Research Journal of Chemical Sciences ISSN 2231-606X
Vol. **15(4),** 53-56, October **(2025)** *Res. J. Chem. Sci.*

Review Paper

A Review on the Green Synthesis, Characterization and Antibacterial activity of Magnesium and Zinc oxide Nanoparticles using citrus species peels

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Available online at: www.isca.in, www.isca.me
Received 18th August 2025, revised 20th September 2025, accepted 10th October 2025

Abstract

Environmental pollution has increased as a result of the extensive usage of synthetic materials for nanoparticle manufacturing. Green synthesis, which uses biodegradable materials like the peels of citrus species, has therefore lately become a viable substitute. The current study's objective was to study the use of citrus peels as a natural precursor for the antimicrobial properties, sustainable production, and characterisation of zinc oxide and magnesium oxide nanoparticles.

Keywords: t-butyl hydroperoxide; microwave; oxidation; supported reagent.

Introduction

Nanotechnology is a foundation for ongoing research in many fields and holds the potential for several breakthroughs. It is described as the procedure used to create applications with engineered materials that have a dimension of at least one nanometer[1]. Nano-materials, which are structural components with a size range of 1-1000 nanometres, are composed of nanoparticles (NP), which are subgroups of particles with a size range of 1-100 nanometres[2].

Conical, spiral, flat, hollow, and other geometries and configurations are all possible for nanoparticles, which also have superior physical properties than their bulk counterparts, such as increased mechanical strength and stability. They are widely used, indicating that they have qualities that are beneficial in a variety of situations[3].

Nanotechnology, or the manipulation of materials at the nanoscale, has revolutionised a variety of fields, including electronics, medicine, and environmental science. Metal oxide nanoparticles (NPs), such as magnesium oxide (MgO) and zinc oxide (ZnO), have garnered a lot of attention due to their numerous applications and unique characteristics. However, traditional chemical methods for producing these NPs usually involve the use of dangerous chemicals and other unwanted byproducts, which raises concerns about the environment[4].

Green synthesis is a more environmentally friendly way to make things that uses plant extracts. Citrus peels, which are full in bioactive chemicals, have become a promising natural source for making metal oxide NPs. This review paper goes into detail on the green synthesis, characterisation, and research of the antibacterial activity of MgO and ZnO NPs made from lemon, orange, and tangerine peels[4].

Green Nanoscience and Nanotechnology

At the moment, green nanotechnology and nanoscience are very popular. A large portion of the studies and applications of chemists and scientists are focused on this area. Nanoparticles are minuscule particles with sizes ranging from one to one hundred nanometers5. Using experimental techniques, nanoscience creates nanoparticles (NPs) with a variety of chemical compositions, sizes, forms, and other characteristics. Instead of employing chemicals or physical processes, scientists have recently looked for methods to create biological nanoparticles. People believe that biological processes for producing NPs are safe for both the environment and humans. They ensure that all hazardous elements are eliminated and are also reasonably priced[6].

The ecology benefits from the green production of nanoparticles7. Without using harmful techniques, people have had great success creating nanoparticles from extracts of various plant parts, such as leaves, stems, flowers, and fruits. This project's objective is to create MgO and ZnO nanoparticles by employing the green synthesis method, which begins with the peels of lemons, oranges, and tangerines. Both oxidising and reducing agents can be found in plant extract[9]. Tangerines, lemons, and oranges are all naturally pale yellow. This hue shields the fruit's interior from the elements. Since its main component is citric acid, it can be utilised as a reducing agent to create various metal oxides, including MgO, TiO_2 , and ZnO10 in the synthesis process[10].

Water is used to mitigate the negative effects of conventional chemicals[11]. Because metal oxides have a bigger surface area and a better surface composition, scientists are quite concerned about them. One of the most significant metal oxides is magnesium oxide (MgO).

Catalysis, refractory materials, paint, superconducting materials, biology, electrochemistry, and medicine are just a few of the many fields that employ it[12]. Because of their unique qualities, such as a high surface area to volume ratio and optical, magnetic, and high surface energy properties compared to bulk materials, metal nanoparticles (NPs) are used in a variety of fields, including biological, electrochemical, environmental, and medical ones. ZnO, SnO_2, WO_3, TiO_2, and other metal oxide semiconductor nanoparticles are among them[12].

MgO Nanoparticles

Magnesium oxide is regarded as safe for human ingestion and is an essential inorganic component. In the medical field, magnesium oxide is used as an antacid to treat a variety of ailments, including heartburn and stomach discomfort. Because of its distinct characteristics in comparison to bulk materials, magnesium oxide stands out among nanoparticles. By focusing on several locations inside living systems, metal-based nanoparticles may lessen the likelihood of medication resistance. Strong chemical stability, great photocatalytic activity, high electrical permittivity, non-toxicity, and other characteristics make magnesium oxide nanoparticles remarkable. The long-lasting antibacterial action of magnesium nanoparticles may result from their low volatility and great temperature endurance[13].

Properties

The growing applications of magnesium oxide nanoparticles have prompted intensive study on metal oxide nanoparticles, which have attracted considerable attention and are now widely employed due to their remarkable features. Magnesium oxide nanoparticles can be readily synthesised, are non-toxic, and are economically viable. They demonstrate antibacterial activities and are efficacious against plant pathogenic microorganisms[14]. Magnesium oxide nanoparticles exhibit a specific surface area of 25 to 50 m^2/g and typically range in size from 5 to 100 nm. Notwithstanding their diminutive size, these metal oxide nanoparticles demonstrate melting and boiling temperatures markedly higher than those of the bulk material, particularly 2852°C and 3600°C, respectively.

MgO nanoparticles are widely employed due to their unique properties, including a simple crystal structure, strong ionic character, exact stoichiometry, and surface structural flaws[15]. Magnesium oxide possesses a cubic or halite structure, denoted by the empirical formula MgO, exhibiting ionic bonding between Mg^{2+} and O_2^- ions organised in a lattice arrangement. At 20°C, the solubility of MgO is quantified at 0.0086 g per 100 ml of water, demonstrating its limited solubility in this solvent[15].

Zinc Oxide Nanoparticles

Zinc oxide, represented by the chemical formula ZnO, is an inorganic compound. This is a white powder that is water-insoluble. The architecture of ZnO nanoparticles has been analysed computationally utilising innovative atomistic potentials. The mechanical properties, including as internal stress and adhesion characteristics, are crucial for maintaining patterning precision and longevity in various nanoparticle applications. ZnO exhibits a hexagonal wurtzite configuration. ZnO crystallizes in the hexagonal wurtzite structure and zinc generally forms alloys[16].

Physical Properties

According to the IZA, ZnO exhibits the following physical properties: i. Molecular Weight: 81.37 g/mol. ii. Colour: Pure microcrystalline zinc oxide appears white. A single crystal of zinc oxide is colourless. Zinc oxide turns lemon yellow when heated and back to white when cooled. iii. Relative density = $5.607 g/cm^3$. iv. Melting Point: Zinc oxide melts under atmospheric pressure and temperatures over 1200^oC. Under high pressure, a melting point of 1975^oC has been calculated. v. Vapour pressure (1500^oC): 12mm. vi. Refractive Index (w = 2.004, e = 2.020). vii. Heat of sublimation between 1350^oC and 1500oC: 129 Kcal/mole (not disassociated vapour) and 193 Kcal/mole (attached vapour). viii. Heat Capacity: Cp = 9.62 cal/deg/mol at 25°C. ix. The coefficient of thermal expansion is 4 x 10(-6)/^{o}C.

Chemical Properties: The IZA states that ZnO displays the subsequent chemical properties: i. Zinc oxide occurs as the mineral zincite or as a white powder known as zinc white. Manganese impurities typically result in an orange or red colouration. ii. Crystalline zinc oxide exhibits thermochromism, transitioning from white to yellow upon heating and reverting to white upon cooling. The colour alteration is attributed to a negligible depletion of oxygen at elevated temperatures. iii. Zinc oxide is amphoteric, indicating its reactivity with both acids and bases. Upon exposure to acid, it generates the widely recognised compound zinc sulphate. iv. When amalgamated with alkali, it produces zincates. v. Commercial zinc oxide exhibits a quantifiable albeit moderate solubility in water of 0.005 g/liter. vi. Zinc oxide, when exposed to air, absorbs both water vapour and carbon dioxide.

Green Synthesis of MgO and ZnO NPs Using Citrus Peels

The eco-friendly synthesis of MgO and ZnO nanoparticles using citrus peel extracts often adheres to a straight forward and basic methodology:

Preparation of Citrus Peel Extract: Citrus peels are subjected to washing, drying, and grinding to attain a fine powder consistency. The powder is then extracted using solvents like ethanol or water to produce a concentrated extract containing several bioactive chemicals, including flavonoids, terpenoids, and organic acids[17].

Synthesis of NPs: Under specific conditions, such as temperature, pH, and reaction duration, the citrus peel extract is combined with a metal salt solution, such as magnesium nitrate or zinc nitrate. The bioactive constituents of the extract function as reducing and capping agents, facilitating the formation and stabilisation of nanoparticles' size and structure[17].

Characterization of MgO and ZnO NPs

A variety of approaches are utilised to characterise the synthesised nanoparticles, including: i. UV-Vis spectroscopy: To ascertain the optical characteristics and size distribution of the nanoparticles. Fourier Transform Infrared (FTIR) Spectroscopy: To ascertain the functional groups implicated in the production and capping of the nanoparticles. ii. X-ray diffraction (XRD): To examine the crystalline structure and phase purity of the nanoparticles (NPs). iii. Transmission Electron Microscopy (TEM): To elucidate the morphology, dimensions, and configuration of the nanoparticles (NPs). iv. Scanning Electron Microscopy (SEM): To examine the morphology of nanomaterials and nanostructures. SEM not only offers images of the morphology of nanostructured materials but also delivers comprehensive information on chemical composition and elemental spectra. v. Particle Size Analysis employing the Zetasizer Nano series: The Zetasizer Nano Series measures three qualities of particles. The three essential characteristics are particle size, zeta potential, and molecular weight.

Antibacterial Activity of MgO and ZnO NPs

Researchers have extensively investigated the antibacterial properties of MgO and ZnO nanoparticles. These nanoparticles may eradicate a wide variety of bacterial strains, including both Gram-positive and Gram-negative varieties. It is believed that its mechanism involves the generation of reactive oxygen species (ROS) that damage the bacterial cell wall and membrane[17].

Research has shown that MgO and ZnO nanoparticles synthesised using orange peel extracts have superior antibacterial efficacy compared to those produced by conventional methods. The orange peel extract contains bioactive compounds that may assist the nanoparticles in combating pathogens[17].

Conclusion

The green synthesis employing citrus fruit extracts provides a sustainable and efficient approach for the production of MgO and ZnO nanoparticles, with potential applications in medicine, agriculture, and environmental science. The unique properties and antibacterial effectiveness of these nanoparticles render them compelling candidates for the development of innovative antibacterial agents and other advanced technologies.

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