanoparticles as binder to improving the physical properties of water based paints. 2019;5:2–18
40. Liufu S-C, Xiao H-N, Li Y-PJoc, science i. Adsorption of cationic polyelectrolyte at the solid/liquid interface and dispersion of nanosized silica in water. 2005;285(1):33–40
41. Archana T, Vijayakumar K, Subashini G, Grace AN, Arivanandhan M, Jayavel RJRA. Effect of co-sensitization of InSb quantum dots on enhancing the photoconversion efficiency of CdS based quantum dot sensitized solar cells. 2020;10(25):14837–45
42. Devadoss A, Srinivasan N, Devarajan V, Grace AN, Pitchaimuthu S. Electrocatalytic properties of two-dimensional transition metal dichalcogenides and their hetrostructures in energy applications. 2D Nanoscale Heterostructured Materials: Elsevier; 2020. p. 215 – 41
43. Song C, Labhasetwar V, Murphy H, Qu X, Humphrey W, Shebuski R et al. Formulation and characterization of biodegradable nanoparticles for intravascular local drug delivery. 1997;43(2–3):197–212
44. Jaiswal J, Gupta SK, Kreuter JJJoCR. Preparation of biodegradable cyclosporine nanoparticles by high-pressure emulsification-solvent evaporation process. 2004;96(1):169–78
45. Soppimath KS, Aminabhavi TM, Kulkarni AR, Rudzinski WEJJocr. Biodegradable polymeric nanoparticles as drug delivery devices. 2001;70(1–2):1–20
46. Tice TR, Gilley RMJJocr. Preparation of injectable controlled-release microcapsules by a solvent-evaporation process. 1985;2:343–52
47. Tabata Y, Ikada YJPr. Protein precoating of polylactide microspheres containing a lipophilic immunopotentiator for enhancement of macrophage phagocytosis and activation. 1989;6(4):296–301
48. Ueda M, Kreuter JJJom. Optimization of the preparation of loperamide-loaded poly (L-lactide) nanoparticles by high pressure emulsification-solvent evaporation. 1997;14(5):593–605
49. Allemann E, Gurny R, Doelker EJEjop, biopharmaceutics. Drug-loaded nanoparticles: preparation methods and drug targeting issues. 1993;39(5):173–91
50. Lemarchand C, Gref R, Passirani C, Garcion E, Petri B, Müller R et al. Influence of polysaccharide coating on the interactions of nanoparticles with biological systems. 2006;27(1):108–18
51. Arun D, Vimala R, Ramkumar KDJB. Investigating the microbial-influenced corrosion of UNS S32750 stainless-steel base alloy and weld seams by biofilm-forming marine bacterium *Macroccoccus equipericus*. 2020;135:107546
52. Koosha F, Muller R, Davis S, Davies MJJocr. The surface chemical structure of poly (β -hydroxybutyrate) microparticles produced by solvent evaporation process. 1989;9(2):149–57
53. Vandervoort J, Ludwig AJIjop. Biocompatible stabilizers in the preparation of PLGA nanoparticles: a factorial design study. 2002;238(1–2):77–92
54. Ubrich N, Bouillot P, Pellerin C, Hoffman M, Maincent PJJocr. Preparation and characterization of propranolol hydrochloride nanoparticles: a comparative study. 2004;97(2):291–300
55. Reis CP, Neufeld RJ, Ribeiro AJ, Veiga FJNN, Biology, Medicine. Nanoencapsulation I. Methods for preparation of drug-loaded polymeric nanoparticles. 2006;2(1):8–21
56. Lambert R, Skandamis PN, Coote PJ, Nychas, GJJJoam. A study of the minimum inhibitory concentration and mode of action of oregano essential oil, thymol and carvacrol. 2001;91(3):453–62
57. Jung T, Kamm W, Breitenbach A, Kaiserling E, Xiao J, Kissel TJEJoP et al. Biodegradable nanoparticles for oral delivery of peptides: is there a role for polymers to affect mucosal uptake? 2000;50(1):147–60

58. Takeuchi H, Yamamoto H, Kawashima YJAddr. Mucoadhesive nanoparticulate systems for peptide drug delivery. 2001;47(1):39–54
59. Bunchongprasert K, Shao JJC, Biointerfaces SB. Effect of fatty acid ester structure on cytotoxicity of self-emulsified nanoemulsion and transport of nanoemulsion droplets. 2020;194:111220
60. Das S, Singh VK, Dwivedy AK, Chaudhari AK, Upadhyay N, Singh A et al. Fabrication, characterization and practical efficacy of *Myristica fragrans* essential oil nanoemulsion delivery system against postharvest biodeterioration. 2020;189:110000
61. Yoo HS, Oh JE, Lee KH, Park TGJPr. Biodegradable nanoparticles containing doxorubicin-PLGA conjugate for sustained release. 1999;16(7):1114–8
62. El-Shabouri MJSps. Nanoparticles for improving the dissolution and oral bioavailability of spironolactone, a poorly-soluble drug. 2002;12(2):97–101
63. SANTOS FSMd. AVALIAÇÃO DO EFEITO NEUROPROTETOR DO EXTRATO HIDROALCOÓLICO DA PRÓPOLIS VERMELHA E DA FORMONONETINA APÓS LESÃO MEDULAR ESPINAL EM ROEDORES. 2020
64. Vargas A, Pegaz B, Debefve E, Konan-Kouakou Y, Lange N, Ballini J-P et al. Improved photodynamic activity of porphyrin loaded into nanoparticles: an in vivo evaluation using chick embryos. 2004;286(1–2):131–45
65. González-Delgado JA, Castro PM, Machado A, Araújo F, Rodrigues F, Korsak B et al. Hydrogels containing porphyrin-loaded nanoparticles for topical photodynamic applications. 2016;510(1):221–31
66. Fessi H, Puisieux F, Devissaguet JP, Ammoury N, Benita SJlJop (1989) Nanocapsule formation by interfacial polymer deposition following solvent displacement 55(1):R1–R4
67. Chorny M, Fishbein I, Danenberg HD, Golomb GJJocr. Lipophilic drug loaded nanospheres prepared by nanoprecipitation: effect of formulation variables on size, drug recovery and release kinetics. 2002;83(3):389–400
68. Fojtik A, Henglein AJBdB-G. Laser ablation of films and suspended particles in a solvent: formation of cluster and colloid solutions. 1993;97(2):252–4
69. Mafuné F, Kohno J-y, Takeda Y, Kondow T, Sawabe HJTJoPCB. Formation and size control of silver nanoparticles by laser ablation in aqueous solution. 2000;104(39):9111–7
70. Takami A, Kurita H, Koda SJTJoPCB. Laser-induced size reduction of noble metal particles. 1999;103(8):1226–32
71. Yang WS, Park B-W, Jung EH, Jeon NJ, Kim YC, Lee DU et al. Iodide management in formamidinium-lead-halide-based perovskite layers for efficient solar cells. 2017;356(6345):1376–9
72. Menazea A, Ahmed MJN-S, Nano-Objects. Silver and copper oxide nanoparticles-decorated graphene oxide via pulsed laser ablation technique: Preparation, characterization, and photoactivated antibacterial activity. 2020;22:100464
73. Vinod M, Jayasree RS, Gopchandran KJCAP. Synthesis of pure and biocompatible gold nanoparticles using laser ablation method for SERS and photothermal applications. 2017;17(11):1430–8
74. Abdi S, Dorranean DJO, Technology L. Effect of CTAB concentration on the properties of ZnO nanoparticles produced by laser ablation method in CTAB solution. 2018;108:372–7
75. Mafuné F, Kohno J-y, Takeda Y, Kondow TJTJoPCB. Dissociation and aggregation of gold nanoparticles under laser irradiation. 2001;105(38):9050–6
76. Bohren C, Huffman D, Kam ZJN. Book-review-absorption and scattering of light by small particles. 1983;306(5943):625
77. Torres-Mendieta R, Ventura-Espinosa D, Sabater S, Lancis J, Mínguez-Vega G, Mata JAJSr. In situ decoration of graphene sheets with gold nanoparticles synthesized by pulsed laser ablation in liquids. 2016;6(1):1–9
78. de Anda Villa M, Gaudin J, Amans D, Boudjada F, Bozek J, Evaristo Grisenti R et al. Assessing the Surface Oxidation State of Free-Standing Gold Nanoparticles Produced by Laser Ablation. 2019;35(36):11859–71
79. Menazea A, Ahmed MJJoMS. Wound healing activity of Chitosan/Polyvinyl Alcohol embedded by gold nanoparticles prepared by nanosecond laser ablation. 2020;1217:128401

80. Luque R, Baruwati B, Varma RSJGc. Magnetically separable nanoferrite-anchored glutathione: aqueous homocoupling of arylboronic acids under microwave irradiation. 2010;12(9):1540–3
81. Bilecka I, Niederberger MJN. Microwave chemistry for inorganic nanomaterials synthesis. 2010;2(8):1358–74
82. Kappe COJACIE. Controlled microwave heating in modern organic synthesis. 2004;43(46):6250–84
83. Nadagouda MN, Speth TF, Varma RSJAoCR (2011) Microwave-assisted green synthesis of silver nanostructures 44(7):469–478
84. Polshettiwar V, Varma RSJAocr. Microwave-assisted organic synthesis and transformations using benign reaction media. 2008;41(5):629–39
85. Kappe COJCIJFC. The use of microwave irradiation in organic synthesis. From laboratory curiosity to standard practice in twenty years. 2006;60(6):308–12
86. Polshettiwar V, Nadagouda MN, Varma RSJAJoc. Microwave-assisted chemistry: a rapid and sustainable route to synthesis of organics and nanomaterials. 2009;62(1):16–26
87. Wang Y, Yin L, Palchik O, Hachohen YR, Koltypin Y, Gedanken AJCom. Sonochemical synthesis of layered and hexagonal yttrium – zirconium oxides. 2001;13(4):1248–51
88. Michalcová A, Machado L, Marek I, Martinec M, Sluková M, Vojtěch DJJoP et al. Properties of Ag nanoparticles prepared by modified Tollens' process with the use of different saccharide types. 2018;113:125–33
89. Kvítek L, Pucek R, Panáček A, Novotný R, Hrbáč J, Zbořil RJJoMC. The influence of complexing agent concentration on particle size in the process of SERS active silver colloid synthesis. 2005;15(10):1099–105
90. Sharma VK, Yngard RA (2009) Lin YJAic, science i. Silver nanoparticles: green synthesis their antimicrobial activities 145(1–2):83–96
91. Le A-T, Huy P, Tam PD, Huy TQ, Cam PD, Kudrinskiy A et al. Green synthesis of finely-dispersed highly bactericidal silver nanoparticles via modified Tollens technique. 2010;10(3):910–6
92. Yin Y, Li Z-Y, Zhong Z, Gates B, Xia Y, Venkateswaran SJJoMC. Synthesis and characterization of stable aqueous dispersions of silver nanoparticles through the Tollens process. 2002;12(3):522–7
93. Rhule JT, Hill CL, Judd DA, Schinazi RFJCR (1998) Polyoxometalates in medicine 98(1):327–358
94. Troupis A, Hiskia A, Papaconstantinou EJACIE. Synthesis of metal nanoparticles by using polyoxometalates as photocatalysts and stabilizers. 2002;41(11):1911–4
95. Zhang G, Keita B, Dolbecq A, Mialane P, Sécheresse F, Miserque F et al. Green chemistry-type one-step synthesis of silver nanostructures based on MoV–MoVI mixed-valence polyoxometalates. 2007;19(24):5821–3
96. An G, Na N, Zhang X, Miao Z, Miao S, Ding K et al. SnO₂/carbon nanotube nanocomposites synthesized in supercritical fluids: highly efficient materials for use as a chemical sensor and as the anode of a lithium-ion battery. 2007;18(43):435707
97. Anastas PJGB. Warner JC Green Chemistry theory and practice Oxford University press. 2000
98. Rheima AM, Mohammed MA, Jaber SH, Hasan MHJDIT. Inhibition effect of silver-calcium nanocomposite on alanine transaminase enzyme activity in human serum of Iraqi patients with chronic liver disease. 2019;12(11):2818–21
99. Dahl JA, Maddux BL (2007) Hutchison JEJCr. Toward greener nanosynthesis 107(6):2228–2269
100. Roy A, Bulut O, Some S, Mandal AK, Yilmaz MDJRa. Green synthesis of silver nanoparticles: biomolecule-nanoparticle organizations targeting antimicrobial activity. 2019;9(5):2673–702
101. Mann SJN. Molecular tectonics in biomineralization and biomimetic materials chemistry. 1993;365(6446):499–505
102. Bibi I, Nazar N, Iqbal M, Kamal S, Nawaz H, Nouren S et al. Green and eco-friendly synthesis of cobalt-oxide nanoparticle: characterization and photo-catalytic activity. 2017;28(9):2035–43
103. Chakravorty A, Biswas B, Sana SS, Rayan RA, Lala NL, Ramakrishna SJMTP. A review on toxicity of turmeric derived Nano-Formulates against bacterial and fungal cells with special emphasis on electrospun nanofibers. 2020

104. Rajasekaran SJ, Raghavan VJD, Materials R. Facile synthesis of activated carbon derived from Eucalyptus globulus seed as efficient electrode material for supercapacitors. 2020;109:108038
105. Nath D, Banerjee PJ, pharmacology. Green nanotechnology—a new hope for medical biology. 2013;36(3):997–1014
106. Mohanpuria P, Rana NK, Yadav, SKJ, J. Biosynthesis of nanoparticles: technological concepts and future applications. 2008;10(3):507–17
107. Rajeshkumar S, Bharath L, Geetha R. Broad spectrum antibacterial silver nanoparticle green synthesis: Characterization, and mechanism of action. Green synthesis, characterization and applications of nanoparticles: Elsevier; 2019. p. 429 – 44
108. Durán N, Marcato PD, Durán M, Yadav A, Gade A, Rai, MJ, Am et al. Mechanistic aspects in the biogenic synthesis of extracellular metal nanoparticles by peptides, bacteria, fungi, and plants. 2011;90(5):1609–24
109. Mortazavi-Derazkola S, Ebrahimzadeh MA, Amiri O, Goli HR, Rafiei A, Kardan M et al. Facile green synthesis and characterization of Crataegus microphylla extract-capped silver nanoparticles (CME@ Ag-NPs) and its potential antibacterial and anticancer activities against AGS and MCF-7 human cancer cells. 2020;820:153186
110. Ghosh P, Han G, De M, Kim CK, Rotello VM, J. Gold nanoparticles in delivery applications 60(11):1307–1315
111. Arefi-Rad MR, Kafashan HJ, OM (2020) Pb-doped SnS nano-powders. Comprehensive physical characterizations 105:109887
112. Aubin-Tam M-E, Hamad-Schifferli KJ, BM. Structure and function of nanoparticle–protein conjugates. 2008;3(3):034001
113. Brown SD, Nativo P, Smith J-A, Stirling D, Edwards PR, Venugopal B et al. Gold nanoparticles for the improved anticancer drug delivery of the active component of oxaliplatin. 2010;132(13):4678–84
114. Dickerson EB, Dreaden EC, Huang X, El-Sayed IH, Chu H, Pushpanketh S et al. Gold nanorod assisted near-infrared plasmonic photothermal therapy (PPTT) of squamous cell carcinoma in mice. 2008;269(1):57–66
115. Melancon MP, Lu W, Yang Z, Zhang R, Cheng Z, Elliot AM et al. In vitro and in vivo targeting of hollow gold nanoshells directed at epidermal growth factor receptor for photothermal ablation therapy. 2008;7(6):1730–9
116. Sperling RA, Gil PR, Zhang F, Zanella M, Parak WJ, CSR (2008) Biological applications of gold nanoparticles 37(9):1896–1908
117. Salata OV, J. Applications of nanoparticles in biology and medicine. 2004;2(1):1–6
118. Ganesh RS, Durgadevi E, Navaneethan M, Patil V, Ponnusamy S, Muthamizhchelvan C et al. Low temperature ammonia gas sensor based on Mn-doped ZnO nanoparticle decorated microspheres. 2017;721:182–90
119. Shabani-Nooshabadi M, Karimi-Maleh H, Tahernejad-Javazmi FJ, JoTES. Fabrication of an electroanalytical sensor for determination of deoxyepinephrine in the presence of uric acid using CuFe₂O₄ nanoparticle/ionic liquid amplified sensor. 2019;166(6):H218
120. Malinovskis U, Poplauskas R, Erts D, Ramser K, Tamulevičius S, Tamulevičienė A et al. High-density plasmonic nanoparticle arrays deposited on nanoporous anodic alumina templates for optical sensor applications. 2019;9(4):531
121. Furman BR, Wellinghoff ST. Electrophoretically deposited strontium fluoride nanoparticle/polymer coatings for medical implants. Google Patents; 2019
122. Lampé I, Beke D, Biri S, Csarnovics I, Csik A, Dombrádi Z et al. Investigation of silver nanoparticles on titanium surface created by ion implantation technology. 2019;14:4709
123. De La Isla A, Brostow W, Bujard B, Estevez M, Rodriguez JR, Vargas S et al. Nanohybrid scratch resistant coatings for teeth and bone viscoelasticity manifested in tribology. 2003;7(2):110–4
124. Park J-S, Kim I-K, Han S, Park I, Kim C, Bae J et al. Normalization of tumor vessels by Tie2 activation and Ang2 inhibition enhances drug delivery and produces a favorable tumor microenvironment. 2016;30(6):953–67
125. Hamouda IM, J. Current perspectives of nanoparticles in medical and dental biomaterials. 2012;26(3):143–51
126. Makvandi P, Wang C, Zare EN, Borzacchiello A, Niu Ln, Tay FR, JAFM. Metal-based nanomaterials in biomedical applications: Antimicrobial activity and cytotoxicity aspects. 2020;30(22):1910021

127. Rasheed T, Bilal M, Iqbal HM, Li CJC, Biointerfaces SB. Green biosynthesis of silver nanoparticles using leaves extract of *Artemisia vulgaris* and their potential biomedical applications. 2017;158:408–15
128. Mahdavi M, Namvar F, Ahmad MB, Mohamad RJM. Green biosynthesis and characterization of magnetic iron oxide (Fe₃O₄) nanoparticles using seaweed (*Sargassum muticum*) aqueous extract. 2013;18(5):5954–64
129. Vivek R, Thangam R, Muthuchelian K, Gunasekaran P, Kaveri K, Kannan SJPB. Green biosynthesis of silver nanoparticles from *Annona squamosa* leaf extract and its in vitro cytotoxic effect on MCF-7 cells. 2012;47(12):2405–10
130. Yew YP, Shameli K, Miyake M, Khairudin NBBA, Mohamad SEB, Naiki T et al (2020) Green biosynthesis of superparamagnetic magnetite Fe₃O₄ nanoparticles and biomedical applications in targeted anticancer drug delivery system. A review 13(1):2287–2308
131. Charbgo F, Ahmad MB, Darroudi MJljon. Cerium oxide nanoparticles: green synthesis and biological applications. 2017;12:1401
132. Sathishkumar P, Gu FL, Zhan Q, Palvannan T, Yusoff ARMJMI. Flavonoids mediated 'Green'nanomaterials: A novel nanomedicine system to treat various diseases–Current trends and future perspective. 2018;210:26–30
133. Shameli K, Ahmad MB, Zamanian A, Sangpour P, Shabanzadeh P, Abdollahi Y et al. Green biosynthesis of silver nanoparticles using *Curcuma longa* tuber powder. 2012;7:5603
134. Al-Dhabi NA, Ghilan A-KM, Arasu MV, Duraipandiyan VJJoP, Biology PB. Green biosynthesis of silver nanoparticles produced from marine *Streptomyces* sp. Al-Dhabi-89 and their potential applications against wound infection and drug resistant clinical pathogens. 2018;189:176–84
135. Singh P, Kim YJ, Singh H, Wang C, Hwang KH, Farh ME-A et al. Biosynthesis, characterization, and antimicrobial applications of silver nanoparticles. 2015;10:2567
136. Yang F, Li Y, Liu T, Xu K, Zhang L, Xu C et al. Plasma synthesis of Pd nanoparticles decorated-carbon nanotubes and its application in Suzuki reaction. 2013;226:52–8
137. Zeng Q, Wen H, Wen Q, Chen X, Wang Y, Xuan W et al. Cucumber mosaic virus as drug delivery vehicle for doxorubicin. 2013;34(19):4632–42
138. Esfandiari N, Arzanani MK, Soleimani M, Kohi-Habibi M, Svendsen WEJTB. A new application of plant virus nanoparticles as drug delivery in breast cancer. 2016;37(1):1229–36
139. Chen Y, Wei JJPO. Identification of pathogen signatures in prostate cancer using RNA-seq. 2015;10(6):e0128955
140. Kobayashi M, Tomita S, Sawada K, Shiba K, Yanagi H, Yamashita I et al. Chiral meta-molecules consisting of gold nanoparticles and genetically engineered tobacco mosaic virus. 2012;20(22):24856–63
141. Chen CC, Stark M, Baikoghli M, Cheng RHJJ. Surface functionalization of hepatitis E virus nanoparticles using chemical conjugation methods. 2018(135):e57020
142. Le DH, Lee KL, Shukla S, Commandeur U, Steinmetz NFJN. Potato virus X, a filamentous plant viral nanoparticle for doxorubicin delivery in cancer therapy. 2017;9(6):2348–57
143. Pugazhendhi A, Prabakar D, Jacob JM, Karuppusamy I, Saratale RGJMp. Synthesis and characterization of silver nanoparticles using *Gelidium amansii* and its antimicrobial property against various pathogenic bacteria. 2018;114:41–5
144. Sanaeimehr Z, Javadi I, Namvar FJCN. Antiangiogenic and antiapoptotic effects of green-synthesized zinc oxide nanoparticles using *Sargassum muticum* algae extraction. 2018;9(1):1–16
145. Venkatesan J, Manivasagan P, Kim S-K, Kirthi AV, Marimuthu S, Rahuman AAJB et al. Marine algae-mediated synthesis of gold nanoparticles using a novel *Ecklonia cava*. 2014;37(8):1591–7
146. Tanzil AH, Sultana ST, Saunders SR, Shi L, Marsili E, Beyenal HJE et al (2016) Biological synthesis of nanoparticles in biofilms 95:4–12
147. Rather GA, Chakravorty A, Bhat BA, Malik IM, Mir FH, Sana SS et al (2020) Routes of Synthesis and Characterizations of Nanoparticles. Applications of Nanomaterials in Agriculture. IGI Global, Food Science, pp 288–309

Figures

Figure 1

Ceramics properties of nanoparticles

Figure 2

Preparation of nanoparticles

Figure 3

Application of nanoparticles