Content available at: https://www.ipinnovative.com/open-access-journals

Indian Journal of Pharmacy and Pharmacology

Journal homepage: https://www.ijpp.org.in/

Review Article

# Inorganic nanoparticles: A review on method and material for fabrication

**Shubhi Tiwari[1,*], Geeta Yadav[1], Sonam Sharma[1], Pranati Srivastava[1], Ajay Kumar[1]**

[1] *Dept. of Pharmacology, School of Pharmaceutical Sciences, CSJMU, Kanpur, Uttar Pradesh, India*

ARTICLE INFO

*Article history:*
Received 14-07-2022
Accepted 02-08-2022
Available online 16-08-2022

*Keywords:*
Inorganic
Production method
Magnetic
Nanotechnology
Biological responses

ABSTRACT

There has been a lot of study in the domain of Nanotechnology employing nanoparticles in the last few years. Inorganic nanoparticles are emerging as a potential medication delivery technology in the field of current material sciences due to their unique physical features, which primarily include size-dependent optical, magnetic, electronic and catalytical capabilities. High stability, wide surface area, adjustable composition, rich physicochemical, multi functionality, and particular biological responses are all characteristics of these nanoparticles. The goal of this review is to analyze inorganic nanoparticle categories, production methods, and analysis techniques.



## 1. Introduction

A category of compounds with at least one dimension between 1 and 100 nanometres is referred to as nanomaterials. Nanomaterials are based on the core premise of nanoscience activities that are w years. Inorganic nanoparticles are emerging as a potential medication delivery technology in the field of current material sciences due to their unique physical features, which primarily developing around the world.[1] Possess the ability to transform into a functionalized alternative that can be further examined Nanomaterials include nanotubes, dendrites, quantum dots (QDs), and fullerenes. Nanomaterials are becoming more popular as a result of their unique optical qualities, which have a significant impact on a number of industries such as electronics, mechatronics, medicine, pharmaceuticals, ionic liquids, polymers, and many others. Cosmetics, sunscreen, and self-cleaning windows are just a few of the commercial applications of nanoscale titanium dioxide. Nanoscale silica as a filler in cosmetics; nanoscale coatings and Nano composites in windows, athletic equipment, bicycles, and vehicles.[2] Redesigning materials at the molecular level, also known as designed nanomaterials, are often not visible in their conventional and bulk counterparts because of their small size and new features.[3] The unique property of these nanomaterials is their high surface area, which leads to the development of a novel theory of quantum effects.[4] The material qualities and traits that lead to unique optical, electrical, and magnetic behaviours can be influenced by the reaction at the nanoscale level. Because of the consequences, be more crucial. Zero-dimensional (0-D), one-dimensional (1-D), two-dimensional (2-D), and three-dimensional (3-D) nanostructures are the four types of nanostructured materials.[5] Nanomaterials' dimensionalities are measured using ultrafine grains of less than or equal to 50 nm in size. Various modulation dimensionalities such as 0-D (e.g. atomic clusters, filaments, and cluster assemblies), 1-D (e.g. multilayers), 2-Db (e.g. ultrafine grained over layers or buried layers), and 3-D (e.g. ultrafine grained over layers or buried layers) can be created (e.g.nanophase materials composed of equated nanometre-sized grains. When a bulk material is broken down into nanoparticles,

* *Corresponding author*.
*E-mail address*: shubhitiwari96832@gmail.com (S. Tiwari).

https://doi.org/10.18231/j.ijpp.2022.028

pressure 1 displays the changes in characteristics (NPs). The goal of this study is to bring together research and applications on inorganic and organic nanomaterials, with a focus on synthesis and preparation, processing, characterization, and applications of organic and inorganic nanomaterials. Analyses of both inorganic and organic nanoparticles.[6] Particulate properties specify additives and bulk qualities in the raw materials needed to make glass, quartz, and desiccants. The qualities of ceramics or metals are linked to material hardness, and polymers are rarely mentioned.[7] By adding additives of small and hard particles in conveying hardness, raw resistance, materials can be value-added into a quality product. A sensitive polymers-Nano particles based on Additives well established, where Nano particulate carbon was developed early in the twentieth century known as carbon black typically made up of more than 10% of a typical car tyre, can be supplementary to a similar approach applied for radiation absorption, magnetization, colour, and reflectivity can be supplementary to a sensitive polymers- Nano particles based on Additives well established, where Nano particulate carbon was developed early in the twentieth century known as carbon black typically made up of The name 'Nano' was obviously coined considerably later.[8] Similarly, numerous well-known chemical products that have recently been introduced are referred to as "Nano." All of these items have been on the market for decades and are well acknowledged as safe. Chemists use thousands of well-known building pieces or subunits to create molecular products. Similarly, numerous well-known chemical products that have recently been introduced are referred to as "Nano.[9]" All of these items have been on the market for decades and are well acknowledged as safe. Scientists use thousands of well-known building components or subunits to generate molecular products.[10]

### *1.1. Classification of nanoparticles*

**Table 1:** lassification of nanoparticles

| | | | |
|---|---|---|---|
| 0 Dimensionality Nanosphers clusters | Quantum dots | Fullerenes | Gold Nanoparticles |
| 1 Dimensionality Nanotubes, wires, rods | Metal Nanorods | Carbon & Metallic Nanotubes | Gold, Nanoparticles |
| 2 Dimensionality thin flims, plates layerd structures | Carbon coated Nanoplates | Graphene Sheets | Polycrystalline |
| 3 Dimensionality Bult NM polycrystals | Liposome | Polycrystalline | Dendrimers |

### *1.2. Zero dimension nanoparticles*

NPs Nano particles are broadly divided into various categories.

### *1.3. Carbon-based nanoparticles*

Carbon nanotubes (CNTs) and fullerenes are the two most common types of carbon-based nanoparticles (NPs). Fullerenes are nanomaterials made up of globular hollow cages, such as allotropic forms of carbon. They have sparked commercial interest due to their electrical conductivity, high strength, and structure.[11,12]

Carbon CNTs are elongated tubular structures with a diameter of 1–2 nm. Based on their diameter telicity, these can be classified as metallic or semiconducting.[13] These have a similar structure to graphite sheet rolling.[14] Their rolled sheets can have one, two, or multiple walls, and are hence referred to as single-walled (SWNTs), double-walled (DWNTs), or multi-walled (MWNTs).[15] Carbon Nanotubes (MWNTs) are a type of carbon nanotube. They're commonly made by depositing carbon precursors, particularly atomic carbons, evaporated from graphite by laser or electric arc onto metal particles. Chemical vapour deposition (CVD) has recently been used to create them.[16,17] These materials are employed in nanocomposites for numerous commercial purposes, such as fillers and efficient gas adsorbents for environmental remediation, due to their unique physical, chemical, and mechanical features. as well as serving as a support medium for several inorganic and organic catalysts.[18]

## 2. Fullerene

A fullerene is a pure carbon molecule that contains at least 60 carbon atoms. A fullerene resembles a soccer ball or a Geodesic dome in shape.It's also known as a buck ball, after Buckminster Fuller, the inventor of the geodesic dome, for whom the Fullerene is more properly named. Fullerenes are being touted as potential components in future micro-electromechanical systems and nanotechnology.[19] Exohedral (within the cage) and endohedral (outside the cage) fullerene compounds can be divided into two groups (outside the cage). Metals encased in a C82 cage, such as lanthanum, are examples of the former, while transition metal complexes are instances of the latter.[20] As the basis of icosohedral symmetry closed cage structure, fullerenes are made up of 20 hexagonal and 12 pentagonal rings. Each carbon atom is sp2 hybridised with three other carbon atoms.[21]

The 6:6 ring bonds, which are considered "double bonds" and are shorter than the 6:5 bonds, make up the C60Molecule. Because it avoids double bonds in the Pentagonal rings, C60 is not "hyper aromatic," resulting in poor electron delocalization. As a result, C60 interacts readily with electron-rich species and behaves like an electron-deficient alkene. The stability of the Molecule is determined by the geodesic and electronic bonding components in the structure. According to theory, there can be an endless number of fullerenes, each with a structure based on pentagonal and hexagonal rings.[22]

Advantages of Fullerenes have properties such as strong tensile strength, electrical conductivity, ductility, heat resistance, and chemical inactivit.[23]

### *2.1. Physical properties of C60[22]*

1. 1.65 g cm (fullerene) density[5]
2. Standard formation heat: 9.08 kcal mol-1
3. Refraction index: 2.2 (600 nm.
4. Boiling point: sublimes at 800 degrees Fahrenheit
5. Vapour density: N/A Resistivity: 1014 ohm m-1 Hexagonal cubic crystal shape
6. 5 x 10-6 psi vapour pressure Organoleptic at room temperature
7. Color: solid black
8. Odour: There is no odour
9. Soot: black powder that has been finely split
10. Fullerite is a brown or black powder
11. The fullerenes have also been discovered to be soluble in ordinary solvents such as water.
12. Benzene, toluene, or chloroform, for example. A crimson solution can be obtained by mixing fullerene Soot with toluene and filtering the combination.

## 3. Gold Nanoparticles

GNPs are available in a range of diameters from 2 to 100 nm, with particle sizes of 20 to 50 nm showing the optimum cellular absorption. Particles with a diameter of 40-50 nm have been discovered to produce particular cell toxicity.[24] Iagnostic0-50 nm particles can quickly diffuse into malignancies and be recovered. Larger particles, such as those with a diameter of 80-100 nm, do not diffuse into the tumour and remain near the blood vessels,[25] During their synthesis and functionalization with various groups, the size of the molecules can be modified. The size of linked nanoparticles is determined by the thiol/gold ratio.[26] When the amount of thiol is high, the particle size will be small.[27]

GNPs have unique physical and chemical properties that promote therapeutic efficacy, drug loading, biocompatibility, capacity to reach the targeted region with blood flow, are non-cytotoxic to normal cells, and may be made in a variety of ways.[28]

GNPs can be made in a variety of ways, including physical, chemical, and biological methods. In order to attain a low yield, physical procedures are first used.[29] Various chemical agents are utilised to reduce the requirement for chemical operations. Nanoparticles are made from metallic ions.[25]

There are several drawbacks to this, such as the usage of toxic chemicals and the production of harmful byproducts.[10]

## 4. One Dimensional Nano Material

### *4.1. Metal nanoparticles*

Metal NPs are produced entirely of metal precursors. These NPs have unusual optoelectrical properties due to well-known localised surface plasmon resonance (LSPR) features.[30]

In the visible zone of the electromagnetic sun spectrum, NPs of alkali and noble metals, such as Cu, Ag, and Au, have a broad absorption band.In today's cutting-edge materials, size and shape controlled synthesis of metal NPs is critical.[31]

Metal NPs are used in a variety of scientific fields due to their excellent optical properties. Gold NPs coating is commonly used for SEM sampling to improve the electronic stream, which aids in the acquisition of high-quality SEM images.[32]

## 5. Ceramics NPs nano particles

Ceramic NPs are inorganic nonmetallic solids that are made by heating and cooling. They come in a variety of shapes and sizes, including amorphous, polycrystalline, dense, porous, and hollow.[31] As a result of their use in applications such as catalysis, photocatalysis, dye photodegradation, and imaging applications, these NPs are attracting a lot of attention from researchers.[33]

## 6. Semiconductor NPs Nanoparticles

Semiconductor materials have properties that fall between between metals and nonmetals, giving them a wide range of applications.According to the literature, semiconductor[34] NPs have broad bandgaps and so show large variations in their features with bandgap tuning. For starters, they're important materials in photocatalysis, photo optics, and electronic devices. A variety of semiconductor NPs nanoparticles have been reported to be highly efficient in water splitting applications due to their ideal bandgap and bandedge positions.features.[35]

Metalic inorganic nanoparticles with specific physiochemical qualities Metallic nanoparticles have piqued the interest of scientists for over a century and are now frequently used in biomedical and engineering research.[36] These materials can be synthesised and modified with various chemical functional groups, allowing them to be conjugated with antibodies, ligands, and drugs of interest, allowing them to be used in biotechnology, magnetic separation, target analyte preconcentration, targeted drug delivery, and vehicle technology. Furthermore, numerous imaging modalities including as magnetic resonance imaging, computed tomography, positron emission tomography, ultrasound, surface-enhanced Raman spectroscopy, and optical imaging have been developed over time to aid in the imaging of various disease states.[37] These imaging methods have different methodologies and equipment, but they all require a Contrast agent. As a result, several nanoparticulate contrast agents, such as magnetic nanoparticles (Fe3O4), gold nanoparticles, and silver nanoparticles, were developed for use in these imaging modalities.[38] In addition, additional multifunctional nanoshells and nanocages have been designed to utilise several imaging techniques in tandem. Nanoparticles such as gold, silver, and magnetic nanoparticles (iron oxide) have been employed and changed over the years to enable their usage as diagnostic and therapeutic agents.[39]

## 7. Two Nanoparticles Dimensional

### *7.1. Silver nanoparticles (AgNPs)*

Until the dawn of the Nanotechnology period, when it was discovered that silver could be created at the nanoscale, it was only known as a metal. Recent engineering technologies have exposed metallic silver, resulting in ultrafine particles with different shapes and features measured in nanometres (nm). Anticancer activity of nano-sized silver particles has been evaluated against a range of human cancer cells, including breast cancer cells.[40]

### *7.2. Iron oxide nanoparticles (INPs)*

Iron (III) oxide (Fe2O3) is a paramagnetic inorganic compound with a reddish brown colour. It's one of three primary iron oxides, with FeO and Fe3O4 being the other two.Fe3O4 is a kind of iron oxide. The development of magnetic nanoparticles in the nanoscale range is a complex process, and numerous chemical techniques for their production have been proposed. Some of these approaches include microemulsions, solgel synthesis, sonochemical reactions, hydrothermal reactions, thermolysis of precursors, flow injection syntheses, and electrospray synthesis.[41] Chemical coprecipitation of iron salts is the most common method for creating magnetite nanoparticles.Furthermore, monocrystalline USPIOs are known as monocrystalline iron oxide nanoparticles (MIONs), whereas MIONs are known as cross-linked Iron oxide nanoparticles (10-30 nm) when cross-linked with dextran.[42] The particles created by these processes agglomerate due to non-covalent interactions. Surfactants and other organic compounds with certain functional groups have been employed to improve the stability of INPs.[43] For the manufacture of INPs for biomedical applications, polyethylene glycol, polyvinyl alcohol, polyamides, and other water soluble stabilisers are particularly beneficial. Stabilizers can be added to INPs at any point throughout the synthesis process to prevent particle coalescence. Changing the stabiliser concentration can also control particle size.[44] The particular Functionality of stabilisers can be employed to attach specific bio Molecular ligands to INPs surface, which can then be used for selective targeting of specific cells, tissues, or organs. I NPs are a great MRI contrast agent. INP's capacity to act as an MRI contrast agent, along with the ability to target specific areas, has led to a wide range of possible uses in MRI-based imaging and diagnostics. Several antibodies and other ligands have been conjugated to INPs and used to image tumours using MRI. A modified cellular enzyme-linked immunosorbent assay (ELISA) called cellular magnetic linked immunosorbent assay (C-MALISA) uses INPs conjugated with cell surface receptor specific ligands.[45] It's also been developed.INPs' magnetic properties have the potential to be used in medication and gene delivery.[46]

### *7.3. Quantum dots (QDs)*

A nanostructure is a solid with a particle size variation of less than 100 nm that can be characterised as (1) two-dimensional, like thin films or quantum wells, (2) one-dimensional, like quantum wires, or (3) zero-dimensional, like dots.[47] Quantum dots are crystals that are the size of nanomaterials. QDs typically range in size from 2 to 20 nanometers.[48] Their diameter, however, must be smaller than 10 nm .The type of material used to make QDs has a significant impact on their size. The essential advantage of quantum dots is that, because of their controlled size, they allow for very precise control of the material's conductive propertie.[49] QDs are extremely useful in optical applications because to their high attenuation coefficient. The ability to adjust quantum do size is useful in a wide range of applications. Larger quantum dots, for example, have a larger red shift in their spectrum and show fewer quantum features than smaller quantum dots. Smaller particles, on the other hand, enable the use of more subtle Quantum effects. Quantum dots have a sharper density of states than higher-dimensional objects because they are zero-dimensional.[50] As a result, their transport and optical qualities are superior. The properties of quantum ddot, which may also be found in nature as the mineral magnetite, are superparamagnetic. Super paramagnetic iron oxide Nanoparticles (SPIONs) have emerged as promising candidates for a variety of biomedical applications, including enhanced resolution contrast agents for magnetic resonance imaging (MRI), targeted drug delivery and imaging, hyperthermia, gene therapy, stem cell tracking, molecular/cellular tracking, and magnetic separation technologies (e.g., rapid DNA sequencing) for early detectable diseases.

## 8. Quantum Dot Propertie

1. When stimulated, the brightness is really high

2. Photobleaching resistance is excellent
3. The size (called the "size Quantization effect"), as well as the composition of their cores and shells, can be used to adjust emission spectra.
4. Broad excitation and narrow symmetric emission spectra make it possible to detect numerous signals simultaneously with a single excitation source.[51]

### *8.1. Procedures for synthesis*

QD has been synthesised using a variety of methods. In general, QD synthesis techniques are classified as either top-down or bottom-up approaches.[52]

## 9. Process of Synthesis From The Top Down

In the top-down approach, a bulk semiconductor is thinned to produce QDs. Electron beam lithography, reactive ion etching, and/or wet chemical etching are commonly used to create QDs with a diameter of less than 30 nm. Controlled forms and sizes with the requisite packing geometries are possible for systematic tests on the quantum confinement phenomenon. Zero-dimension dot arrays have also been created using focussed ion or laser beams. Two key drawbacks of these technologies are impurities in the QD and structural faults generated by patterning.

## 10. Process of Synthesis From The Bottom Up

The QD was made utilising a number of different self-assembly processes, which can be divided into two categories: wet chemical and vapor-phase approaches.

Microemulsions, sol gels, competitive reaction chemistry, hot solution decomposition, and electrochemistry are just a few examples of wet chemical processes. Self-assembly of nanostructures in material created by molecules.

### *10.1. Application of nanomaterials in coronavirus treatment, anti-infection, and detection*

moleular beam Epitaxy, sputtering, liquid metal ion sources, and aggregation of gaseous monomers are examples of vapour phase processes.Nanotechnology and Nanomedicine have a lot of potential for dealing with a variety of health problems, including viruses, which are a severe medical concern. A revolutionized thanks to nanobiotechnology. The Middle East respiratory syndrome coronavirus, the severe acute respiratory syndrome coronavirus, and the severe acute respiratory syndrome coronavirus-2 are all well-known and dangerous coronaviruses that must be controlled. This article aims to provide a summary of recent research on the use of nanoparticles as diagnostic or antiviral tools against highlighted in the issue.

## 11. Conclusion

The availability of a variety of inorganic nanoparticles as well as a variety of synthetic processes has facilitated the development of innovative drug delivery systems. Before bringing these inorganic nanosystems into clinical trials, numerous important challenges must be addressed. Nanomaterials, which are distinguished by their incredibly small feature sizes, offer a wide range of industrial, biological, and electronic applications. Nanoparticles will be used in a variety of biotechnology applications and are expected to take main stage in many new and emerging applications in the coming year. Identifying a simple, efficient, and controllable approach to mass produce nanomaterials as well as bridge their application in optoelectronics will be appealing.

## 12. Source of Funding

None.

## 13. Conflict of Interest

None.

## References

1. Viswanath B, Kim S. Influence of nanotoxicity on human health and environment: The alternative strategies. *Rev Environ Contamination Toxicol*. 2016;242:61–104.
2. Redesigning materials at the molecular level, also known as designed nanomaterials, are often not visible in their conventional and bulk counterparts because of their small size and new features; 2016.
3. Tarafdar JC, Sharma S, Raliya R. Nanotechnology: Interdisciplinary science of applications. *African J Biotechnol*. 2013;12(3):220–6.
4. Maghsoodlou A, Sabu S, Rafiei S. Foundations of Nanotechnology; 2014. p. 420.
5. Guo D, Xie G, Luo J. Mechanical Properties of Nanomaterials. *J Physics D: Applied Physics*. 2021;47(1):013001.
6. Adams F, Barbante C. Chemical Imaging Analysis. vol. 69. Elsevier; 2015. p. 480.
7. Wohlleben AJC, Wendelin J, Philipp R, Stoessel W. Industrial applications of nanoparticles. *Chem Soc Rev*. 2015;44(16):5793–5.
8. Wendelin J, Philipp R, Stoessel W, Wohlleben AJCSR, Hafner. Industrial applications of nanoparticles. *Chem Soc Revi*. 2015;44(16):5793–5805.
9. Li J, Tian M, Cui L, Dwyer J, Fullwood NJ, Shen H. Low-dose carbon-based nanoparticle-induced effects in A549 lung cells determined by biospectroscopy are associated with increases in genomic methylation. *Sci Rep*. 2016;6(1):1–11.
10. Khan I, Saeed K, Khan I. Nanoparticles: Properties, applications and toxicities. *Arabian J Chem*. 2019;12(7):908–31.
11. Singh S, Arkoti NK, Verma V, Pal K. Nanomaterials and Their Distinguishing Features. In: Nanomaterials Adv Technol. Springer; 2022. p. 1–18.
12. Feng J, Hui Y. Ab initio study of electronic and optical properties of multiwall carbon nanotube structures made up of a single rolled-up graphite sheet. *Physical Rev B*. 2005;72(8):85415.
13. Eatemadi A, Daraee H, Karimkhanloo H, Kouhi M, Zarghami N, Akbarzadeh A, et al. Carbon nanotubes: properties, synthesis, purification, and medical applications. *Nanoscale Res Lett*. 2014;9(1):1–13.
14. Rathinavel S, Priyadharshini K, Panda D. A review on carbon nanotube: An overview of synthesis, properties, functionalization, characterization, and the application. *Materials Sci Eng*. 2021;268:115095.

15. Creighton JR, Ho P. Introduction to chemical vapor deposition (CVD). *Chem Vapor Deposition*. 2001;2:1–22.
16. Agboola O, Fayomi I, Ayodeji A, Ayeni AO, Alagbe EE, Sanni SE, et al. A review on polymer nanocomposites and their effective applications in membranes and adsorbents for water treatment and gas separation. *Membranes*. 2021;11(2):139–139.
17. Richeson DS. Euler's gem: the polyhedron formula and the birth of topology. *Membranes* . 2019;11(2):139.
18. Akasaka S, Xing L, Feng T. Current status and future developments of endohedral metallofullerenes. *Chem Soc Rev*. 2012;41(23):7723–60.
19. Yadav BC, Kumar R. Structure, properties and applications of fullerenes. *Int J Nanotechnol Appl*. 2008;2(1):15–24.
20. Stankevich IV, Vyacheslav I. The fullerenes-new allotropic forms of carbon: molecular and electronic structure, and chemical properties. *Russian Chem Rev*. 1993;62(5):419.
21. Mohammed AM, Pascual CD, Marco MA, Gómez I. Novel melt-processable poly (ether ether ketone)(PEEK)/inorganic fullerene-like WS2 nanoparticles for critical applications. *J Physical Chem B*. 2010;114(35):11444–53.
22. Dykman LA, Khlebtsov NG. Uptake of engineered gold nanoparticles into mammalian cells. *Chem Rev*. 2014;114(2):1258–88.
23. Perry JL, Kevin G, Reuter J, Luft GV, Pecot W, Zamboni JM, et al. Mediating passive tumor accumulation through particle size, tumor type, and location. *Nano lett*. 2017;17(5):2879–86.
24. Liu J, Lu Y. Preparation of aptamer-linked gold nanoparticle purple aggregates for colorimetric sensing of analytes. *Nature Protocols*. 2006;1(1):246–52.
25. Rogach A, Kornowski A, Gao M, Eychmüller A, Weller H. Synthesis and characterization of a size series of extremely small thiol-stabilized CdSe nanocrystals. *J Physical Chem B*. 1999;103(16):3065–9.
26. Pavlopoulou M, Nikolaos M, Tsekenis G, Evangelos C, Balanikas A. Gold nanoparticles, radiations and the immune system: Current insights into the physical mechanisms and the biological interactions of this new alliance towards cancer therapy. *Pharmacol Ther*. 2017;178(1):1–17.
27. Butterworth KT, Stephen J, Mcmahon FJ, Currell KM. Physical basis and biological mechanisms of gold nanoparticle radiosensitization. *Nanoscale*. 2012;4(16):4830–8.
28. Jamkhande P, Bamer MG, Namrata W, Ghule AH. Metal nanoparticles synthesis: An overview on methods of preparation, advantages and disadvantages, and applications. *J Drug Deliv Sci Technol*. 2019;53:101174.
29. Mhatre RY, Kaushik N, Snehit S. Biological synthesis of metallic nanoparticles. *Nanomed Nanotechnol Biol Med*. 2010;6(2):257–62.
30. Długosz O, Szostak K, Staroń A. Methods for reducing the toxicity of metal and metal oxide NPs as biomedicine. *Mater (Basel)*. 2020;13(2):279.
31. Shenashen MA, Sherif A, El-Safty EA. Synthesis, morphological control, and properties of silver nanoparticles in potential applications. *Part Partic Syst Characterization*. 2014;31(3):293–316.
32. Niewa R. Metal-Rich Ternary Perovskite Nitrides. *Eur J Inorganic Chem*. 2019;32:3647–60.
33. Chauhan D, Kumar N, Sharma K. A critical review on emerging photocatalysts for syngas generation via CO2 reduction under aqueous medium: a sustainable paradigm. *Mater Adv*. 2022;3:5274–98.
34. Bairuty GA. Histopathological effects of metal and metalic nanoparticles on the body systems of rainbow trout (Oncorhynchus mykiss). 2013;Available from: https://pearl.plymouth.ac.uk/handle/10026.1/2879.
35. Zavaleta C, Ho D, Chung EJ. Theranostic nanoparticles for tracking and monitoring disease state. *SLAS Technol*. 2018;23(3):281–93.
36. Mody VV, Siwale R, Singh A, Mody HR. Introduction to metallic nanoparticles. *J Pharm Bioallied Sci*. 2010;2(4):282.
37. Rai M, Shegokar R. Metal nanoparticles in pharma. Springer International Publishing; 2017. p. 258–78.
38. Pandey P, Dahiya M. A brief review on inorganic nanoparticles. *J Crit Rev*. 2016;3(3):18–26.
39. Hasany S, Abdurahman N, Sunarti A, Jose R. Magnetic iron oxide nanoparticles: chemical synthesis and applications review. *Curr Nanosci*. 2013;9(5):561–75.
40. Mody VV, Siwale R, Singh A, Mody HR. Introduction to metallic nanoparticles. *J Pharm Bioall Sci*. 2010;2(4):282–9.
41. Niu L, Li Z, Fan W, Zhong X, Peng M, Liu Z. Nano-Strategies for Enhancing the Bioavailability of Tea Polyphenols: Preparation, Applications, and Challenges. *Foods*. 2022;11(3):387.
42. Pandey P, Dahiya M. A brief review on inorganic nanoparticles. *J Crit Rev*. 2016;3(3):18–26.
43. Pan C, Wenhao Z, Huang Y, Huang X. Updates on the applications of iron-based nanoplatforms in tumor theranostics. *Int J Pharm*. 2020;589:119815.
44. Heremans JP, Dresselhaus MS. 27 Low-Dimensional Thermoelectricity; 2006. p. 740–70.
45. Nie S, Warren CW, Maxwell DJ, Gao X, Bailey RE, Han M, et al. Luminescent quantum dots for multiplexed biological detection and imaging. *Curr Opin Biotechnol*. 2002;13(1):40–6.
46. Choudhary RK, Madhuri A. Nanotechnology in agricultural diseases and food safety. *J Phytol*. 2010;2(4):83–92.
47. Tiwari KS, Jitendra N, Rajanish N. Zero-dimensional, one-dimensional, two-dimensional and three-dimensional nanostructured materials for advanced electrochemical energy devices. *Progress Mater Sci*. 2012;57(4):724–803.
48. Pandey P, Dahiya M. A brief review on inorganic nanoparticles. *J Crit Rev*. 2016;3(3):18–26.
49. Zou J. Synthesis of silicon nanoparticles:. University of California, Davis; 2005. p. 286.
50. Dhiman R, Inderbir R, Arora H. Carbon quantum dots: Synthesis, characterization and biomedical applications. *Turk J Pharma Sci*. 2018;15(2):219–30.
51. Wu W, Wu Z, Yu T, Jiang C, Kim WS. Recent progress on magnetic iron oxide nanoparticles: synthesis, surface functional strategies and biomedical applications. *Sci Technol Adv Mater*. 2015;16(2):23501.
52. Hashemi B, Behnam FA, Akram H, Amirazad H, Dadashpour M, Sheervalilou D, et al. Emerging importance of nanotechnology-based approaches to control the COVID-19 pandemic; focus on nanomedicine iterance in diagnosis and treatment of COVID-19 patients. *J Drug Deli Sci Technol*. 2021;67:102967.


## Author biography


**Shubhi Tiwari,** Research Scholar

**Geeta Yadav,** Research Scholar

**Sonam Sharma,** Research Scholar

**Pranati Srivastava,** Assistant Professor

**Ajay Kumar,** Assistant Professor



**Cite this article:** Tiwari S, Yadav G, Sharma S, Srivastava P, Kumar A. Inorganic nanoparticles: A review on method and material for fabrication. *Indian J Pharm Pharmacol* 2022;9(3):158-163.