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Antimicrobial studies and characterization of ZnO nanoparticles by chemical method

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Abstract

Nowadays, nanotechnology is receiving worldwide recognition due to being its applications in various fields. Medium temperature and eco-friendly methods have shown great potential among nanoparticle synthesis. Many reducing agents are available for the synthesis of ZnO nanoparticles; here we presented a simple solution method for the development of nano crystalline Zinc Oxide particles. Zinc acetate dihydrate was used as a starting material and synthesized particles were characterized by UV-Visible, FT IR, SEM, and EDAX analysis. Characterization studies revealed hexagonal nano crystalline Zinc Oxide particles with excellent morphological properties. The synthesized nanoparticles exhibit excellent antimicrobial activities against gram-positive and gram-negative bacteria.

Keywords: Zinc Oxide nanoparticles; Simple solution method; characterization; antimicrobial studies

1. Introduction

Recently, there has been an expanding interest in the advancement of nano-sized semiconductors due to their noteworthy electrical and optical properties which are profoundly valuable in creating nano scaled optoelectronic and electronic gadgets with multifunctionality [1-2]. What not can be accomplished with the huge and cumbersome, may all the more effectively be finished with the little and slick [3]. That is the reason nanotechnology which is the study of the minuscule, and the peculiar and jumpers properties brought about by diminutiveness alone have gained such a great amount of enthusiasm during the most recent decades [4]. It is a broad field associated with science, physical science, medication, material science just as to applied advances. The measure of potential applications is tremendous, and the expected advantage of innovation and society are viewed as immense. Although a few applications based on ideas of nanotechnology have been at the market for quite a while, the field can even now be considered as a youthful one and a ton of things are left to be done, found, portrayed, clarified, and abused [5].

A ton of examination is accordingly going on around the world, and the European Union considers nanotechnology as a field of most elevated need [6]. Not just has this Zinc oxide had numerous flexible properties for UV gadgets, spintronic gadgets, and sensor applications. Additionally ZnO has been usually utilized in its polycrystalline structure more than a hundred years in a wide scope of uses. This lights many exploration minds everywhere on over the world and makes eagerness to create legitimate development and preparing strategies for the blend of Zinc oxide [7]. Zinc oxide is otherwise called "Lu-Gan-Stone" in China, Zinc oxide has been utilized in clinical treatment for the very number of 2years in China. The exploration of ZnO is bursting into flames directly from the earliest starting point of 1950, with various surveys on electrical and optical properties like N-type conductivity, assimilation spectra, and electroluminescence rot boundary. The idea of excited atom in semiconductors which was examined by Haynes

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supporting a key distribution by Park et al worried about the excitonic discharge of ZnO is the absolute first stride put for the development and improvement of ZnO research in the mid of 1960 [8].

In 1966 the Raman Effect investigation of ZnO by Damen and Porto prompts the ID of ZnO phonon energies. The time of 1970 for ZnO dies in assembling of less difficult ZnO gadgets like fired varistors, piezoelectric transducers, and so forth. In the field of ZnO research, the last decade was mainly concerned with the optimization of different growth parameters and processing techniques [9]. Thus currently research work related to the production of high quality, reproducible Ptype conducting ZnO for device application is the main focus. ZnO has now become one of the most studied material in the last seven years as it presents very interesting properties for optoelectronics and sensing applications, in nano range synthesis [10]. While talking about nanotechnology is the question of what it is, A chemist may state that atoms and molecules have been nano all the time, but usually single atoms and molecules are not considered while discussing the nano concept even when they are in the size regime of nanometers. An extreme answer at the other end of the scale is to consider everything that has at least one dimension smaller than one hundred nanometers as nanotechnology [11].

The possible shapes and structures of nano objects is vast and fascinating, spanning for example dots, pillars, spirals, flowers, cups, donut and many more where a small selection is displayed in Picture (1).

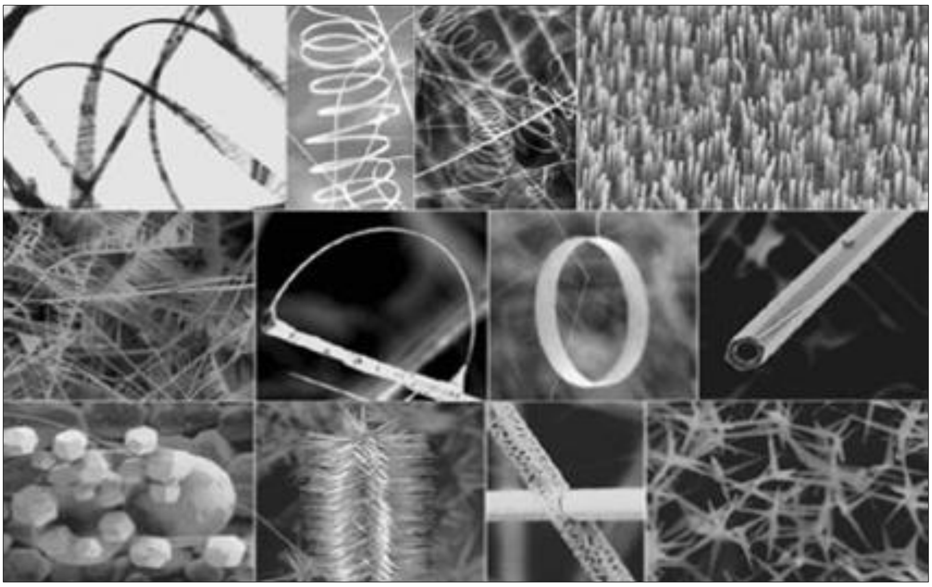

Figure 1 Examples of nanostructures of ZnO

2. Material and methods

Zinc acetate dihydrate (as a zinc source) and ammonia were used as precursors for the formation of the zinc oxide nanopowder. Deionized water was used for dilution. All chemicals used in the experiment are of analytic reagent grade. Zinc acetate dihydrate and purchased from Merck, India. Double distilled deionized water was used throughout the experiment. Herein, we reported a simple solution method to prepare ZnO nanoparticles, using ammonia as the solvent and zinc acetate as the zinc source. The reaction was carried out in the air and ZnO nanoparticles were obtained in one step. During this process, 2.19g of Zinc acetate dehydrate is weighed and dissolved in 400ml of deionized distilledwater.100ml of ammonia added drop by drop till the completion of the reaction. After the completion of the reaction, the obtained product was kept in a shaker for the next 24 hours. After 24 hours the precipitate obtained was decanted and filtered. The filtered precipitate was dried to 100 degrees Centigrade in a hot air oven.

2.1. Characterization of ZnO nano powder

The X-ray diffraction studies of ZnO NPs were carried out using the Rigaku 600Miniflex X-ray diffraction instrument (XRD) with Cukα radiation (λ = 1.5412 Å) in the scanning range of 100-800. To confirm the absorbance of ZnO NPs and to observe the changes in the absorbance caused due to variations in reaction conditions, UV–visible (UV–vis) spectra were carried in the wavelength range of 200–600 nm using Agilent Technologies, Cary 60 UV–vis.

To identify the characteristic functional groups present on the surface of the ZnO, Fourier transforms infrared (FTIR) spectra of all samples were recorded by using JASCO INC 410, Japan, in a range of 400–4000 cm−1. The surface morphology of all synthesized ZnO was studied by field emission scanning electron microscopy (FE SEM) and elemental analysis was performed by energy-dispersive X-ray (EDX) spectroscopy (JSM-6701F, JOEL, Japan).

2.2. Structural characterization

To get exact information about the crystal structure, surface morphology, particle size, etc. the following characterization techniques are applicable.

- XRD (X-ray Diffraction)
- SEM (Scanning electron microscope)

2.3. Optical characterization

As we know zinc oxide has a wide range of applications in the field of optoelectronics devices on putting the sample to following characterization techniques gives information related to optical properties.

- UV-Visible Spectroscopy
- Fourier Transform Infrared Spectroscopy (IR)

3. Results and discussion

3.1. XRD Analysis

Figure 2 shows the XRD diffraction pattern of the ZnO nanoparticles. The peaks are indexed as31.82º(100),34.54º(002),36.42º(101),47.46º(102),56.74º(110),62.92º(103),66.06º(200),68.42º(112),69.06º (201) and 78.82º (202) respectively. All diffraction peaks of the sample correspond to the characteristic hexagonal wurtzite structure of zinc oxide nanoparticles Similar, X-ray diffraction patterns were reported. Diffraction patterns corresponding to impurities are found to be absent. This proves that pure ZnO nanoparticles were as synthesized. X-ray diffraction shows a high degree of orientation. It is found that form is anisotropic that on average crystallites may be regarded as cylinders but they are right prisms whose cross-section is an irregular hexagon. The size of the crystals was also calculated using Scherrer's equation .X-ray diffraction data indicates that ZnO nanoparticles have a hexagonal unit cell structure. Individual nanoparticles having size nm were found. There is an excellent agreement between experimental and theoretical data.

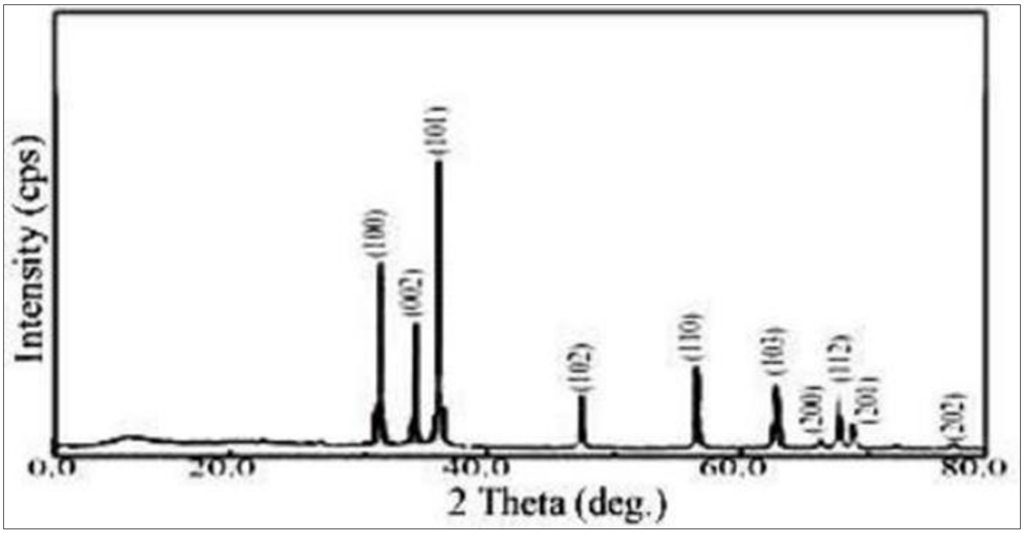

Figure 2 XRD graph of ZnO nanoparticles

3.2. SEM and EDAX Analysis

SEM studies were conducted to examine the morphology of the prepared nanopowder. The SEM images of the obtained ZnO nanopowder are shown in Figure (3) Morphology of the sample was investigated using SEM, Figure (3) shows typical SEM images of the sample. Scanning electron microscopy shows the hexagonal structures of zinc oxide Figure (3) SEM images demonstrate that a bulk quantity of flower-like bunches exists. Figure (4) indicates EDAX studies revealed the elemental analysis of the synthesized sample.

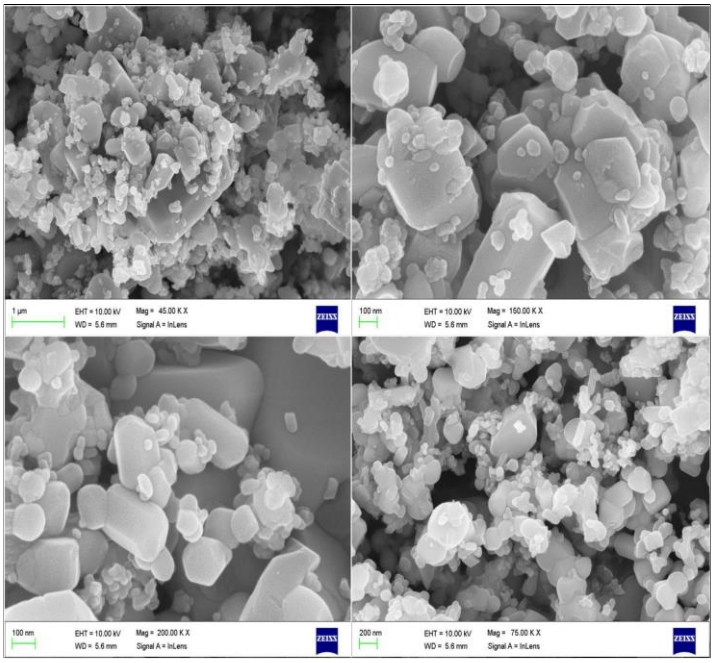

Figure 3 SEM image of ZnO nanoparticles

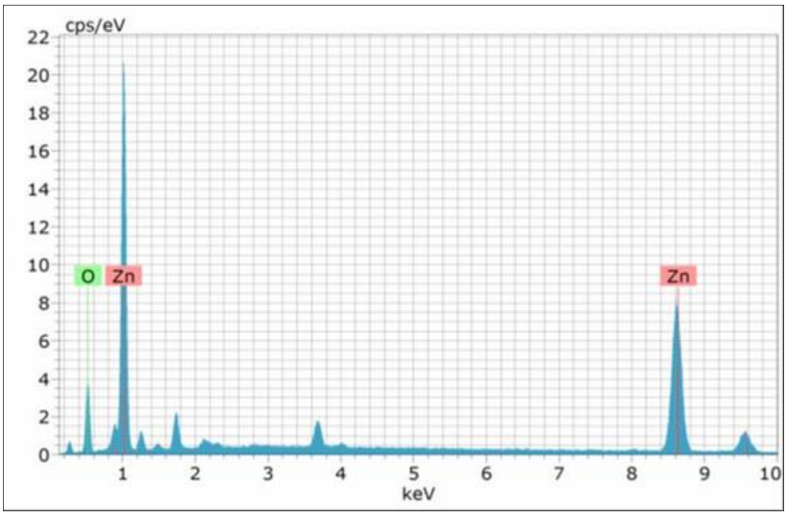

Figure 4 EDAX image of ZnO nanoparticles

3.3. FTIR Analysis

Figure (4) shows FTIR spectra of ZnO nanoparticles. Infrared studies were carried out in order to ascertain the purity and nature of the metal nanoparticles. Metal oxides generally give absorption bands in fingerprint region i.e. below 1000 cm^{-1} arising from inter-atomic vibrations. The peak observed at 3452.30 and 1119.15 cm^{-1} are may be due to O-H stretching and deformation, respectively assigned to the water adsorption on the metal surface. The peaks at 620.93 cm^{-1} are corresponding to Zn-O stretching and deformation vibration, respectively. The metal-oxygen frequencies observed for the respective metal oxides are in accordance with literature values reported similar FTIR spectra observed of zinc oxide nanoparticles in the investigation.

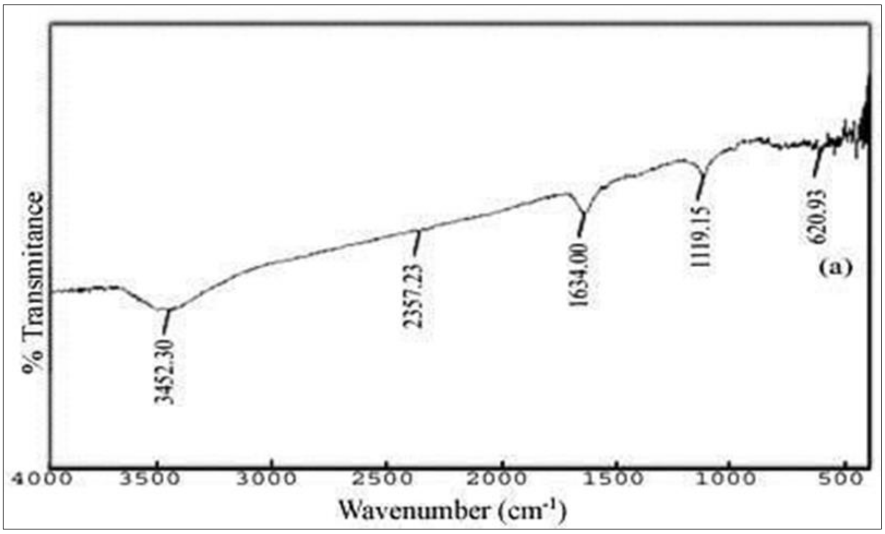

Figure 5 FTIR spectrum of ZnO nanoparticles

3.4. UV–VIS Spectroscopy Analysis

In order to observe the UV spectroscopy of synthesized ZnO nanoparticles, they were sonicated in distilled water for about 15min and UV spectra were recorded. The absorption peak was recorded in each spectrum in range of 360–380nm which is a characteristic band for the pure ZnO.

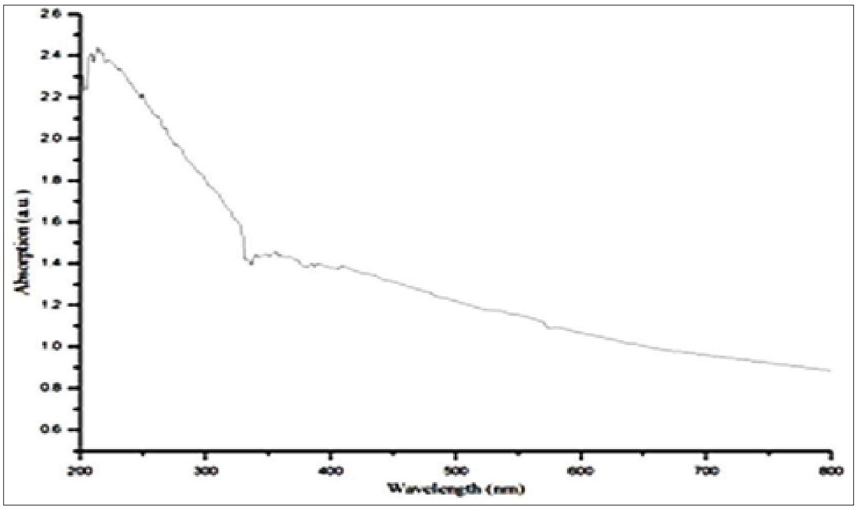

Figure 6 UV-Visible spectroscopy graph of ZnO nanoparticles

3.5. Anti-microbial studies

Antimicrobial study of different ZnO NPs was performed by agar well diffusion method. The relative activities of these samples were studied against both Gram-positive *Staphylococcus aureus* and Gram-negative *E.coli* bacteria. In this method, in each well 1mg/ml concentration of all ZnO NPs was inoculated on nutrient agar plates which were previously seeded by 100 µl of 24h old bacterial inoculate. ZnO samples were sonicated for 15min in distilled water before inoculation. Then the plates were incubated at 37°C for 24h for the growth of microorganisms. Antimicrobial activity was observed by measuring the inhibition zone diameter (mm). Standard and control studies were depicted in figure 6 and 7.

Table 1 Antibacterial studies of synthesized nanoparticles

S. No.	Test Organism	Zone of Inhibition (mm)		Results
		50 (µL)	100 (µL)	
1.	*E. coli*	6	10	Activity
2.	*S.aureus*	8	12	Activity

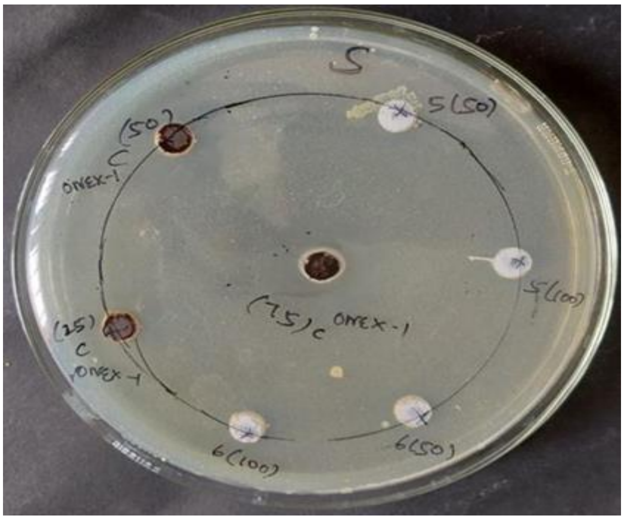

Figure 7 Gram Positive *S.aureus*

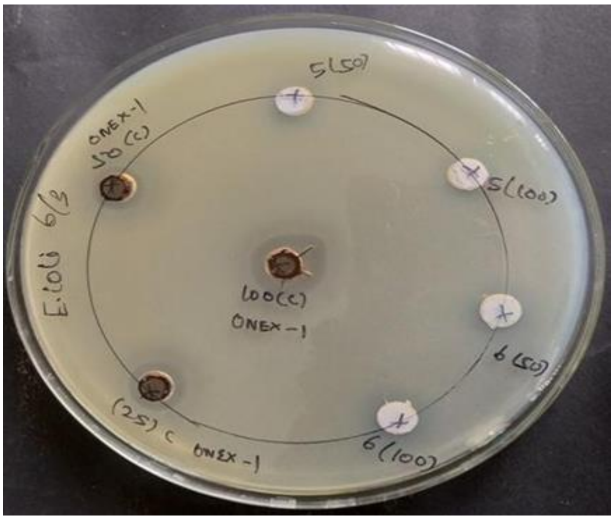

Figure 8 Gram negative *E. coli*

4. Conclusion

ZnO nanoparticles have been synthesized by using simple solution method and the characterization was done using XRD, SEM, EDAX, UV-Visible and IR. The antimicrobial studies were also done. These studies confirmed the prepared nanoparticles exhibit hexagonal wurtzite. From UV-Visible spectroscopy, the absorption peak was recorded in each spectrum in range of 360– 380nm which is a characteristic band for the pure ZnO, however ZnOs shows band gap of 3.3 eV at room temperature**.** From FTIR, the stretching and bending was found to be 620.93cm^{-1} which proved to be Zn-O Stretching. The particle size and structure was found using XRD and the values match with the reference. These ZnO nanoparticles have many applications in many industries such as in the manufacture of lasers fluorescent tubes and so forth. Additionally the antibacterial activity of the ZnO nanoparticles was examined against *E.coli* and *S. aureus* . The ZnO nanoparticles showed a slightly high degree of antibacterial activity when compared to control samples.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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