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MgO nanoparticles' optical properties affect their antibacterial skills

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ABSTRACT

This work inspects the making of magnesium oxide (MgO) nanoparticles and nanocomposites for possible uses in medicine and fighting bacteria. We checked how they interact with light using UV-Vis and fluorescence methods, spotting where the nanomaterials start to absorb light. With Fourier transform infrared (FTIR), we verified which chemical groups were in the created nanocomposites. In tests, MgO and its mixes showed good action against Staphylococcus aureus (S. aureus), a Gram-positive germ.

Keywords: MgO, nanocomposites, biocompatibility

INTRODUCTION

Nanoscience and nanotechnology have been emerging disciplines in science over the past 10 years, having a significant impact on a number of fields.Nanotechnology emphasizes the development of materials with rich physical, chemical, and biological properties that arise from their nano-scale dimensions. Such as a result it has become like a hot topic for researchers around the world to take on.Key factors that influence nanoparticle properties consist of size, shape, composition, and crystallinity. These in turn define their functionality and potential application.

To be consistent across different physical characteristics, overly narrow-size-range nanoparticles were created by a variety of tactics including hydrothermal treatment, co-precipitation and microemulsion. As for the wet chemical synthesis men- tioned so frequently, it has got the advantage of being both easy and large scale.Inorganic materials,in particular metal oxides,such as TiO2, ZnO, MgO and CaO,have earned notoriety from their capacity for withstanding severe treatment and safety as human or animal usage.

Magnesium oxide (MgO) is a very important base oxide used in the field of catalysis, adsorption, and refractory ceramics. Its large characteristic ionic charge and simple geometric arrangement coupled with the ability to control both particle size and morphology make it a vital material. The surface of MgO nanoparticles has numerous ripples, holes and other forms of structural defects, which gives them the highly effective antimicrobial efficiency that they have in all kinds of living things.That they are smaller than 100 nanometers in size contributes to this fact as well.

This study focuses on creating a simple way to make MgO nanoparticles and examining how they interact with light and bacteria. The created MgO nanoparticles were analyzed using X-ray diffraction (XRD). Their ability to fight S. aureus bacteria was tested using the agar diffusion method at a calcination temperature of 500 °C.

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EXPERIMENTAL

SYNTHESIS OF MGO NANOPARTICLES

For the sol-gel synthesis, MgCl2•6H2O was dissolved in 100 mL of distilled water. Citric acid was then put into the solution at a 1:1 molar ratio with the magnesium ions. The solution was stirred constantly and heated to 80 °C to get rid of any extra water, which created a uniform gel. The gel was dried at 120 °C to remove any dampness, and then calcined at 500 °C for 2 hours to break down any organic stuff and help the MgO nanopowder crystallize. The white nanopowder that was made was gathered, kept in a dry place, and then used for more tests and antibacterial studies (Fig. 1).

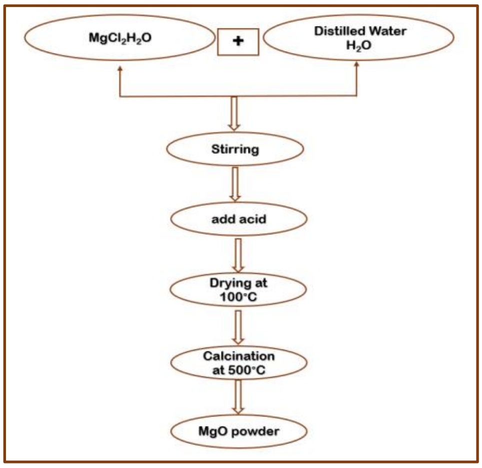

Fig. 1. Fabrication of the preparation method.

FTIR SPECTROSCOPY

The FTIR spectra of magnesium oxide (MgO) nanoparticles provide insight into the vibrational modes and chemical bonds present in the material. The analysis reveals several characteristic peaks associated with the structural and surface properties of MgO nanoparticles, as shown in Figure 2.

Key peaks observed in the FTIR spectrum include a prominent peak at 435.91 cm^{-1}, which corresponds to the Mg–O stretching vibration, indicative of the crystalline structure of MgO. The peaks at 459.06 cm^{-1} and 648.08 cm^{-1} also support that Mg–O bonds are in the nanoparticles. Other peaks at 879.54 cm^{-1} and 1010.70 cm^{-1} could link to surface hydroxyl groups or Mg-O-H stretching vibrations. This comes from contact with moisture in the air when the substance is made or tested. Peaks at 1427.32 cm^{-1} and 1573.91 cm^{-1} point to carbonate (CO_3^{2-}) on the nanoparticle surface, probably from contact with CO_2 in the air. The wide band at 3441.01 cm^{-1} and a sharper peak at 3695.61 cm^{-1} usually mean O–H stretching vibrations, which show hydroxyl groups on the nanoparticle surface. These traits point to the water-loving nature of MgO nanoparticles and their active surface. This makes them work well in catalysis and antimicrobial materials. FTIR testing backs up that MgO nanoparticles are pure and chemically stable. It gives us a full picture of their structure.

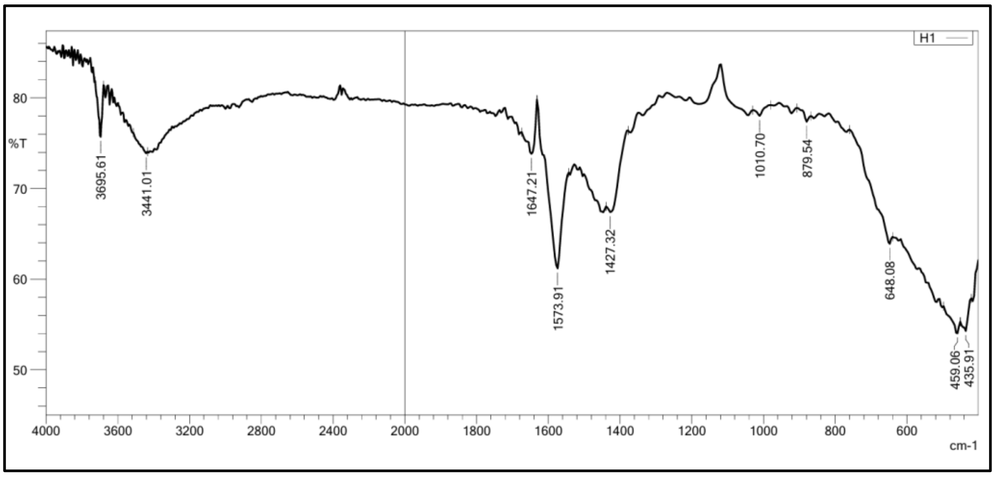

Fig. 2. FTIR spectra for MgO NPs

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OPTICAL PROPERTIES

We worked out the bandgap energy (Eg) of the MgO nanoparticles from the UV–Vis data using Tauc's relation, as shown in Equation (1):

$$(\alpha h\nu)^2 = B(h\nu - Eg)^2 \quad (1)$$

In this equation, Eg stands for optical bandgap energy, hν for photon energy, α for the absorption coefficient, and B for a material-specific constant. The bandgap energy of the MgO nanostructures, calculated using this method, is 4.95 eV (as shown in Figure 3). This value aligns with the expected bandgap for MgO, suggesting good optical purity and stability. Because MgO nanoparticles have a wide bandgap, they are suited for optoelectronics, photocatalysis, and UV shielding. Their strong absorption in the UV spectrum but transparency in the visible range makes them applicable to uses such as energy-saving coatings and biomedical imaging. This suggests MgO nanostructures are valuable as optical materials.

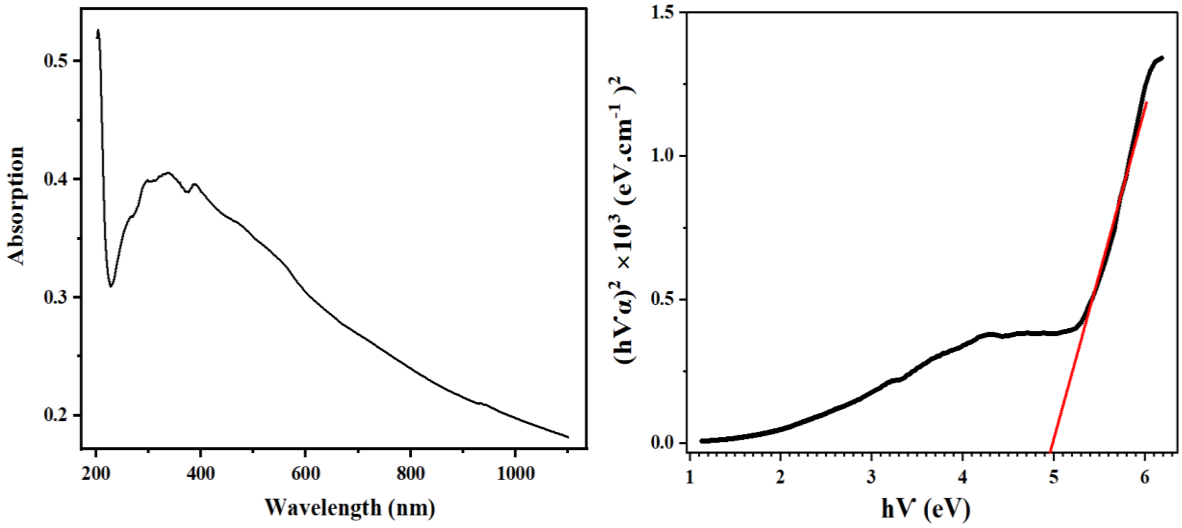

Fig. 3. Shows the energy gap of pure MgO

ANTIBACTERIAL PERFORMANCE

We explored how magnesium oxide (MgO) nanoparticles combat Staphylococcus aureus (S. aureus), a Gram-positive bacterium, using agar disc diffusion. In our procedure, discs holding MgO nanoparticles were placed on bacterial cultures, followed by a day of growth at 37°C. Referring to Figure 8(a-e) and Table 3, we observed zones of inhibition (ZOI) around the discs, measuring 10 mm, suggesting the nanoparticles' antibacterial . Against Gram-negative Escherichia coli (E. coli), MgO nanoparticles also showed success, indicated by ZOIs surrounding the treated areas. The antibacterial action of these nanoparticles appears to disrupt bacterial cells, impairing their structure and essential functions. This cellular damage compromises the bacteria, hindering reproduction and causing cell death. The size of the nanoparticles is very important for how well they kill bacteria. Smaller MgO nanoparticles are better at killing bacteria because they have more surface area compared to their size, which means they can interact with more bacterial cells. Also, smaller nanoparticles create more reactive oxygen species (ROS), which helps kill bacteria even more. These results suggest that MgO nanoparticles could be good antimicrobial agents, offering a helpful way to fight bacterial infections, especially as we see more antibiotic resistance.

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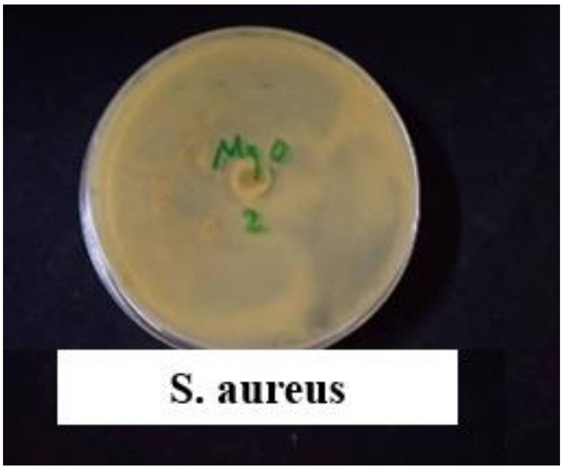
Table 3: The relationship between the diameter of Gram-positive Staphylococcus aureus (S. aureus) strains and magnesium oxide nanoparticles.



ZOI (mm)	**10**

CONCLUSION

Magnesium oxide (MgO) nanoparticles were successfully made and studied, and they show good optical and antibacterial traits, so they may be helpful in biomedical and environmental uses. The sol-gel method made MgO nanoparticles that are highly crystalline with clear structural traits, as shown by FTIR and XRD. FTIR spectra showed peaks for Mg–O bonds and surface hydroxyl groups, showing the material is pure and has high surface reactivity. Optical analysis using UV-Vis spectroscopy showed the bandgap energy of MgO nanoparticles is 4.95 eV, which lines up with expected values. This wide bandgap and clear absorption edge show they could be used for optoelectronics, photocatalysis, and UV-shielding. Antibacterial tests showed that MgO nanoparticles work well against Staphylococcus aureus and Escherichia coli, with clear zones of inhibition. This strong antibacterial action is due to the nanoparticles' small size, large surface area, and ability to make reactive oxygen species (ROS), which damage bacterial cells. These results show that MgO nanoparticles are useful materials with great optical and antimicrobial traits. Later studies should look at adding MgO nanoparticles to composites or coatings for better uses in medicine, water treatment, and energy tech.

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