



A Comprehensive Review on Nanoparticles: Classification, Synthesis, Characterization, Applications

Rutvaben Patel^[1*], Disha Patel^[2], Himani Patel^[2], Dr. Nisha Patel^[3], Dr. Pankaj Prajapati^[3]

Department of Pharmaceutics Shri Sarvajanic Pharmacy College Mehsana, Gujarat, India

Received: 25 January 2026

Revised: 10 February 2026

Accepted: 26 February 2026

ABSTRACT:

Nanoparticles are a subset of materials that fall within the nanometric range of 1-100 nm in size ($\sim 1 \times 10^{-9}$ m). Nanoparticles are generally classified into one of three categories depending upon whether they are inorganic, organic, or carbon-based and demonstrate improvement in their physical and/or chemical properties over their bulk version. Some characteristics that may improve with reduction in size include: increased strength, higher sensitivity (e.g. to light), higher reactivity, increased stability, and increased surface area. They can be synthesized (created) by a number of different methods for the purpose of research or commercial use and can be classified into three categories of methods for creation – chemical methods, physical methods and mechanical methods which allow researchers have been making rapid advancements. In this paper, we will provide a comprehensive review of the various types of nanoparticles, the different methods of characterizing them, the various methods of creating them, as well as their potential applications for addressing some environmental issues.

Keywords: Nanoparticles, Classification, Physical, Chemical, Methods, Characterization

INTRODUCTION

Nanotechnology refers to an area of science that deals with systems made up of particles at a scale called "nanoscale", which is derived from the Latin word "nanus" meaning small. Therefore, the term "nanoparticle" describes a particle that is composed of material but has a dimension that is less than 100 nanometers in at least one of its dimensions (i.e., its length, width, or height).^[1] Nanoparticles can be created by any type of means, and they can be made from numerous different materials, including carbon, metals, metal oxides, or organic materials.^[2] The physical and chemical properties of nanoparticles compared to their larger-sized counterparts are enhanced and/or have unique characteristics associated with them, including having a greater surface area-to-volume ratio (known as high specific surface area), increased reactivity, as well as increased stability. The characteristics of a nanoparticle stem primarily from its size and shape.

Generally, the structure of a nanoparticle can be quite complex and can consist of 3 layers like a core layer, a shell layer that is chemically dissimilar to the core, and a functionalization layer that can be attached to the surface of the nanoparticle using various types of molecules (e.g., metal ions, surfactants, or polymers). The majority of the physical and chemical properties of a nanoparticle are dictated by the core material of the nanoparticle.

Classification

Nanoparticles can be divided into three major categories based on their composition – organic, inorganic, and carbon.

Organic nanoparticles: They are typically made from organic materials, including lipids and polymers. Dendrimers, liposomes, micelles, and ferritin are all types of organic nanoparticles, which are generally considered environmentally friendly, biodegradable, and non-toxic. Because of these properties, organic nanoparticles are suitable for use in biomedical applications (particularly for drug delivery). In addition, micelles and liposomes are considered nano capsules because they have a hollow core and are very sensitive to heat and electromagnetic radiation.^[3]

Inorganic Nanoparticles: Inorganic Nanoparticles are defined as those not consisting of carbon. Inorganic nanoparticles can be further classified into:



➤ **Metal-Based Nanoparticles:** They consist of metals (e.g., gold, silver, copper, iron, and zinc).^[4] Many transition metals are used to create metal-based nanoparticles because of their ability to undergo redox reactions due to their partially filled d-orbitals. Because of their high surface area to volume ratios and high reactivity, metal-based nanoparticles can be used in a variety of research areas.

➤ **Nanoparticles with Metal Oxides:** They are produced by converting a metal particle into a metal oxide particle (ex: Fe₂O₃, TiO₂, ZnO). Compared to their metal counterparts, these materials tend to exhibit greater reactivity and efficiency.^[5]

➤ **Ceramic Nanoparticles:** Ceramic Nanoparticles are inorganic (non-metallic) solids composed of solid-state compounds that are formed through heating and combining various types of materials (example: carbides, oxides, phosphates) to create compounds that can serve a wide variety of uses such as catalysis and photodegradation – two of their many properties.

➤ **Semiconductor Nanoparticles (Quantum Dots):** Semiconductor Nanoparticles are materials that display properties somewhere between those of metals and non-metals. Typically, these compounds have wide energy bandgaps, examples include: Cadmium Selenide (CdSe) or Indium Phosphide (InP). Quantum dots have applications primarily in electronics, optic type products, and photocatalysis.^[6]

Carbon based Nanoparticles: It's properties will vary depending upon the shape of the nanoparticles. The structure of the carbon nanoparticles can be tubelike (Example: Tubes), horn-like (Example: Horns), or sphere-like (Example: Spheres). Major categories of carbon-based nanoparticles:^[7]

➤ **Fullerenes:** Fullerene is discovered in 1985, are typically spherically shaped molecules comprised of carbon atoms with these molecules being composed of 60 individual carbon atoms known by scientists as C₆₀ (buckyballs). All of these individual carbon atoms within the fullerene are sp² hybridized and are linked together through 20 hexagonal shapes and 12 pentagonal shapes.

➤ **Carbon Nanotubes (CNTs):** Carbon Nanotubes were first discovered in 1991 and are essentially tube-like forms of thousands of graphene sheets rolled up tightly to create a single structure. The CNT is noted for having exceptional strength, reasonably high rigidity, and exceptional electrical and thermal conductivity properties. CNTs are classified based on whether they are single-walled (SWCNT) or multiple-walled (MWCNT).

➤ **Graphene:** Graphene is a single layer of two-dimensional carbon arranged in a honeycomb structure with a thickness of approximately 1 nm.

➤ **Carbon Nanofibers (CNFs):** Carbon Nanofibers is also a carbon-based material, made up of multiple layers of graphene but arranged to create structures resembling stacked cones, cups, and plates.

➤ **Carbon Black:** A type of amorphous, spherical nanoparticle of pure carbon formed as a by-product of incomplete combustion that can be found in everyday products like laser printer ink and pigments used in plastics.

Synthesis of Nanoparticles

Nanoparticles (NPs) with regulated size, shape, dimensions, and structure have been created using a variety of techniques.

1. Top-Down Methods

The reduction of bulk materials into nanoparticles by destruction (the process is also called 'Top-Down') is an example of how nanoparticles can be created from a variety of bulk materials. The following methods have been successfully used to produce nanoparticles mechanically, chemically or both: mechanical milling, nanolithography, laser ablation, sputtering and thermal decomposition.

➤ **Mechanical Milling:** Among the many methods of creating nanoparticles through top-down approaches, mechanical milling is the most commonly utilized. The mechanical milling techniques used to synthesize nanoparticles consist of two main parts: the production of nanoparticles through mechanical means such as milling and the annealing of these same milled nanoparticles. The actual mechanical milling of the nanoparticles is done in an inert gas atmosphere with different materials being milled together.^[8] Each process done during mechanical milling has certain aspects that can change the physical characteristics of the nanoparticles; plastic deformation will change the shape of nanoparticles, fracture will reduce the size of nanoparticles, and cold welding will increase the size of nanoparticles.



- **Laser ablation:** The process known as Laser Ablation Synthesis in Solution (LASiS) is widely used to create nanoparticles out of different types of liquids. A laser beam hits a piece of metal that has been put into some sort of liquid, and this interaction produces a plasma cloud and then means the formation of a large number of nanoparticles were created by condensation and chemical reaction.^[9] Furthermore, this method known as top-down manufacturing is the only alternative to conventional methods utilized for reducing metals by using chemicals to manufacture nanoparticles out of both organic and water-based liquids. Finally, because of the continued stability of manufacturing nanoparticles through this process and the fact that it produces no need for enabling or otherwise harmful substances, this process can be classified as a 'green' manufacturing process.
- **Nanolithography:** Nanolithography relates to creating nanometer sized material structures (size range 1-100 nm in one of the three dimensions) using different techniques such as light, electron, laser and scanning-probe techniques.^[10] Lithography consists of the ability to use a photo-sensitive material to create a shape or structure on to a material's surface. The ability to use nanolithography to create a single nanoparticle and to produce multiple nanoparticles is an advantage. However, the equipment required to perform nanolithography and the resultant cost of the equipment are both disadvantages.^[11]
- **Thermal decomposition:** chemical bonds are broken due to heat causing an endothermic reaction. The temperature at which a material undergoes thermal decomposition is referred to as the decomposition temperature.^[12] Thermally decomposed metals produce nanoparticles that may also contain secondary products resulting from a chemical reaction during decomposition.
- **Sputtering:** Ions will collide with the bulk material's surface, ejecting particles from that surface and depositing onto another surface as nanoparticles. This method deposits uniformly thin layers of material and typically follows an annealing process to form nanoparticles. Nanoparticle characteristics, such as shape, size, and distribution, are determined by the thickness of the sputtered layer, substrate type, annealing temperature, and duration.^[13]

2. Bottom-up method

The constructive or bottom-up method consists of creating materials from simple atoms through clusters and out to nanoparticles. The bottom-up methods by which these nanoparticles are synthesized include sol-gel, spin coating, chemical vapor deposition (CVD), pyrolysis, and biosynthesis.

- **Sol-gel:** A sol is a colloidal suspension of solid particles in a liquid, and a gel is a solid macromolecule in the presence of a solvent. Sol-gel is considered the method of choice for bottom-up construction because it is very simple, and virtually all types of nanoparticles can be synthesized using this method. It is a wet chemical processing where the chemical solution is acting as a precursor to an integrated system of discrete particles. In the sol-gel method, typically metal oxides and chlorides are used as precursors.^[14] The next step is to disperse the precursor with the liquid host by one of the following methods: shaking, stirring, or sonication. Once the precursor and host have been mixed, the resulting mixture is called a liquid-solid system and consists of a liquid phase and a solid phase. Phase separation is used to separate the two phases and recover the nanoparticles using one of several separation techniques: sedimentation, filtration and centrifugation. The moisture content of the recovered nanoparticles is removed by drying.
- **Pyrolysis:** Pyrolysis is a widely employed industrial process for large-scale nanomaterial production via the combustion of raw materials/precursors with flame. Pyrolysis involves introducing a precursor (as vapor or liquid) into a furnace via a small inlet pipe, burning it in combustion with flame (i.e., producing combustion gases).^[7,15] Combustion gases produced can be separated out from the by-products of combustion through air classification methods to produce / recover nanoparticles. Some pyrolyzers utilize laser heating instead of flames to create the high temperatures necessary for evaporating precursors. The pyrolytic processes offer several advantages, such as being an easy to perform process, that has high efficiency and low cost; as well as producing continuously at high yields.

Biological synthesis of Nanoparticles

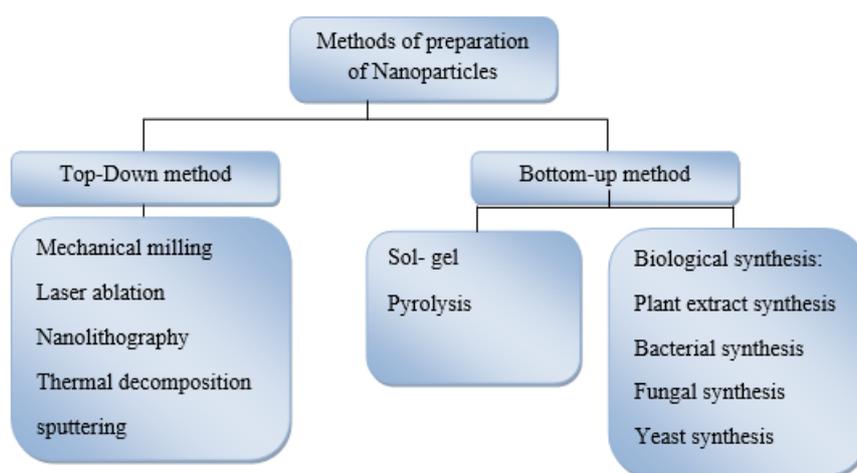
There are following methods are used in biological synthesis:

- **Plant Extract Synthesis:** Plant Extract Synthesis is an environmentally safe and therefore preferred method for NP synthesis because of its lack of toxicity and the fact that it produces less contaminated products than NPs synthesized from other sources or methods. Gold and Silver NPs can be synthesized from plant extracts such as Geranium, Aloe Vera, Sun Dried Cinnamon, Camphora, Azadiracta Indica, and many more.^[16]
- **Bacterial Synthesis:** There has recently been a large increase in the number of NPs synthesized from bacteria because of their diverse and many applications. Some species of Bacillus species have been used to produce a variety of different types of metal NPs

because of their ability to synthesize/extrude NPs in an extracellular manner. They typically range from 10 nm - 20 nm and may also produce Au NPs.^[17]

- **Fungal Synthesis:** A variety of fungal species are capable of synthesizing NPs including *Aspergillus Niger*, *Aspergillus Orizae*, and *Fusarium Solani*. However, *Phoma Globerta* has been identified to have the ability to produce Ag NPs that are effective against *E. coli*, *S. aureus*, and *P. aeruginosa*.^[18]

- **Yeast Synthesis:** By utilizing both *Candida Glabarta* and *Schizosaccharomyce Pombe*, it is possible to convert Cd to NPs. The potential to create Ag and Au NPs from a number of different types of yeast, including an extreme environmental yeast strain isolated from natural acid mine drainage, has been explored. Also, they have used marine yeast *Rodosporidium Diobovatum* in the synthesis of stable PbS NPs.^[19]



Characterization of Nanoparticles

- **Zeta Potential:** Zeta potential is one of the most common forms of characterization for nanoparticle properties. The Zeta potential is a measure of the electrical potential of a particle and is affected by the characteristics of the particle as well as by the characteristics of the liquid in which the particle is suspended. Zeta potentials between -10 and the +10mV are considered neutral, therefore nanoparticles with Zeta potentials greater than 30 mV are considered strongly cationic and nanoparticles with Zeta potentials less than -30 mV are considered strongly anionic.^[20] The Zeta potential can also be used as an indication of whether a charged active ingredient is located inside the centre of the nano capsule or adsorbed onto the surface of the nano capsule. The magnitude of the Zeta Potential is a measure of the stability of a particle; the greater the magnitude of the Zeta Potential, the greater the electrostatic repulsion between particles, therefore the greater the stability of the particles.

A stability reference for Zeta potentials is as follows:

- 0 mV - 5 mV: Agglomeration and/or aggregation of particles is likely to occur
- 5 mV - 20 mV: Particles have some stability
- 20 mV - 40 mV: Particles are moderately stable
- Greater than 40 mV: Particles are extremely stable

It should also be noted that the stability of the charge on a nanoparticle will depend on the pH of the solution containing the nanoparticles.

The calculation of the zeta potential(z) uses the Henry equation.

$$U_e = \frac{2\varepsilon z f(ka)}{3\eta}$$



Where, U_e = Electrophoretic mobility

ϵ = Dielectric constant

η = Zero-shear viscosity of the medium

k_a = Double layer thickness

- **UV- visible absorption spectroscopy:** Absorbance spectroscopy is used to characterize the optical properties of a liquid sample by sending a beam of light through it and measuring how much light is absorbed by the sample. The absorbance of a solution may be measured by varying the wavelength of the light and measuring the absorbance for each distinct wavelength, thus allowing you to determine the concentration of the sample using Beer-Lambert's law.^[21] UV-Visible spectrophotometry may be used to identify certain compounds based on the unique absorption peaks they produce at specific wavelengths such as 410 nm.
- **Fourier Transform Infrared [FTIR] spectroscopy:** An infrared spectrum collected with Fourier Transform infrared (FTIR) spectroscopy measures infrared radiation intensity versus wavelength and can be used to ascertain the chemical functional groups present and structural characteristics of biological material containing nanoparticles. The spectra calculated reveal the underlying property of optical spectra for nanoparticles. A number of silver nanoparticles produced by a green synthesis through various leaf extracts were analyzed by FTIR spectroscopy, each of which produced a characteristic peak.
- **Microscopic techniques:** The main techniques used for examining the morphology of nanoparticles are scanning electron microscopy (SEM) and transmission electron microscopy (TEM).^[22] These two techniques have been utilized by numerous researchers to demonstrate that the nanoparticles produced were approximately uniform in size and shape.
- **Scanning Electron Microscope:** The SEM technique allows researchers to evaluate the morphology, size, shape, and other characteristics of nanoparticles formed during a particular procedure; SEM produces a high-quality image that reflects the appearance of a sample. When examining both samples through SEM and optical microscopes, scientists use the same basic principle; however, while optical microscopes rely on the detection of light (photons), SEM's use electrons emitted from the surface of a sample provides a much smaller wavelength than that of a photon.^[22] It enables an image produced via this device to be magnified by up to 200 000 times. The measurement of the particle size and characterization of the particle can be performed with a conductive or sputtered-coated sample, as well as with a very low sensitivity to particles as small as one nanometer.
- **Transmission electron microscopy (TEM):** Transmission electron Microscopy (TEM) is a microscopy style that captures images based off the transmission (or passing) of a beam of electrons through an ultra-thin sample (specimen), interacting with that specimen while passing through it, creating an image of the electron transmission. The electron transmission through the specimen is focused and magnified either on to an imaging device (fluorescent screen), onto a layer of photographic film or by some detection system (CCD camera) to produce the image to be viewed.^[22] TEM provides major analytical methods across multiple disciplines including both physical and biological science, and finds applications in cancer research, virology, material science, pollution, nanotechnology, and semiconductors.
- **X-ray diffraction (XRD) analysis:** X-ray Diffraction (XRD) is the conventional technique used to determine the crystallographic structure and morphology of a material. The intensity of the peaks increases or decreases with increasing or decreasing amounts of the constituent in the crystalline structure. The XRD technique can also identify whether the materials are metallic or non-metallic in nature, and it provides information on the translational symmetry, the size and shape of the unit cell from the position of the peaks, and the electron density inside the unit cell (where the atoms are located) from the intensities of the peaks.^[23]

The calculated XRD patterns were obtained using a X per Rota flex diffractometer (Cu K radiation, $\lambda = 1.5406 \text{ \AA}$). The Crystallite size is determined by the Scherrer equation:

$$CS = K/\cos$$

where, CS = Crystallite Size, K = 0.94 is the width of the peak at half maximum (full width) measured in radians, and θ has the following formula:

$$[\beta] = FWHM \times \pi/180\lambda$$



where β is the FWHM in radians, θ is the Bragg angle (degree), λ is the X-ray wavelength in Å, and π is a mathematical constant (approximately equal to 3.14159).

Using X-ray Diffraction (XRD) with several types of nanoparticles, many researchers have studied how to achieve high crystallinity of the nanomaterial prepared.

Benefits of Nanoparticles:

- The bioavailability level increases as the solubility of the drug increases.
- Allows targeted delivery of a drug.
- Increased drug resistance time.
- Biodegradable polymers are used in making nanoparticles which help reduce toxicity for the patient.
- Can be given by different routes including oral, parenteral and intraocular routes.
- Drug incorporation can occur without a chemical reaction.^[24]
- By changing the matrix materials, characteristics of degradation and pattern of release can be modified.

Limitation of Nanoparticles:

- Nanoparticles have a high amount of free energy; therefore, they can undergo agglomeration/aggregation because of the processes of Ostwald ripening.
- Operating with nanoparticles is more complex than with bulk forms.
- Nanoparticles are more prone to contamination.
- Due to their small size and large surface area, nanoparticles can be very difficult to handle in both liquid and solid forms.
- Because of the large surface area and small size of nanoparticles, they are highly reactive with their environment.^[25]

Applications:

Nanoparticles display distinctive physical and chemical characteristics like; electrical, optical; mechanical; magnetic; and thermal. This is why they have been used for a wide variety of applications. Some examples of common applications of nanoparticles are summarized below:

1. Medicine:

Nanoparticles have had a huge impact on clinical medicine by providing means for drug delivery and medical imaging. Most often, iron oxide nanoparticles, such as magnetite (Fe_3O_4) and its oxidized form (hematite, Fe_2O_3), have been used in biomedical applications. Because of the ability of Ag nanoparticles (NPs) to kill bacteria with minimal toxicity to surrounding tissue, Ag NPs have increased use in wound dressings, catheters, and other consumer products. Gold nanoparticles (GNPs) present unique opportunities for use as a treatment for cancer because they may be used to deliver drugs, provide heat via photothermal therapy, as contrast agents, and as radiosensitizing agents.^[26-28] Biodegradable NPs have been of great interest over the last several decades with their potential to be used effectively as a drug delivery device. Several different types of polymers have been explored through research focused on drug delivery, as they demonstrate effective & targeted delivery of the drug maximising the therapeutic effect which, in turn, will reduce unnecessary or undesired side effects.

2. Mechanical Industries:

NPs are widely used in mechanical industries because of their high Young's modulus, and also due to their superior stress and strain properties. These properties lead to NPs being used in coatings, lubricants^[29] and in the manufacturing of nanodevices that are much



stronger than conventional devices. The authors of this paper have created a method for producing a hydrophobic coating on cotton fabric, by using silver nanoparticles (AgNP) in combination with a fluorine-free silane monomer called 3-(Trimethoxysilyl) propyl methacrylate (TMSPM) as part of their two-step dip-coating process.^[30]

3. Food:

Increasingly, food companies are using nanoparticles in their packaging materials for controlling the atmosphere around food products and preventing spoilage by preventing microbial growth and contamination.^[31] In particular, inorganic metallic nanoparticles (NPs) are being utilized in the food industry as substitutes for plastics made from petroleum for food packages because they allow for the easier addition of antimicrobial agents to the surface of the package films.^[32]

4. Environmental Remediation:

Nanoparticles are commonly utilized for environmental cleanup, as they are highly adaptable to both in-situ and ex-situ uses in aquatic systems. Silver nanoparticles (AgNPs) are extensively used to disinfect water due to their antibacterial, antifungal, and antiviral properties.^[33] TiO₂ nanoparticles (TiO₂ NPs) have been increasingly researched for applications in solid waste treatment, air purification, the self-cleaning of surfaces, and as photocatalysts in the use of water treatment applications, due to their low cost, lack of toxicity, semiconductor properties, photocatalytic and electronic properties, gas-sensing and energy-converting capabilities.^[34-36]

5. Energy Harvesting:

As a result of dwindling fossil fuel resources, scientists have been moving toward different types of renewable energy resources to help meet voice consumption at a much lower price than traditional fossil fuels. Nanoparticles (NPs) have an appropriate amount of surface area, optical properties, and catalytic properties to serve as energy sources for these types of applications. NPs have been successfully employed in the production of energy through both PEC and electrochemical water splitting. In addition to PEC and electrochemical water splitting,^[37] other advanced forms of energy generation include electrochemical reduction of CO₂ from raw materials into fuel precursors, solar photovoltaic (PV) cells and piezoelectric generators.

Conclusion:

Nanoparticle research is a vast and diverse area of study due to the many different types of nanoparticles, as well as how they can be synthesized and characterized. The unique physical and chemical properties of nanoparticles have prompted extensive applications in medicine, electronics, environmental remediation, and energy production. Continued investigation into the synthesis and characterization of nanoparticles will likely result in innovations and advances in nanotechnology.

REFERENCES:

1. Cho EJ, Holback H, Liu KC, Abouelmagd SA, Park J, Yeo Y. Nanoparticle characterization: State of the art, challenges, and emerging technologies. HHS public access manuscript, 2013; 10(6): 2093-2110.
2. Hasan S. A Review on Nanoparticles: Their Synthesis and Types Biosynthesis and Mechanism. Res J Rec Sci. 2015; 4: 1-3.
3. Liu Z, Robinson JT, Sun X, Dai H. PEGylated Nanographene Oxide for Delivery of Water-Insoluble Cancer Drugs. J Am Chem Soc. 2008;130: 10876-10877.
4. Tiwari DK, Behari J, Sen P. Application of Nanoparticles in Waste Water Treatment. World Appl Sci J, 2008; 3(3): 417-433.
5. Sathyanarayanan, MB, Balachandranath R, Srinivasulu GY, Kannaiyan SK, Subbiahdoss G. The effect of gold and iron-oxide nanoparticles on biofilm-forming pathogens. ISRN Microbiol. 2013: 272086.
6. Salavati-niasari M, Davar F, Mir N. Synthesis and characterization of metallic copper nanoparticles via thermal decomposition. Polyhedron. 2008; 27(17): 3514-3518.
7. Bhaviripudi S, Mile E, Iii SAS, Zare AT, Dresselhaus MS, Belcher AM, Kong J. CVD Synthesis of Single-Walled Carbon Nanotubes from Gold Nanoparticle Catalysts. J Am Chem Soc.2007; 129(6): 1516-7.
8. Maruyama T, Fujimoto Y, Maekawa T. Synthesis of gold nanoparticles using various amino acids. J Colloid Interface Sci. 2015; 447: 254-257.
9. Hulteen JC, Treichel DA, Smith MT, Duval ML, Jensen TR, Van Duyne RP. Nanosphere Lithography: Size-Tunable Silver Nanoparticle and Surface Cluster Arrays. J Phy Chem. 1999; 103(19): 3854-63.
10. Yadav TP, Yadav RM, Singh DP. Mechanical Milling: a Top Down Approach for the Synthesis of Nanomaterials and Nanocomposites. Nanoscience and Technology, 2012; 2(3): 22-48.
11. Pimpin A, Srituravanich W. Review on Micro-and Nanolithography Techniques and their Applications. Eng J. 2011; 16(1): 37-55.



12. Shah P, Gavrin A. Synthesis of nanoparticles using high-pressure sputtering for magnetic domain imaging. *J Magn Magn Mater.* 2006; 301: 118–23.
13. Amendola V, Meneghetti M. Laser ablation synthesis in solution and size manipulation of noble metal nanoparticles. *Phys. Chem. Chem. Phys.* 2007; 11(20): 3805–21.
14. Mann S, Burkett SL, Davis SA, Fowler CE, Mendelson NH, Sims SD, Walsh D, Whilton NT. Sol - Gel Synthesis of Organized Matter. *J. Mater. Chem.* 1997; 9: 2300-2310.
15. Kammler BHK, Madler L, Pratsinis SE. Flame Synthesis of Nanoparticles. *Chemical Engineering Technology.* 2001; 24(6): 583–596.
16. Amato RD, Falconieri M, Gagliardi S, Popovici E, Serra E, Terranova G, Borsella E. Synthesis of ceramic nanoparticles by laser pyrolysis: From research to applications. *J Anal Appl Pyrolysis.* 2013; 104: 461–69.
17. Noruzi M. Biosynthesis of gold nanoparticles using plantextracts. *Bioprocess Biosyst Eng.* 2015; 38(1): 1–14.
18. Jo JH, Singh P, Kim YJ, Wang C, Mathiyalagan R, Jin C, Yang DC. *Pseudomonas deceptionensis* DC5-mediated synthesis of extracellular silver nanoparticles. *Artif Cells Nanomed Biotech.* 2015; 44(6): 1-6.
19. Alghuthaymi MA, Almoammar H, Rai M, Said-Galiev E, Abd-Elsalam KA. Myconanoparticles: synthesis and their role in phytopathogens management. *Biotech Biotechno Equip.* 2015; 29(2): 221–236.
20. Bououdina MS, Rashdan JL, Bobet Y, Ichiyanagi. Nanomaterials for biomedical applications: synthesis, characterization, and applications. *J. Nanomater.* 2013: 240 -501.
21. Murugan A, Kumara K, Shanmugasundaram. Biosynthesis and characterization of silver nanoparticles using the aqueous extract of vitex negundo. *linn. World J. Pharm. pharm. Sci.,* 2014; 3(8): 1385 -1393.
22. Zhang X, Liu Z, Shen W, Gurunathan S. Silver Nanoparticles: Synthesis, Characterization, Properties, Applications, and Therapeutic Approaches. *Int J Mol Sci.* 2016; 17(9): 1534.
23. Mourdikoudis S, Pallares RM, Thanh Nguyen TK. Characterization techniques for nanoparticles: comparison and complementarity upon studying nanoparticle properties. *Nanoscale.* 2018; 10: 12871-12934.
24. Welch MJ, Hawker CJ, Wooley K. The advantages of nanoparticles for PET. *J Nucl Med.* 2009; 50: 1743-1746.
25. Tasleem A, et al. Therapeutic and Diagnostic Applications of Nanotechnology in Dermatology and Cosmetics. *J Nanomed Biothera Discov.* 2015; 4: 1-6.
26. Cai W, Gao T, Hong H, Sun J. Applications of gold nanoparticles in cancer nanotechnology. *Nanotech Sci App.* 2008; 1: 17-32.
27. Jain, S, Hirst DG, O'Sullivan J. Gold nanoparticles as novel agents for cancer therapy. *Br J Radiol.* 2012; 85(1010): 101-113.
28. Sztandera K, Gorzkiewicz M, Klajnert-Maculewicz B. Gold nanoparticles in cancer treatment. *Mol Pharm.* 2018; 16(1): 1-23.
29. Ghaednia H, Hossain MS, Jackson RL. Tribological performance of silver nanoparticle-enhanced polyethylene glycol lubricants. *Tribol Trans.* 2016; 59(4): 585-592.
30. Pal S, Mondal S, Pal P, Das A, Maity J. Fabrication of AgNPs/Silane coated mechanical and washing durable hydrophobic cotton textile for self-cleaning and oil-water separation application. *J Ind Chem Soc.* 2021; 99: 100283.
31. Bhardwaj M, Saxena DC. Preparation of Organic and Inorganic Nanoparticles and their Subsequent Application in Nanocomposites for Food Packaging Systems: A Review. *Ind J Sci Tech.* 2017; 10(31): 1-8.
32. Hoseinnejad M, Jafari SM, Katouzian I. Inorganic and metal nanoparticles and their antimicrobial activity in food packaging applications. *Crit Rev Microbio.* 2018; 44(2): 161-181.
33. Zhang C, Hu Z, Li P, Gajaraj S. Governing factors affecting the impacts of silver nanoparticles on wastewater treatment. *Sci Total Environ.* 2016; 572: 852-873.
34. Haider A, Al-Anbari R, Kadhim G, Jameel Z. Synthesis and photocatalytic activity for TiO₂ nanoparticles as air purification. *MATEC Web Conf.* 2018; 162(5): 05006.
35. Veziroglu S, Hwang J, Drewes J, Barg I, Shondo J, Strunskus T, Aktas OC. PdO nanoparticles decorated TiO₂ film with enhanced photocatalytic and self-cleaning properties. *Mater Today Chem.* 2020; 16: 100251.
36. Peng Y, Yu Z, Pan Y, Zeng G. Antibacterial photocatalytic self-cleaning poly (vinylidene fluoride) membrane for dye wastewater treatment. *Poly Adv Tech.* 2018; 29(1): 254-262.
37. Avasare V, Zhang Z, Avasare D, Khan I, Qurashi A. Room-temperature synthesis of TiO₂ nanospheres and their solar driven photoelectrochemical hydrogen production. *Int J Energy Res.* 2015; 39(12): 1714-1719.

How to cite this article:

Rutvaben Patel et al. *Ijppr.Human*, 2026; Vol. 32 (3): 378-386.

Conflict of Interest Statement: All authors have nothing else to disclose.

This is an open access article under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.



1*	Rutvaben Patel Student of M.Pharm Shri Sarvajanik Pharmacy College, Near Arvind Baug, Mehsasna-384001, Gujarat, India
2	Disha Patel Student of M.Pharm Shri Sarvajanik Pharmacy College, Near Arvind Baug, Mehsasna-384001, Gujarat, India
2	Himani Patel Student of M.Pharm Shri Sarvajanik Pharmacy College, Near Arvind Baug, Mehsasna-384001, Gujarat, India
3	Dr. Nisha Patel Assistant Professor, Department of Pharmaceutics Shri Sarvajanik Pharmacy College, Near Arvind Baug, Mehsasna-384001, Gujarat, India
3	Dr. Pankaj Prajapati Professor, Department of Pharmaceutics Shri Sarvajanik Pharmacy College, Near Arvind Baug, Mehsasna-384001, Gujarat, India