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RESEARCH ARTICLE

Synthesis and Characterization of ZnO Nanoparticles by Simple Chemical Method

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ABSTRACT

In this present study, Zinc nitrate was used to create ZnO nanoparticles using the precipitation process. UV-vis absorbance, X-ray diffraction, Scanning Electron Microscopy (SEM) with Energy Dispersive X-Ray Analysis (EDX), and transmission electron microscopy (TEM) investigations were used to characterize the nanoparticles. The hexagonal unit cell structure of ZnO nanoparticles was revealed by XRD patterns. The produced ZnO nanoparticles' shape and particle size are visible in SEM and TEM images. The hexagonal wurtzite crystal structure of the zinc oxide nanoparticles was shown by the XRD data, indicating their high degree of crystallinity. The SEM picture demonstrated the spherical shape of the nanoparticles made for this investigation.

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Introduction

Recently, there have been possible scientific and technological uses for nanoscience and technology. Materials that are specifically nanocrystalline are considered appropriate for those uses. For the majority of these new material classes' uses, extensive research was done (Bayda et al., 2019; Sim & Wong, 2021). Because of its special qualities, ZnO with particle sizes in the range of few nm is considered the only nanocrystalline material that is appropriate for a variety of applications (Alnehia et al., 2022; Anantha kumar et al., 2018). Since of their unique characteristics, nanoparticles with sizes between 1 and 100 nm have attracted a lot of interest for application. Zinc oxide nanoparticles have drawn the most interest among the many nanoparticles (Sirelkhatim et al., 2015; Zhou et al., 2023). ZnO is a wide band gap (3.37 eV) semiconductor with outstanding electrical conductivity and high transparency. At ambient temperature, it has a huge excitation binding energy of 60 meV, which is significantly bigger than that of other materials (Amin et al., 2023; Maher et al., 2023; Zhou et al., 2023). Due to its similar qualities to GaN, Zinc oxide is a promising choice for optoelectronic applications in the short wavelength range (green, blue, and UV), information storage, and sensors (Ding et al., 2018; Panchakarla et al., 2007). ZnO nanoparticles show great potential as candidates for a number of uses, including solar cells (Hames et al., 2010), varistors (Jun et al., 2002), gas sensors (Cheng et al., 2004), biosensors (Topoglidis et al., 2001), nanogenerators (Gao et al., 2005), photodetectors (Dwivedi et al., 2013), and photocatalysts (Kamat et al., 2002). The literature review revealed that a number of methods, including sol-gel, microemulsion, spray pyrolysis, thermal breakdown of organic precursor, electrodeposition, ultrasonic, microwave-assisted procedures, chemical vapor deposition, hydrothermal and precipitation methods, have been developed for the preparation of ZnO nanopowders. While chemical synthesis has been widely employed since it is less expensive and simpler to use, the majority of these approaches have not been used substantially on a big scale. In the current work, we report on the chemical synthesis of ZnO nanoparticles and discuss their characterization through UV-vis absorbance, X-ray diffraction, Scanning Electron Microscopy (SEM) with Energy Dispersive X-Ray Analysis (EDX), and transmission electron microscopy (TEM).

Material and Methods

Preparation of Zinc oxide nanoparticles

Zinc sulfate was dissolved in deionised water. Meanwhile, Buffer solution (dissolving sodium hydroxide and sodium carbonate in water) was prepared and the solution was added drop wise into zinc sulfate solutions and thoroughly stirred until a white precipitate could be observed. The precipitates was filtered, washing with distilled water, drying at 100°C for 2h and by placing the samples directly in the electrical furnace calcinations at 300°C.

Characterization of the synthesized semiconductor nanoparticles

The nanoparticles are generally characterized by their size, morphology and surface charge, using such advanced microscopic techniques as UV-Visible absorption spectroscopy, X-ray Diffraction (XRD), scanning electron microscopy (SEM) with EDAX and transmission electron microscopy (TEM).

Results and Discussion

UV-Visible absorption spectroscopy

The UV-vis absorption spectra of zinc oxide nanoparticles are shown in Fig 1. The zinc oxide nanoparticle was dispersed in ethanol with concentration of 0.1% wt and then the solution was used to perform the UV-vis measurement. The spectrum reveals a characteristic absorption peak of zinc oxide at wavelength of 378 nm is the characteristic peak for hexagonal wurtzite ZnO. Compared with bulk ZnO, the blue shift observed in the ZnO structure is due to the size effect (Dhoke, 2023).

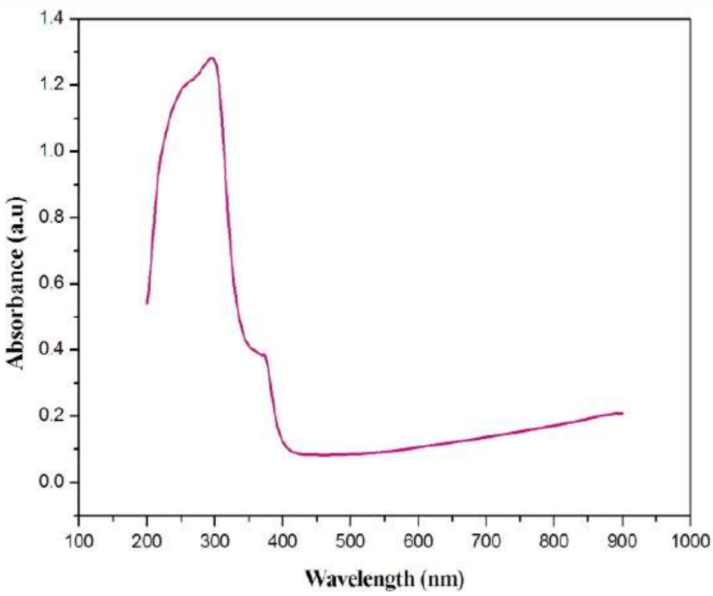

Fig 1. UV-Visible absorption spectrum of ZnO nanoparticles

XRD Analysis

The ZnO nanoparticles are of a wurtzite structure (hexagonal phase). All the diffraction peaks can be well indexed to the hexagonal phase of ZnO reported in JCPDS card (No. 36-1451, a = 0.3249 nm, c = 0.5206 nm). The results revealed that the products were consisted of pure phases. The XRD pattern did not show any diffraction peaks associated with the contaminants, indicating that the synthesised product was extremely pure. Additionally, it was evident that the diffraction peaks in (Fig 2) were smaller and more intense, suggesting that the as-synthesised ZnO product had an excellent crystalline character (Ali et al., 2022). The crystalline size of the ZnO nanoparticles (D) is evaluated according to the Debye–Scherrer equation, $D = K\lambda/(\beta\cos\theta)$, where K is the scherrer constant, λ the X-ray wavelength, β the peak width of half maximum, and θ is the Bragg diffraction angle. The particle size of zinc oxide nanoparticles has been found to be 45.2 nm.

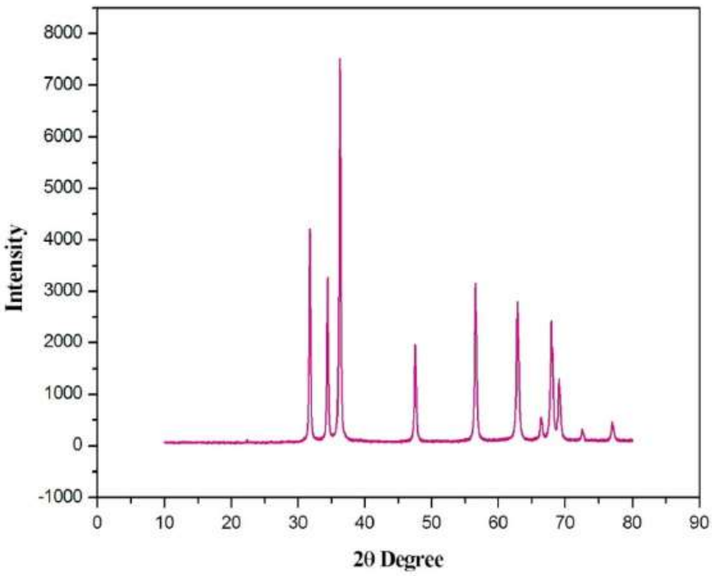

Fig 2. XRD pattern of ZnO nanoparticles

SEM with EDX Analysis

The surface morphology of the chemically synthesized zinc oxide nanoparticles was identified by Scanning Electron Microscope (Jayachandran et al., 2021). The zinc oxide nanoparticles have a spherical form (Fig 3). Agglomeration of particles is clearly visible in the nano-sized ZnO powders, and this is consistent with the agglomeration coefficient. The EDAX spectra of zinc oxide nanoparticles are presented in Fig 4. The peaks corresponding to Zn and O are clearly observed in the EDX spectrum at their normal energy and the results are clearly indicating the formation of zinc oxide nanoparticles (Faisal et al., 2021; Umar et al., 2019).

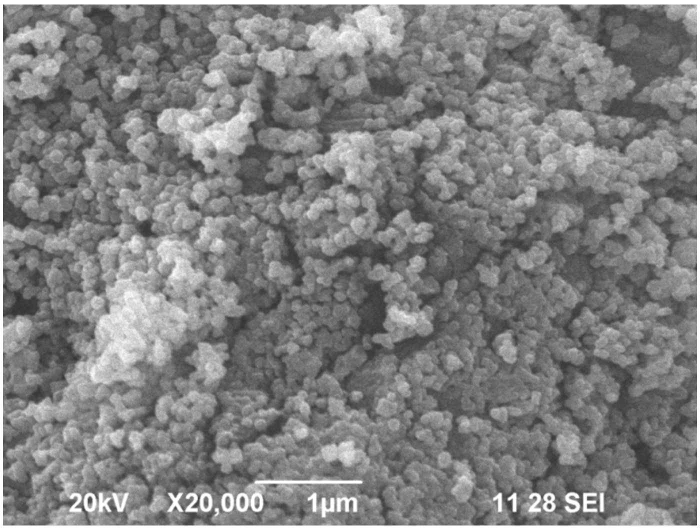

Fig 3. SEM image of ZnO nanoparticles

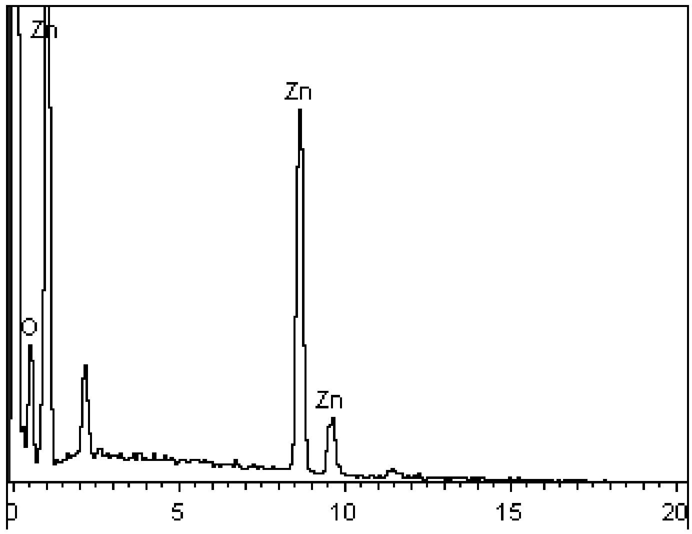

Fig 4. EDX image of ZnO nanoparticles

TEM Analysis

Transmission electron microscopy was used to better characterise the chemically synthesised nanoparticles. TEM analysis was used to look at the sample's form and particle size (Malatesta, 2021; Smith, 2015). Figure 5 displays the TEM pictures of zinc oxide nanoparticles produced using a straightforward technique. Figure 5 depicts the TEM picture of the zinc oxide nanoparticles, which reveals spherical-shaped metal oxide nanoparticles dispersed throughout the size range of 30–50 nm.

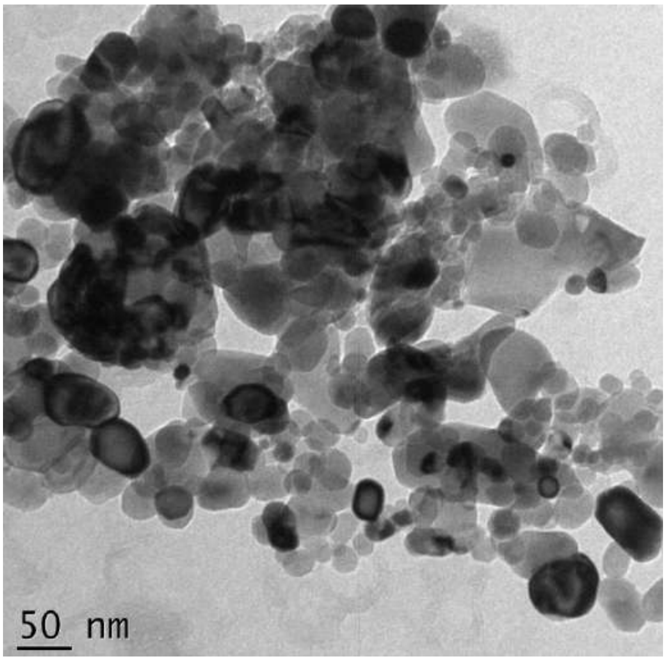

Fig 5. TEM image of ZnO nanoparticles

Conclusion

The zinc oxide nanoparticles have been synthesized by simple chemical route and were characterized by using UV-Visible absorption spectroscopy, XRD, SEM with EDX and TEM analysis. The ZnO nanopaticles were crystalline nature and hexagonal wurtzite phase are indicated by the XRD pattern. The acquired pictures of the zinc oxide from scanning electron microscopy and transmission electron microscopy show that the particles are essentially spherical in shape. The material's good yield and purity are confirmed by an EDX spectrum. The synthesized zinc oxide nanoparticle is a promising candidate for the applications in various fields especially in water purification.

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Conflict of interest

All authors declare that there is no conflict of interest in this work.

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