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ZnO: SnO_2 nanocomposite efficacy for gas sensing and microbial applications

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The unique characteristics of 2-dimensional hetero structure offers efficient gas sensing with high selectivity to identify gases from the interference gases which is quite difficult. In the present work, ZnO: SnO_2Nano composite clusters (NCC) is prepared. A resistive metal oxide volatile organic compound (VOC) gas sensor is fabricated with nullifying the effect of humidity by increasing temperature optimally. A single-step SOL-GEL (SG) synthesis is used to prepare ZnO: SnO_2 NCC with maximum Zn/Sn molar concentration ratio of 3. The morphological studies through Scanning Electron Microscopy (SEM), electrical properties due to oxygen vacancies and energy band variations of Nanocomposite are measured. The enhancement of gas sensor sensitivity due to highly mesoporous nature of the composite is observed. From the findings, the abundant mesopores in the range of 2 nm-14 nm and specific surface area of 54.2 m^2 g^{-1} with the average crystal size of 14.236 nm, and polar surface area of the composite 25.9651Åis achieved. When compared to bare ZnO and SnO_2 gas sensors, the present gas sensor offers the higher selectivity with enhanced performance due to the mesoporous structure. Fast repeatability rate of 2200 sec at 350°C to ethanol is attained and the overall selectivity of the sensor increased twice as 2.085. The NCC compound is tested firstly with micro organisms such as *B. subtilis* (B. S), *Bacillus cereus* (B. C), *B. coagulans* (B. C), *Pseudonymous auriginosa* (P. A) are considered for antimicrobial activity. From the findings, zinc stannate compound showed good efficacy towards B. cereus Gram positive and P.A gram-negative. A bacterial growth is arrested highly with *B. cereus*.

Keywords: Breath biomarkers, Semi-conductor metal oxide (SMO) sensors, Sol-gel, VOC gas sensors

Detection of VOCs by using hetero Nano composite cluster (NCC) can be performed rather than bare gas sensors such as ZnO, SnO_2 individually. In the gas sensors research such as VOC Emission and assessments the technological sensors such as semiconductor-based, polymer-based, metal oxide, conductive electro active polymers, optical, saw-based, Electrochemical sensors are popular. Gas detection is useful in biomedical diagnosis, cancer detection[14], personal health monitoring, safety sensors, SMO materials based novel probes for diagnostic and therapeutic applications[10] and respiratory system disease detection by estimating the VOC exhalation of humans using biomarker analysis[5]. To achieve this, many researchers over the decades developed few VOC gas sensors by choosing materials from group III–V elements such as stannous oxide, ITO, WO_3, In_2O_3, Zinc combinations and TiO_2 are a few modern Nano-Structures. In this work, the importance of developing a VOC gas sensor that evokes volatile organic compound (VOC) detection with which finding a pain less non-invasive disease detection through biomarker analysis antimicrobial activity test through Ager well diffusion method is the main objective. Initially, COMSOL Multiphysics used to perform simulation of the device[1,2,5], Qin Tang, P[3] demonstrated that gas sensing tests with ultrathin ZnO-SnO_2 heterojunction Nano sheets showed ethanol gas, Pakhare K.S[4] studied SnO_2–ZnO Nanocomposite at room temperature using chemical bath deposition (CBD) method, Ying Wei and GuiyunYi[6] measured the specific surface area and pore size of the Ag/SnO_2/RGO composite by the BET method, the mesoporous structure can offer more adsorption to ethanol. Cho Y, Parmar N S[7] discussed the fabrication of high-quality Zn: SnO_2/Ag/Zn: SnO_2 multilayer transparent conducting electrode on flexible substrates by Essential McLeod Program (EMP). Kumar S, Nigam R[8] gave Sol-gel synthesis of ZnO–SnO_2 NCC. Tao, Yu[9] mentioned that On-chip MEMs VOC gas bio sensor with ZnO: SnO_2 NCC with metal electrodes used in the diagnostics. S.H. Yan, S.Y. Ma, Cheng[10] gave synthesis of SnO_2–ZnO hetero structured nano fibers for

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ethanol performance. Hamrouni A, Moussa N[11] gave Sol-gel synthesis and photo catalytic activity of ZnO: SnO_2 NCC. Tang W, Wang J, Yao PJ, Du HY, Sun YH[12] mentioned the preparation, characterization, and gas sensing mechanism of ZnO-doped SnO_2 Nanofibers. Cesare Malagu, Barbara Fabbri[13] discovered a device that may represent a non-invasive and potentially inexpensive pre-screening method for the diagnosis of CRCs. W. Tang, J. Wang, P.J. Yao[14] studied Hollow SnO_2–ZnO composite Nanofibers with electro spinning method for detecting methanol, Thanh. T, Chinh[15] performed that the thermal evaporation and the spray-coating to prepare synthesis of SnO_2–ZnO core–shell nano wires gave better ethanol sensing performance. Y.G. Zheng, J. Wang, P.J. Yao[16] team specified electro spun of Ni O-doped SnO_2Nanofibers to estimate the Formaldehyde sensing. Xiao Hua Jia[17] implemented that the SnO_2 doped with ZnO Nanosheets, the sensor is capable of detecting ethanol vapor in the range of 10-100 ppm with excellent response.

In the development of gas sensors unsatisfied selectivity and long-term stability are the main drawbacks identified Humidity and ethanol in breath are two major cross-sensitive agents that might hinder the efficacy of a metal oxide ethanol vapor sensor from exhaled breath. In many mentioned previous works, the effect of humidity has been nullified or reduced to a great extent by simply increasing the temperature, and doping the second material. In order to overcome those, two main key aspects are followed. One is doping with the suitable metal oxides such as Pd on SnO_2, SnO_2-In_2O_3, Ce doped with SnO_2, ZnO-SnO_2 nano fibers[10,12,14], ZnO-SnO_2 coated with reduced graphene oxide[6], Ag Coated ZnO- SnO_2 nano fibers[7], Ni-ZnO[16]. Another technique is adding the second composite material due to the surface modification distributes free charge carriers, thereby increases electron concentration in the conductance band and conductivity of the sensor improved which is as shown in (Fig. 2). By increasing the calcination temperatures a decrease in the oxygen vacancies within the hetero structures is observed. The sensing response of ZnO: SnO_2 n-n hetero junction increases as the Zn/Sn molar ratio raised to maximum of 3. Sensor selectivity depends on ZnO: $SnO_2$with suitable molar ratios produced an average crystal size of 54.47 nm-42.29 nm which are best suitable for VOC gas sensors to measure low ppm range (105 ppm) of ethanol. The compound is also tested firstly with organisms called *B. subtilis*, *B. cereus*, *B. coagulans*, *P. auriginosa* are considered for the a antimicrobial activity which are basically gram–positive and gram negative type bacteria causes systemic infections in immune compromised patients like diabetic. *B. coagulans* for irritable bowel syndrome (IBS), diarrhea, gas, airway infections, and respiratory tract infection, these cells fight off and response to influenza A and adenovirus exposure diseases.

Synthesis

Synthesis of Nanomaterials can be performed chemical bath deposition (CBD) method[4], hydrothermal method[6,] hydrothermal BET method[7], EMP method[8],Sol-Gel method[9,12], green synthesis techniques based on applications, mechano-chemical methods, chemical vapor deposition (CVD) method, Solvo-Thermal, Nano porous composite using packed bed and network structured ZnO: SnO_2 by two-step[16]Solvo-Thermal preparations, high gravity reactive precipitation methods are few synthesizing techniques.

In the present work stannous oxide and Zinc chloride AR grade elements were considered to prepare heterogeneous ZnO: SnO_2 Nanocomposite cluster single-step SOL-GEL (SG) method is followed. To measure its grain size, elemental composition weight percentage, and average crystal size, structural studies performed and compared with previous works. Through Scanning Electron Microscopy (SEM) the morphological changes were estimated. Material compositions for the synthesis are given in the (Table 1). ZnO: SnO_2NCC heterogeneous structures as-synthesized is represented in (Fig. 1A-D), successive ultra spinning up to 800-1100 rpm with magnetic stirrer, filtration and extraction of the

Table 1 — Materials used for synthesis of ZnO: SnO_2 NC Cluster

Synthesis Composite materials used	Chemical formula	Weight (%)	Purity
Zinc Chloride	$ZnCl_2$	M=136.3g/ Mol	95.99%
Stannous/Tin Chloride	$SnCl_2$	M=284.4g/ Mol	99.9%
Tri Sodium Citrate	capping agent	$C_6H_5Na_3O_7$. $2H_2O$	99.9%
Sodium hydroxide	NaOH	Pellets	95%
Ethanol & Di-Water	C_2H_5OH	H_2O	Sufficient %

precipitate compound over 24 h, kept in a hot air oven a thermal process from 80°C to 120°C for 3 h is carried, then the compound is given to muffle furnace to perform annealing at particular temperature. The synthesized material is given to deposition and further optimization process at various Sintered temperature in the clean room environment.

Characterization

X-ray diffraction analysis

Synthesized samples of ZnO: SnO_2 Nanocomposite powders are given to an X-ray diffractometer (XRD) to study 2-θ variations. The Rigaku X-ray diffractometer XRD 3kW with target atomic number 29 target and Cu-kα1 radiation of 1.540593 nm intensity is used to obtain the patterns of ZnO: SnO_2 Nanocomposite, XRD peaks are as shown in the (Fig. 2). Elemental molar ratios are varied to a maximum Zn/Sn molar concentration ratio is adjusted to 3. Visualization models and electronic configuration structure of ZnO: SnO_2 composite is obtained as OpenGL version: 4.5.0 - Build 23.20.16.4973 with maximum supported width and height, OpenGL depth buffer bit: 16 and the structure parameters are as shown in the following (Table 2).

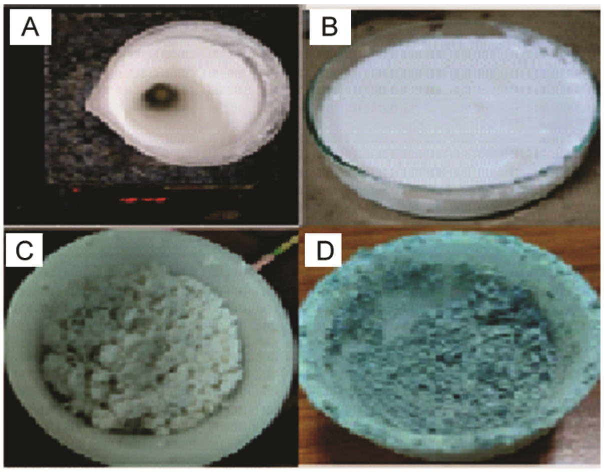

Fig. 1(A-D) — Preparation levels of ZnO: SnO_2 Nanocomposite cluster

The above (Fig. 3A-C) show the visualization models and electronic configuration structure of ZnO: SnO_2 composite in space ball and stick mode, filling mode and wire frame render modes, respectively.

XRD patterns of ZnO: SnO_2 Nano Composite concluded that tetragonal rutile structure of SnO_2 and Monolithic structures of ZnO obtained from the as-synthesized Nanocomposite. The Average crystal size (D) is measured, respectively, using Equation (1). The average crystal size 14.234 nm measured is as shown in (Table 3). FWHM values are calculated and compared with[10] is represented in the (Table 4) for each peak to know the D-spacing and crystal structures Debye-Scherrer's formula is used.

At appropriate anneal temperatures of 600-800°C the crystallinity of ZnO: SnO_2NCCimproved due to the enhancement in the surface diffusion and mobility of the oxygen atoms on the surfaces and removal of O^- atoms shown in (Fig. 4A).

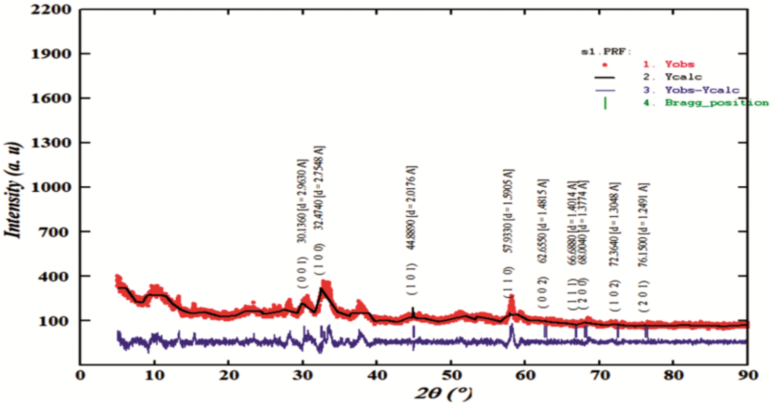

Fig. 2 — Intensity *vs* Positional 2- θ patterns from XRD

Table 2 — Elements Occupancy in the orbitals

S. No	Element	X	Y	Z	Occupancy	Orbital (u)
1	Sn Sn1	0.00	0.00	0.00	0.150	1a
2	Sn Sn2	0.33	0.67	0.50	0.850	1d
3	Zn Zn1	0.00	0.00	0.00	0.150	1a
4	Zn Zn2	0.33	0.67	0.50	0.150	1d

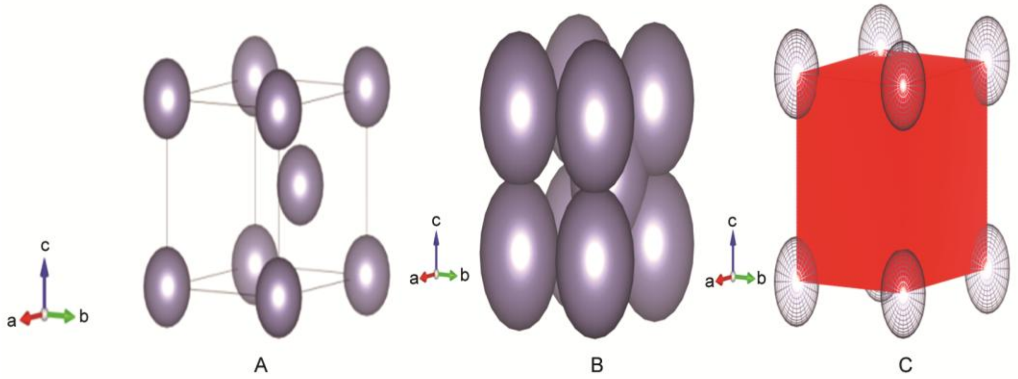

Fig. 3 — (A) Ball-Stick mode; (B) filling mode; and (C) wire frame rendering modes

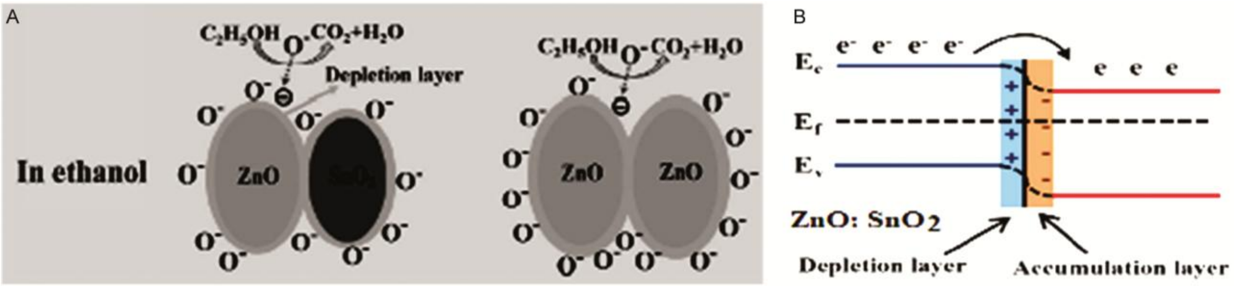

Fig. 4 — (A) Energy band diagram of ZnO: SnO_2(A) NCCfor reducing gas ethanol; and (B) hetero junction Nanocomposite

Table 3 — The average crystal sizes calculated based onDebey-Scherrer's formula

Average crystal size (D) in (nm)	Without anneal	With annealing pore size (nm)		
	At room temp (°C)	At 600°C	At 700°C	At 800°C
	14.236 nm	54.47	44.39	42.29

Table 4 — ZnO: SnO_2 composite Positional values

Molar ratio	2 θ	FWHM	D (nm)	2 θ	FWHM	D (nm)
		Previous works [11]			*(As-synthesized)*	
Pure ZnO	36.18	0.306	27	24.3	0.32	31.76
ZnO in(comp)	36.14	0.32	25.2	34.23	0.31	33.89
SnO_2	26.52	0.65	12.1	7.8	0.33	6.95
SnO_2 (comp)	26.50	0.37	21	21	0.35	26.71

Scanning Electron Microscopy (SEM)

ZnO: SnO_2 morphological changes are studied using Scanning Electron Microscopy (SEM) Images of ZnO: SnO_2 NCC are shown in (Fig. 5A-C). The grain size, shape, and surface properties in terms of morphology with different magnifications of 1µm scale-200 nm with 5, 50,100k times of magnification was observed from the SEM images. The peaks of ZnO were formed hexagonal wurtzite structure shown in (Fig. 5A) and SnO_2 with tetragonal rutile structure no other phases detected as in (Fig. 5B). A mixed ZnO: SnO_2 interwoven small crystalline nature of phases and very closely bounded Nanoclusters are detected as shown in (Fig. 5C).Finally, when ZnO (Ø = 5.2 eV, X = 4.3 eV, E_g = 3.37eV is coupled with SnO_2 (Ø = 4.9 eV, X = 4.5 eV, Eg = 3.5 eV hetero junction formed. SEM Image of Nano composite cluster as shown in (Fig. 5A) shows that the Nano composite has red color marked hexagonal rod like structures are observed. These rods are of Nano rods correspond to Zn compositions. SEM Image of NCC as shown in (Fig. 5B) shows that the Nano composite has foam like white structures are observed. These foams are of Nano composite corresponds to Sn compositions. SEM Image of NCC as shown in (Fig. 5C) shows that the complete Nano composite has rod like structures are observed with foams surrounded on rods, hetero structures turned in to meso porous nature at 200 nm level of SEM is observed in the (Fig. 5B).

The energy band diagram ofthe ZnO: SnO_2 Nanocomposite with the ease of diffusion of mobility of electrons is represented as shown in (Fig. 4B). The specific surface area (SSA) of mixed samples was higher than that of ZnO, lower than that of SnO_2 and improves significantly with the Sn composite ratio content of 54.2 m^2g^{-1} comparably high than that of BET SSA with 44.5 m^2g^{-1}. The elemental compositions confirmed that proper atomic weight percentages are adjusted during the synthesis so that the improved adsorption of oxygen as shown in (Fig. 4B).

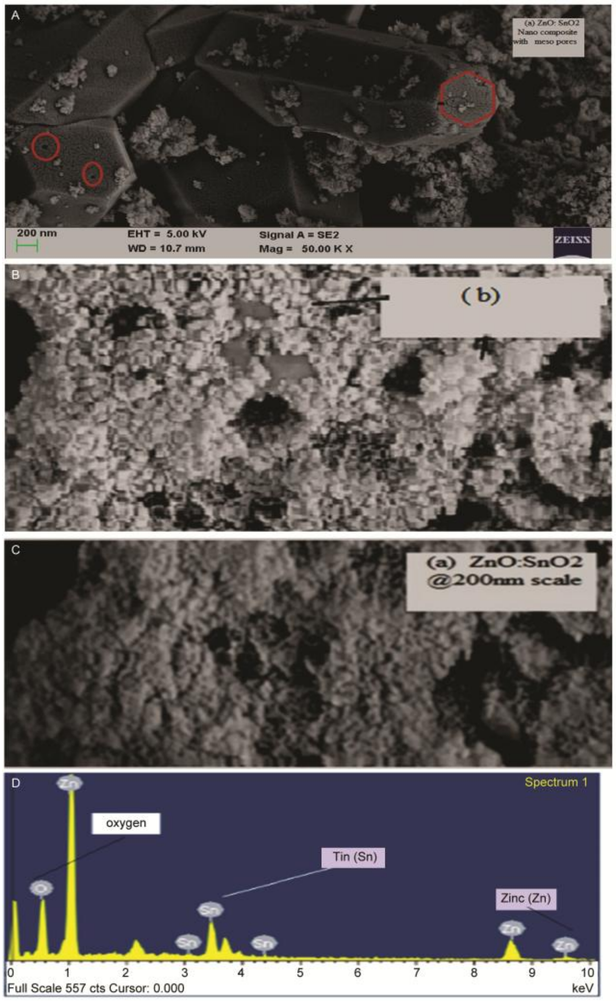

Fig. 5 — (A) SEM image for ZnO: SnO2 (A) Nano rods; (B) Nanocomposite cluster (porous nature foams observed); (C) Images from SEM at 200 nm 100 k X times magnified ZnO:SnO_2 Nanocomposite clusters; and (D) EDS spectral Images confirms Zn, Sn, Oxygen Elements

Energy Dispersive X-ray spectrometer (EDX)

The spectrum of EDX revealed that the presence of oxygen (O), Zinc (Zn), Tin (Sn) in the composite. The elemental weight percentages of zinc (Zn) and oxygen (O) and Tin (Sn) are shown in (Table 5). The Energy density spectrum results were extracted at 50, 60, 90 µM different atomic weight % of Zn, Sn Composites adjusted to total 100. The element composition says that the weight (%) of oxygen is reduced with increase in annealing temperatures there by enhances the gas sensing nature.

Results and Discussion

The ZnO: SnO_2NCCat 200nm shows respectable morphology with less agglomeration a transition from Nanorods to Nano flower structures occurred and deposited on the surface of ZnO Nano rods as shown in the (Figs 5A-C). Elements in the nanocomposite is confirmed by EDS spectral information as shown in (Fig. 5D) from which Zn, Sn, O is confirmed. When ZnO Nano-wires are surface functionalized with SnO_2 Nanoparticles, the effective enhancement in response to analyte is achieved, slight changes in response to other reducing gases are also observed. The remarkably improved selectivity makes it possible for ZnO–SnO_2 hetero-structured NCC to detect ethanol with a maximum response is 162.69 at I_{air}=1.1475 µA and I_{gas}=3.0144 µA observed as shown in (Table 6). When ethanol is introduced the adsorbed oxygen and ethanol on the hetero-junction semiconductor surface can be reacted as shown in the equations[2,3]. The performance plots of the gas sensor indicate as-synthesized ZnO: SnO_2 sensing layer has highest selectivity at maximum currents I_{air} is 0.082 µA and I_{gas}=4.627 µA are measured as shown in the (Fig. 6A).

$$C_2H_5OH\,(ads) + 6O^-(ads) \rightarrow 2CO_2 + 3H_2O + 6e^- \quad \ldots (1)$$

$$C_2H_5OH\,(ads) + 6O^{2-}(ads) \rightarrow 2CO_2 + 3H_2O + 12e^- \quad \ldots (2)$$

Table 5 — Element Weight and Atomic percentage of ZnO: SnO_2Nano cluster

Elements	Weight%	Atomic%	Weight%	Atomic%	Weight%	Atomic%
Zinc (Zn)	51.04	30.62	52.14	30.93	49.35	31.71
Tin(Sn)	23.87	7.89	22.38	7.31	28.47	10.07
Oxygen	25.09	61.49	22.38	61.76	22.18	58.22
Total	100		100		100	

Table 6 — Response of As-synthesized ZnO: SnO_2 Nanocomposite

ZnO: SnO_2NCCat 200nmTemperature (°C)	Ia (mA/µA)	Ig(mA/µA)	Response
Room Temp. at 25	0.41187 mA	0.41198 mA	0.027
50	0.40746 mA	0.40436 ma	0.767
100	0.39748 mA	0.39706 mA	0.106
150	0.38819 mA	0.38578 mA	0.625
200	0.36946 mA	0.36572 mA	1.023
250	0.30616 mA	0.28880 mA	6.011
300	1.1085 µA	2.3942 µA	115.99
350	1.1475 µA	3.0144 µA	162.69

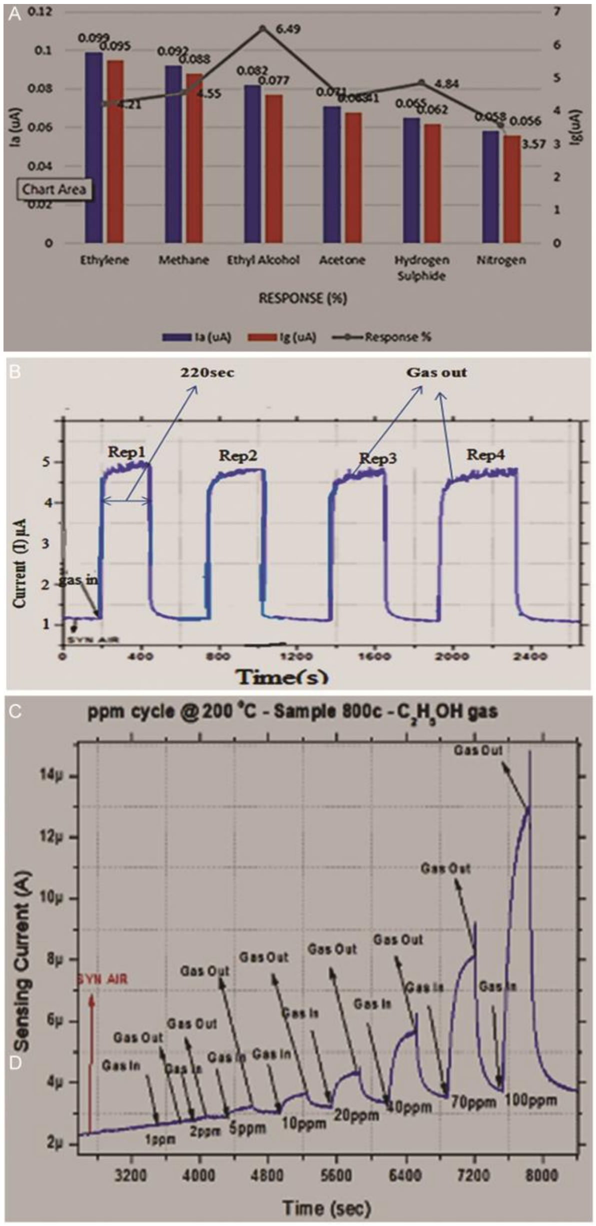

Fig. 6 (A) — Selectivity Performance of the fabricated ZnO: SnO_2 Nanocomposite gas sensor; (B) Repeatability of ZnO: SnO_2NCC gas Sensor; and (C) ZnO: SnO_2 NCC gas sensor ppm cycles

some of the chemisorbed oxygen ions in the form of O^{-} (ads), O^{2-}(ads) are removed for oxidizing gasC_2H_5OH, releasing electrons, reduction in the oxygen ions is observed from the (Table 5) and back to the conduction band (E_c), thereby improves electron conductivity causes a deeper extension of the electron depletion layer at the hetero-junction interface into the SnO_2 due to the lower work function of SnO_2 than that of ZnO. Subsequently, a great reduction in the potential barrier across the interface contributing to the enhanced ethanol adsorption kinetics thereby increasing gas sensing mechanism as represented in (Fig. 4B)[10]. The as-synthesized ZnO-SnO_2 n-n heterojunction gas sensor gave best repeat ability in the range of currents 4.5 µA to 4.9 µA in lesser intervals of time T=400 sec. Highest Ethanol selectivity of 9.7 ppm is among interference gases like Ethylene, Methane, Acetone, Hydrogen Sulphide, and Nitrogen is shown in (Fig. 6B) and a maximum of 13 µA sensing current and number of ppm cycles repeated 200°C as shown in (Fig. 6C). Present VOC gas sensor offers fast repeatability better selectivity to ethanol, when compared to the core shell Nano structures, Nano fibers. Thus, as-synthesized ZnO-SnO_2 Nano clusters are preferred with better result of 2.0859 times in termsresponse. The achieved results are quoted and compared with previous works in (Table 7).

The repeatability of the sensor by sample IDE 700°C recorded as 220 sec which is shown in (Fig. 6B).

Test for antimicrobial activity of a ZnO: SnO_2 Nano composite

From the literature, Evstropiev[18] prepared ZnO-SnO_2 films by polymer salt method. ZnO nanocrystals added with SnO_2 additions change the coatings. Crystal structure variations are observed and making their spatial orientation more random and enhance antibacterial activity against gram-positive (*Staphylococcus aureus ATCC 209P*) and gram-

Table 7 — Overall Selectivity of VOC ZnO: SnO_2 gas sensor

Analyte type	ZnO:SnO2 Nanocomposite	Type of Synthesis	Temp. (°C)	Response	Selectivity among gases	Ref
1, 2, 5, 10, 20, 50, 100 and 200 ppm ethanol	ZnO-SnO2 heterojunctions @ ZnSnO- 3-500	SnO2/ZnSn(OH) x nanosheetsby urea decomposition method	240	80 140	Ethanol	[3] Qin table [3]
24 ppm lower concentration	Nano-Diced SnO2–ZnO Composite	Chemical Route	275	59.67	Ethanol	[4]
100ppm Ethanol	Nano Fiber type	Electro Spun	300	78	Acetone, Methanol Acetic Acid	[10]
100 ppmEthanol	Core - Shell structure	2-step process	400	14.1	CO, H_2, NH_3 and LPG	[15]
Formaldehyde 100 ppm	NiO- SnO_2 Nano Fibers	Electro Spinning	200	20	Ethanol, Ammonia	[16]
As-synthesized ZnO:SnO_2 Nanocomposite	ZnO: SnO_2 Nano Clusters	Single step Sol-Gel (HCPSSG)	350	162.69	Ethanol, Methane, Nitrogen, H_2S.	[This work]

Table 8 — Zone Inhibition in (Cm) With Nutrient Ager Diffusion method

Micro organism used	600°C sample	700°C sample	800°C Sample
B. subtilis	0.2	0.2	0.1
B. cereus	1.5	2.5	2
B. coagulans	1.6	2.3	2.2
P. aeruginosa	0.8	1.8	1.1

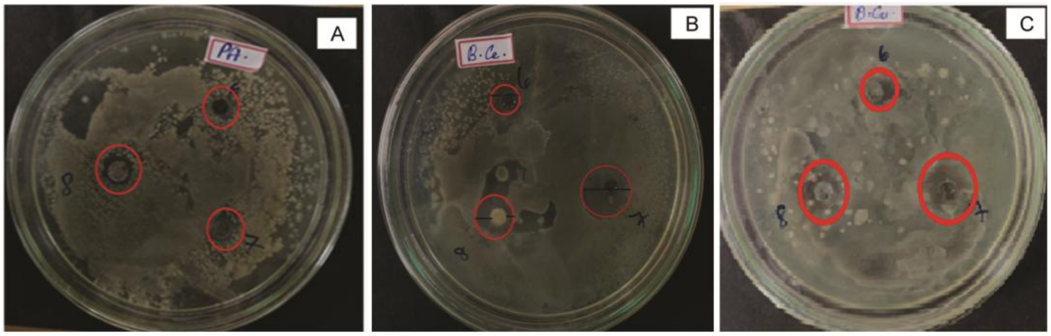

Fig.7 — (A-C) — Zone inhibition with nutrient Ager well bore diffusion method

negative (*Escherichia coli ATCC 25922*) bacteria. Mohri *et al.*[19] studied the development of new protective, antibacterial and antifouling coatings by a simple anodization of oriented tin foils. An efficient photo biocides towards bacterial the strong influence of aloe Vera extract as an oxidizing medium for the conversion of tin (II) ion to tin (IV) ion (tin (IV) oxide) and also restricting the crystallite growth. From those findings nano composite of Sn Zn does not show any anti bacterial activity while, the composite, SnZnAV synthesized with aloe Vera extract as medium showed enhanced action against both bacteria *E. coli* and *Staphylococcus aureus*. Sudhaparimala *et al.*[20] pathogens like *E. coli*. Phenomena were observed. Hsueh[21] studied that ZnO NPs can affect *B. subtilis* viability through the inhibition of cell growth, cytosolic protein expression, and bio film formation to understand how ZnO NPs affect and their impact on *B. subtilis* growth was studied. The present work test organisms *B. Subtilis*, *B. cereus*, *B. coagulans*, *P. aeruginosa* are considered for the antimicrobial activity, then small round pits/ wells are made in the solid medium with the help of sterile borers and over test sample material is placed in the pits carefully with micro pipette and the Petri plates are kept in an incubator for 24-48 h at 30°C - 32°C temperature. After 24 h, the clear inhibition zone is observed around the pits as shown in the following (Fig. 7A-C). The inhibited zones are measured and the diameters of the ring shapes are obtained with different micro organisms are represented in the (Table 8).

B. cereus is a Gram positive, anaerobic bacterium characterized by large rod-shaped cells and an ability to form heat-resistant endospores. *B. cereus* grows best in a temperature range of (4°C) to (48°C).

Table 9 — Comparision of Efficacy towards various anti- microorganisms

Methods	Gram positive	Gram negative	Zone Inhibition	Ref
polymer-salt spectroscopic, luminescent methods	*Staphylococcus aureus*	*E. coli*	1.5 mm -150 mm	[18]
Agar well diffusion method	*staphylococcus aureus* (S.A) 17, 21, 24 mm	*E. Coli* 20, 23, 25 mm	17-25 mm	[20]
A plant- bacterium protein	ZnO NPs affect - *B.Subtilis*	---	Fts Z ring 0.58 mm	[21]
Turbidity method or reading optical density	*Listeria monocytogenes*	*Escherichia coli, Aspergillus niger*	Zone form	[25]
Sol–Gel & Agar well diffusion method	*Bacillus cereus*	*Pseudomonas aeruginosa*	2.8 Cm With GP 1.8 Cm with GN	[Present work]

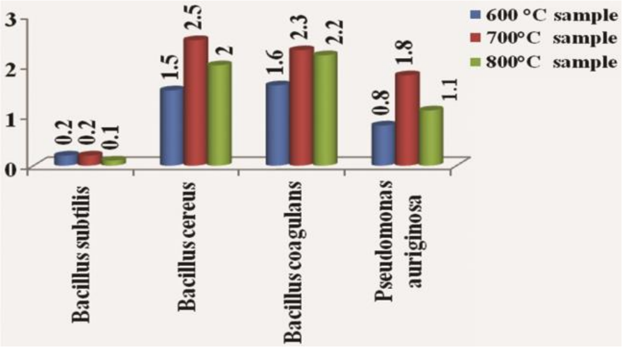

Fig. 8 — Antimicrobial activity test zone inhibition of a ZnO: SnO_2 Nano composite with gram positive and gram negative bacteria

Optimal growth occurs within the narrower temperature range of (28°C) to (35°C) and a pH range of 4.9 to 9.3. *B. cereus* can cause serious, life-threatening, systemic infections in immune compromised patients. The ability of microorganism to form bio film on biomedical devices can be responsible for catheter-related bloodstream infections. Other manifestations of severe disease are meningitis, Endo carditis and surgical and traumatic wound infections. The most common feature in true bacteremia caused by *Bacillus* is the presence of an intravascular catheter[22]. Antimicrobial activity test zone inhibition results of a ZnO: SnO_2 Nano composite with gram positive and gram negative bacteria is shown in (Fig. 8) and compared its efficacy towards various microorganisms with previous works is represented in (Table 9). From the findings, medium reacted highly to ethanol dissolved solvent rather than water solvent which is represented in (Fig. 7A-C), compound reacted to *B. cereus* Gram positive highly than that of *Pseudomonas Aeruginosa* (*P.A*) Gram-negative. A moderate value obtained with *B. coagulans* which effects on the immune system is shown in the (Fig. 8).

Conclusion

As-synthesized ZnO: SnO_2 Nanocomposite VOC gas sensor with heterogeneous co-precipitation single-step sol-gel (SG) gave average crystal size 14.236 nm and pore size in the range of 2-14 nm is obtained. Higher selectivity with maximumresponse of 162.69 at optimal temperature is exhibited. This achievement is due to the improvement in the oxygen vacancies thereby conductivity is greatly enhanced. Gas sensing investigations reveals that the ZnO: SnO_2 composite Nanocluster sensor shows the highest response to ethanol with good stability, maximum of 13 μA sensor current, present sensor offers good selectivity and fast repeatability rate to ethanol, comparably an overall selectivity of the sensor increased to 2.0859 time at 350°C. As synthesized ZnO: SnO_2 Nanocomposite VOC gas sensor can be best possible solution for ethanol sensing and can be used as exhale breath biomarker sensor. The antimicrobial activity studies found high efficacy to gram positive *B. cereus* rather than gram negative *Pseudomonas aeruginosa* (*P.A*).

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Conflict of interest

All authors declare no conflict of interest.

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