# Synthesis and Characterization of Zinc Oxide Nanoparticles

A report

submitted in partial fulfillment

FOR THE DEGREE OF

**MASTER OF SCIENCE IN CHEMISTRY**

Under The Academic Autonomy
National Institute of Technology, Rourkela


**BY**

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## ACKNOWLEDGEMENTS

I would like to take this opportunity to express my deep sense of gratitude and admiration to my research supervisor Dr. Aparna Mondal, Department of Chemistry, National Institute of Technology, Rourkela, for introducing the present project topic and for her inspiring guidance and valuable suggestion. I most gratefully acknowledge her constant encouragement and help in different ways which will help me to complete this project.

I would also like to acknowledge to Prof. N. Panda, Head, Department of Chemistry, National Institute of Technology, Rourkela, for allowing me to use the facilities in the laboratory.

My sincere gratitude is to Mr. Amar Kundu and Mr. Bappaditya Mondal for their guidance, and valuable suggestions in doing the experimental work & preparing this report.

I thank all the faculty members & staff members of Department of Chemistry for their support and help. I would also like to thank all my friends. Last but not the least, I remember with gratitude my family members who were always a source of strength, support and inspiration.

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## ABSTRACT

In the present work, pure zinc oxide nanoparticles (ZnO) were successfully synthesized by a precipitation method using zinc acetate dehydrate and sodium hydroxide as the precursor materials. The as-prepared precursor was calcined at 500°C and 800°C temperatures for 2h. The samples were characterized by X-ray diffraction (XRD). The XRD spectra indicate that the ZnO crystal has a hexagonal wurtzite structure. Different compositions of zinc/iron oxides nanocomposites will be synthesized and characterized using XRD, IR, SEM, UV-Vis, and PL studies. The prepared nanocomposites will also be applied for removal of toxic metal ions from aqueous solutions.

## 1. Literature Review

Zinc oxide (ZnO) is an inorganic compound and usually appears as a white powder. Nanostructured ZnO powder is a versatile and technologically interesting semiconductor materials and widely used as an additive into numerous materials and products including plastics, glass, cements, rubber, ceramics, lubricants, pigment in paints with UV-protective and fungistatic properties, adhesives, foods (source of zinc nutrients), batteries, spacecraft protective coatings, first aid tapes, fire retardants, as a catalyst, photocatalyst, cigaret filters and healing ointments, semiconductor devices, in optical waveguides, in piezoelectric materials, and many more [1-8].

ZnO is II-VI semiconductor because zinc and oxygen appear to the $2^{nd}$ and $6^{th}$ group of periodic table, respectively. This semiconductor is an important material and used in emerging applications for transparent electrode in liquid crystal displays and in energy-saving or heat-protecting windows owing to its several properties such as good transparency, high electron mobility, wide band group, strong room temperature luminescence, etc. ZnO as thin-film transistor and light-emitting diode are forthcoming. Because of such versatile properties, it has great potential in applications like transparent conducting electrode in flat panel displays and window layers in thin film hetero junction solar cells, laser diode, optoelectronic devices and devices for solar energy conversion [9]. Apart from this, ZnO also demonstrates a significant growth inhibition of a broad spectrum of bacteria [10]. The ZnO nanostructures are also found to have potential application in nano devices such as nano gas sensor. ZnO in the form of nanostructures would enhance the gas-sensing properties of sensors as its surface area is high.

Zinc oxide mainly crystallizes in three forms: (i) hexagonal wurtize, (ii) cubic zincblende, and the rarely observed (ii) cubic rock salt. At ambient conditions, the wurtzite structure is most stable. The zincblende form can be stabilized by the growth of ZnO on substrates with cubic lattice structure. The zinc and oxide centers are tetrahedral in nature in both the cases. The rocksalt (NaCl-type) structure is observed only at relatively high pressure about 10 GPa. In earth crust, ZnO is present as a mineral zincite; however, most ZnO used commercially is synthesized synthetically.

A method for economical mass production and determination of conditions favorable for the synthesis of ZnO nanostructures would be very useful. That is why the study of synthesis and understanding of ZnO nanostructures is of great interest and technological important [6-10].

Various solution-phase methods including solvothermal [11], sol-gel [12], template-based [13], and templateless [14] chemical methods have been consolidated and are now fashionable for synthesizing ZnO nanoparticles. Although the vapor-phase growth of ZnO nanostructures is one of the most widely explored methods for obtaining high quality crystals, but they require sophisticated instrumental systems and expensive source materials [15,16]. Solution-phase methods are very attractive and popular as compared to the vapor-phase methods because they can be obtained with good productivity and cheaper and also the shape and size are easily tunable. As the shape of the ZnO particles such as rods, wires, plates, rings, flowers, triangles, hierarchical structures, and dendrites depends on the reaction conditions during their formation, different physical or chemical methods have been used to synthesize ZnO nanoparticles [17,18]. Indeed, a lot of studies have been conducted regarding the synthesis of ZnO to tune the size, shape, and hence the properties of such materials. Among all these different methods, the precipitation is one of the most important methods to prepare nanopowder.

## 2. Objective of Present Work

1. Synthesis of pure ZnO nanocrystals through solution phase synthesis route using zinc acetate dehydrate and sodium hydroxide as the precursor materials.
2. Effect of calcination temperatures on crystallite size of ZnO nanomaterials.
3. Characterization of the crystals structure by using X-ray diffraction patterns.
4. To characterize the morphology of the ZnO nanoparticles by scanning electron microscopy.
5. Characterization of the optical properties of ZnO nanoparticles.
6. Application of the prepared materials for removal of heavy metal ions.

## 3. Preliminary Work Done

### 3.1. Experimental Procedures

**Synthesis of ZnO Nanostructure**

In this experiment all the chemicals used are of analytical grade and used without further purification. Nanostructure ZnO particles were synthesized through hydrolysis of zinc acetate dehydrate [$Zn(C_2H_3O_2)_2.2H_2O$] in the presence of sodium dodecyl sulfate [$(CH_3(CH_2)_{11}OSO_3Na)$] acting as anionic surfactant. In this procedure [$Zn(C_2H_3O_2)_2.2H_2O$] was

dissolved in distilled water with continuous stirring. Then SDS was added to it. Finally, NaOH was added dropwise to the SDS modified [$Zn(C_2H_3O_2)_2 \cdot 2H_2O$] solution until desired pH was achieved. Then the precipitate was filtered, washed with distilled water and then with ethanol several time and dried and finally grounded to powder. The powder was calcined at different temperatures and studied using different characterization techniques.

**Result & Discussion**

Figure 1 shows the X-ray diffractogram of ZnO nanopowder prepared with SDS surfactant and heated 800°C temperature. It shows well crystalline single phase wurzite structure. All the reflections of ZnO, which is corresponding to wurzite structure, are observed. The broadness of the XRD peaks is due to small crystallites and the crystallite size is about 22 nm.

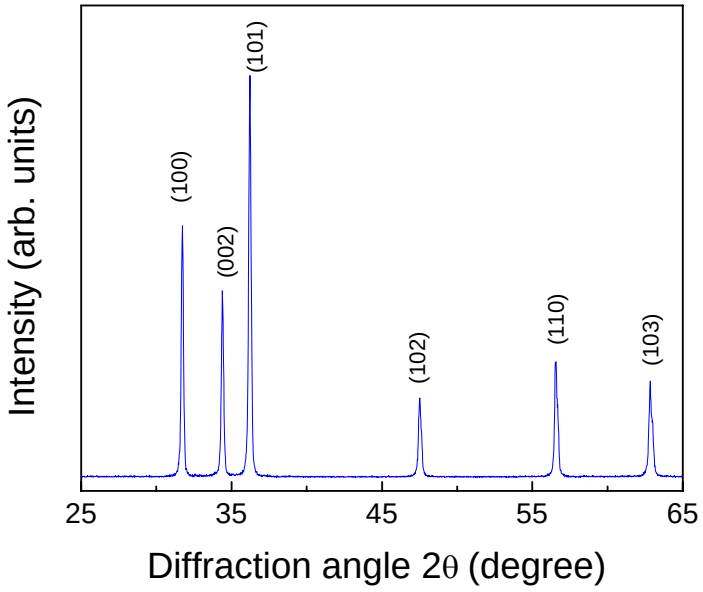


**Fig. 1.** X-ray diffractogram of ZnO nanopowders calcined at 800°C.

**Summary and Conclusion**

- Phase pure ZnO nanopowders were synthesized through a solution phase synthetic route using zinc acetate as metal ion precursor and NaOH as precipitating agent.
- FTIR results show that ZnO nanopowder heated at 800° C is free from surfactant.
- The crystal structure of synthesized ZnO was wurtzite type.

**Future Work**

- In this study, several zinc/iron oxide nanocomposites will be synthesized taking different weight ratios of $Fe^{2+}$ and $Zn^{2+}$ ions.
- Study the effect of dopant on the crystal structure and particle size.
- Characterization of the prepared materials using XRD, FESEM, FTIR, UV-Vis, and PL studies.
- Application of the prepared materials for removal of toxic heavy metals from aqueous solutions.

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