JOURNAL OF NANO- AND ELECTRONIC PHYSICS
Vol. **13** No 3, 03002(4pp) (2021)
ЖУРНАЛ НАНО- ТА ЕЛЕКТРОННОЇ ФІЗИКИ
Том **13** № 3, 03002(4cc) (2021)

Antibacterial and Optical Activities of Microwave Aided Zn_2SnO_4 Nanorods

S. Kumar[1], K.K. Sivakumar[2,*], Mohammed Kaso Sado[1], Gutu Ofgaa Ternesgen Garoma[1]

[1] *Wollega University, Ethiopia*
[2] *Academy of Maritime Education and Training Deemed to be University, India*

(Received 10 January 2021; revised manuscript received 14 June 2021; published online 25 June 2021)

The zinc stannate (Zn_2SnO_4) nanorods were synthesized via facile microwave assisted method using ammonia with cubic spinel structure. The crystallography and optical properties were studied using X-ray diffraction (XRD) and photoluminescence spectroscopy (PL). The morphology of the nanoparticles was observed using field emission scanning electron microscopy (FESEM). The antibacterial effect of Zn_2SnO_4 nanoparticles tested against Gram-positive and Gram-negative pathogenic bacteria were investigated.

Keywords: Antibacterial activity, Zinc stannate, PL, Nanoparticles, Nanoarchitectonics.

DOI: 10.21272/jnep.13(3).03002 PACS number: 61.46.Km

1. INTRODUCTION

The Zn_2SnO_4 an inverse structure of AB_2O_4 compound (space group Fd3m), has fascinated and unique properties rendering it suitable for a wide variety of applications such as chemical sensors, photoelectrical devices, transparent conducting electrodes, functional coatings and photocatalysts [1-3]. And also, as an important transparent semiconductor with wide band gap of 3.6 eV, Zn_2SnO_4 is known to have high chemical sensitivity, high electrical conductivity and low visible absorption [4]. In order to realize the universal application of nanomaterials, the key point is to devise simple and efficient methods for their preparation on a large scale at low cost. Various methods have been employed to produce Zn_2SnO_4 nanostructures such as mechanochemical synthesis, thermal evaporation method by heating metal or metal oxide powder at high temperatures, simple co-precipitation method and hydrothermal synthesis [5-7].

Metal oxide nanoparticles (NPs) are the most widely used antimicrobial agent in the food industry applications [8]. Gram positive and Gram-negative microorganisms are mentioned [9]. The antimicrobial activity of Zn_2SnO_4 NPs is mainly based on the following mechanisms: (a) release of Zn^{2+}/Sn^{2+} ions which bind to electron donor groups in molecules containing sulphur, oxygen, or nitrogen, (b) disruption of DNA replication and (c) oxidative stress through the catalysis of reactive oxygen species (ROS) formation [10]. ROS contain the most reactive hydroxyl radical (OH), the less toxic superoxide anion radical ($^{\cdot}O_2^-$) and hydrogen peroxide with a weaker oxidizer (H_2O_2). This can damage DNA, cell membranes, etc., leading to cell death [11].

In the present work, Zn_2SnO_4 nanorods were prepared by a microwave assisted method. The structural properties of the nanorods were characterized in detail. In addition, further development of wide range of optical behavior of Zn_2SnO_4 nanorods and the antibacterial activity were also investigated.

2. EXPERIMENTAL METHODS

2.1 Synthesis

The subsequent high purity chemicals such as zinc (II) nitrate, tin (II) chloride dihydrate and ammonia solution were used as precursors without further purification.

Zn_2SnO_4 nanoparticles were prepared in different ratios of Zn and Sn (2:1, 1:1 and 1:2) by microwave-assisted precipitation method. Zinc (II) nitrate and tin (II) chloride aqueous solutions (50 ml) of appropriate amount were prepared and stirred together for 1 h 20 min to get a homogeneous mixture. Then ammonia solution was added to get a white precipitate and stirred at room temperature for 15 min. The product solution was transferred to a polypropylene capped autoclave bottle and the solution was irradiated by a microwave oven with the power of 600 W for 10 min. After irradiation, the solution was allowed to cool down naturally to room temperature. The schematic diagram for the preparation of Zn_2SnO_4 nanorods is shown in Fig. 1.

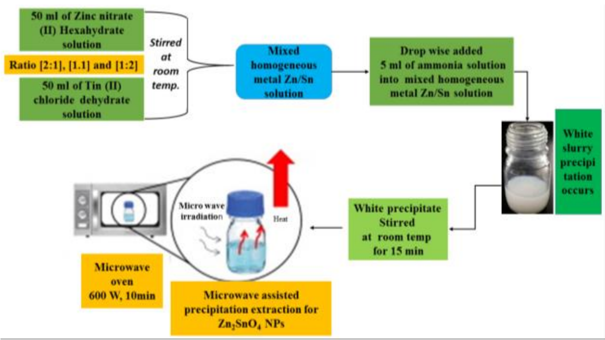

Fig. 1 – Schematic diagram for the formation of Zn_2SnO_4 nanorods

2.2 Antibacterial Assays

The antibacterial activity of microwave assisted Zn_2SnO_4 nanorods was tested against *Streptococcus pneumoniae, Escherichia coli, Klebsiella pneumoniae and Shigella dysenteriae bacterial strain* were carried

* sivakumarccet@gmail.com
The results were presented at the International Conference on Innovative Research in Renewable Energy Technologies (IRRET-2021)

out in agar by well diffusion method. The antibacterial activity was tested at a concentration of 1 and 1.5 mg/ml of the Zn_2SnO_4 nanorods dispersed in dimethylsulphoxide (DMSO). The zone of inhibition levels (mm) was measured subsequently after 24 h at 37 °C. For positive control, standard antibiotic Amoxicillin (30 µg disc) was used.

2.3 Characterization Techniques

The structural properties were investigated from the X-Ray diffraction patterns obtained using X'PERT PRO Panalytical Diffractometer. The morphology of Zn_2SnO_4 nanorods was examined by FESEM (Carl Zeiss Ultra 55) with EDAX (Inca). The functional groups were analyzed from FT-IR spectra in the range of 400-4000 cm^{-1}. Photoluminescence (PL) spectra were taken using a spectrometer JASCO spectrofluorometer FP-8200 to study the optical properties.

3. RESULTS AND DISCUSSION

3.1 FESEM Analysis

The surface morphology of microwave assisted synthesis of all Zn_2SnO_4 nanorods was examined through FESEM analysis is shown in Fig. 2a, b. FESEM images clearly show the synthesized Zn_2SnO_4 exhibits, rod like structure and average particle size in the nanoscale range. The formation of nanorods may be due to two reasons such as crystal nucleation and crystal growth direction. The growth mechanism of Zn_2SnO_4 nanorods can be explained in terms of chemical reactions and crystal growth, as follows. From the crystallization point of view, the synthesis of an oxide during an aqueous solution reaction is expected to experience a hydrolysis-condensation process. Growth of Zn_2SnO_4 nanorods occurs according to the reaction.

$$Zn(\mathrm{s}) \xrightarrow{\Delta} Zn(\mathrm{g})$$

$$Sn(\mathrm{s}) \xrightarrow{\Delta} Sn(\mathrm{g})$$

$$2\mathrm{Zn(g)} + \mathrm{Sn(g)} + 2\mathrm{O_2} = \mathrm{Zn_2SnO_4(s)}.$$

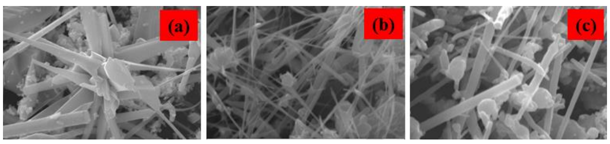

Fig. 2 – (a), (b) SEM images of Zn_2SnO_4 nanorods

3.2 Photoluminescence Spectroscopic Studies

The photoluminescence spectra of microwave assisted Zn_2SnO_4 nanorods are shown in Fig. 3 (P1-P3). The Zn_2SnO_4 nanorods measured at the excitation wavelength of 460 nm. The two blue-green emission, four green emissions, and orange-yellow emission are located at (484, 499, 508, 519, 526, 541, 555, 566, and 584 nm), (484, 498, 508, 523, 540, 551, 566, and 582 nm) and (484, 499, 509, 519, 526, 541, 555, 566, and 579 nm) for P1, P2 and P3, respectively. The blue-green emission found to be (484-499 nm) for all Zn_2SnO_4 nanorods, which is attributed to oxygen vacancies [16, 17]. The green emission observed at (508-551 nm) for P1, P2 and P3 samples respectively, usually the oxygen vacancies existing in Zn_2SnO_4 [18, 19]. The yellow-orange emission centered at (566 nm and 579 nm) for Zn_2SnO_4 nanorods respectively, due to the interaction between oxygen vacancies, tin interstitials and oxygen interstitials can be accountable for the yellow-orange emission [20], and defects has formation of a huge number of trapped states and sum of meta stable energy levels in the band gap of the as-synthesized Zn_2SnO_4 NPs.

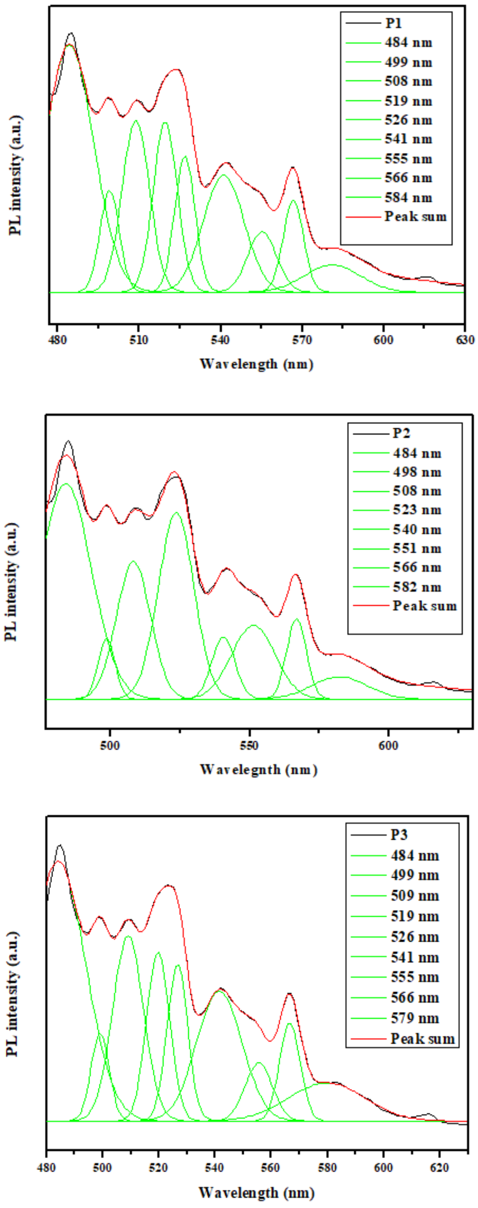

Fig. 3 – PL spectra of Zn_2SnO_4 NPs

However, for the P3 sample, green emission values (579 nm) increased as compared to the P2 (582 nm) and P1 (584 nm) for Zn_2SnO_4 nanorods samples, respectively. From the optoelectronic application generally depends on decrease in defect level, which in mainly influenced via electron phonon coupling interaction. In the present work, the P3 samples emission decreased as compared to P1 and P2 samples, this results sustenance for the future development of optoelectronic application.

3.3 Antibacterial Activity

Fig. 4a, b shows antibacterial activity of microwave assisted Zn_2SnO_4 NPs tested against *Streptococcus pneumoniae, Escherichia coli, Klebsiella pneumoniae and Shigella dysenteriae* bacterial strains to determine by the well diffusion method. Zn_2SnO_4 NPs and amoxicillin show the antibacterial activity, which clearly shows the inhibition zone and specifies the biocidal action of Zn_2SnO_4 NPs. The maximum zone of inhibition was observed *E. coli* as compared to the other *S. pneumoniae, K. pneumoniae and S. dysenteriae bacterial strain* (Fig. 5). In the present work, increasing the concentration (P3) of Zn_2SnO_4 NPs the inhibition zone also gets increased.

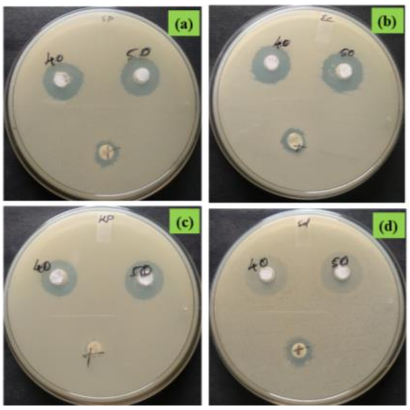

Fig. 4 – Progressive antibacterial activity of G+ and G– bacteria

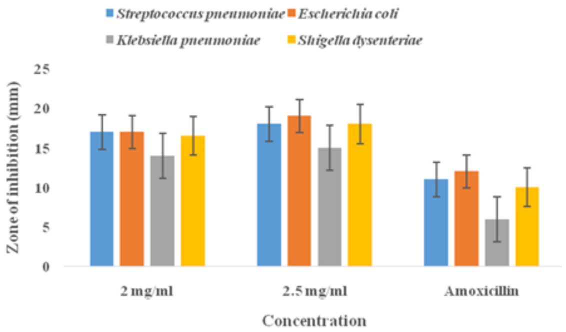

Fig. 5 – Zone of inhibition for various bacterial strain treated with Zn_2SnO_4 NPs

The antibacterial activity generally depends on production of reactive oxygen species (ROS) [21-23]. This ROS on the surface of these nanoparticles in light causes oxidative stress in microbial cells membrane, ultimately leading to the death of the cells.

The ROS production can be given in equation form as the following:

$$Zn_2SnO_4 + h\nu \rightarrow e^- + h^+$$
$$h^+ + H_2O \rightarrow {}^{\bullet}OH + H^+$$
$$e^- + O_2 \rightarrow O_2^-$$
$${}^{\bullet}O_2^- + H^+ \rightarrow HO_2^{\bullet}$$
$$HO_2^{\bullet} + H^+ \rightarrow H_2O_2$$

The Zn_2SnO_4 nanorods through defects can be activated via both UV and visible light, electron-hole pairs (e^- h^+) can be created. The holes fragmented H_2O molecules hooked on OH^- and H^+. Dissolved (O_2) can be converted to (${}^{\bullet}O_2^-$)radical anions. The (${}^{\bullet}O_2^-$) superoxide radical anions in turn react with H^+ to create ($HO_2^{\bullet}$) radicals. The hydrogen ions (H^+) react with ($HO_2^{\bullet}$) to produce molecules of H_2O_2. The production of H_2O_2 be able to penetrate the cell membrane and finally the bacteria die [24]. On the other hand, Zn^{2+}/Sn^{2+} ions released by Zn_2SnO_4 come into contact with microbial cell membranes, cell membranes with (–) charge and Zn^{2+}/Sn^{2+} ions with (+) charge mutually attract. The Zn^{2+}/Sn^{2+} metal ions penetrate hooked on the cell membrane and react by sulfhydryl groups inside the cell membrane. As a result, the microbe synthetase activity is damaged and cells lose their ability to divide cells, which leads to the death of bacterial cells.

4. CONCLUSIONS

In summary, the Zn_2SnO_4 nanorods were prepared and XRD patterns showed that synthesized nanorods exhibits spinel cubic structure. Nanorod-like morphology and chemical composition were observed through FESEM and EDAX spectra. In case of FT-IR spectra, the Zn-Sn-O stretching bands were observed at 502, 475 and 460 cm^{-1} for all Zn_2SnO_4.

ACKNOWLEDGEMENTS

Authors are grateful to the Management of Wollega University, Ethiopia and Academy of Maritime Education and Training Deemed to be University, India.

REFERENCES

1. Monaam Ben Ali, Fatiha Barka-Bouaifel, Habib Elhouichet, Brigitte Sieber, Ahmed Addad, Luc Boussekey, Mokhtar Férid, Rabah Boukherroub, *J. Colloid Interface Sci.* **457**, 360 (2015).
2. Jia Zeng, Mu Di Xin, Kun Wie Li, Hao Wang, Hui Yan, Wen Jun Zhang, *J. Phys. Chem. C* **112** No 11, 4159 (2008).
3. W.-W. Wang, Y.-J. Zhu, L.-X. Yang, *Adv. Funct. Mater.* **17** No 1, 59 (2007).
4. Gang Fu, Huan Chen, Zhexiong Chen, Jinxiu Zhang, Heinz Kohler, *Sensor. Actuat. B: Chem.* **81**, 308 (2002).
5. Vladimir Šepelák, Sebastian M. Becker, Ingo Bergmann, Sylvio Indris, Marco Scheuermann, Armin Feldhoff, Christian Kübel, *J. Mater. Chem.* **22** No 7, 3117 (2012).
6. M. Mary Jaculine, C. Justin Raj, S. Jerome Das, *J. Alloy. Compd.* **577**, 131 (2013).
7. Yang Zhao, Ying Huang, Qiufen Wang, Ke Wang, Meng Zong, Lei Wang, Wei Zhang, Xu Sun, *RSC Adv.* **3** No 34, 14480 (2013).
8. A. Raja, S. Ashokkumar, R. Pavithra Marthandam, J. Jayachandiran, Chandra Prasad Khatiwada, K. Kaviyarasu, R. Ganapathi Raman, M. Swaminathan, *J. Photochem. Photobiol. B: Biol.* **181**, 53 (2018).
9. S. Dinesh, S. Barathan, V.K. Premkumar, G. Sivakumar, N. Anandan, *J. Mater. Sci.: Mater. Electron.* **27** No 9, 9668 (2016).
10. Abdulrahman Syedahamed Haja Hameed, Chandrasekaran Karthikeyan, Abdulazees Parveez Ahamed, Nooruddin Thajuddin, Naiyf S. Alharbi, Sulaiman Ali Alharbi, and Ganasan Ravi, *Sci. Report.* **6**, 24312 (2016).

11. Howard A. Foster, Iram B. Ditta, Sajnu Varghese, Alex Steele, *Appl. Microbiol. Biotechnol.* **90**, 1847 (2011).
12. P.P. Hankare, P.A. Chate, D.J. Sathe, P.A. Chavan, V.M. Bhuse, *J. Mater. Sci.: Mater. Electron.* **20** No 4, 374 (2009).
13. Y. Wang, X. Liao, Z. Huang, G. Yin, J. Gu, Y. Yao, *Colloid. Surf. A* **372**, 165 (2010).
14. G. Vijayaprasath, P. Soundarrajan, G. Ravi, *J. Mater. Sci.: Mater. Electron.* **29** No 14, 11892 (2018).
15. J.X. Wang, S.S. Xie, Y. Gao, X.Q. Yan, D.F. Liu, H.J. Yuan, Z.P. Zhou, *J. Cryst. Growth* **267** No 1-2, 177 (2004).
16. J.X. Wang, S.S. Xie, H.J. Yuan, X.Q. Yan, D.F. Liu, Y. Gao, Z.P. Zhou, *Solid State Commun.* **131** No 7, 435 (2004).
17. Jianxiong Wang, Xiao Wei Sun, Shishen Xie, Weiya Zhou, Yi Yang, *Crystal Growth Design* **8** No 2, 707 (2007).
18. Han Sung Kim, Seon Oh Hwang, Yoon Myung, Jeunghee Park, Seung Yong Bae, Jae Pyoung Ahn, *Nano Lett.* **8** No 2, 551 (2008).
19. Jian-Wei Zhao, Li-Rong Qin, Li-De Zhang, *Solid State Commun.* **141** No 12, 663 (2007).
20. Qilin Li, Shaily Mahendra, Delina Y. Lyon, Lena Brunet, Michael V. Liga, Dong Li, Pedro J.J. Alvarez, *Water Res.* **42** No 18, 4591 (2008).
21. Howard A. Foster, Iram B. Ditta, Sajnu Varghese, Alex Steele, *Appl. Microbiol. Biotechnol.* **90** No 6, 1847 (2011).
22. Martin R. Wilson, Janet H. Lightbody, Ken Donaldson, Jill Sales, Vicki Stone, *Toxicol. Appl. Pharmacol.* **184** No 3, 172 (2002).
23. Ming Fang, Ji-Hua Chen, Xiu-Li Xu, Pei-Hong Yang, Hartmut F. Hildebrand, *Int. J. Antimicrob. Agents* **27** No 6, 513 (2006).

Антибактеріальна та оптична активність нанострижнів Zn_2SnO_4, синтезованих під дією мікрохвиль

S. Kumar[1], K.K. Sivakumar[2], Mohammed Kaso Sado[1], Gutu Ofgaa Ternesgen Garoma[1]

[1] *Wollega University, Ethiopia*
[2] *Academy of Maritime Education and Training Deemed to be University, India*

Нанострижні станату цинку (Zn_2SnO_4) синтезували простим методом з використанням мікрохвиль, застосовуючи аміак з кубічною структурою шпінелі. Кристалографію та оптичні властивості вивчали за допомогою рентгенівської дифракції (XRD) та фотолюмінесцентної спектроскопії (PL). Морфологію наночастинок спостерігали за допомогою автоелектронної скануючої мікроскопії (FESEM). Досліджено антибактеріальну дію наночастинок Zn_2SnO_4, протестованих проти грампозитивних та грамнегативних патогенних бактерій.

Ключові слова: Антибактеріальна активність, Станат цинку, Фотолюмінесценція (PL), Наночастинки, Наноархітектоніка.