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Structural, morphological and optical properties of MgO nanoparticles for antibacterial applications

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ABSTRACT

Magnesium oxide (MgO) nanoparticles have been synthesized by wet chemical reaction method. The structural, optical and morphologies of MgO nanoparticles have been characterized by X-ray diffraction (XRD), UV–vis Spectrophotometry, Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM). The synthesized nanoparticles were well-dispersed spherical nanoparticles with the average size of 16 nm. The SEM and TEM reveal the formation of almost spherical shaped MgO nanoparticles. XRD shows the face cubic centred structure of the MgO nanoparticles. The observed antibacterial properties, suggest the possible utilization of prepared nanoparticles in water purification.

1. Introduction

Water is one of the purest symbols of wealth, health, tranquility, beauty and originality. Pure water, which is free of toxic chemicals and pathogenic bacteria, is necessary for human health. Waterborne pathogens including helminthes, protozoa, fungi, bacteria, rickettsiae, viruses and prions, can cause many diseases. In India 80% of the diseases are due to bacterial contamination of drinking water. Keeping this in mind, the removal or deactivation of pathogenic bacteria in water is described in the present study.

Nanostructured oxide materials have been studied extensively because of their large surface areas, unusual adsorptive properties, surface defects and fast diffusivities. They are not only stable in cruel method conditions but also observed as secure materials to human beings and animals. Nanoparticles exhibit novel material properties due to their small size, that are significantly different from those of their bulk counterparts. Among the known metal oxide nanoparticles, magnesium oxide (MgO) has been widely studied because it is a unique solid of high ionic character, simple stoichiometry and crystal structure, and surface structural defects, and its novel applications in areas such as electronics, adsorption, catalysis, ceramics, petrochemical products, reflecting and antireflecting coatings, detection and remediation of chemical waste and warfare agents, and many other fields [1–8]. MgO nanoparticles can be synthesized using various physicochemical techniques [9–14]. The morphology and properties of the prepared MgO nanoparticles differ and depend on the synthesis route and processing conditions. Wet chemical synthesis of nanoparticles is one of the most sensitive methods which will be advantageous over other conventional process as it will be a simple, inexpensive and fast method [15]. Antibacterial activities of MgO nanoparticles against various pathogens have also been established [13,16–18]. Main objective of this present study is to synthesize MgO nanoparticles using wet chemical reaction method and show its function as a antibacterial agent so that it may be used for water purification application.

2. Experimental details

All the chemical reagents were of analytical grade and used without further purification. Synthesis was carried out by simple chemical reaction method by using magnesium nitrate and sodium hydroxide. In a typical preparation, 1:2 M ratio of the metal ions to hydroxide ions were added and kept under constant stirring for 2 h for entire dissolution of contents and allowed to settle for 24 h at room temperature to form magnesium hydroxide. The

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supernatant liquid was then discarded carefully and the remaining solution was centrifuged (10,000 rpm) for 20 min. The Centrifugate was washed several times with double distilled water in an ultrasonic bath at a frequency of about 200 kHz for 5 h, to remove the by products that bound with the nanoparticles. Finally the sample was dried in hot air oven for 3 h at 100 °C and calcined at 400 °C for 5 h to obtain the purest form of MgO nanoparticles.

The structure of the dried samples were characterized by XRD using X'Per PRO (PANalytical) X-ray Diffractometer with CuKα radiation $\lambda = 1.5406$ Å, at the scanning rate of 0.05°. UV study was carried out by using Double Beam UV–vis Spectrophotometer (LMSP UV 1900). Morphology studies were made using a JEOL TEM 2010 High Resolution TEM with an accelerating voltage of 200 kV and SEM using a Hitachi S-3000P.

3. Results and discussion

3.1. Structural studies

Fig. 1(a) indicates the XRD pattern of MgO nanoparticles calcined at 400 °C. The diffraction peaks are narrower at this higher temperature. The result confirmed the formation of MgO nanopowders. The peaks at 2θ values of 36.9°, 42.9°, 62.3° and 74.6° and 78.6° in the 2θ range can be indexed to the (1 1 1), (2 0 0), (2 2 0), (3 1 1) and (2 2 2) planes of the Face Centred Cubic (FCC) structured MgO nanopowders with space group of Fm-3m (JCPDS file no. 89-7746). No other peaks were detected in the XRD pattern confirming high purity of the obtained MgO nanoparticles. The average crystallite size ranging from 12 nm was estimated by using Scherrer's formula. The lattice constant and volume were found to be $a = 4.211$ Å and 74.67 $(Å)^3$ respectively, which is agreement with the literature report ($a = 4.219$ Å and $V = 75.14$ $(Å)^3$, JCPDS no. 89-7746). The values of surface area to volume ratio (SA:V), Specific Surface Area (SSA), average strain (ε) and dislocation density (δ) are calculated as 0.47, 131.96 m^2/g, 0.124×10^{-2} and 34.79×10^{14} m^{-2} respectively [19–22].

3.2. UV–vis studies

The optical properties of MgO nanoparticles have been recorded by absorption spectrum in the UV–visible wavelength range of 200–500 nm and are shown in Fig. 2. It exhibits absorption at 212 nm. This absorption is considerably higher than that of the bulk MgO due to bulk excitonic transitions for single crystals of

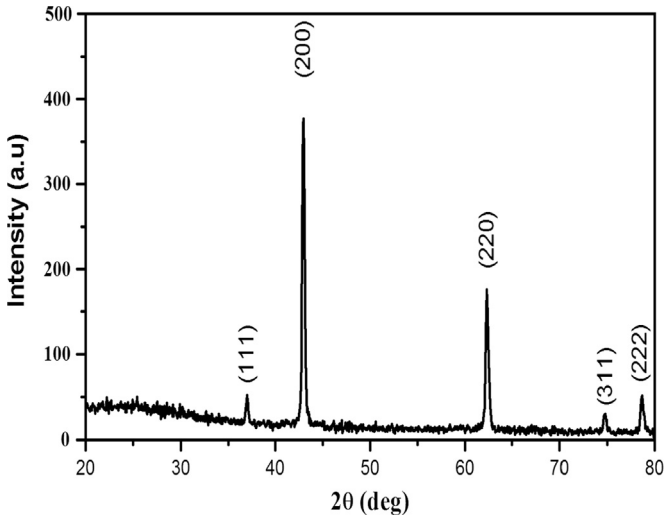

Fig. 1. XRD pattern of obtained MgO nanoparticles.

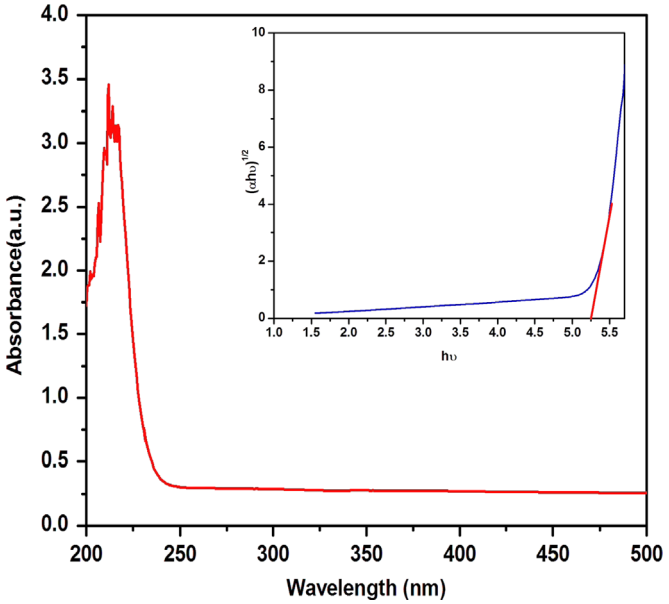

Fig. 2. Optical absorption spectra of MgO nanoparticles (inset) A plot of $(\alpha h\nu)^{1/2}$ versus $h\nu$.

MgO (163 nm). The absorption at 212 nm accredited to coordination of surface oxide ion, the high wavelength of the surface exciton associated with it indicating low coordination. This is because electrostatic potential of a O^{2-} ion in MgO gradually decreased as the coordination decrease, and on the whole process needs less energy. The band gap of MgO nanoparticles is calculated based on the equation $\alpha = A(h\nu - E_g)^{1/2}/h\nu$ where α, E_g and A are the absorption coefficient, band gap and constant respectively. The evaluated optical band gap energy of MgO nanoparticle is 5.25 eV and agrees well with values obtained in other works [23,24]. The results show that MgO is a wide and direct-gap semiconductor. This observed band gap value is red shifted from the standard value of bulk E_g (7.65 eV) [25]. The red shift of the direct band gaps exhibit the effect of the morphologies of crystals having various main active facets and response various excitation energy and so having different direct band gaps, and may be due to the quantum size effect.

3.3. Morphological studies

Fig. 3(a) and (b) shows the TEM and SEM images of MgO nanoparticles. These results show that the particles were in almost spherical shape with smooth surfaces. It was observed that some of the particles were well dispersed and most of them were aggregated. It shows the presence of almost spherical nanoparticles with average size of 16 nm ranging from 7 to 38 nm size were observed at Fig. 3(a, b). The observed nanostructures grow by a process involving rapid reduction, assembly and room temperature sintering of spherical nanoparticles. The TEM image is in good agreement with the sizes obtained from TEM image agree reasonably well with the XRD data. The high specific surface area and surface area to volume ratio of the prepared nanoparticles also tends to smaller particles as explained in XRD pattern of MgO.

3.4. Antibacterial activity

The antibacterial activity of prepared MgO nanoparticles was performed against Gram negative pathogen *Pseudomonas aeruginosa* and Gram positive pathogen *Staphylococcus aureus,* which are commonly found in water (Fig. 4). In our case, the MgO nanoparticles are more effective against Gram positive pathogen than