Research Article

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Biosynthesis of ZnO Nanoparticles using Phyllanthus Emblica Seed Powder and its Structural and Optical Characterization Studies

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ABSTRACT

Presently the progress of green chemistry in the synthesis of nanoparticles (NPS) with the use of plants has engrossed great attention. This study reports the exploit of aqueous extract of Phyllanthus Emblica seed powder as an eco-friendly agent for the pattern of Zinc Oxide nanoparticles. The present exploration describes the synthesis and characterization of ZnO nanoparticles prepared by a green technique using X-ray diffraction studies (XRD), Tunnelling electron microscopy studies (TEM), Energy dispersive analysis of X-ray (EDAX), Fourier transform infrared spectroscopy (FTIR), and Photoluminescence studies (PL).

Keywords: Green technique; Phyllanthus Emblica; TEM; XRD; Zinc oxide.

1. INTRODUCTION

ZnO is a direct bandgap (3.36 eV at room temperature) n-type semiconductor with a large exciton binding energy of 60 meV, which has promising applications in optoelectronics and photonics (Muthukumaran *et al.* 2012). It has attracted intensive research effort due to its unique properties and vast applications in pigments (Johnson *et al.* 2003), gas sensors (Comini *et al.*1869; Kang and Kim, 1993), rubber additives (Versloot *et al.* 1992), solar cells (Aranovitch *et al.* 1979), varistors (Clarke, 1999), UV lasers (Tang *et al.* 1998) and other optical and optoelectronic devices (Arnold *et al.* 2003). Different physical or chemical synthetic methods have been used to prepare the ZnO nanoparticles, such as thermal decomposition method, thermolysis method (Niasari *et al.* 2011), sol-gel method, chemical vapor deposition method (Yang *et al.* 2011), vapor phase oxidation (Hu *et al.* 2002), spray pyrolysis, precipitation method (Yang *et al.* 2004), Thermal vapor transport, condensation (Lao *et al.* 2003), co-precipitation method (Chauhan *et al.* 2010), and hydrothermal method (Savu *et al.* 2009). These chemical methods are very costly and lead to the presence of some toxic chemicals adsorbed on the surface that may have adverse effects (Pranjal Chandra *et al.* 2013).

Increasing awareness towards green chemistry and biological processes has led to the development of an eco-friendly approach for the synthesis of nanoparticles. The use of environmentally benign plant leaf extract for the synthesis of zinc oxide nanoparticles offers copious profit of eco-friendliness where toxic chemicals are not used (Warren 2001; Vijayaraghavan and Nalini 2010). Based on the environmentally friendly method, in the present study, we have prepared ZnO nanoparticles by using Phyllanthus Emblica aqueous seed powder used as a reducing agent. The synthesized ZnO nanoparticles are characterized by X-ray diffraction studies (XRD), Tunnelling electron microscopy studies (TEM), Energy dispersive analysis of X-ray (EDAX), Fourier transform infrared spectroscopy (FTIR), and Photoluminescence studies (PL).

2. EXPERIMENTAL METHODS

2.1 Synthesis of ZnO NPs by using *Phyllanthus Emblica* Seed Powder Extract

15 g of finely powdered seeds of *Phyllanthus Emblica* were weighed. Then, 150 ml of double distilled water was added and boiled at 60 ºC for 15 min. The obtained extract was filtered using Whatman No. 1 filter paper, and the filtrate was collected in 250 ml Erlenmeyer flask. Thereafter, 0.1 M zinc nitrate hexahydrate ($Zn(NO_3)_2.6H_2O$) solution was added into 150 ml of powder extract of seeds, and it was stirred constantly at 80 ºC for 6 h. A yellow color precipitate was obtained. Further, the precipitate was dried at 120 ºC for 6 h. The obtained ZnO NPs were annealed at 600 ºC for 7h.

3. RESULTS & DISCUSSION

3.1. Structural Analysis

Phase and structural analysis of ZnO NPs prepared using Phyllanthus Emblica is carried out by XRD analysis and shown in Fig.1. All marked diffraction peak positions in Fig.1 are in good agreement with the standard JCPDS Card (Joint Committee on Powder Diffraction Standards Card no. 36-1451). The corresponding X-ray diffraction peaks at (100), (002), (101), (102), (100), (103), (112), and (201) planes confirm the formation of hexagonal wurtzite structure of ZnO. The observed line broadening of diffraction peaks is an indication that the synthesized ZnO NPs are in the nanometer range. The full width at half maxima (FWHM) of major peaks increases and confirms the grain size reduction. The average crystallite size of ZnO NPs is calculated from the X-ray line broadening using the Scherrer formula

$$D = \frac{k\lambda}{\beta D \cos\theta} \qquad (1)$$

where D is the size in nanometers, X is the wavelength of the radiation (1.5406 Å for Cu kα), k is a constant (0.94). βD is the peak width at the half-maximum intensity, and θ is the peak position. The average crystallite size of the synthesized ZnO NPS is 31 nm.

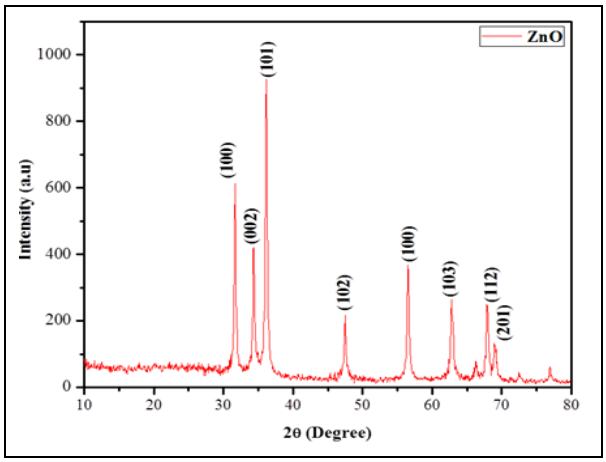


Fig. 1: XRD Pattern of Green Synthesized ZnO Nanoparticles

3.2 TEM Studies

The particle size and structural morphology of the synthesized ZnO NPs were investigated using TEM. The TEM images of the synthesized ZnO NPs are demonstrated in Fig.2, which explicates that most of the base ZnO NPs are quasi-spherical, and their diameter is about 30 nm. Due to the large specific surface area and high surface energy, the same nanoparticles aggregate. The aggregation occurred probably during the process of drying.

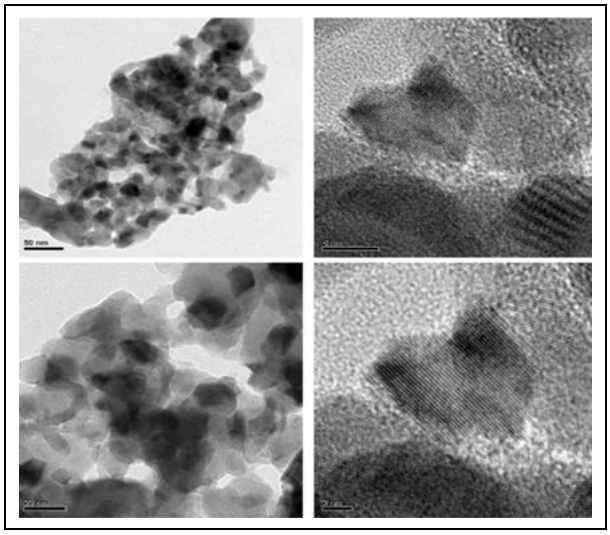


Fig. 2: TEM Images of Green Synthesized ZnO Nanoparticles

3.2 Energy Dispersive Analysis X-ray (EDAX) Spectra

EDAX is used to analyze the amount of Zn and O elements are present in the sample. The typical EDAX spectra of synthesized ZnO NPs are shown in Fig. 3. It clearly shows that the elemental composition of Zn – 82.58 % and O – 17.42 % were observed in the sample. It reveals that there are no more impurities present in the synthesized sample.

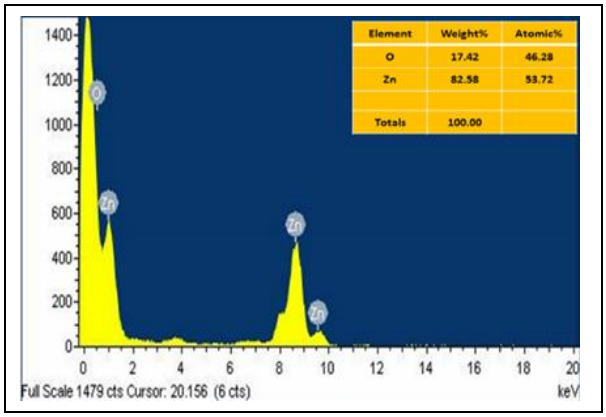


Fig. 3: EDAX Analysis of Green Synthesized ZnO Nanoparticles

3.3 FTIR Studies

Fig. 4 shows the FTIR spectrum of synthesized ZnO nanoparticles. FTIR spectra exhibit strong vibrations at around 682 and 432 cm^{-1} which are assigned to Zn-O stretching vibration frequencies (Mohammed Arshad *et al.* 2011). A broad signal at 3450 cm^{-1}

originates from the hydroxyl group may be attributed to green extract. The peak observed at 2927 cm^{-1} corresponds to the stretching vibrations of the alkane group. C=O stretching frequency possibly appeared at 1635 cm^{-1} (Anirudhan and Senan, 2011; Li *et al.* 2010), and the $–CH_3$ group has appeared at 1043 cm^{-1}.

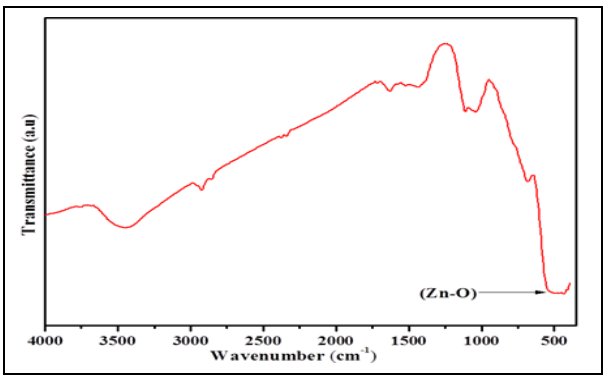


Fig. 4: FTIR Analysis of Green Synthesized ZnO Nanoparticles

3.5 Photoluminescence Property

The optical property of as-prepared ZnO NPs is studied by PL spectroscopy. A sharp and strong UV emission band is recorded at 388 nm. However, no defects mediated visible emission is recorded, as shown in Fig.5. The UV emission is slightly red-shifted as compared to bulk ZnO. Generally, the UV emission band originates from the direct recombination of the free excitations through an exciton-excited collision process, while the visible emission is due to the impurities and structural defects in ZnO crystals (Rai *et al.* 2012).

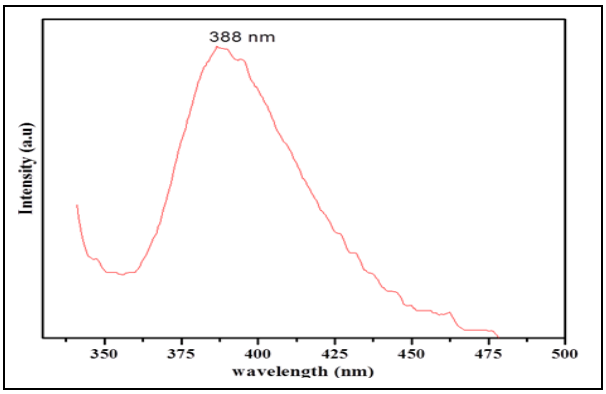


Fig. 5: Room Temperature PL Spectrum of Green Synthesized ZnO Nanoparticles

4. CONCLUSION

The *Phyllanthus Emblica* seed powder aqueous extractis an accountable for the synthesis of Zinc oxide nanoparticles. XRD study reveals that the average size was 31 nm in this green synthesis method. EDAX studies confirmed the purity of the synthesized ZnO nanoparticles. FTIR spectra confirmed that the Zn-O stretching vibration frequencies around 682 and 432 cm^{-1}. The PL studies confirmed that red shifted value was observed at 388 nm due to defect crystal structure in ZnO NPs. Though chemical and green methods are trendier for nanoparticle synthesis, biogenic green fabrication is a better choice due to eco-friendliness.

REFERENCES

Anirudhan, T. S., Senan. P., Adsorption characteristics of cytochromes C onto cationic Langmuir monolayers of sulfonated poly (glycidylmethacrylate) -grafted cellulose: mass transfer analysis, isotherm modeling and thermodynamics, *Chem. Eng. J.*, 168, 678-690(2011). https://doi.org/10.1016/j.cej.2011.01.056

Aranovitch, J., Ortiz A., Bube, R. H., Optical and electrical properties of ZnO films prepared by spray pyrolysis for solar cell applications, *J. Vac. Sci. Technol.*, 16, 994-1003(1998). https://doi.org/10.1116/1.570167

Arnold, M., Avouris, P., Pan Z., Wang, Z., Field-Effect Transistors Based on Single Semiconducting Oxide Nanobelts, *J. Phys. Chem. B*, 107, 659-663(2003). https://doi.org/10.1021/jp0271054

Chauhan, R., Kumar, A., Chaudharya, R. P., Synthesis and Characterization of Copper doped ZnO nanoparticles, *J. Chem. Pharm. Res.*, 2(4), 178-183(2010).

Clarke, D. R., Varistor Ceramics, *J. Am. Ceram. Soc.*, 82, 485-502(1999). https://doi.org/10.1111/j.1151-2916.1999.tb01793.x

Comini, E., Faglia, G., Sberveglieri, G., Pan, Z., and Wang, Z., Stable and highly sensitive gas sensors based on semiconducting oxide nanobelts, *Appl. Phys. Lett.*, 81, 1869-1871(2002). https://doi.org/10.1063/1.1504867

Hu, J. Q., Li, Q., Wong, N. B., Lee, C. S., Lee, S. T., Synthesis of Uniform Hexagonal Prismatic ZnO Whiskers, *Chem. Mater.*, 14, 1216-1219(2002). https://doi.org/10.1021/cm010732

Johnson, J. A., Heidenreich, J. J., Mantz, R.A., and Baker, P. M., A multiple-scattering model analysis of zinc oxide pigment for spacecraft thermal control coatings, Prog. Org. Coat., 47, 432-442(2003). https://doi.org/10.1016/S0300-9440(03)00133-4

Kang, W. P., and Kim, C. K., Catalyst-adsorptive oxide-semiconductor gas sensors, Sens. Actuat., B, 13-14, 682-684(1993). https://doi.org/10.1016/0925-4005(93)85143-X

Lao, J. Y., Huang, J. Y., Wang, D. Z., Ren, Z. F., ZnO Nanobridges and Nanonails, Nano Lett., 3, 235-238(2003). https://doi.org/10.1021/nl025884u

Li J., Fan, H., Jia, X., Multilayered ZnO Nanosheets with 3D Porous Architectures: Synthesis and Gas Sensing Application, J. Phys. Chem.C, 114, 14684-14691(2010). https://doi.org/10.1021/jp100792c

Mohammed Arshad, Ameer Azam, Arham Ahamed, S., Mollah, S., Alim H., Effect of Co substitution on the structural and optical properties of ZnO nanoparticles synthesised by sol-gel route, J. Alloys Comp., 509, 8378-8381(2011). https://doi.org/10.1016/j.jallcom.2011.05.047

Muthukumaran, S., Gopalakrishnan, R., Structural, FTIR and photoluminescence studies of Cu doped ZnO nanopowders by co-precipitation method, Opt. Mater., 34, 1946-1953(2012). https://doi.org/10.1016/j.optmat.2012.06.004

Niasari, M. S., Davar, F., Khansari, A., Nanospherical and nanobundles of ZnO: Synthesis and characterization, J. Alloys Comp., 509, 61-65(2011). https://doi.org/10.1016/j.jallcom.2010.08.060

Pranjal Chandra, Jai Singh, Amardeep Singh, Ananya Srivastava, Rajendra N. Goyal and Yoon Bo Shim, Gold Nanoparticles and Nanocomposites in Clinical Diagnostics Using Electrochemical Methods, J. Nanopart., 535901, 1-12(2013). https://doi.org/10.1155/2013/535901

Rai, P., Kim, S. G., Yu, Y. T., Microwave assisted synthesis of flower-like ZnO and effect of annealins atmosphere on its photoluminescence property, J. Mater. Sci: Mater. Electron., 23, 344-348(2012). https://doi.org/10.1007/s10854-011-0384-z

Savu, R., Parra, R., Joanni, E., Jancar, B., Elizario, S. A., de Camargo, R., Bueno, P. R., Varela, J. A., Longo, E., Zaghate, M. A., The effect of cooling rate during hydrothermal synthesis of ZnO nanorods, J. Cryst. Growth, 311, 4102-4108(2009). https://doi.org/10.1016/j.jcrysgro.2009.06.039

Tang, Z. K., Wong, G. K. L., Yu, P., Kawasaki, M., Ohtomo, A., Koinuma, H., Segawa, Y., Room-temperature ultraviolet laser emission from self-assembled ZnO microcrystallite thin films, Appl. Phys. Lett., 72, 3270-3272(1998). https://doi.org/10.1063/1.121620

Versloot, P., Haasnoot, J. G., Reedijk, J., van Duin, M., Duynstee, E. F. J., Put, J., Sulfur Vulcanization of Simple Model Olefins, Part I: Characterization of Vulcanization Products of 2,3-Dimethyl-2-Butene, Rubber Chem. Technol., 65, 343-349(1992). https://doi.org/10.5254/1.3538616

Vijayaraghavan, K., Nalini, S. P. K., Biotemplates in the green synthesis of silver nanoparticles, Biotechnol. J., 5(10), 1098-1110(2010). https://doi.org/10.1002/biot.201000167

Warren, D., Green Chemistry. A Teaching Resource, Royal Society of Chemistry, Cambridge(2001).

Yang, J., Feia, L., Liua, H., Liua, Y., Gaoa, M., Zhanga, Y., Yanga, L., A study of structural, optical and magnetic properties of Zn0.97−xCuxCr0.03O diluted magnetic semiconductors, J. Alloys Comp., 509, 3672-3676(2011). https://doi.org/10.1016/j.jallcom.2010.12.157

Yang, Y., Chen, H., Zhao, B., Bao, X., Size control of ZnO nanoparticles via thermal decomposition of zinc acetate coa ted on organic additives, J. Cryst. Growth, 263, 447-453(2004). https://doi.org/10.1016/j.jcrysgro.2003.12.010