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Research Article

SYNTHESIS, CHARACTERIZATION AND ANTIBACTERIAL ACTIVITY OF ZnO NANOPARTICLES

K. RAVICHANDRIKA[1], P. KIRANMAYI[1*] AND R.V.S.S.N. RAVIKUMAR[2]

[1]Department of Biochemistry, Acharya Nagarjuan university, Nagrjuna Nagar - 522510, India, [2]Department of Physics, Acharya Nagarjuna University, A.P., India. *Email: kiranmayikodali@rediffmail.com

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ABSTRACT

In this paper, ZnO nanoparticles were prepared by a wet chemical method. The sample was characterized by X-ray diffraction (XRD), UV–Vis spectroscopy, Fourier transform infrared (FTIR) spectroscopy and photoluminescence. The average crystal size of the prepared ZnO nanopowder was determined by XRD. UV absorption spectrum revealed three bands at 448 nm, 536 nm and 818 nm respectively. The quality and purity of ZnO nanomaterial crystalline samples were confirmed by photoluminescence spectra. Disk diffusion method was used to determine the antibacterial activity of various classes of antibiotics in the presence of ZnO nanoparticles.

Keywords: X-ray diffraction, FTRI, ZnO nanoparticles, Antimicrobial activity.

INTRODUCTION

Nanoparticles are solid colloidal particles ranging in size from 10-1000 nm in which the active principle (drug or biologically active material) is dissolved, entrapped or encapsulated and/or to which the active principle is adsorbed or attached[1]. The nanoparticles possess unique physico-chemical, optical and biological properties which can be manipulated suitably for desired applications[2]. Nanotechnology is emerging as a rapidly growing field with its application in science and technology for the purpose of manufacturing new materials at the nanoscale level[3]. Zinc oxide has significant attention due to its various applications such as UV light-emitting diodes, laser diodes and catalysts[4]. The high exciton binding energy of ZnO would allow for excitonic transitions even at room temperature, which could mean high radiative recombination efficiency for spontaneous emission as well as a lower threshold voltage for laser emission[5]. ZnO is widely used to treat a variety of skin conditions, in products such as baby powder, barrier creams to treat diaper rashes and in calamine cream, antidandruff shampoos and antiseptic ointments[6]. In the present study, we report the synthesis of ZnO nanoparticles using wet chemical method. The characterization of ZnO nanoparticles using X-ray diffraction, Fourier transform infrared (FTIR), UV-Vis absorbance and photoluminescence spectra is discussed and also investigate the effect of zinc oxide nanoparticles on the antibacterial activity of different antibiotics.

MATERIALS AND METHODS

The zincoxide (ZnO) nanoparticles were prepared by wet chemical method[7]. The crystal structure of the sample was analyzed by means of X-ray diffractometer (PANalytical Xpert powder diffractometer (XRD). The absorbance spectra were recorded on ultraviolet – visible (UV-Vis) spectrometer (JASCO V-670). The composition quality of the synthesized material was characterized by Fourier transform infrared (Thermo Nicolet 6700 FT-IR spectrophotometer) spectroscopy in the mid-infra red range (400–4000 cm^{-1}). The photoluminescence (PL) spectra were measured on a spectrofluorometer (Horiba jobin-yvon Fluorolog-3) at room temperature.

Determination of antimicrobial activity

The test organism, *Proteus vulgaris* (MTCC 742) was procured from MTCC, Chandigarh, India. The agar disc diffusion method was employed to determine the antimicrobial activities of the ZnO nanoparticles. Disc-assay was found to be a simple, cheap and reproducible practical method[8]. A suspension of each sample of tested microorganism diluted prior to 10^{-1}, 10^{-2} and 10^{-3} (1 ml of 108 cells/ml) was spread on a solid agar medium in petridishes (Nutrient agar). Filter paper discs (4 mm in diameter) were soaked in 5 µl of the sample and placed on the inoculated plates and allowed to dry for 15 min, then incubated at 37°C for 24 h. The diameters of the inhibition zones were measured in millimeters[9].

RESULTS AND DISCUSSION

X-ray diffraction studies

XRD pattern of the prepared Zinc oxide nanopowder is shown in fig.1. The observed diffraction peaks of ZnO at 2θ = 31.72°, 34.38 °, 36.26°, 47.54° and 56.58° are associated with (100), (002), (101), (102) and (110). All the reflections can be assigned to the standard powder pattern for the pure hexagonal phase of ZnO with lattice constants a= 3.2516 Å, c = 5.2000 Å. The (hkl) values are agreed well with the standard card of ZnO powder sample (JCPDS file No: 36-1451) [10]. The crystallite size (t) of the prepared nanopowder can be calculated by using Scherrer's formula [11]

$$t = 0.9\lambda/\beta \cos \theta$$

Where λ is the wavelength of X rays used (1.54060 Å), β is the full width at half maximum (FWHM) and θ is the angle of diffraction. The crystallite size of prepared nano powder is found to be around 27 nm which is in the order of nano size.

UV- optical absorption spectroscopy

The UV – optical spectra of ZnO suspended in deionized water were recorded in SPECORD 50 Analytik Jena spectrophotometer from 200-800 nm. Optical absorption spectrum of ZnO nanoparticles are shown in fig.2. ZnO nanoparticles show three absorption bands in the UV-VIS-NIR region. In the present investigation, three bands are observed for ZnO nano particles, the bands at 448 nm, 536 nm and 818 nm respectively.

FT-IR spectroscopy

FT-IR spectrum of the synthesized ZnO nanoparticles showed (fig. 3) the fundamental mode of vibration at 3258.97 which correspond to the O-H stretching vibration, 2928.3 which corresponds to C-H stretching vibration and 1365 corresponds to C=O asymmetric C=O stretching vibration. 1637 corresponds to C=O symmetric stretching vibration. O-H bending of the hydroxyl group at 559 is observed. The absorption at 857 cm^{-1} is due to the formation of tetrahedral coordination of Zn. The peak at 1148 cm^{-1} indicated the saccharide structure and the bond at 1075 cm^{-1} is due to the C-O stretching vibration. The peak at 758 attributed to the C-O bond stretching. 642.85, 699.53 and 515.80 indicates the stretching vibrations of Zno nano particle.

Photoluminescence spectroscopy

PL spectrum of the present work recorded at room temperature (~300 K), showed three emission bands: one UV excitonic and two visible defect level emissions. The visible emissions in ZnO may originate from various defect levels such as (a) structural impurities (doping) (b) intrinsic defects due to interstitial Zn ion (c) ionized oxygen vacancies etc. However, as no dopants were added in the

present sample, structural impurities need not be considered as a factor influencing luminescence. As discussed in the following, intrinsic defects due to oxygen vacancy were applicable in explaining the prominent defect-related peaks in the PL spectra.

Photoluminescence spectrum of ZnO nanoparticles are shown in fig. 4. The emission spectrum of ZnO nanoparticles shows three bands. The bands are observed at 495 nm, 615 nm and 741 nm under the photon excitation.

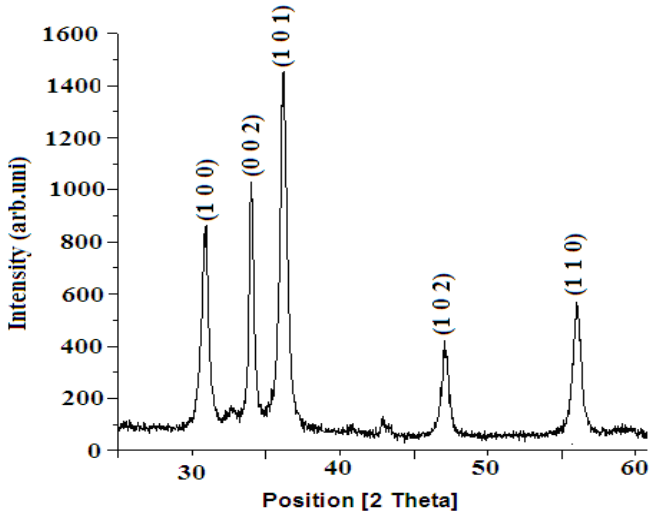

Fig. 1: X-ray powder diffraction patterns of the ZnO nanoparticles

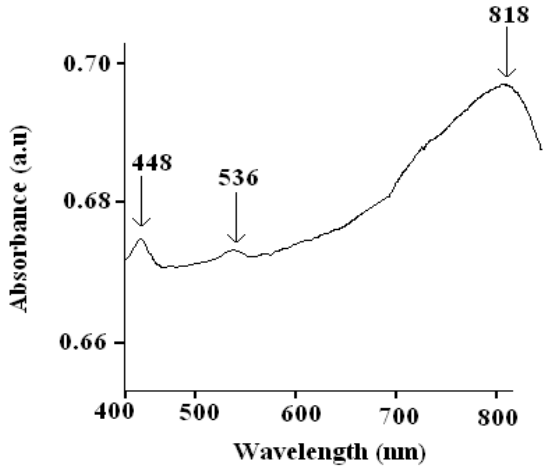

Fig. 2: UV–Vis absorption of the ZnO nanoparticles

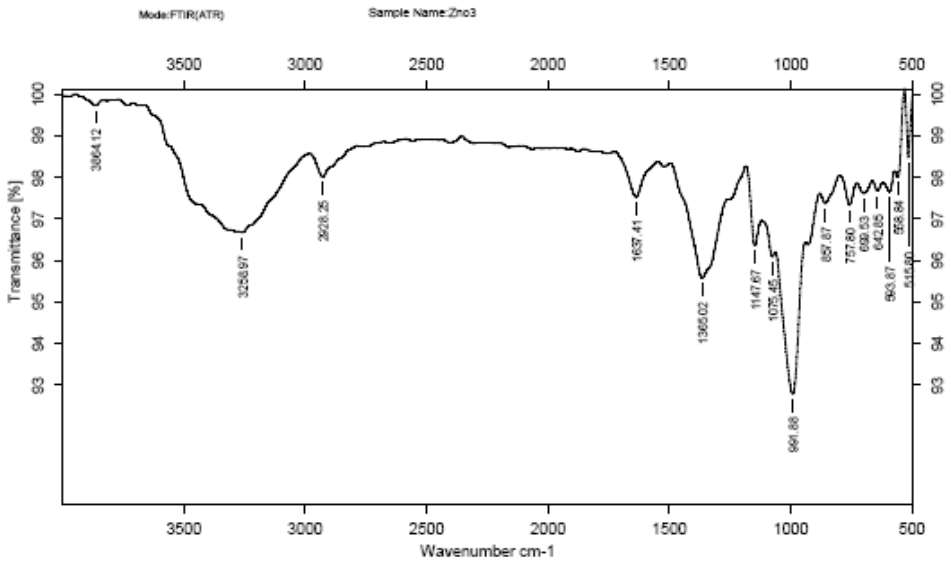

Fig. 3: FTIR spectrum of the ZnO nanoparticles

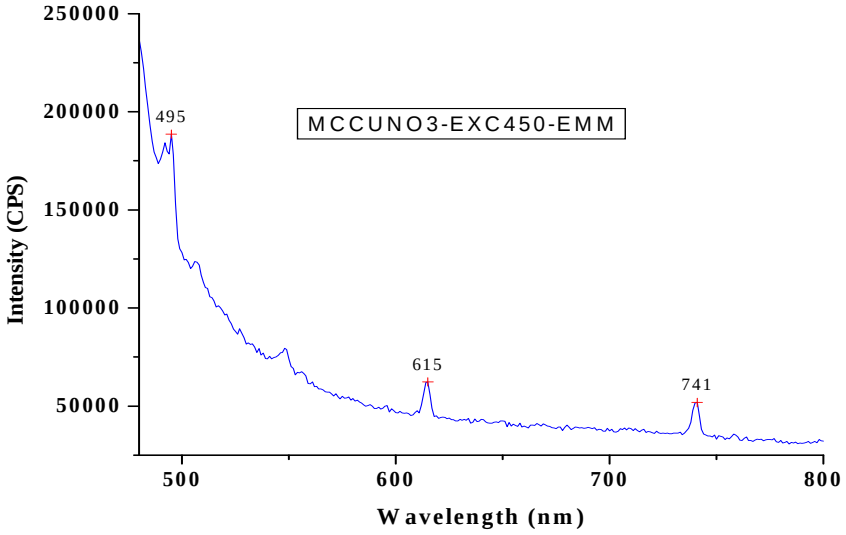

Fig. 4: PL spectra of the ZnO nanoparticles

Antibacterial activity

The antibacterial activity of antibiotics along with ZnO nanoparticles was investigated against pathogenic bacterium, *Proteus vulgaris* using disc diffusion technique. The diameter of inhibition zones around each disc is represented in table-1. *Proteus vulgaris* was resistant against penicillin and ampicillin but the highest increase in the inhibition zones (antibiotic with ZnO nanopraticles) were observed for erythromycin (4.5 mm). The moderate increase in inhibition zones were against penicillin (2.2 mm) followed by Ampicillin (2 mm) in combination with ZnO nanoparticles. In the present study 5 µl of the nanoparticles was taken as final product for antimicrobial assay.

Table 1: Zone of inhibition for *Proteus vulgaris*

Antibiotic	Zone of inhibition by antibiotic (mm)	Zone of inhibition by antibiotic with ZnO nanoparticles (mm)
Erythormycin	1 – 4.2	1 – 4.5
Penicillin	-	1 – 2.2
Ampicillin	-	1 - 2

CONCLUSIONS

ZnO nanoparticles have been prepared using wet chemical synthesis method. The structural characterization of synthesized nanoparticles is crystalline in structure and their diameter was around 27 nm. These structures clearly evident from XRD. The synthesized ZnO nanoparticles exhibit the UV absorption peak at 448 nm. The estimated direct band gaps are obtained to be 448 nm, 536 nm and 818 nm. In FT-IR spectroscopy pure ZnO nanoparticles shows stretching vibrations at 500-4000 cm^{-1}. The synthesized ZnO nanoparticles exhibit photoluminescence at 400-800 nm. The estimated direct band gaps are obtained to be 495, 615 and 741 nm. The present work proves it is simple and low cost for producing ZnO nanoparticles and the results signify that the ZnO nanoparticles potentiate bactericidal efficacy of macrolides and beta lactum antibiotics.

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