

Preparation and Characterization of ZnO Nanoparticles Using a Liquid-Phase Chemical Route

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Abstract

ZnO nanoparticles (NPs) were successfully synthesized using a liquid-phase synthesis via the co-precipitation method. The structural, morphological, optical, and electrical properties of the synthesized nanoparticles were systematically investigated. X-ray diffraction (XRD) analysis confirmed the formation of a highly crystalline hexagonal wurtzite structure of ZnO without any secondary phases. The average crystallite size was found to be in the nanometer range. Scanning electron microscopy (SEM) revealed the presence of nearly spherical and hexagonal-shaped nanoparticles with slight agglomeration. These results suggest that the synthesized ZnO nanoparticles are promising for applications in electronic and sensing devices.

Keywords: ZnO Np's; liquid-phase synthesis; XRD; SEM

1. Introduction

Nanomaterial's can generally be synthesized by three major approaches: liquid-phase synthesis, gas-phase synthesis, and vapour-phase synthesis. Among these methods, liquid-phase synthesis is widely used due to its simplicity, low cost, and ability to produce nanoparticles with controlled size and morphology. Various techniques under liquid-phase synthesis include co-precipitation, sol-gel processing, hydrothermal synthesis, microwave synthesis, and son chemical synthesis. [1-2].

Zinc oxide (ZnO) is an important n-type semiconducting metal oxide with a wide direct band gap of 3.37 eV at 300 K and a large exciton binding energy of about 60 meV. Due to its excellent electrical, optical, and piezoelectric properties, ZnO has attracted considerable attention for applications in sensors, optoelectronic devices, pigments, coatings, and cosmetics [3-5].

In the present work, ZnO nanoparticles were synthesized by a liquid-phase co-precipitation method, which is simple, cost-effective, and environmentally friendly. The synthesized samples were characterized using X-ray diffraction (XRD) and scanning electron microscopy (SEM).

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2. Experimental

• Method of Preparation

ZnO nanoparticles were synthesized by the liquid-phase co-precipitation method. In this process, 0.2 M zinc acetate dehydrate was dissolved in 100 mL of deionized water and ground for 15 minutes to obtain a homogeneous solution. This solution was then mixed with a 0.02 M sodium hydroxide (NaOH) solution with continuous stirring using a glass rod. After mixing, the solution was kept under constant magnetic stirring for 15 minutes and subsequently ground again for 30 minutes. During this process, a white precipitate was formed at the bottom of the solution.

The supernatant liquid was carefully discarded, and the obtained precipitate was washed several times with deionized water and methanol to remove unwanted by-products and impurities. The product was then filtered using Whatman filter paper to obtain the precipitate in the form of a white paste. This paste was dried in a vacuum oven at 80°C for 4 hours to remove moisture and obtain a dry product.

The dried material was then crushed into a fine powder using a grinding machine. Finally, the obtained powder was calcined at 800°C for 6 hours in an auto-controlled muffle furnace (Gayatri Scientific, Mumbai, India) to remove remaining impurities and to obtain the final ZnO nanoparticles with improved crystallinity [6-8].

3. Results and Discussion:

• XRD pattern of the ZnO nanoparticles:

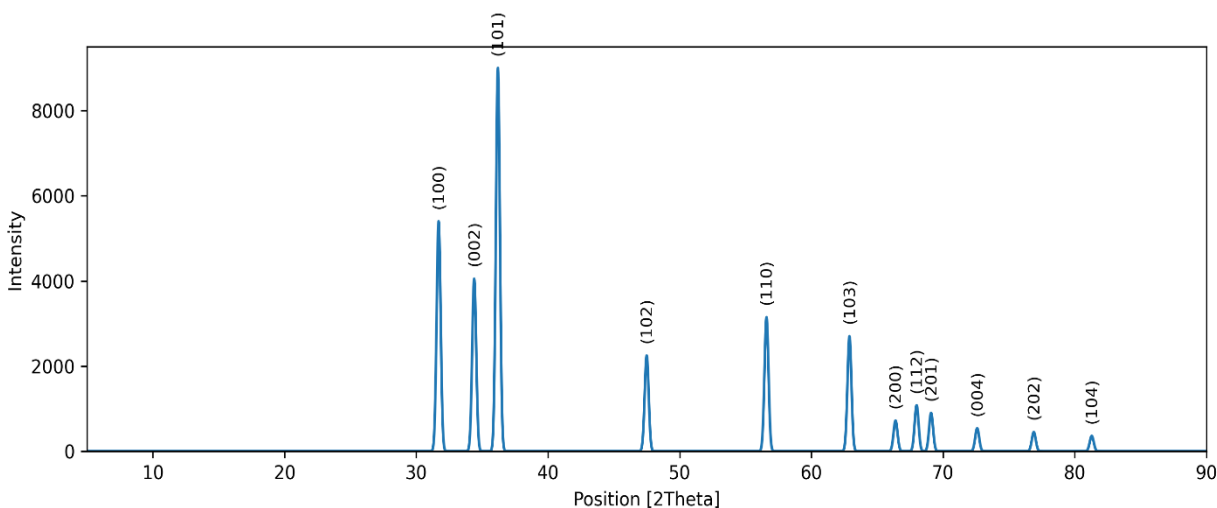


Figure 1. XRD pattern of the ZnO nanoparticles

The crystalline structure and phase purity of the synthesized ZnO nanoparticles were investigated using X-ray diffraction (XRD) analysis. The XRD pattern Fig. 1. exhibits several distinct diffraction peaks located at 2θ values around 31.7°, 34.4°, 36.2°, 47.5°, 56.6°, 62.9°, 66.4°, 68.0°, 69.1°, 72.6°, 76.9°, and 81.3°, which correspond to the crystallographic planes (100), (002), (101), (102), (110), (103), (200), (112), (201), (004), (202), and (104), respectively. These diffraction peaks are well indexed to the hexagonal wurtzite crystal structure of ZnO and are in good agreement with the standard JCPDS data (card no. 36-1451). The absence of any additional impurity peaks in the XRD pattern confirms the high purity of the synthesized ZnO nanoparticles.

Among the observed peaks, the (101) reflection shows the highest intensity, indicating the preferred orientation and good crystallinity of the ZnO nanoparticles. The sharp and well-defined diffraction peaks further suggest the formation of highly crystalline ZnO nanostructures. The average crystallite size of the ZnO nanoparticles can be estimated using the Debye–Scherer equation based on the full width at half maximum (FWHM) of the most intense diffraction peak. The Nan scale broadening of the peaks indicates that the synthesized particles are in the nanometer size range. These results confirm that the liquid-phase co-precipitation method successfully produced pure and crystalline ZnO nanoparticles with a hexagonal quartzite structure [9-11].

- **Scanning Electron Microscopy (SEM) of the ZnO nanoparticles**

Figure 2. (a) And (b) shows the SEM micrograph of ZnO nanoparticles synthesized by using Liquid-phase method via co-precipitation. It is observed from micrographs, particles are in both spherical and hexagonal shape with an average size of 47 nm. The particle size observed in SEM measurement is less than the crystallite size 52 nm using XRD measurement [12-14].

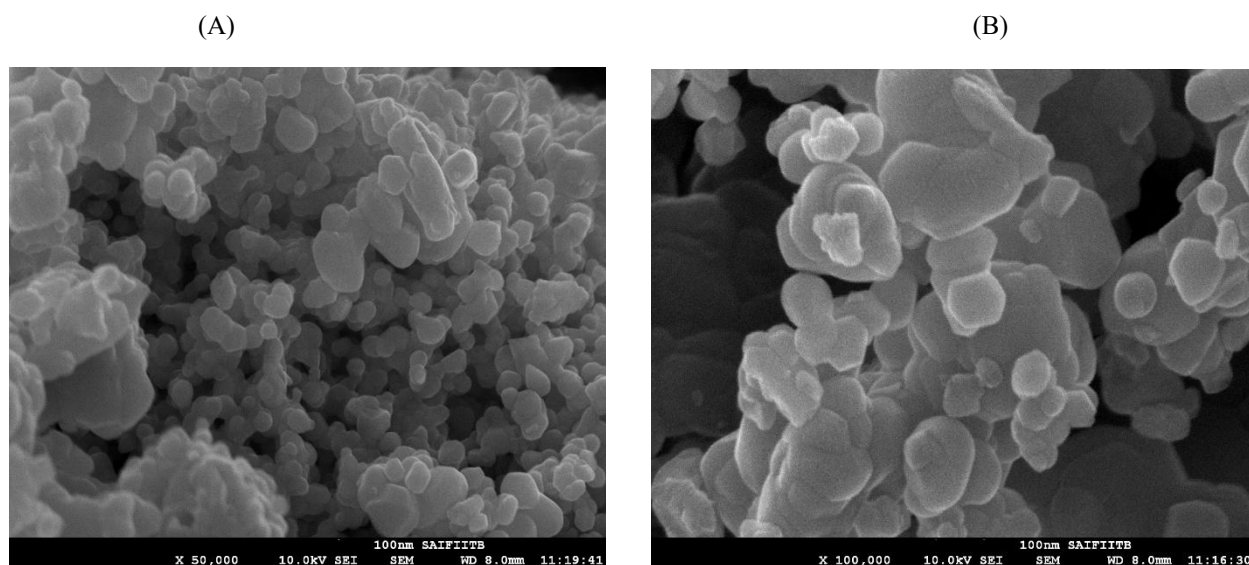


Figure 2. (A) (B) SEM micrograph of ZnO nanoparticles

4. Conclusion

In the present work XRD results confirmed the formation of crystalline ZnO with a hexagonal quartzite structure and indicated good phase purity of the synthesized nanoparticles. The average crystallite size was found to be in the nanometer range, confirming the successful formation of ZnO nanostructures. SEM analysis revealed the morphology and surface features of the synthesized ZnO nanoparticles, showing the formation of well-defined nanostructured particles with relatively uniform distribution. The results demonstrate that the liquid-phase co-precipitation method is a simple, cost-effective, and efficient technique for the synthesis of ZnO nanostructures. Therefore, the prepared ZnO nanoparticles may be suitable for various potential applications in electronics, sensors, photo catalysis, and optoelectronic devices.

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