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Orginal Research Article

Antibacterial activity of magnesium oxide nanostructures prepared by hydrothermal method

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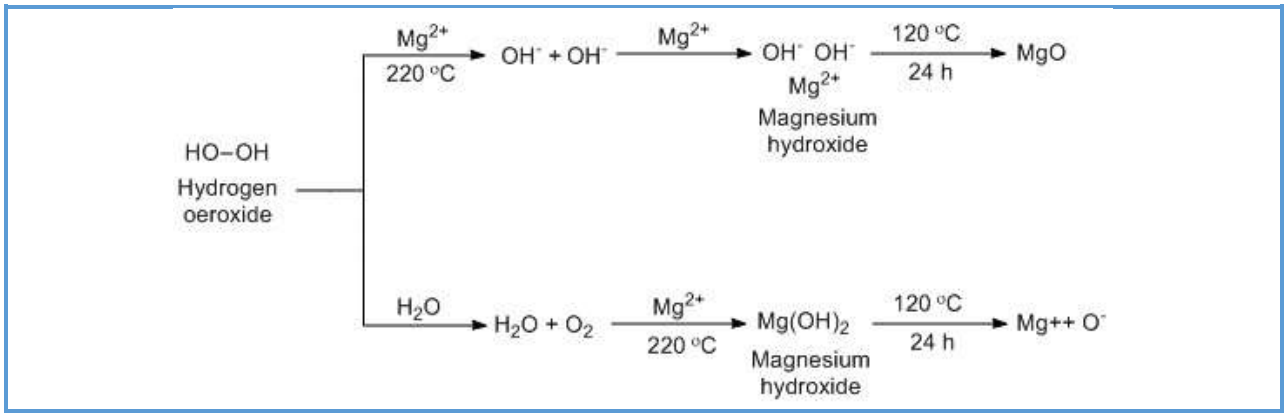
ABSTRACT

In this research study, the magnesium oxide nanoparticles were synthesized using an inexpensive and simple hydrothermal method. A pure magnesium metal powder, de-ionized water, and hydrogen peroxide (H_2O_2) was utilized as the starting materials. The synthesized MgO was dense, uniformly distributed with a relatively spherical shape, without any cracks and voids as confirmed by the scaning electron microscopy (SEM) analysis. The structure was crystalline with a high purity. No other peak corresponding to any other material or metal could be ascertained from powder X-ray diffraction (XRD) pattern. The crystallite size of the prepared samples was found to be nearly 18 nm which was favorable for antibacterial activity. The antibacterial activity of MgO nanostructures was carried out by using disc diffusion method. The inhibition zones of diameters = 1 mm were observed in case of *salmonella* and *Staphylococcus aureus*, however, in case of *E. Coli* inhibition zones of diameter = 2 mm was obtained.

Graphical Abstract



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Introduction

Metal oxides such as Cu_2O, TiO_2, ZnO, Al_2O_3, and MgO are of specific interest due to their high stability under harsh processing conditions [1]. At very low concentrations, metals and their salts are usually noxious to microbes. These bind themselves to intracellular proteins of the microbes and inactivate them and then finally kill the microbes [2].

To stop infectious diseases, nanoparticles of silver and zinc oxide have proven themselves viable agents due to their interesting antimicrobial properties. Health concerns together with customer gratification have made functionally finished textiles a fast-paced and fast growing industry [3]. Magnesium oxide is an attention-grabbing basic oxide with several interesting applications in catalysis and refractory ceramics [4–7]. MgO can be prepared by several methods with various particle size and morphology. It possess simple stoichiometry, and a simple crystal structure and it is one of the unique solids possessing high ionic character [8]. In addition, the morphology and the size of the magnesium oxide nanostructures endow them with high specific surface and reactivity, because of the high concentration of edge/corner sites and structural imperfections on their surface [9].

In the present research study, a simple method such as hydrothermal was employed to synthesize the MgO nanoparticles. The prepared nanoparticles were characterized using powder X-ray diffractometry (XRD) and scanning electron microscopy (SEM). Antibacterial studies of the prepared MgO nanoparticles were carried out using *S. Aureus* (gram positive), *E.coli* (gram negative) and *Salmonella* by employing Agar Disc Diffusion method.

Experiment

To synthesize the magnesium oxide nanoparticles, a closed cylindrical Teflon lined stainless steel chamber was used. Magnesium powder was utilized as a starting material, and de-ionized water as well as hydrogen peroxide were used as a reaction medium. In a typical preparation process, 0.4 g of magnesium powder was added to 14 mL of water along with 1 mL of hydrogen peroxide in a glass veil. Hydrogen peroxide serve the role of oxidizing agent in this synthesis process. The reaction mixture was sonicated for about 30 min in a glass veil, transferred into a stainless steel Teflon lined metallic bomb of 50 mL capacity and sealed under inert conditions. The closed chamber was then placed in a preheated box furnace, heated slowly at the rate of 2 degrees per min to reach the maximum temperature of 220 °C. The mixture was maintained at this temperature for 48 h. Thereafter, the furnace was allowed to cool and the resulting suspension was centrifuged to retrieve the product. The product was washed and finally vacuum dried at 120 °C for 24 h. The experimental process is shown in Figure 1.

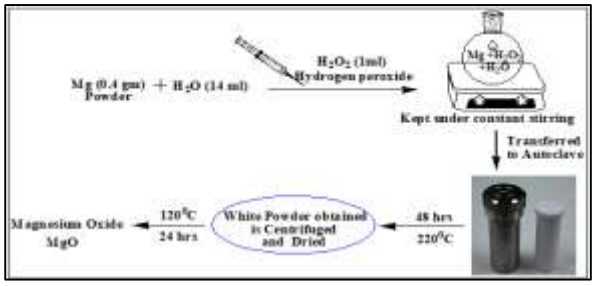

Figure 1. Schematic presentation for the synthesis of magnesium oxide nanoparticles

Results and discussion

XRD pattern of the MgO was obtained using X-ray diffractometer (Aeris Research Edition, Malvern Panalytical a Spectris Company, Cu Kα radiation; λ = 1.54Å). The obtained XRD pattern of the MgO is presented in Figure 2. The

observed peaks are well indexed to cubic MgO crystallites with the lattice parameter a = 0.421 nm (JCPDS 45-946). No extra peak was ascertained in the pattern which depicted the high phase purity of the samples. The crystallite size of the MgO nanoparticles was estimated using the Debye-Scherrer equation [10].

$$D = \frac{k\lambda}{\beta cos\theta},$$

where D is the crystallite size, k is the shape factor, which commonly takes a value of about 0.9 [11], λ is the wavelength of X-ray source used, β is the full width at half-maximum (FWHM), and θ is the Bragg diffraction angle. The crystallite size of the MgO nanoparticles, using the most intense peak corresponding to (200) planes, was estimated to be 18 nm.

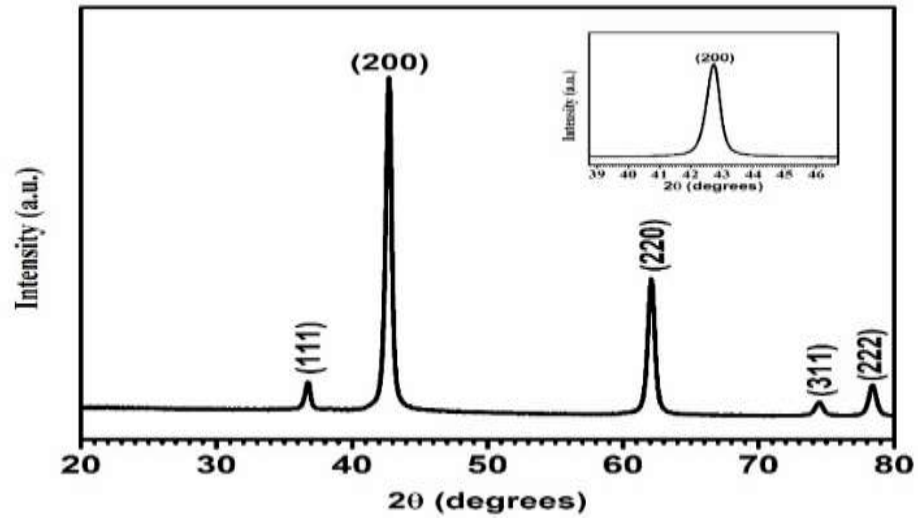

Figure 2. X-ray diffraction pattern of MgO nanostructures

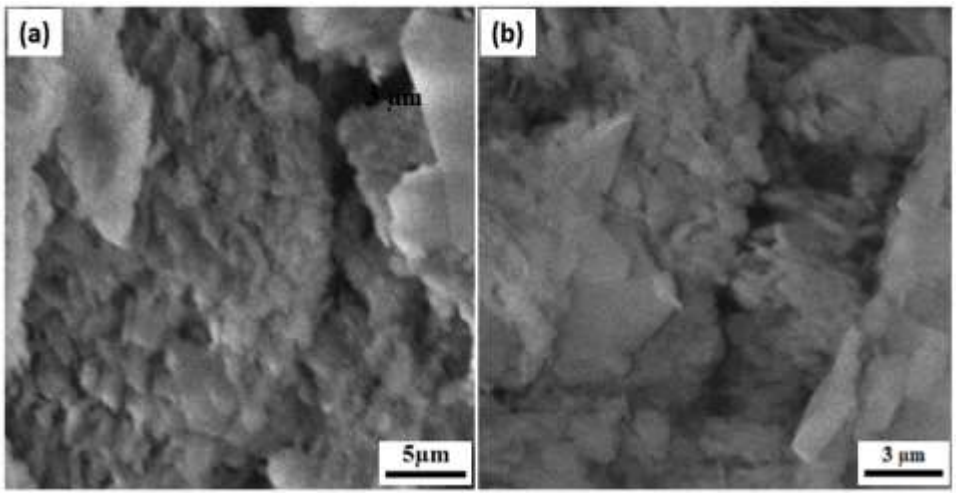

Figure 3. SEM images of the pure magnesium oxide

The morphological analysis of the synthesized powder was carried out using scanning electron microscope (SEM, HITACHI S-3600N, Japan). Figure 3 shows the SEM images of the as prepared samples. The nanostructures were nearly spherical, dense and without any

defects such as cracks and voids within the grains.

For antibacterial activity, bacteria like S. Aureus (gram positive), *E. coli* (gram negative) and *Salmonella* were chosen. Figure 4 reveals the inhibition zones formed in case of bacteria such as *S. Aureus* (gram positive), *E. coli* (gram negative) and *Salmonella*.

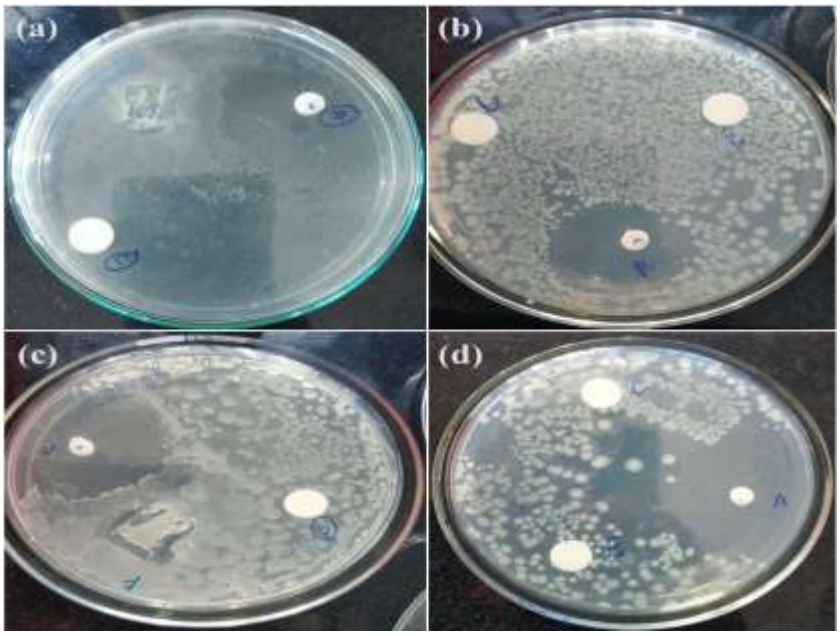

Figure 4. Zone formation a) DMSO b) *S. Aureus* c) *E.coli* d) *Salmonella*

The disc diffusion method of *Rahman* and *Rashid* (2008) [12] was used to test antimicrobial activity of the nanoparticles. Discs containing the test materials were placed on to nutrient agar medium uniformly seeded with the test microorganisms. These plates were then kept at low temperature (4 °C) for 24 h to allow maximum diffusion of the test materials. The plates were then incubated at 37 °C for 24 h to allow maximum growth of the organisms.

Table 1. Diameters of zones of inhibition of different bacteria in mm

Item	Salmonella	E-coli	S. aureus
DMSO	0.0	0.0	0.0
MgO	1.0 mm	2.0 mm	1.0 mm

The test material having antimicrobial activity inhibited the growth of the microorganisms and a clear, distinct zone of inhibition was visualized surrounding the discs. The antimicrobial activity of the test agents was determined by measuring the diameter of zone of inhibition triplicate and the mean value was reported. DMSO served as Positive control. In case of DMSO no inhibition was observed revealing that DMSO has no effect on bacterial growth. The zone formation was observed and limited to few millimeters in case of MgO nanoparticles because nanoparticles penetrated and blocked the cell walls by attaching at the surface of the microorganisms. Because of this, these prevented micro-organisms to perform the natural activity and ultimately their growth was limited. In addition, several reports attributed the antibacterial mechanism of MgO nanoparticles to the

formation of reactive oxygen species (ROS) for instance superoxide anion (O^{2-}). Furthermore, increase in the surface area of magnesium oxide structures at the nanoscale resulted in the increase of the O^{2-} concentration in the solution and consequently lead to the effective annihilation of the cell wall of the bacteria and ultimately death of the micro-organisms [13, 14].

Table 1 shows the diameter of the various inhibition zones. The inhibition zones of diameters = 1 mm were observed in case of *Salmonella* and *S. aureus*, however, in case of *E. Coli* inhibition zones of diameter = 2 mm was obtained.

Conclusion

The present study investigated the possibility of engineering structural properties of MgO by employing hydrothermal method. The antimicrobial activity of the test agents was determined by measuring the diameter of zone of inhibition triplicate. The results revealed that the highest diameter (2 mm) was observed in case of *E. Coli*, however, in case of Salmonella and S. aureus diameters of inhibition zones were 1 mm. It would be an efficient material against bacteria provided the synthesis conditions must be optimized to achieve the smallest possible particle size and appropriate dopants have to be explored to enhance its efficiency.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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