

# Optical and Photocatalytic Studies of Zinc Strontium Oxide Nanocomposite for Technological Applications

C.R. Indulal<sup>1,a)</sup>, R. Ravikumar<sup>1</sup>, R. Biju<sup>2</sup>, M. Akhil<sup>1</sup>, Kichu Suresh<sup>3</sup>

*1Department of Physics, S.G. College, Kottarakara, Kerala, India*

*2Nanoscience Research laboratory, S.N. College, Kollam, Kerala, India*

*3Department of Mechanical Engineering, University of Ottawa, Ottawa, Canada*

<sup>a)</sup>Corresponding author: ltrindulal@gmail.com

**Abstract.** Nanocomposite of Zinc Strontium Oxide (ZnSrO) has been synthesized by chemical co-precipitation method. Structural properties of the samples are studied using XRD technique. The optical bandgap analyses of the samples are carried out using UV-Visible spectroscopy. Photocatalytic degradation power of the nanocomposite is measured with congo red and malachite green dyes.

## INTRODUCTION

Nanotechnology is one of the important technologies, which play a vital role especially in the field of water purification. The nanostructures offer large surface to volume ratios. Recently the major water resources in India are contaminated by different organic dyes that are originated from various industries<sup>1-3</sup>. Such organic pollutants show toxic nature even in low concentrations and may be harmful to aquatic animals and human beings<sup>4</sup>. Several physical processes like coagulation, adsorption and flocculation can remove pollutants from the environment. But the prior process does not promote the degradation of organic dyes in water resources<sup>5-6</sup>. So the scientific community searches an efficient method for the degradation of organic dyes which results in the purification of polluted water. Photocatalysis can be considered as an effective method for the degradation of such organic dyes. In photocatalysis a semiconductor surface is activated in the presence of UV-light which generates free radicals from OH-adsorbed species and such radicals degrade the contaminant molecules<sup>7</sup>. Early report shows that TiO<sub>2</sub> and ZnO are efficient and extensively used semiconductors which promote photocatalysis<sup>8-10</sup>. ZnO is one of the widely used photocatalysts for the removal of organic dyes from waste water with higher efficiency due to its high redox potential, high exciton binding energy, easy synthesis, non-toxicity, superior physical and chemical stability, inexpensiveness at room temperature etc. The reported optical direct bandgap of ZnO is nearly 3.37eV<sup>11-16</sup>.

The addition of transition metals, noble metals and non-metals is an efficient method to improve the photocatalytic activities of the nano samples. Elements such as Sr, Al, Cr, La, Ta, Ag etc. have been used along with ZnO to improve photocatalytic performance<sup>17</sup>. Lakshmana Perumal reported that photocatalytic activities of the Sr-doped ZnO decreases with increase in Sr-concentrations<sup>18</sup>.

## MATERIAL AND METHODS

Zinc Oxide (ZnO) nanoparticles were synthesized by chemical co-precipitation method. 50ml solution of 0.1M Zinc nitrate and 50ml solution of 0.02M citric acid were prepared using doubly distilled water and were collectively taken in a beaker. 50ml solution of 0.5M sodium hydroxide was taken in a burette and added drop by drop in to the solution taken in the beaker and were stirred well using a magnetic stirrer arrangement. The precipitate so formed was allowed to settle down under the effect of gravity. The precipitate was then centrifuged and washed several times using distilled water to remove all the remaining impurities. The washed precipitate was dried under sunlight and powdered using an agate mortar. The dried precipitate then annealed at a temperature of 800°C for two hours to obtain Zinc oxide nanoparticles from there corresponding hydroxide.

Similar procedures were used for the synthesis of Strontium oxide nanoparticles and Zinc Strontium oxide nanocomposite. For the synthesis of Strontium oxide (SrO) nanoparticles, 0.1M solution of strontium nitrate was used instead of zinc nitrate. However in the synthesis of zinc strontium oxide (ZnSrO) nanocomposite, 0.1M zinc nitrate and 0.1M strontium nitrate solutions were used. All the dried precipitates after washing were annealed at 800°C for two hours to obtain their corresponding metal oxide counterparts.

## RESULTS AND DISCUSSION

### XRD ANALYSIS

XRD analyses of the nanoparticles/nanocomposite were carried out with the help of XPERT-PRO model powder diffractometer having Cu- $\alpha$  radiation operating at 40KV, 30mA. The particle size determination was carried out using Debye-Scherrer equation;  $t = K\lambda / \beta_{hkl} \cos \theta_{hkl}$ <sup>19</sup>; where 't' is the average crystallite size normal to the reflecting planes, 'K' is the shape factor which depends on how the width is determined, the shape of the crystal and the size distribution on the shape of the grains, ' $\lambda$ ' is the wavelength of X-rays used,  $\beta_{hkl}$  is the full width at half maximum of the diffraction line in radians and  $\theta_{hkl}$  is the Braggs angle corresponding to the diffraction line arising from reflections from the planes designated by Miller indices (h k l). The  $\beta$ -value corresponding to the major peaks were determined using Pseudo Voigt curve-fit method using origin software 8.5. XRD patterns of the nanoparticles of ZnO, SrO and ZnSrO nanocomposite are shown in figures 1(a) to 1(c) respectively.

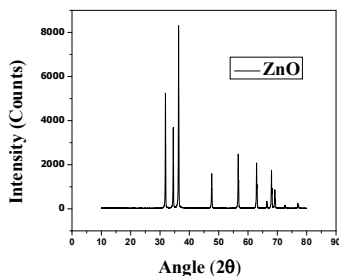


FIGURE 1(a). XRD Pattern of ZnO

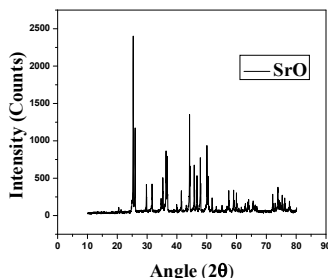


FIGURE 1(b). XRD Pattern of SrO

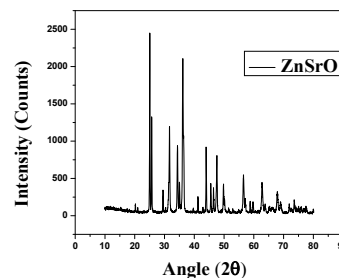


FIGURE 1(c). XRD Pattern of ZnSrO

The average particle sizes are found to be 43 and 65nm for ZnO and SrO nanoparticles respectively. However the particle size of ZnSrO nanocomposite is found to be 48nm.

### UV SPECTROSCOPIC STUDIES

The UV absorption spectroscopy studies were carried out with the help of JASCO V650 UV/Vis spectrophotometer in the wavelength range of 210nm to 870nm with 1nm resolution. The optical bandgaps of nanoparticles/nanocomposite were found out with the help of Tauc's relation<sup>20</sup> which is given by;  $\alpha h\nu = A(h\nu - E_g)^n$ ; where  $E_g$  is the optical bandgap of the material, 'A' is a constant, ' $\alpha$ ' is the absorption coefficient and 'n' is the allowed transition state. The optical bandgaps of the samples were determined using Tauc's plot, which was plotted by taking  $(\alpha h\nu)^{1/n}$  along Y-axis and  $h\nu$  along X-axis. On extrapolating the straight line portion of the graph into the energy axis, optical bandgap is obtained. The wavelength-absorbance graphs of the nanoparticles of ZnO, SrO and ZnSrO nanocomposite are shown in figures 2(a) to 2(c) respectively. Tauc's plots of the nanoparticles of ZnO, SrO and nanocomposite of ZnSrO are shown in figures 3(a) to 3(c) respectively.

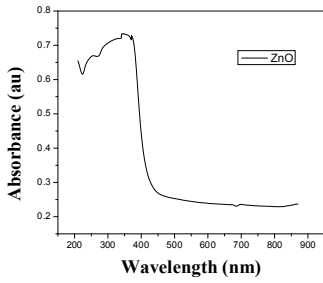


FIGURE 2(a). UV spectrum of ZnO

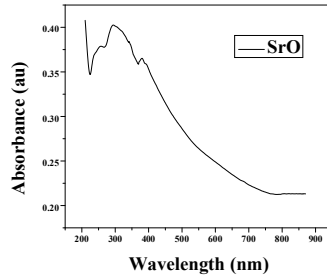


FIGURE 2(b). UV spectrum of SrO

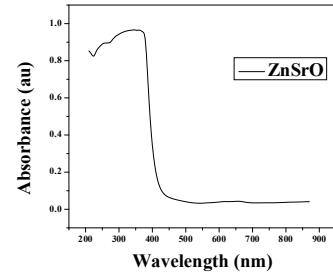


FIGURE 2(c). UV spectrum of ZnSrO

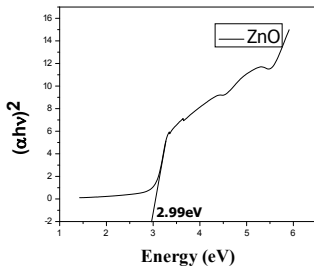


FIGURE 3(a). Optical bandgap of ZnO

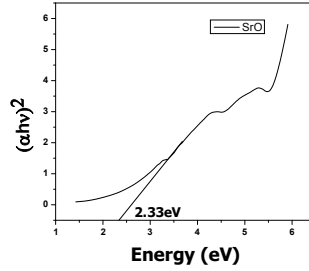


FIGURE 3(b). Optical bandgap of SrO

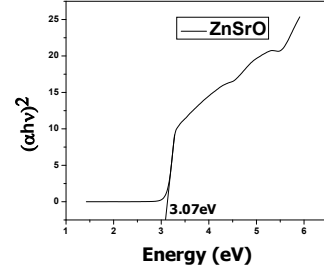


FIGURE 3(c). Optical bandgap of ZnSrO

Using Tauc's relation the optical bandgap is 2.99eV for ZnO nanoparticles, 2.33eV for SrO nanoparticles and 3.07eV for ZnSrO nanocomposite.

## PHOTOCATALYTIC DEGRADATION STUDIES OF ZNSRO NANOCOMPOSITE

Photocatalytic degradation studies of ZnSrO nanocomposite were carried out using a photo catalytic cell. The efficiency of ZnSrO nanocomposite in some selected organic dyes such as congo red and malachite green under UV light was investigated in detail.

50ppm solutions of both the dyes were prepared and were placed in to a photo catalytic cell. 0.1gm of catalyst was added into the dye solution and irradiated with UV light. After every 15minutes, 10ml of samples from the dye solution were collected. First centrifuge it and analyzed absorption level with the help of UV visible spectrophotometer. Graphs are drawn by taking the absorbance along Y-axis and wave length along X-axis. The wavelength-absorbance graphs of the catalyst in congo red and malachite green dyes are shown in figures 4(a) and 4(b) respectively.

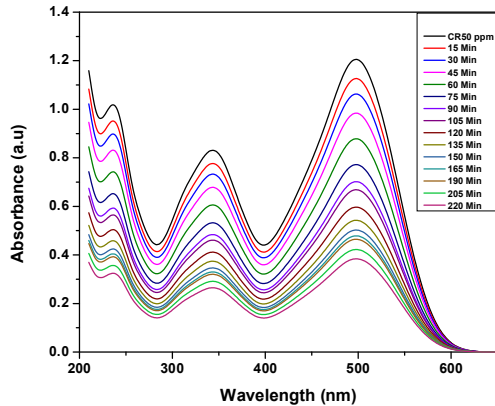


FIGURE 4(a). Photocatalytic studies in Congo red dye

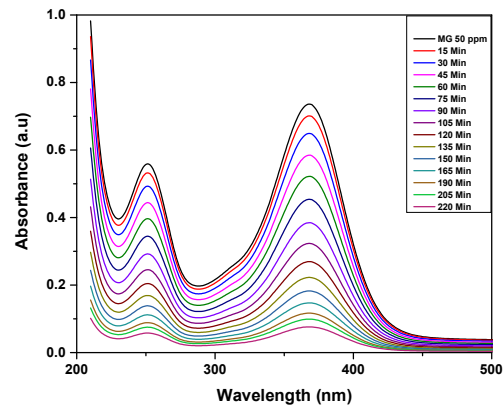


FIGURE 4(b). Photocatalytic studies in Malachite green dye

Detailed photocatalytic degradation studies were done with ZnSrO nanocomposite<sup>21</sup> upto 220minutes at a step size of 15minutes. The result shows that both the dyes are degraded very effectively with ZnSrO nanocomposite. After 220minutes the percentage of absorbance of congo red and malachite green dyes reaches nearly to zero value showing that ZnSrO is a better catalyst for the removal of organic dyes. However the degradation percentage is found to be comparatively high for malachite green dye than congo red dye.

## CONCLUSION

Nanoparticles of Zinc Oxide, Strontium Oxide along with the nanocomposite of Zinc Strontium oxide have been synthesized by chemical co-precipitation method. The sharp but broad peaks in the XRD patterns reveal that the samples synthesized were nanocrystalline in nature. The direct optical bandgaps of the nanoparticles of Zinc Oxide, Strontium Oxide and Zinc Strontium oxide nanocomposite were studied using Tauc's relation. Photocatalytic activities of Zinc Strontium oxide nanocomposite were evaluated by photocatalytic oxidation of congo red and malachite green dyes. Results show that the degradation percentage of malachite green dye is better than congo red dye.

## ACKNOWLEDGMENTS

Authors are grateful to Kerala State Council for Science Technology and Environment, Trivandrum, Kerala, India for fruitful discussions and financial support during the preparation of the samples and manuscript.

## REFERENCES

1. D. Lončarević, J. Dostanić, V. Radonjić, L. Živković and D. M. Jovanović., *Mechanisms and Catalysis* **118(1)**, 153-164 (2016).
2. Y. Li, W. P. Zhang, X. Li and Y. Yu, *Journal of Physics and Chemistry of Solids* **75(1)**, 86-93 (2014).
3. S. Bhatia, N. Verma and R. K. Bedi, *Optical Materials* **62**,392-398 (2016).
4. F. F. Brites, V. S. Santana and Fernandes-Machado, *Catalysis* **54(1)**, 264-269 (2011).
5. H. Xu, Y. Zhang, Q. Jiang, N. Reddy and Y. Yang, *Journal of Environmental Management* **125**, 33-40 (2013).
6. V. K. Gupta, I. Ali, T. A. Saleh, A. Nayak and S. Agarwal, *ChemInform* **43(45)**, 6380-6388 (2012).
7. E. Alzahrani, *Current Analytical Chemistry* **12(5)**, 465-475 (2016).
8. A. Tolosana-Moranchel, J. A. Casas, J. Carbajo, M. Faraldos and A. Bahamonde, *Applied Catalysis B: Environmental* **200**, 164-173 (2016).
9. N. A. Savastenko, I. I. Filatov, V. A. Lyushkevich, N. I. Chubrik, M. T. Gabdullin and T. S. Ramazanov, *Journal of Applied Spectroscopy* **83(5)**, 757-763 (2016).
10. J. Kaur, S. Bhukal, K. Gupta, M. Tripathy, S. Bansal and S. Singhal, *Materials Chemistry and Physics* **177**, 512- 520 (2016).
11. M. Azarang, A. Shuhaimi, R. Yousefi, A. Moradi Golsheikh and M. Sookhakian, *Ceram. Int.* **40**, 10217–10221 (2014).
12. O. Akhavan, *ACS Nano* **4**, 4174–4180 (2010).
13. A. Nezamzadeh-Ejhieh and S. Khorsandi, *J. Ind. Eng. Chem.* **20**, 937–946 (2014).
14. A. Saffar-Teluri, S. Bolouk and M.H. Amini, *Res. Chem. Intermed.* **39**, 3345–3353 (2013).
15. M.A. Behnajady and Y. Tohidi, *Photochem. Photobiol.* **90**, 51–56 (2014).
16. G. Mahmodi, S. Sharifnia, M. Madani and V. Vatanpour, *Sol. Energy* **97**, 186–194 (2013).
17. Danli, Jian-Feng Huang and Li-Yun Cao, *Ceramics International* **40**, 2647-2653 (2014).
18. S. Lakshmana perumal, P. Hemalatha, M. Alagar, K. Navaneetha, *International Journal of Chemical and Physical Sciences* **4** 1-13(2015).
19. B. D. Cullity, *Elements of X-ray diffraction*(Addison-wesley publishing company Inc.California, pp. 102-110 (1970).
20. D. Mohanta, S. S. Nath, N. C.Mishra and A. Choudhury, *Bull. Mater. Sci.* **26**, 289-294 (2003).
21. Nimisha N. Kumaran and K. Muraleedharan, *Journal of water process engineering* **17**, 264-270 (2017).