Zno: Sno_2 Nano-Composite by Laser Ablation Method to Fight Diseases-Causing Bacterial and Fungi

Mazin Mohammed Mawat[1], Harakat Mohsin Roomy[2], Wedian K. Abad[3], Ahmed N. Abd[4]
[1] Wasit University, College of Medicine, Waist, Iraq
[2] Dept. of physics, Ministry of Education, Baghdad, Iraq
[3] Applied Physics Branch, Department of Applied Science, University of Technology- Iraq
[4] Departments of Physics, College of Science, Mustansiriyah University, Iraq.
Email: ahmed_naji_abd@uomustansiriyah.edu.iq

Abstract
Nano-particles of zinc oxide (ZnO) and tin oxide (SnO2) have been produced by the process of pulsed laser ablation in water. the optical, structural, morphological, and of all samples (ZnO, SnO2, and ZnO: SnO2 composite) Nano-particles were examined by employing UV–Vis spectroscopy, X-ray diffraction (XRD), atomic force microscopy, and evaluation of anti-bacterial and antifungal properties respectively. The XRD patterns demonstrate that generated ZnO Nano-particles are nano-0crystalline and have a hexagonal wurtzite structure, whereas the structure of tin oxide is tetragonal rutile. It was discovered that the direct optical energy gap of each and every sample fell somewhere in the range of (4.8), (4.8), and (4.9) eV, respectively. Anti-bacterial and antifungal activities can be observed in the Nano-particles that were produced.
Keywords: ZnO, SnO2, laser ablation, zinc oxide, nano-composite, anti-bacterial, antifungal

1. Introduction

Since nanotechnology has been employed to manufacture particles with dimensions in the nanometer range, the anti-bacterial capabilities of zinc oxide Nano-particles (also known as ZnO-NPs) have garnered a lot of interest from researchers all over the world. microbes can range in size from hundreds of nanometers to tens of micrometers. There are many different kinds of microbes in this range. ZnO is an example of a semiconducting II-VI metal oxide that has a broad band gap of 3.37 eV. ZnO-NPs offer very appealing features from an anti-bacterial standpoint. Because of their larger specific surface area and smaller particle size, which together lead to an increased particle surface reactivity. SnO_2 is an n-type material that has a band gap that ranges from 3.5 to 3.6 eV. ZnO and SnO_2 are two potential materials that could be used in a variety of applications. ZnO and SnO_2 can be mixed together to produce a wide variety of composite materials, such as ZnO/ SnO_2, ZnSnO3, $Zn2SnO_4$, as well as Zn-doped SnO_2 and Zn-doped ZnO. There have been numerous ZnO/SnO2 structures developed, such as nano-fibers, nano-rods, and Nano- flowers [1–5]. Nanosized linked ZnO- SnO_2composites are crucial in many domains of chemistry, physics, and solid state physics due to the size-dependent physical and chemical properties that they exhibit [6]. Using coupled oxides like ZnO and SnO_2, which are both n-type semiconductors, could improve charge separation and expand the photooxidation energy range. This would result in changes to optical properties like band gap, refractive index, and extension coefficient, all of which are essential for optoelectronic applications [7-9]. It is believed that investigating the properties of composites will be advantageous because the recombination of electron hole pairs, which is directly related to the properties of the material, can be easily modified by the connection of two types of semiconductors with differing band gaps [10]. Both of these materials are notable for their excellent optical transparency and low resistance throughout the visible spectrum, as well as their enormous band gaps. In addition, the high chemical stability of these compounds makes them particularly well-suited for use in applications involving semiconductors. In this research, we have described the production of ZnO,SnO2 NPs and ZnO:SnO2 by nanosecond Nd:YAG laser ablation of samples target immersed in distilled water at room temperature. Additionally, we have studied the characteristics of these compounds and evaluated their anti-bacterial and antifungal activities.

2. Experimental part

In the initial step of the process, the two powders of zinc and tin were thoroughly ground by a ceramic grinder and filtered into very small particles. After this, they were pressed with 5 tons for ten minutes to produce a solid pellet that had a diameter of 1.5 centimeters. In the second step, a Nd: YAG laser of type HUAFEI, operating at 1064 nanometers with a pulse duration of 250 nanoseconds, was used. Each pellet was positioned at the bottom of a glass container that held 5 mL of distilled water. . The process of ablation was carried out at a standard pressure and in open air, using a laser with an energy output of 480 mJ per pulse for a duration of ten

doi.org/10.31838/hiv23.03.305 Received: 19.11.22, Revised: 27.12.22, Accepted: 19.01.23.

minutes in order to produce nanoparticles, as shown in figure 1. A colloidal solution taken with a ratio of 1:1 , mixed with a magnetic stirrer for an hour at a temperature of 40 degrees Celsius, and then placed in an ultrasonic machine for an hour in order to generate a more homogeneous colloidal solution of ZnO: SnO_2 nano-composite, as shown in figure 1.

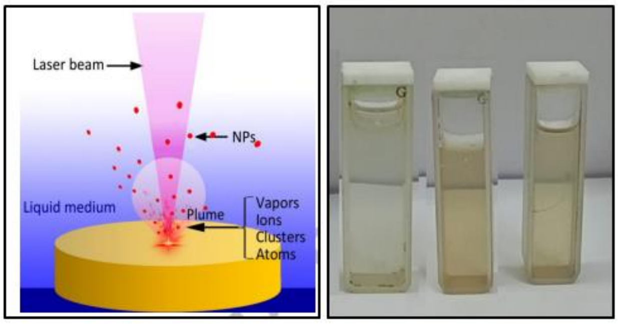

Figure1: Schematic diagram of laser ablation method and samples(on left SnO_2,ZnO and ZnO: SnO_2 composite)

3. X-ray diffraction of samples

X-ray diffraction (XRD) is a technique that uses an X-ray diffractometer (Model Brucker D-8with Nickel filtered Cu K (wavelength = 0.15404 nm) radiation in order to examine the phase formation and purity of ZnO-NPs that were generated using plus laser ablation method and deposited on substrate using drop casting method. According to the results of the XRD examination, there were three different diffraction peaks located at 31.2, 34.0, and 47.1, which corresponded to (100), (002), and (102) (figure2a) .In accordance with the hexagonal crystalline structure of ZnO, each and every peak in the diffractogram has been assigned an index. These findings are in accordance with the Standards, JCPDS No. (36-1451). The Shrrer equation was used to determine that the average grain size of the zinc oxide Nano-particles that were generated in the process of pulse laser ablation was 39.94 nm. [11,12]. The diffraction pattern of SnO_2 peaks can be seen at (110), (211), and at a 2 diffraction angle of 26, 51.8 degrees in successive order in the XRD results of the SnO2 sample shown in Figure (2b). Cassiterite crystal phase with tetragonal rutile structure (JCPDS No. 41-1445) [13]. These peaks correspond to the cassiterite crystal phase. Crystals that are, on average, 53.5 nanometers in size. The XRD patterns of the ZnO: SnO2 composite are displayed in Figure (2c). Crystalline ZnO has been successfully grown on the exterior of the SnO2 nanoparticles, as can be observed. This was a very important step in the process. where the findings of the XRD analysis showed that the typical peaks of SnO2 and ZnO Nano-particles are located at 26.4 and 31.0 respectively. [14].

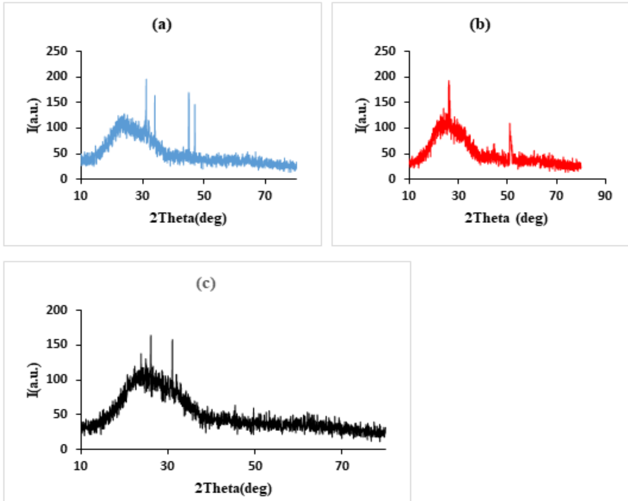

Fig.2: XRD analysis of (a)-ZnO,(b)- SnO_2 and (c)-ZnO: SnO_2 thin films.

Figure(3a-c) shows two-dimensional images of the surfaces of zinc oxide and tin oxide films prepared by laser ablation and deposited on glass bases by droplet casting method, with four drops on each substrate at a temperature of 80 °C, and left to dry completely for an hour. We note Nano-particles of different sizes and within the nanoscale distributed over the surface is in the form of peaks to the top with a spherical and semi-spherical shape, and others have pointed peaks. We notice in the composite film that the particles are lined up horizontally in the form of peaks, and the concentration and size of the particles are larger. Perhaps the reason is due to a larger number of interacting particles during the preparation process.

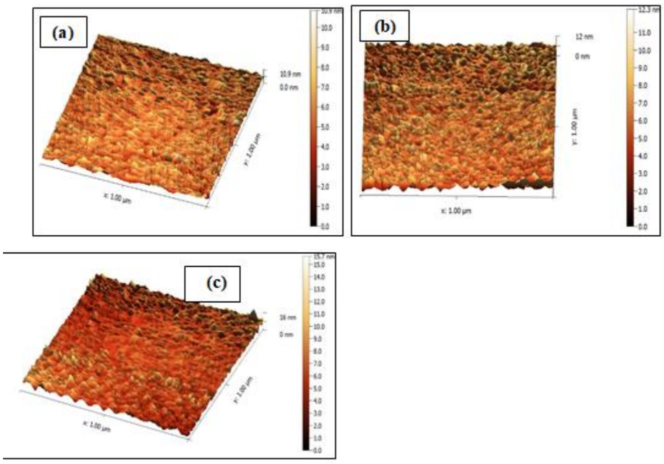

Figure 3: AFM image of (a)-ZnO,(b)-SnO_2 and (c)-Zn:SnO_2 composite.

FTIR spectroscopy is typically utilized for the purpose of verifying the presence of various organic and inorganic species, in addition to OH groups. ZnO, SnO_2, and Zn:SnO_2 composite nanoparticles'

FTIR spectra were recorded at room temperature using the KBr pellet technique, and the resulting spectra are presented in Figure (4). The wavelength range covered by the spectrum is 4000–500 cm-1. The O–H antisymmetric stretching vibration of water molecules on the surface of ZnO, SnO_2, and composite is the cause of the absorption band that can be seen at 3439,3440, and 3435 cm-1 respectively. The band that is centered at 677 cm-1 is attributable to the vibrations of tin oxide [18,19]. The band that is found at 1636,1637 cm-1 is due to the bending vibration of water molecules [15-17]. The stretching vibrations of ZnO nano particles are shown by the peak at 674 cm-1, which may be seen in composite samples, where it is noted that the major bonds do not change and that there is no appearance of a new bond. The results of the XRD experiment can be connected with the IR bands' findings, which show that ZnO and SnO_2 Nano-particles have formed [20,21].

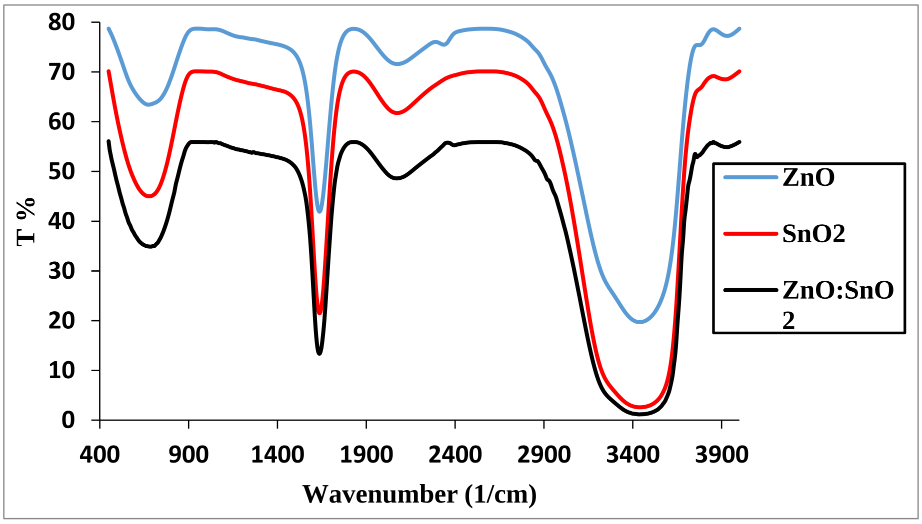

Figure 4: FT-IR spectra of ZnO,SnO_2 and ZnO:SnO_2 composite .

Table 2: summary of FTIR spectra of ZnO,SnO2 and ZnO:SnO_2 nano-composite.		
Samples	wavenumber (cm^{-1})	Type of bond
ZnO	3439.07	O-H
	2074.97	C-N
	1636.96	O-H
	674.08	Zn-O
SnO_2	3440.07	O-H
	2073.72	C-N
	1637.36	O-H
	677.34	Sn-O-Sn
ZnO: SnO_2 Composite	3435.94	O-H
	2070.07	C-N
	1636.20	O-H
	688.00	Sn-O-Sn Zn-O

The UV-Visible near IR absorption spectrum was used to explore the optical characteristics of ZnO, SnO_2, and ZnO: SnO_2 that were synthesized by plus laser ablation. The wavelength range for this investigation was 200–1100 nm. The UV-visible absorbance spectra of ZnO, SnO, and Zn: SnO_2 are depicted in figure 5.It was noticed that the absorbance decreased at wavelengths greater than 250 nm; hence, all of the samples are transparent in this region, which is where they can be used in a variety of applications involving semiconductors. Plasmon resonance is a phenomena that is found to take place when there is a modest peak at a wavelength of about 250 nanometers, which indicates the production of particles on the nanoscale. The fact that the peak in the composite sample was split into two smaller peaks suggests the existence of distinct particles (ZnO and SnO_2, specifically).It is anticipated that the absorbance will be influenced by a number of parameters including the band gap, the oxygen shortage, and the surface roughness. It is anticipated that small particle size will result in quantum confinement effects, which can be observed as a blue shift of the optical absorption edge due to a widening of the band gap in the ultraviolet range. The Tauc's relation, which was utilized in the process of calculating the band-gap for ZnO, SnO_2, and Zn: SnO_2 samples, is depicted in Figure (6a-c). The optical energy gap can be found by determining where the tangential line intersects with the h axis. It takes 4.8 and 4.9 eV to bridge the energy gap between ZnO, SnO, and the ZnO: SnO_2 composite. This broad band-gap range is owing to the small size of the nanoparticles, which is why the method results in a significantly greater band gap (the quantum size effect)[22,23]. The research that has been done on this topic makes it abundantly clear that a smaller particle size is correlated with a larger band gap. There is a good chance that the energy levels of the Nano-particles are influenced by additional factors one of which is the lattice strain [21].

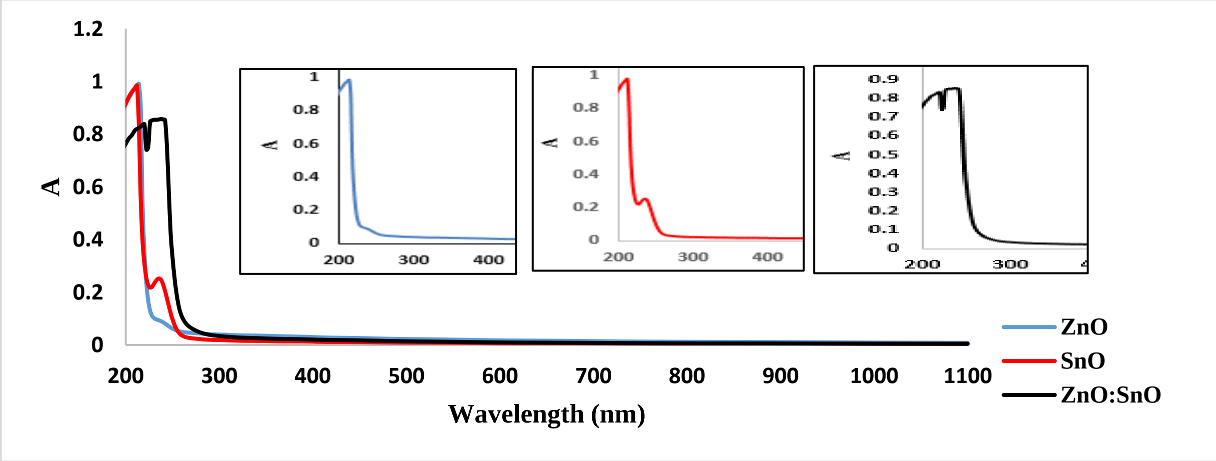

Figure 5: UV-visible absorption spectrum of ZnO (blue line), SnO_2 (red line) and ZnO: SnO_2 nano-particles(black line).

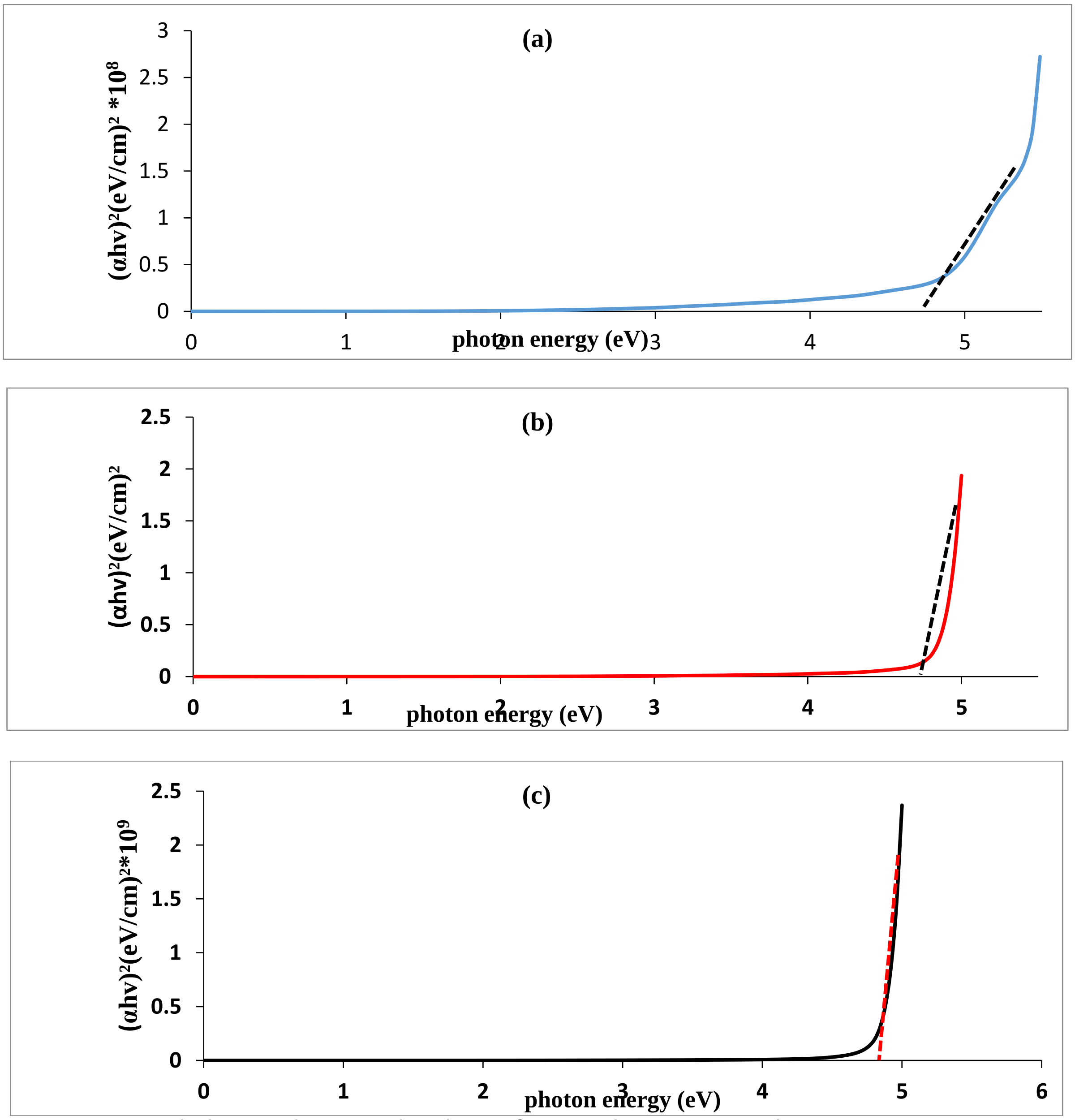

Figure 6: Graph showing the energy band gap of (a)-ZnO,(b)- SnO_2NPs and(c)- ZnO: SnO_2 composite .

Table 3: the values of energy gap of samples.		
E_g of ZnO	E_g of SnO2	E_g of ZnO: SnO2
4.8 eV	4.8eV	4.9eV

In most cases, bacteria may be recognized by the fact that the cells that make up their bodies contain cytoplasm, a cell wall, and a cell membrane. The great majority of the cell wall can be located on the surface of the cell that is not covered by the cell membrane. This particular portion of the cell wall is a layer of homogenous peptidoglycan that is made up of amino acids and sugars. The osmotic pressure that is found within the cytoplasm is due to the fact that the cell wall is responsible for both the maintenance of the characteristic shape of the cell as well as the presence of the cell wall. Gram-positive bacteria possess a single cytoplasmic membrane that is made up of numerous layers of peptidoglycan polymer and a cell wall that ranges in thickness from 20 to 80 nanometers. Additionally, these bacteria have an outside membrane that is constructed of peptidoglycan polymer. Gram-negative bacteria, on the other hand, have a cell wall that is made up of two cell membranes: an outer membrane and a plasma membrane that has a thin coating of peptidoglycan that is between 7 and 8 nanometers thick. These membranes are separated by a peptidoglycan layer that is between 7 and 8 nanometers thick. These size ranges of NPs are easily able to penetrate through the peptidoglycan, which results in severe harm being done to the cell. The cytoplasm is a fluid that has a viscosity similar to jelly and contains all of the components of a cell with the exception of the nucleus. Cytoplasm may be found inside of every cell in the body. This organelle is responsible for carrying out the processes of replication and growth in addition to its role in metabolism. Because of this, the cytoplasm is almost entirely composed of water (about 80% of its overall composition), as well as salts, ions, proteins, carbohydrates, and nucleic acids. This composition makes a contribution toward the improvement of the cellular structure's electrical conductivity [24], which is a positive outcome. The bacterial cell membranes found on the outside of the cell have a net negative charge. Figure 7 is a representation of the cellular architecture that bacteria possess. According to The American Heritage Medical, the process by which bacterial multiplication is stopped or hindered is referred to as anti-bacterial activity. You may also consider it in terms of the overall amount of surface area that is in contact with the bacteria. . Anti-bacterial pharmaceuticals are medications with a specific concentration that, despite being able to hurt or limit the development of bacteria, are safe for the host and do not pose any risk to them in any way. Anti-bacterial pharmaceuticals are an example of this type of drug. These chemicals have the potential to be employed as chemotherapeutic drugs, meaning that they can either treat bacterial infections or prevent them from occurring. The ability of an anti-bacterial agent to either kill bacteria or stop their growth is what determines whether or not the agent is bactericidal or bacteriostatic. Bactericidal agents kill bacteria, whereas bacteriostatic agents prevent germs from growing. The anti-bacterial and antifungal activity of ZnO, SnO_2 nanoparticles, and ZnO: SnO_2 nano-composite on the microorganism gram negative and gram positive as well as one strain of fungus (candida) was tested and analyzed (Figures 8–10). The results showed that ZnO and SnO2 Nano-particles inhibited the growth of the microorganisms. As can be seen in figures 8–10, all of the nanomaterials that were produced by the laser ablation method were proved effective against gram-positive and gram-negative bacteria, as well as fungus. This was deduced from the presence of inhibitory zones. Gram-negative bacteria cultures show a lower amount of growth inhibition when exposed to ZnO, SnO2 nanoparticles, and ZnO: SnO2 nano-composite. This is likely due to the more complex cell walls that gram-negative bacteria cultures have. Gram-negative bacteria cultures distinguished by this from their gram-positive counterparts. The anti-bacterial activity of the ZnO: SnO_2 composite material improved as a direct result of an increase in the concentration of Nano-particles in the material. Because of this, a higher concentration of Nano-particles is required for an action that is relevant in terms of its bactericidal effects. SnO_2NPs were found to be more effective than ZnONPs and the ZnO: SnO_2 nano-composite while the test was being conducted in the fungal inhibitory zone. The results are summarized in table (2) below. According to some reports, Nano-particles have the ability to kill bacteria in two distinct ways: first, by disintegrating and producing reactive oxygen species, as demonstrated in figure (11), and second, by electrostatically interacting with the cell walls of bacteria. Because of these interactions between bacterial cells and nanostructures, zones of inhibition (ZOI) are produced in the region surrounding the nanomaterials. The magnitude of the zone of inhibition (ZOI) is directly proportional to the bactericidal activity of the Nano-particles [25-29].

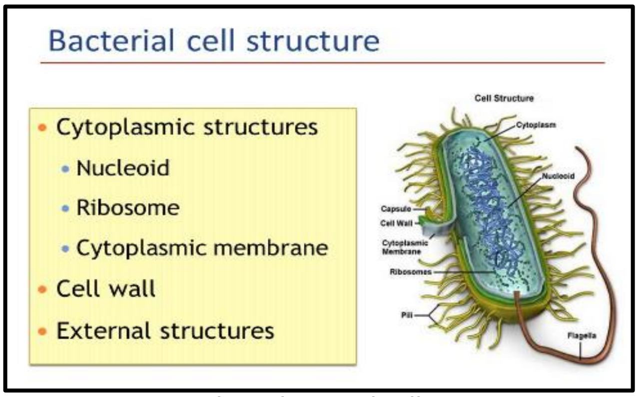

Figure 7: shows bacterial cell structure.

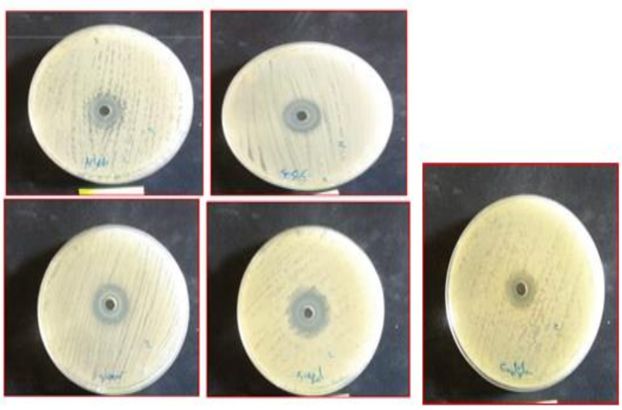

Figure8: shows the inhibition zone of bacterial and fungi for ZnONPs

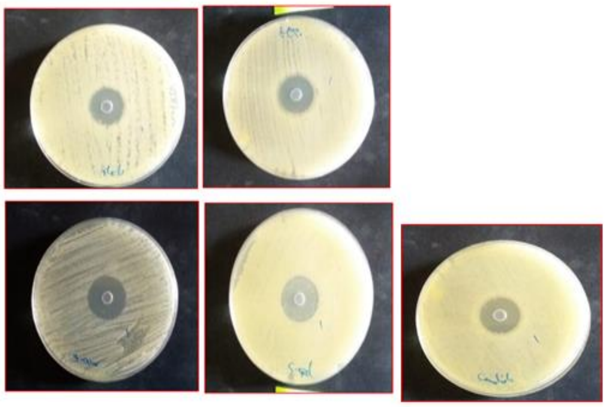

Figure9: shows the inhibition zone of bacterial and fungi for SnO2NPs

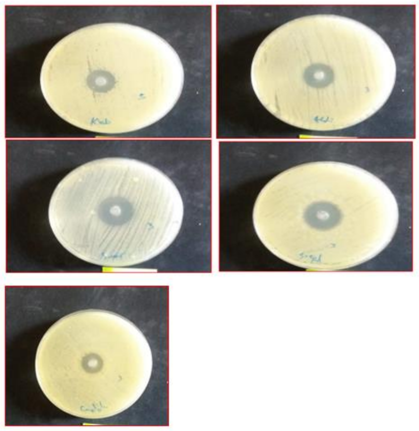

Figure10: shows the inhibition zone of bacterial and fungi for ZnO:SnO2NP-composite.

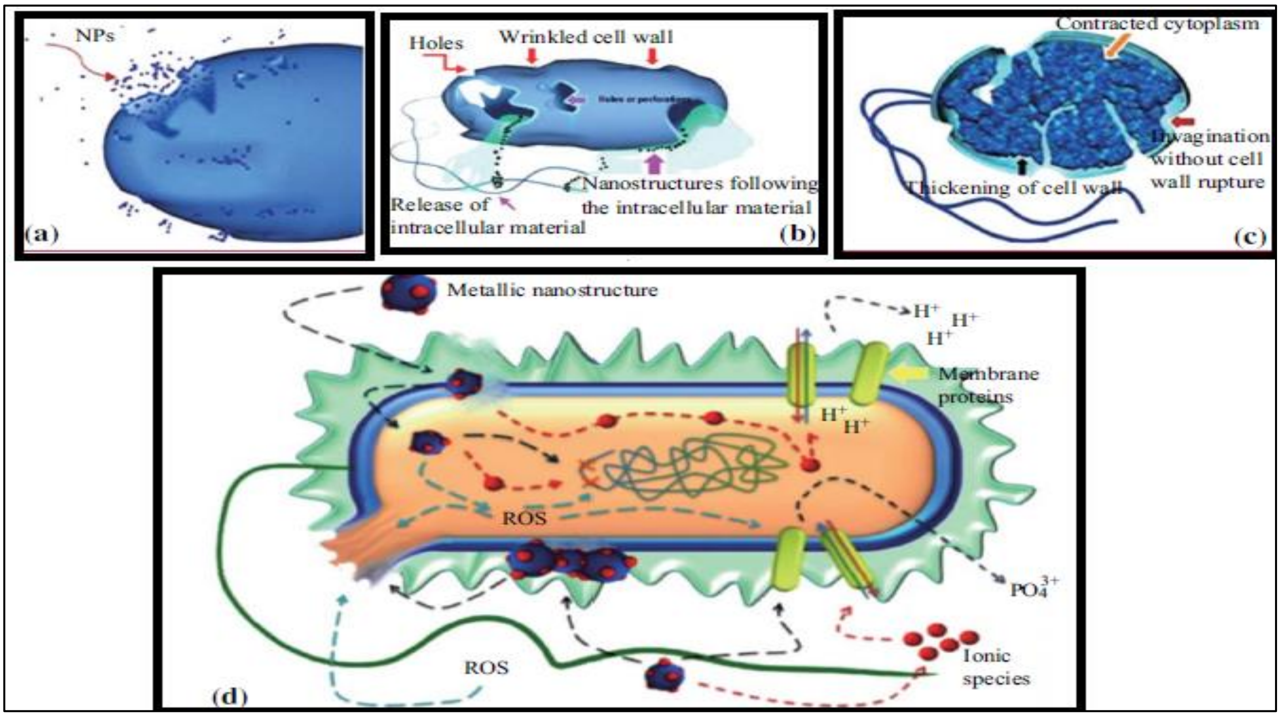

Figure 11: Schematic diagram showing possible mechanism of anti-bacterial activity.

Table 4: Diameter of inhibition zone			
Types	SnO2NPs (mm)	ZnONPs (mm)	ZnO: SnO2 nano-composite(mm)
Klebsiella sp.	18	16	17
E-Coli	19	20	19
Stap. aur.	22	20	23
Stap. empid.	21	21	23
Candida	20	15	17

4. Conclusion

The different morphologies of NPs have a substantial impact on the level of toxicity they exhibit. It has been shown that the shape of ZnO and SnO2 nanostructures can have an effect on their process of internalization [30,31]. For example, rods and wires are more able to penetrate the cell walls of bacteria than spherical structures. ZnO and SnO2 are both able to highly absorb UV light [32], and ZnO has a better response to UV light than SnO2 does. As a result, its conductivity dramatically improves, and this property significantly stimulates the contact that ZnO has with bacteria. This results in an increase in the production of ROS since the energy gap is quite substantial. also Surface imperfections have a significant impact on the toxicity of both ZnO and snO2. For instance, the anti-bacterial action of ZnO-NPs or SnO2 is owing to the membrane injury induced by defects such as edges and corners, which results from the abrasive surface of ZnO or SnO2. This injury causes ZnO-NPs or SnO2 to have an anti-bacterial effect.

1. References

[1] Alkaream Taher, H.A. Abd, A.N. , Jafar, A.M., Organo-Lead Halide Perovskite Materials CH3NH3PbI2X, X is I, Br, or Cl, in Solar Cell Applications ,International Journal of Nano-sciencethis link is disabled, 2023, 2350022
[2] Ismail, S.N. Alwan, B.J. , Ali, E.M. Abd, A.N. , Preparation of Cadmium Oxide Nanoparticles by Green Synthesis Method for Against Gram-Positive

and Gram-Negative Bacterial Strains AIP Conference Proceedingsthis link is disabled, 2022, 2398, 020053
[3]Y Caglar, M Caglar, S Ilican, A Ates "Morphological, optical and electricalproperties of CdZnO films prepared by sol–gel method", J. Phys. D: Appl.Phys. 42,065421, (2009).
[4]MR Abadi, M. Behdani, H Arabshahi, N Hosseini, " Indium-doped zinc oxide thin films by sol–gel method",Int. Rev. Phys. 12,3, (2009).
[5] Biosynthesis Of Cadmium Oxide Nanoparticles (CdO NPS) Using Aqueous Rhizome Extract Of Curcuma For Biological Applications
Skheel, A.Z, . Jaduaa, M.H. Abd, A.N. , AIP Conference Proceedingsthis link is disabled, 2022, 2398, 020030
[6] Hrbe, Z.A., Jaduaa Alzubaidy, M.H., Abd, A.N. , ZnO:CuO Nanocomposite Produced by Laser Ablation in Water for Antibacterial Activity ,Journal of Pharmaceutical Negative Resultsthis link is disabled, 2022, 13, pp. 165–172
[7] C.S. Chou, F.C. Chou, Y.G .Ding, P.Wu, The effect of ZnO-coating on the performance of a dye-sensitized solar cell, Solar Ener. Adv. Mat. Res. 88(6) ,1435-1442, (2012).
[8] Baqi, Z.H., Nasser, Z.S., Sulaiman, L.H., Abd, A.N. ,The anti-bacterial activity of Selenium dioxide Nano-particles and prospects for the future , Journal of Physics: Conference Seriesthis link is disabled, 2022, 2322(1), 012085
[9] M. Carotta, A. Cervi, A. Fioravanti, S. Gherardi, A. Giberti, , A novel ozone detection at room temperature through UV-LED-assisted ZnO thick film sensors, Thin Solid Films 520 ,939-946(2011).
[10] Mashkoor, S.J., Mahan, N.K., Rasool, K.H., Abd, A.N., Biosynthesis of Sulphur Nano-particles and discovering its effectiveness for some biological applications Journal of Physics: 2022, 2322(1), 012067
[11] Faraj, M.A., Jabbar, M.A., Abd, A.N.,Inhibitory Effect of Bi_2O_3NPs Produced by green synthesis method ,Journal of Physics: disabled, 2022, 2322(1), 012083
[12]Saima Mehar1 , Sadaf Khoso1 , Wenwu Qin , Iqra Anam , Anam Iqbal and Kanwal Iqbal"Green Synthesis of Zincoxide Nano-particles from Peganum harmala, and its biological potential against bacteria" Frontiers in Nanoscience and Nanotechnology, doi: 10.15761/FNN.1000188 Volume 6: 1-5,(2019).
[13]Aminuddin Debatarajaa,b, Daryl Widia Zulhendria , Brian Yuliartoa,d, Nugrahaa,d, Hiskiac , Bambang Sunendara,d " Investigation of Nanostructured SnO2 Synthesized with Polyol Technique for CO Gas Sensor Applications" Engineering Physics International Conference, 170 ,60 – 64, (2017)
[14] A. Ghaderi1 , S. Abbasi , F. Farahbod,"Synthesis of SnO2 and ZnO Nano-particles and SnO2-ZnO Hybrid for the Photocatalytic Oxidation of Methyl Orange" Iranian Journal of Chemical Engineering Vol. 12, No. 3 (2015).
[15]N.M.A. Hadia, S. García-Granda, J.R. García, Effect of the temperature on structural and optical properties of zinc oxide nanoparticles, J. Nanosci. Nanotechnol. 14 ,5443–5448, (2014).
[16]M. Shoyama, N. Hashimoto, Effect of poly ethylene glycol addition on the microstructure and sensor characteristics of SnO2 thin films prepared by sol – gel method, Sensors Actuators B. 93 ,585–589, (2003).
[17]-Bertoluzza A, Fagnano C, Morelli MA ,Raman and infrared spectra on silica gel evolving towards glass. J Non-cryst Solids 48:117–128, (1982)
[18]. Tazikeh S, Akbari A, Talebi A, Talebi E ,Synthesis and characterization of tin oxide Nano-particles via the Co-precipitation method. Mater Sci Pol 32:98–101, (2014).
[19]. Gnanam S, Rajendran V ,Synthesis of tin oxide Nano-particles by sol–gel process: effect of solvents on the optical properties. J Sol–Gel Sci Technol 53:555–559, (2010).
[20] Shuang Zhan 1,2 , Dongmei Li , Shengfa Liang , Xin Chen and Xia Li ,"A Novel Flexible Room Temperature Ethanol Gas Sensor Based on SnO2 Doped Poly-Diallyldim-ethylammonium Chloride " Sensors, 13, 4378-4389; (2013).
[21]V.K. Vidhu, Daizy Philip "Biogenic synthesis of SnO2 nanoparticles: Evaluation of anti-bacterial and antioxidant activities" Spectro-chimica Acta Part A: Molecular and Biomolecular Spectroscopy Volume 134, 5, Pages 372-379, . (2015)
[22]Subramaniam Mohana Priya, A. Geetha & K. Ramamurthi " Structural, morphological and optical properties of tin oxide Nano-particles synthesized by sol–gel method adding hydrochloric acid " J Sol-Gel Sci Technol 78(2),pp365-372,(2016)
[23]. Periathai RS, Pandiyarajan J, Jeyakumaran N, Prithivikumaran N (2014) Role of temperature on the properties of SnO2 Nano-particles synthesised by sol–gel process. International Journal of ChemTech Research 6(3):2132-2134,(2014).
[24] Guifen Fu, Patricia S. Vary, and Chhiu-Tsu Lin" Anatase TiO2 Nano-composites for Antimicrobial Coatings " J. Phys. Chem. B, 109, 8889-889,(2005)
[25]Zainab Ali Hrbe1* , Muneer H. Jaduaa Alzubaidy2 , Ahmed N. Abd "ZnO:CuO Nano-composite Produced by Laser Ablation in Water for Anti-bacterial Activity", Journal of Pharmaceutical Negative Results ,Vol.13. S. I.3 (2022)
[26]V.K. Vidhu, Daizy Philip "Biogenic synthesis of SnO_2 nanoparticles: Evaluation of anti-bacterial and antioxidant activities", / Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy 134 ,372–379, (2015).
[27]Mushtak A.Jabbar , Wedian K. Abad, Ahmed N. Abd."Green Syntheses of CdO NPs: The Biological efficacy study against human pathogens (E-coli and candida)" Journal: HIV Nursing ,23,3,pp1662-1666,(2023)
[28] A. N. Abd, M. F. Al-Marjani, and Z. A. Kadham, "Synthesis of CdO NP S for antimicrobial activity," Int. J.Thin Film Sci. Technol., vol. 7, no. 1, pp. 43–

47, doi: 10.18576/ijtfst/070106. (2018).
[29] Omar Fadhil Abdullah1, Saadoo M. Abulkarem, Wedian K. Abad"Selenium Dioxide Nano-particles from Hibiscus Sabdariffa Flower Extract Induce Apoptosis in Bacterium (Gram-negative, Gram-positive) and Fungi" NeuroQuantology, ,20: 198-203, (2022).
[30]. S. Pal, Y.K. Tak, J.M. Song, Does the anti-bacterial activity of silver Nano-particles depend on the shape of the nanoparticle? A study of the gram-negative bacterium Escherichia coli. Appl. Environ. Microbiol. 73(6), 1712–1720 (2007).
[31] . H. Yang, C. Liu, D. Yang, H. Zhang, Z. Xi, Comparative study of cytotoxicity, oxidative stress and genotoxicity induced by four typical nanomaterials: the role of particle size, shape and composition. J. Appl. Toxicol. 29(1), 69–78 (2009)
[32] M. Nirmala, M.G. Nair, K. Rekha, A. Anukaliani, S. Samdarshi, R.G. Nair, Photocatalytic activity of ZnO nanopowders synthesized by DC thermal plasma. Afr. J. Basic Appl. Sci. 2(5–6), 161–166 (2010)