Research Journal of Physical Sciences ISSN 2320–4796
Vol. **14(1),** 1-3, February **(2026)** *Res. J. Physical Sci.*

Study of Optical and Photoluminescence Properties of ZnO Nanoparticles

Rajnish Kumar Yadav, Sunil Kumar Yadav, Jaiprakash Singh and Ramesh Kumar*
P.G. Department of Physics, V.K.S.U, Ara, Bihar, India
rameshphysicsdu@gmail.com

Available online at: www.isca.in, www.isca.me
Received 9th December 2025, revised 15th January 2026, accepted 1st February 2026

Abstract

Zinc Oxide (ZnO) nanoparticles are synthesized by hydrothermal method. Then the prepared samples are characterized by various structural and surface morphological studies such as XRD, Raman, PL and UV-Visible. In the XRD measurement , characteristics peaks are observed at an angle of 31.5°, 34.34°, 36°, 47.4°, 56.54°, 62.68° and 67.76° *which corresponds to (100), (002), (101), (102), (110), (103) and (112), plane respectively. In the Raman spectroscopy, The E_2 (High) mode and E_1 (LO) mode are observed at 437cm^{-1} and 578cm^{-1}, respectively. The UV–visible absorption and Photoluminescence (PL) measurements are performed at room temperature and sample exhibit characteristics UV band at around 395 nm.*

Keywords: Nanoparticles, Photoluminiscence, UV-Visible, Spectroscopy, Optical properties.

Introduction

Zinc Oxide (ZnO) nanoparticles have unique and promising properties towards photoluminescence applications due to their ability to cause oxidation, chemical stability, non-toxic nature and low cost production[1]. It has attracted wide interest due to its characteristic features, tunable and novel applications in global scientific researches and industries. Many research in the field of various applications which primarily include beauty products, medicinal applications, pigment, transducers based on piezoelectric materials and catalysts are reported in literature[2]. ZnO as such exhibits various properties such as optoelectronics, piezoelectric, semiconducting, pyroelectric and catalysis[3]. It is as such an n-type semiconductor and having structure of hexagonal wurtzite. It has optical transparency in the range of visible spectrum[4].

ZnO is basically a wide band gap semiconductor of energy of around 3.37 eV and a larger exciton binding energy of around 60 meV which is around 2.4 times of the room-temperature thermal energy[5]. It is also known that the optical properties of ZnO nanomaterials are different from the bulk crystalline materials[6,7]. The reduction in size to nanometer range can tune the bandgap as well as luminescent properties of ZnO near ultra violet and visible regions[8-11]. However, nanostructured materials have emitted visible photoluminescence much stronger than bulk structures to the concentration of oscillator strength in just few transitions[4]. It is also reported that the emission properties of ZnO nanostructures are depend on their synthesis method and the surface defects[5]. In this paper, the synthesis of ZnO nanoparticles is reported by hydrothermal method. This methods yields well crystalized and quasi-nanorods type structures. The wide applicability of this method leads to controlled shape and size nanostructures for luminescence study.

Sample Preparation

ZnO nanoparticles are synthesized by hydrothermal method. In this method Zinc acetate 50mM solution is prepared in methanol. The prepared solution is refluxed for 2 hours at temperature of 150°C. After that olayamine solution of 30 mM is added to it. In the next step, 1M NH_3 is added to it. It increases the alkaline nature of solution. After that the KOH solution is added to the mixture and it will act as reducing agent. The reaction is taken place at same temperature for 2 hours. In the final stage, solution was brought at room temperature for cooling and filter it by using centrifugation. The prepared sample washed with distilled water for several times to obtained ZnO nanoparticle. The obtained samples annealed in vacuum for 4 hours at 300°C.

Sample Characterization

Raman measurements were performed at Renishaw InVia laser Raman microscope having the excitation laser wavelength 514.5 nm. FTIR measurement carried out at RX I spectrometer by Perkin Elmer. The surface morphology of the prepared samples was measured with Field Emission Scanning Electron Microscope (FESEM, Tescan, MIRA3). The UV-Vis measurement is performed at room temperature with the help Shimadzu UV-2600 and Photoluminescence investigations are performed by a Thermo Scientific evolution 220 at IIT, Patna.

Results and Discussions

XRD Studies: The prepared sample is characterized by XRD measurement and characteristics peaks is observed at 2θ value of 31.5°, 34.34°, 36°, 47.4°, 56.54°, 62.68° and 67.76° and it corresponds to (100), (002), (101), (102), (110), (103) and (112), plane respectively as shown in Figure-1. The peaks of the

XRD measurement graph well matched with available JCPDS Data No. 36-1451 and it shows wurtzite phase.

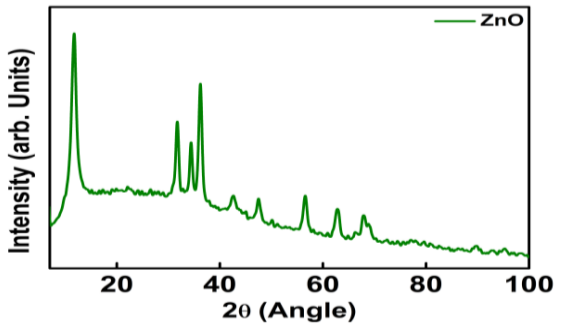

Figure-1: The XRD measurement of ZnO nanoparticles.

FT-IR Studies: The FTIR spectrum of the ZnO nanoparticles is provided in Figure-2. The transmission peak at 3374.61 cm^{-1} corresponds to OH groups stretching vibrations[13]. The C–C bond located at 1645.77cm^{-1} correspond the stretching vibration of the carbonyl groups. The stretching vibration mode of Zn–O bond is present at 567.34cm^{-114}.

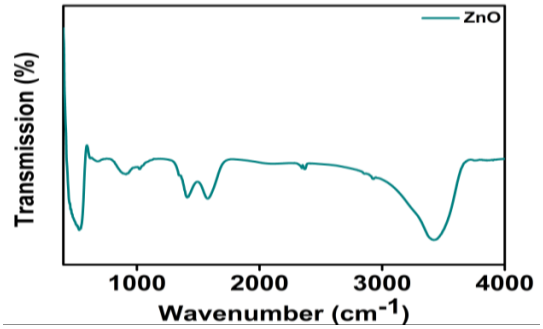

Figure-2: The FTIR measurement of ZnO nanoparticles.

Raman Studies: The mode due to oxygen vibration is observed as E_2 (High) Raman mode is observed at 437 cm^{-1} [15] as shown in Figure-3. The band which originates from second-order Raman scattering is present at 578$cm^{-1}$and assigned as E_1 (LO) mode. The mode is mainly depend upon the presence of impurities and/or defects. The peaks at 1398, 1450 and 1690 cm^{-1} refers to C-H bending, C-O stretching and C-H_3 stretching, respectively[16].

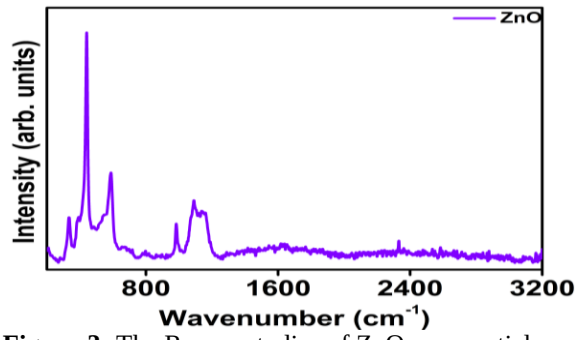

Figure-3: The Raman studies of ZnO nanoparticles.

SEM Studies: In the Figure-4, the surface morphology of the prepared samples is observed and it is found to be dimension of 20-30 nm.

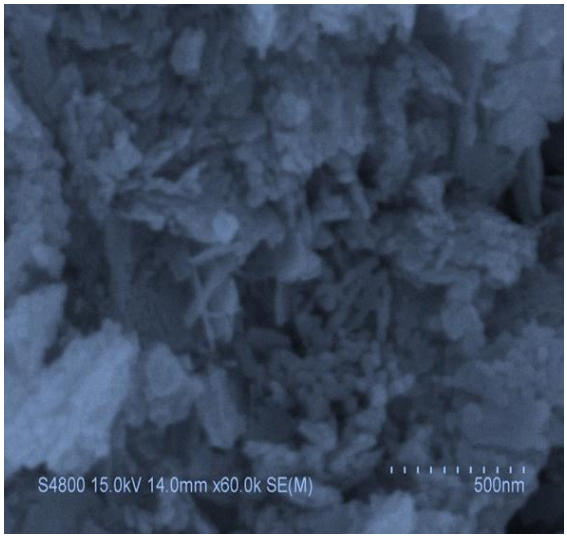

Figure-4: The SEM micrograph of ZnO nanoparticles.

UV-Vis Measurement: In the Figure-5, the sample exhibits plateau between 300 and 350 nm which is nearly 4.11 and 3.53 eV. After that the sharp decrease is observed. The main characteristic peak is observed at around 372 nm which refers to band gap of 3.32 eV^4.

Photoluminescence Measurement: The PL spectrum of ZnO nanoparticles is investigated as shown in Figure-6. The strong emission characteristic of the excitation band is observed in the visible range centred at 514 nm (~2.4 eV). This corresponds to oxygen vacancies of singly ionized or zinc interstitials[4,5].

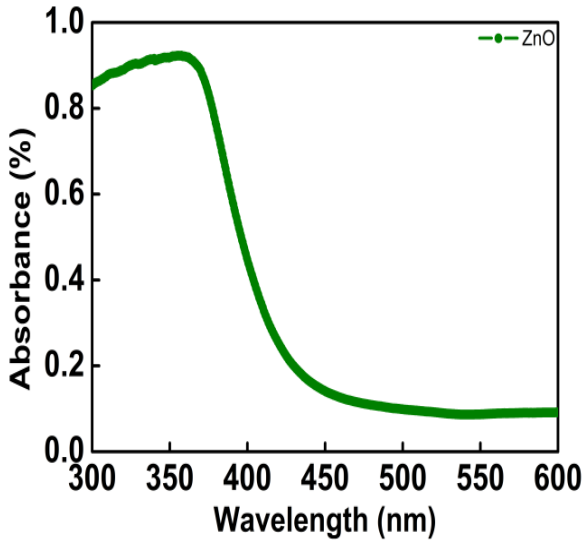

Figure-5: The ZnO nanoparticles UV absorption spectra.

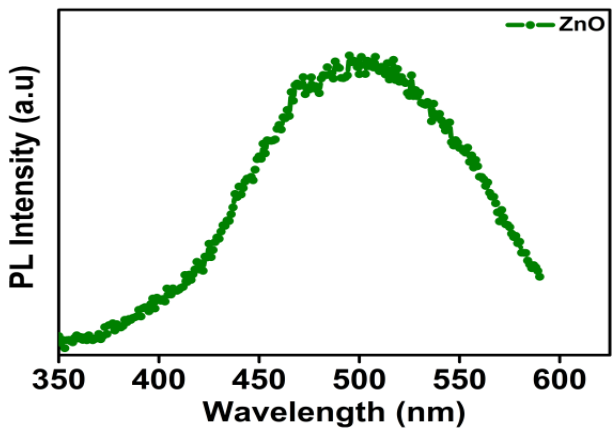

Figure-6: The PL measurement of ZnO nanoparticles.

Conclusion

The ZnO nanoparticles are prepared by chemically hydrothermal method. The prepared sample is characterized by the XRD measurement, FTIR study, Raman studies, SEM studies, UV-Vis and PL measurement. The ZnO nanoparticle of dimension 20-30 is formed with the band gap of 3.32 eV. In the PL measurement, the strong emission characteristic of the excitation band is observed in the visible range centred at 514 nm. This is related to oxygen vacancies of singly ionized or zinc interstitials.

Acknowledgements

Authors are thankful to Vice Chancellor, Veer Kunwar Singh University, Ara, Bihar, India. Thanks extended to IIT, Patna for providing characterization facilities. Authors are thankful to Prof. Amarjeet Kaur, Department of Physics and Astrophysics, University of Delhi for her guidance.

References

1. Jinendra, U., et al. (2024). Investigations of adsorption and photoluminescence properties of encapsulated Al-ZnO nanostructures: Synthesis, morphology and dye degradation studies. *Heliyon*, 10, 34427.

2. Chitradevi, T., et al. (2020). Structure, morphology and luminescence properties of sol-gel method synthesized pure and Ag-doped ZnO nanoparticles. *Materials Research Express*, 7, 015011.

3. Kripal, R., et al. (2011). Photoconductivity and photoluminescence of ZnO nanoparticles synthesized via co-precipitation method. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, 79, 1605–1610.

4. Zhao, J., et al. (2016). Photoluminescence of ZnO nanoparticles and nanorods. *Optik*, 127, 1421–1426.

5. Martinez, A., et al. (2020). Photoluminescence of ZnO Nanowires: A Review. *Nanomaterials*, 10, 857.

6. Raoufi, D., et al. (2013). Synthesis and photoluminescence characterization of ZnO nanoparticles. *Journal of Luminescence*, 134, 213–218.

7. Irshad, M. A., et al. (2021). Efficient chromium removal from leather industrial wastewater in batch experimental study: Green synthesis and characterization of zinc oxide nanoparticles using Ficusbenghalensis extracts. *Ecotoxicology and Environmental Safety*, 212**,** 111978.

8. Vargas, L. M. B., et al. (2023). Using energy transfer to obtain warm white-emitting and thermally stable $Ca_3Y(AlO)_3(BO_3)_4:Dy^{3+}$, Eu^{3+} phosphors. *Journal of Luminescence*, 260, 119873.

9. Moore, J. C., & Thompson, C. V. (2013). A Phenomenological Model for the Photocurrent Transient Relaxation Observed in ZnO-Based Photodetector Devices. *Sensors*, 13, 9921–9940.

10. Cho, S., et al. (1999). Photoluminescence and ultraviolet lasing of polycrystalline ZnO thin films prepared by the oxidation of the metallic Zn. *Applied Physics Letters*, 75, 2761–2763.

11. Khanzode, P. M., et al. (2025). Highly Flexible and Low-Cost ZnO-Based UV Photodetector on Paper with Enhanced Performance and Stability. *ACS Applied Engineering Materials*, 3, 1678–1685.

12. Islam, M. B., et al. (2023). Synthesis and characterization (optical and antibacterial) of silver doped zinc oxide nanoparticles. *Open Ceramics*, 14, 100370.

13. Albarakaty, F. M., et al. (2023). Zinc Oxide Nanoparticle Green Synthesis Using Black Cumin Seed Aqueous Extract: Its Characterization and in vitro Anti-Hyperglycaemic Properties. *Journal of King Saud University – Science*, 35, 102434.

14. Taghizadeh, S. M. (2020). Green and Economic Fabrication of Zinc Oxide (ZnO) Nanorods as a Broadband UV Blocker and Antimicrobial Agent. *Nanomaterials*, 10, 530.

15. Silva, R., & Franco Jr., A. (2020). Correlation of defects and crystallite size of ZnO nanoparticles synthesized by mechanical milling. *Materials Science in Semiconductor Processing*, 119, 105227.

16. Sharma, A., et al. (2012). Emerging trends in food packaging. *Surface Science*, 606, 13–17.