



**International Journal of Biology, Pharmacy
and Allied Sciences (IJBPAS)**

'A Bridge Between Laboratory and Reader'

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**COPPER NANOPARTICLES: REVIEW ON SYNTHESIS, CHARACTERIZATION
AND APPLICATION**

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Received 16th Nov. 2023; Revised 18th Dec. 2023; Accepted 2nd June 2024; Available online 1st March 2025

<https://doi.org/10.31032/IJBPAS/2025/14.3.8855>

ABSTRACT

Field of science “Nanotechnology” which is involved in manipulation of atoms and molecules has shown great potential in all fields of sciences. Nanotechnology deals with nanoparticles ranging from size 1 to 100 nm in diameter, due to small size and high surface area eventually increases the state of activity. Various methods for the synthesis of copper nanoparticles employing chemical, physical and biological techniques considering bottom-up and top-down methods synthesis have been studied.

Nanoparticles, especially copper nanoparticles (CuNPs), have gained significant attention in recent years due to their unique physical, chemical, and biological properties, leading to a wide range of applications in various fields. This paper provides a comprehensive overview of different synthesis methods employed for the fabrication of copper nanoparticles and highlights their diverse applications. The synthesis methods discussed include chemical reduction, physical methods, green synthesis, and biological approaches. Chemical reduction methods involve the reduction of copper ions using various reducing agents, resulting in controlled size and shape of nanoparticles. Physical methods encompass techniques such as laser ablation, ball milling, and sputtering, providing distinct advantages in terms of size control and purity. Green synthesis, utilizing plant extracts, microorganisms, or other eco-friendly sources, has gained popularity for its sustainability, and reduced environmental impact. The paper explores the influence of synthesis parameters on the size, shape, and stability of copper nanoparticles, emphasizing the importance of tailoring these properties for specific applications.

Keywords Nanotechnology, Copper nanoparticles, synthesis methods, physical chemical properties

INTRODUCTION

Nanotechnology is being used to create materials at the nanoscale. This branch of research involves the manipulation of molecules and atoms. A nanoparticle is an ultrafine particle, defined as a substance with a diameter between 1 and 100 nm and a length between 1 and 1000 nm in one dimension.

The method of reduction and the environment in which the nanoparticle is found determine its size. Nanoparticles have applications in many fields of science and medicine, such as diagnostics, biomarkers, bioimaging, cosmetics, immune system, cardiology, genetic engineering, and medication delivery for the treatment of cancer and other infectious syndromes. Abstract Nanotechnology, a young branch of science that deals with the manipulation of atoms and molecules, has demonstrated tremendous promise in all branches of science.

Considering their small size and large surface area, nanotechnology works with particles with diameters between 1 and 100 nm. This raises the state of activity. This review mainly focuses on the green synthesis, characterization, and application of copper nanoparticles, as well as metal and metal oxide nanoparticles.

Metal nanoparticles, such as gold, copper, and others, have demonstrated excellent potential for raising living standards, and

their requirement for biological synthesis has grown significantly. The majority of metal and other metal oxide nanoparticles (NPs) used in paints to give them an antifungal, anti-algal, and antibacterial activity are titanium dioxide (TiO₂) and silicon dioxide. Nano silver NPs also exhibit antibacterial properties via attaching to the proteins of bacterial cells, as well as deodorising, hydrophobicity, and a less harmful effect, according to AZO NANO. These NPs play a significant part in cosmeceuticals, which have a therapeutic and pharmacological effect on the skin and hair as well as on photo-aging, wrinkles, dark spots, and other skin conditions. To demonstrate its effects, several Nano carriers that encapsulate the targeted medicine are developed in cosmetics.

Copper and copper oxide (Cu and CuO) can be combined in an environmentally friendly economically advantageous way. Molecular biology, bioengineering, genetic engineering, bioremediation, biomedicine, pharmaceuticals, colour degradation, catalysis, cosmetics, and textiles are just a few of the fields that use copper nanoparticles. Copper nanoparticles' structural characteristics and biological impacts show promise in the realm of life sciences.

More specifically, copper nanoparticles (CuNPs) are used in building constructions

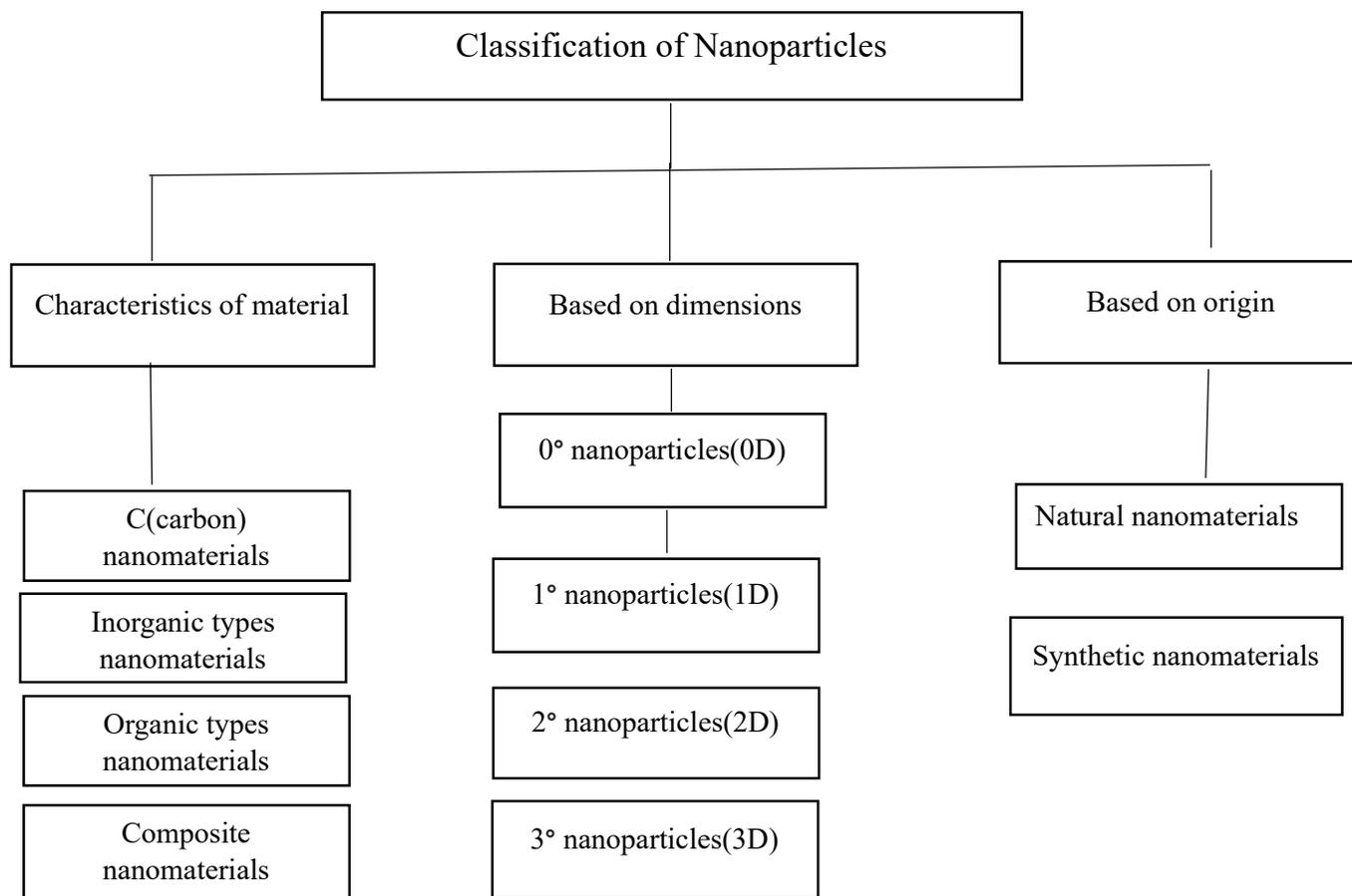
because they smooth down steel, increasing its activity like corrosion resistance, thermal conductivity, and heat transfer, and because polymer-coated CuNPs have antibacterial and hydrophobic qualities. Recent advances have been achieved in the synthesis of inorganic NPs, which contain all metals and metal oxides and have a wide range of uses in all industries.

There are mainly two types of method for synthesis, in which both method like top down and bottom-up, the green synthesis method of the Bottom-up approach is frequently seen as a financially advantageous, nontoxic, and

environmentally responsible manner of producing nanoparticles. These nanoparticles can be applied in a wide range of scientific disciplines. As a result, the emphasis of this review will be on metal nanoparticles, including their environmentally friendly creation, methods for characterising them, and applications.

CLASSIFICATION OF NANOPARTICLES:

There are various classifications of nanoparticles depending upon characteristics of material, dimensions, and origin [1-4].



METHODS OF NANOPARTICLES

A variety of techniques have been employed to create Cu nanoparticles, and the following list outlines the most prominent approaches, along with the corresponding particle sizes typically obtained [5, 6].

Mainly 4 methods

- 1) Physical method
- 2) Chemical method
- 3) Biological method
- 4) Other methods

1) Physical method

Physical methods for nanoparticles synthesis are laser (pulse) ablation, vacuum vapor deposition, pulsed wire discharge (PWD) and mechanical milling. Physical methods may create a wide range of nanoparticles with little modification for different metals. However, the key disadvantage is the lower product quality compared to chemical methods. Typically, these procedures require expensive vacuum systems or equipment to prepare nanoparticles (plasmas).

2) Chemical method

Chemical reduction, microemulsion techniques, sono-chemical reduction, electrochemical, microwave-assisted, and hydrothermal syntheses are the main techniques for the synthesis of

nanoparticles through the chemical approach. chemical synthesis process of copper nanoparticles, the growth and morphology can be controlled by optimizing reaction conditions, such as surfactant's temperature and concentration, precursor, capping, stabilizing agent, and the type of solvent.

3) Biological method

The need for biosynthesis of nanoparticles use as the physical and chemical processes are costly and hazardous. Therefore, in the search for cheaper pathways for nanoparticle synthesis, scientists used microorganisms and then plant extracts for synthesis. Nature has evolved several techniques for the synthesis of nano- and micro-length scaled inorganic materials, which have helped to develop a relatively new and mostly unknown area of research centred on nanomaterial biosynthesis.

4) Other methods

Other methods like, hydrothermal approach [7] thermal oxidation method, [8] alcohol-thermal synthesis, [9] liquid ammonia [10], microwave-assisted synthesis [11] all methods used for the synthesis of copper nanoparticles.

Table 1: Different Methods Used for Synthesis of CuO Nanoparticles

S. No.	Method	Size (nm)	Shape	Highlights	References
1	Physical method	16-28	star-like or polyhedral	Two electrodes used one is copper plate and second is Ar plasma in NaCl.	[12]
		22-100	nanodisk	Disk shape CuO nanoparticles were prepared by thermal decomposition method.	[13]
		550 (L) 35(D)	nanorods	Galvanostatic method used.	[13]
		200-300(L) 20-50 (D)	Nanospheres nano spindles/nanorods	copper was used as an electrolyte or sodium nitrate used as electrode.	[14] [15]
		~20-22	Nano formulations with spherical morphology	Potentiostatic setup with ultrasound-assisted electrochemistry.	[16]
		~22	sphere-like assembly	conventional electrodeposition method used.	[17]
2	Chemical method	5-7	flake-like	hydrothermal method used	[18]
		27.7 (Hydrothermal) 12(Reflux)	Spherical shape	hydrothermal or reflux type methods used.	[19]
		7.7	Accumulates	Solvothermal method used	[20]
		16- 60	flower/spindle	Different precursor of copper salts used for different morphology study	[21]
		210-510	cubic/rod/belt like structure	Using different precursors for optimization of different morphology studies.	[22]
		180-200(C) 60-100 (S)	cubic (C) or spherical(S)	Morphology characteristic study	[23]
		38	Spherical like shape	microwave-assisted chemical method	[24]
		75-105	Spherical shape	microwave-assisted chemical reduction method	[25]
		600	needle-shaped	Sono chemical synthesis method	[26]
		15-50	Spherical like structure or shape	Sono chemical synthesis method	[26]
3	Biological method	30-50	Spherical	Pure extract from <i>Thymus vulgaris</i> L. leaves used reducing agent.	[27][28]
		15-30	Spherical	Pure extract <i>aloe barbadensis</i> Miller leaves were employed as a reactant.	[29]
		20-30	Spherical	leaf extract of <i>Calotropis gigantean</i> used for synthesis.	[30]
		60-70	Spherical	<i>Tamarix gallica</i> leaf extract used as a reducing agent.	[31]
		15-25	Spherical	<i>Camellia japonica</i> leaf extract used as a reductant	[32]
		10-20	spherical	Pure extract used <i>Rheum palmatum</i> L. root.	[33]
		18-58	spherical	<i>Anthemis nobilis</i> flowers extract used as a reducing agent.	[34]
		500 (S) 1252 ±12(O)	Spherical(S) and octahedral (O) type	aqueous extract of <i>Aloe vera</i> used as a reductant	[35]
		140-145	Rod like	<i>Carica papaya</i> leaves extract used	[36]
		12-22	spongelike	leaf extract of <i>Rauvolfia serpentina</i> used.	[37]
		38-40	spherical	<i>Theobroma cacao</i> L. seeds extract used.	[38]
		7-20	spherical	white-rot fungus <i>Stereum hirsutum</i> used.	[39],[40]

APPLICATIONS: Because of their small size and large surface area, nanoparticles have numerous applications in biomedicine and pharmaceuticals. The major fields of science that benefit from CuNPs are listed below [41].

- 1) Biological Application:** Copper nanoparticles shows antimicrobial activity and antifungal activities. Also gives efforts against viruses such as human influenza A (H1N1), avian influenza (H9N2), and many more including COVID-19 virus reducing its viability, and half-life. copper has found promising against cancer. Copper and copper oxide nanoparticles exhibit anti-cancerous activity against HeLa cells, MD A-MB-231 (human breast cancer cell lines), Caco-2 (human colon cancer cells), and HepG2 cells (Hepatic cancer cells) and Mcf-7 breast cancer cells. Cutaneous wound healing was also studied in vivo by synthesis of copper NPs by *Falcaria vulgaris* leaf extract and also showed potent cytotoxicity, antioxidant, antifungal, antibacterial activities. Copper nanoparticles have anti-inflammatory and anti-arthritis activities [42-47].
- 2) Textile:** Promethane Particles, in collaboration with textile companies and research institutes, is developing

Personal Protective Equipment (PPE) and designing fabrics incorporating Nano-copper into polymer fibres such as nylon, using the melt extrusion method, as well as generating antimicrobial fabrics that are under evaluation [47, 48].

- 3) Biocatalyst and Bioremediation:** Copper nanoparticles used as bioremediation, catalytic activities and also having adsorbent capacity [49-51].
- 4) Therapeutics:** Nanoparticles provide site specific drug delivering system, due to its small size, large absorptive surface for drug to carry and shows improved therapeutic efficacy with less toxicity. Chitosan coated copper nanoparticles are used in different types of cancers [52].
- 5) Other Application:** Copper nanoparticles also shows applications in food packaging and agriculture for crop improvement. Copper nanoparticle shows wide range of application in field of biological, physical, and chemical sciences.

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