

RESEARCH

Influence of CNT Concentrations on Structural and Morphological Properties of PANI-SnO₂-CNT Nanocomposite Thin Films and the Sensitivity Performance to Detect *E. coli* in Water

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ABSTRACT

Carbon nanotubes (CNTs) are particularly attractive for use in sensors for environmental and health monitoring. This study proposes a new approach in developing polymer-metal-based sensor for *E. coli* detection by using CNTs incorporation. PANI-SnO₂ nanocomposite thin films were combined with CNTs to be fabricated as biosensing devices. PANI-(SnO₂)_{1-x}-CNT_x nanocomposite thin films were synthesized using sol-gel method and deposited on a glass substrate by spin coating technique. The prepared thin films were characterized by X-ray diffraction (XRD), field scanning electron microscopy (FESEM), atomic field microscopy (AFM) and ultraviolet-visible (UV-vis) spectroscopy. The sensitivity performance of PANI-(SnO₂)_{1-x}-CNT_x nanocomposite thin films were conducted by using current-voltage (*I*-*V*) measurements. From the results, XRD patterns show the appearance of PANI, SnO₂ and C peaks and the increasing crystallite size with the increasing of CNT concentration. FESEM images show the spherical shape of SnO₂ and the nanotubes of carbon in the diameter size range 30 – 100 nm and 150 – 220 nm respectively. AFM analysis has found out the roughness parameter has increased when CNT percentage was increased. The peaks from UV-Vis absorbance bands indicated the presence of CNT and SnO₂ at wavelength 270 nm and 370 nm respectively. From *I*-*V* measurement of the sensor, PANI-(SnO₂)_{1-x}-CNT_x with *x* = 0.03 performed the highest sensitivity which is 16.32%. The results demonstrate that the increasing of CNT concentrations was increasing the sensitivity of PANI-(SnO₂)_{1-x}-CNT_x thin films towards *E. coli*.

KEYWORDS

Polyaniline, SnO₂, CNT, *E. coli*, sensor.

INTRODUCTION

Cases of food poisoning and infection have happened a lot among school students because of non-hygiene food preparation or contaminated raw food with the presence of bacteria such as *Escherichia coli* (*E. coli*) [1,2]. Food-borne outbreaks are caused by *E. coli* spread through ground beef,

dairy products, drinking water, food vehicle, person-to-person outbreaks, recreational water and animal contact [3]. *E. coli* lives in humid areas and can live on surfaces such as wet floors. *E. coli* bacteria are basically harmless to humans and rarely cause dangerous diseases to humans, but there are several types of *E. coli* that contain pathogens that can cause stomach aches and diarrhea. *E. coli* bacteria are

generally easily spread through unclean or contaminated water and are present in the human intestine. *E. coli* also has dangerous and harmless strains. That type of *E. coli* can cause early symptoms such as cramping and bloody diarrhea. Among the harmless symptoms are diarrhea, abdominal pain, and vomiting. It is very important to identify bacteria or microorganisms to avoid contamination of food and water. Methods to detect microbes quickly are very important, but the methods that are often used require the use in the laboratory which will take a large cost and a long time to get the results.

Fast and cost-effective detection methods to detect bacteria are crucial. In this paper, *I-V* measurement is the method used to detect *E. coli* because this method has a low-cost experimental set-up and can perform fast response from bacteria reaction to electrical signal. The other conventional methods such as polymerase chain reaction (PCR), enzyme-linked immunosorbent assay (ELISA) and microscopic agglutination test (MAT) require high-end instruments, giant laboratory and time-consuming [4-6]. Through these conventional methods, the sample required to move from water resources to the laboratory, high-cost, complicated equipment usage, complex procedures, and the requirement of skilled specialist to cope with the complexity which limit their widespread practice in water quality detection [7]. To overcome those problems, electrochemical detection like *I-V* measurement method has begun to be widely used in the research field. Nowadays, the use of electrochemical detection as *E. coli* sensor method is very widespread in bio-sensing field because of its highly sensitive, specific, portability and simple detection method [8-10]. Amperometric sensor is one of the electrochemical methods in detecting *E. coli*. Amperometric detection method uses the current measurement during oxidation and reduction process by reaction material at a constant applied voltage [11]. The change in current-voltage (*I-V*) characteristics of the polymer thin films after exposure to various microorganisms is a measure of microbial sensitivity and their sensitivity is directly depending on the concentration of the microorganisms or the material in the thin film.

The combination of conducting polymer such polyaniline (PANI) and metal ion increases the electrical property which is good for the sensor fabrication [12]. Using metal and PANI shows promise in detecting microorganisms. PANI as a conducting polymer helps to identify bacteria by detecting heat and charges emitted by them [13,14]. The nanosize of tin (IV) oxide (SnO_2) thin films has engrossed considerable interest nowadays due to their fascinating electrical and chemical properties. SnO_2 has been studied by previous researchers in antibacterial activity against *E. coli* [15,16]. Carbon nanotubes (CNTs) exhibit excellent properties such as more biocompatible, fast electron transfer kinetics, chemical inertness, and wide number of antibacterial properties. In sensing applications, CNT has been widely used recently in many fields such as

gas sensing to detect methane (CH_4) and nitrogen dioxide (NO_2) gas [17,18], chemical sensing to detect hazardous and noxious substances (HNS) [19], mechanical sensing to detect strain [20,21] and medical field to detect COVID-19 virus [22]. The combination of CNTs with various conducting polymers such as polyaniline can fabricate portable, more stable, highly sensitive, cost-effective and energy efficient sensor [23]. CNTs can play a significant role in the fabrication of sensors for detecting various pathogenic bacteria [24]. Combining polyaniline with CNT enhances its capability to detect bacteria [25,26]. These techniques can aid in preventing food and water contamination.

This study proposes a new approach in developing polymer-metal-based sensor for *E. coli* detection by using CNTs incorporation. Herewith, we demonstrate PANI- SnO_2 -CNT nanocomposite thin film as an electrochemical amperometry sensor to detect *E. coli* in water. The CNT concentration is diversified to study the influence of CNT concentration on structural and morphological properties and the sensitivity performance of PANI- SnO_2 -CNT against *E. coli*. The effects of CNT concentrations on PANI- $(\text{SnO}_2)_{1-x}\text{-CNT}_x$ nanocomposite thin films were analyzed by X-ray diffraction (XRD), field scanning electron microscopy (FESEM), atomic field microscopy (AFM) and ultraviolet-visible (UV-vis) spectroscopy. The sensitivity performance of PANI- $(\text{SnO}_2)_{1-x}\text{-CNT}_x$ nanocomposite thin films were conducted by using current-voltage (*I-V*) measurements. To verify the performance of the proposed material as a *E. coli* sensor, the *I-V* characteristics were measured.

EXPERIMENTAL

The synthesis of PANI-SnO₂-CNT nanocomposite

Polyvinyl alcohol (PVA, 99% hydrolysis and molar weight 85000-124000 g/mol), aniline monomer ($\text{C}_6\text{H}_5\text{NH}_2$), tin (II) chloride (SnCl_2), carbon nanotubes (CNTs) powder and nitric acid (HNO_3) were used in the synthesis of PANI- SnO_2 -CNT nanocomposite. Samples of *E. coli* bacteria with concentration of 10^8 CFU/mL were obtained from a research laboratory at Faculty of Health Sciences, Universiti Kebangsaan Malaysia, located in Kuala Lumpur. Firstly, 0.5 g of PVA was dissolved in 40 mL of deionized water and continuously stirred for 30 minutes on a hot plate at a temperature between 85°C – 100°C . At the same time, 0.5 g of tin SnCl_2 was dissolved in 10 mL of ethanol to become SnO_2 . After obtaining the diluted PVA solution and SnO_2 solution, both liquids were mixed together and PVA- SnO_2 nanocomposite was produced. Various compositions of SnO_2 and CNT were prepared using the formula $(\text{SnO}_2)_{1-x}\text{-CNT}_x$ (with $x = 0.00, 0.01, 0.02$ and 0.03) to study the effects in sensor performance. To achieve various compositions of PANI- SnO_2 -CNT, the weight percentage of SnO_2 and CNT have been calculated as shown in **Table 1**. CNT acts as a dopant to enhance the

biosensing capability for detecting the presence of *E. coli*. CNT powder was added into the PVA-SnO₂ mixture, followed by the addition of aniline and nitric acid. Aniline monomer was polymerized to be polyaniline and embedded into SnO₂ nanoparticles. After continuous stirring for 24 hours, a dark blue solution appeared and indicated the successful production of PANI-SnO₂-CNT nanocomposite solution. This sol-gel technique has been widely used by researchers in the preparation of PANI-SnO₂ nanocomposite because of low-cost and ease of preparation [27,28]. The whole steps of preparation PANI-SnO₂-CNT nanocomposite thin films have been summarized in Fig. 1 below.

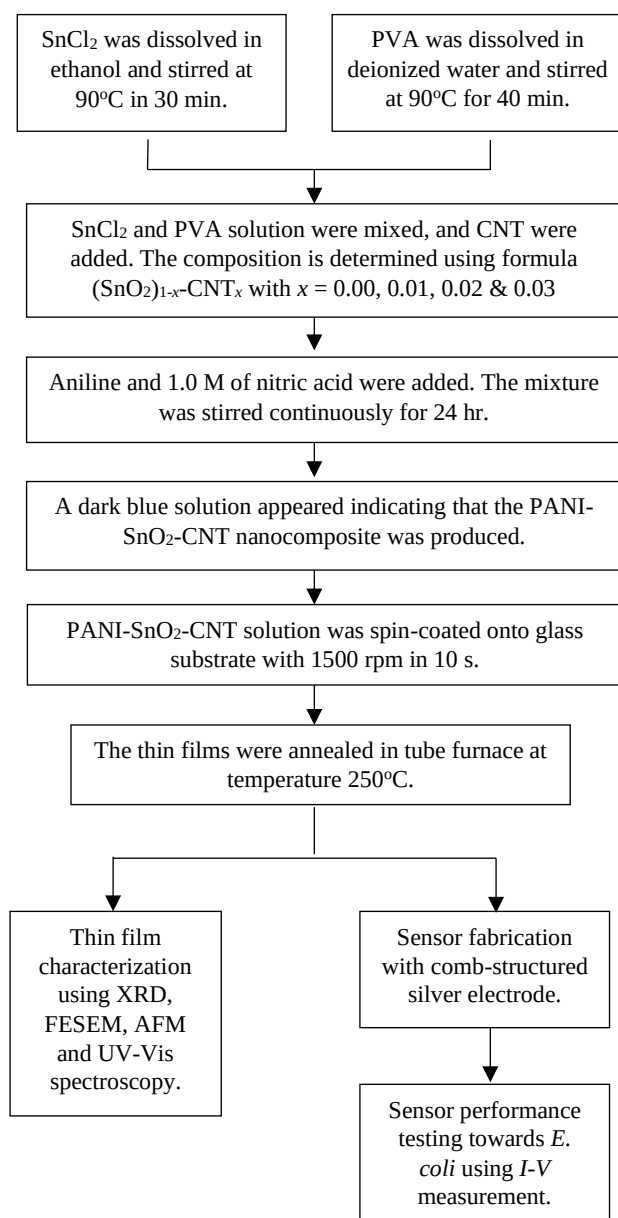


Fig. 1. Methodology flow-chart of the preparation of PANI-SnO₂-CNT nanocomposite thin films as an *E. coli* sensor.

Table 1. The weight percentage of SnO₂ and CNT for the synthesis of PANI-SnO₂-CNT nanocomposite.

Sample	SnO ₂ ratio	CNT ratio	SnO ₂ (g)	CNT (g)
1	1	0	0.500	0
2	0.99	0.01	0.495	0.005
3	0.98	0.02	0.490	0.010
4	0.97	0.03	0.485	0.015

The fabrication of PANI-SnO₂-CNT thin films sensor

PANI-SnO₂-CNT nanocomposite solution was deposited on the glass substrate at the speed of 1500 rpm in 10 s by using spin-coater machine to get five layers of thin films. The thin film samples that have been successfully rotated were annealed in a tube furnace with maximum temperature of 250 °C. The prepared thin films are used for measurement and characterization analysis.

The thin films that have been successfully fabricated have size measurement of 2 cm × 2 cm. Silver paste was structured on the surface of the PANI-SnO₂-CNT nanocomposite thin films. Silver paste has conductive properties which enable the thin films to detect current. The shape of the comb is designed to apply the silver paste as shown in Fig. 2. A conductivity test is being conducted to test the capability of the thin films.

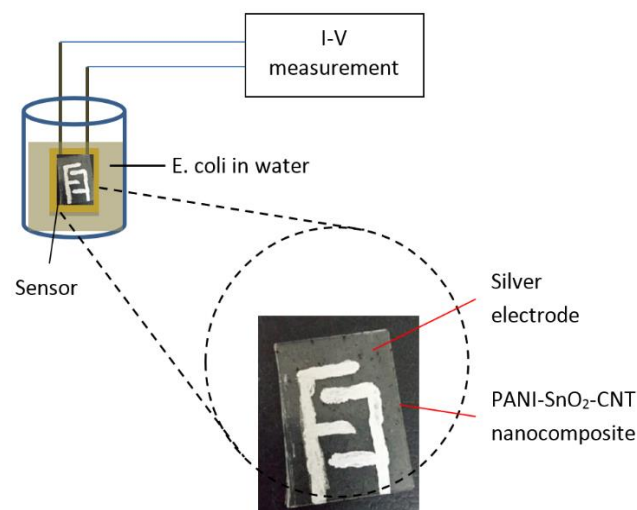


Fig. 2. The comb-structured silver electrode on PANI-SnO₂-CNT nanocomposite thin film and the sensor performance experimental setup.

Analysis equipments

X-ray diffraction (XRD) analysis of PANI-SnO₂-CNT nanocomposite thin films were conducted using Advanced Bruker model D8 X-ray diffractometer from 2θ 20° to 60° with step of 0.05° in 1 second and wavelength 1.5496 Å. The morphology of the films and the cross section were analyzed by field emission scanning electron microscopy

(FESEM) by Zeiss model LEO Supra 55 VP with magnitude 30 kx and 200 nm scale for all captures. Surface morphology of the films was measured by atomic field microscopy (AFM) instrument model NT-MDT, NTEGRA Prima. Ultraviolet-visible (UV-Vis) spectroscopy analysis was measured from 200 to 800 nm wavelength using Perkin Elmer Lambda 950 UV-Vis spectrophotometer. For sensor performance, the sensitivity towards *E. coli* was measured via current-voltage (*I-V*) by electrochemical impedance spectroscopy Gamry model Series G 300.

RESULTS AND DISCUSSION

X-ray diffraction (XRD) analysis

Fig. 3 shows the XRD spectra of PANI-(SnO₂)_{1-x}-CNT_x nanocomposite thin films with $x = 0.00, 0.01, 0.02$ and 0.03 . The broad peaks appeared at $2\theta = 15^\circ$ to 25° are attributed to the amorphous peaks of PANI. The tall, sharp and narrow peaks that appeared at 34.40° and 36.25° are attributed to the rutile tetragonal structure of SnO₂ at plane (1 0 1) and (2 0 0). Besides that, the other SnO₂ peaks also lie at plane (0 0 2) and (3 1 0) while carbon is at (1 0 0). The crystallite size of PANI-SnO₂-CNT nanocomposite thin films were calculated based on the dominant peaks at plane (2 0 0). For tetragonal lattice, it was found by simple geometry consideration where the interplanetary space, d depends on the unit cell parameter, a and Miller indices based on the Bragg's equation:

$$\frac{1}{d_{hkl}^2} = \frac{h^2 + k^2}{a_o^2} + \frac{l^2}{c_o^2} \quad (1)$$

$$2d_{hkl} \sin \theta_B = \lambda \quad (2)$$

To determine the crystallite size, D , the classic Scherrer's equation has been used:

$$D = \frac{K\lambda}{\beta \cos \theta_B} \quad (3)$$

where d is the interplane space, $h k l$ is Miller index, a_o and c_o are lattice parameter, D is the crystallite size, λ is the wavelength of X-ray ($1.5406 \text{ \AA}$ m), K is Scherrer's constant (0.9), β is the full width at half maximum (FWHM) of the highest observed peak and θ_B is the diffraction angle in radian. **Table 2** shows the crystallite size, D and lattice parameter, a_o of PANI-(SnO₂)_{1-x}-CNT_x nanocomposite thin films. The crystallite sizes were found to increase from the CNT percentage $x = 0.00$ to $x = 0.03$. For the lattice parameters, all the values are the same except for sample $x = 0.01$ where the a_o value is slightly higher than the others. The difference in a_o value is caused by the distortion that occurs in the lattice parameters which shows that there is a structural change in the SnO₂ and C atom due to its combination with the atoms in PANI [29].

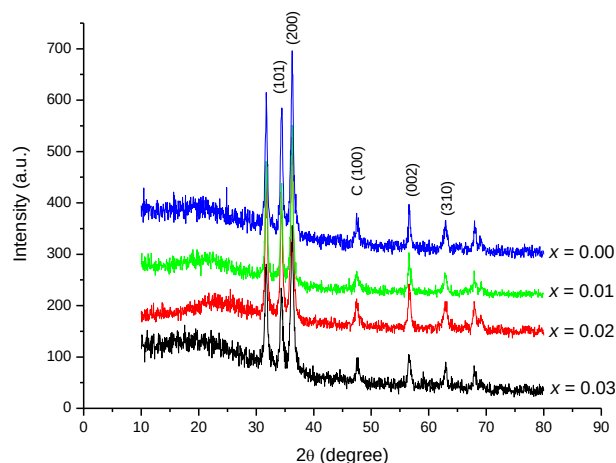


Fig. 3. X-ray diffraction spectra of PANI-(SnO₂)_{1-x}-CNT_x nanocomposite thin films with $x = 0.00, 0.01, 0.02$ and 0.03 .

Table 2. Crystallite sizes and lattice parameters of PANI-(SnO₂)_{1-x}-CNT_x nanocomposite thin films with $x = 0.00, 0.01, 0.02$ and 0.03 .

No.	CNT percentage	Crystallite size, D (nm)	Lattice parameter, a_o (Å)
(a)	$x = 0.00$	23.87	4.287
(b)	$x = 0.01$	25.71	4.292
(c)	$x = 0.02$	27.85	4.287
(d)	$x = 0.03$	27.85	4.287

Field Emission Scanning Electron Microscopy (FESEM) analysis

Fig. 4 shows the FESEM images of PANI-(SnO₂)_{1-x}-CNT_x nanocomposite thin films with $x = 0.00$ and 0.03 . **Fig. 4(a)** is the morphology image of PANI-SnO₂ nanocomposite thin films without CNT ($x = 0.00$). It can be seen the spherical shape of SnO₂ nanoparticles with nearly uniform size. It also can be observed that the particles were agglomerated. The agglomeration effect depends on the size of the particles. The size of the particles was estimated to be around 30 – 90 nm. **Fig. 4(b)** is the morphology image of PANI-(SnO₂)_{1-x}-CNT_x ($x = 0.03$) nanocomposite thin films. The incorporation of 3% of CNT into PANI-SnO₂ produces the formation of C nanotubes embedded into the agglomerations of SnO₂ nanosphere. The nanotubes were estimated to be 150 – 220 nm in diameter and the nanosphere particles size is around 30 – 100 nm. The particle size in sample $x = 0.03$ is slightly larger than that in the sample $x = 0.00$ due to the increased agglomeration formation when CNTs are added [30]. The increasing of agglomeration with the addition of CNT percentage is due to its poor wettability, which causes CNT difficult to disperse uniformly in the SnO₂ matrix and leads to poor interfacial bonding strength of CNT and SnO₂. **Fig. 4(c)** and **Fig. 4(d)** are the cross-sectional images of PANI-SnO₂

($x = 0.00$) and PANI-(SnO₂)_{1-x}-CNT_x ($x = 0.03$) nanocomposite thin films. The thickness was estimated to be around 4.779 μm for $x = 0.00$ and 5.305 μm for $x = 0.03$. It is clearly shown that the thickness of sample $x = 0.03$ is more than sample $x = 0.00$ due to the large size of carbon

nanotube particles. The film comprised a series of interlinked microparticles attached to the glass substrate. The high surface roughness combined with the low surface energy exposed showed this interconnection between them [31].

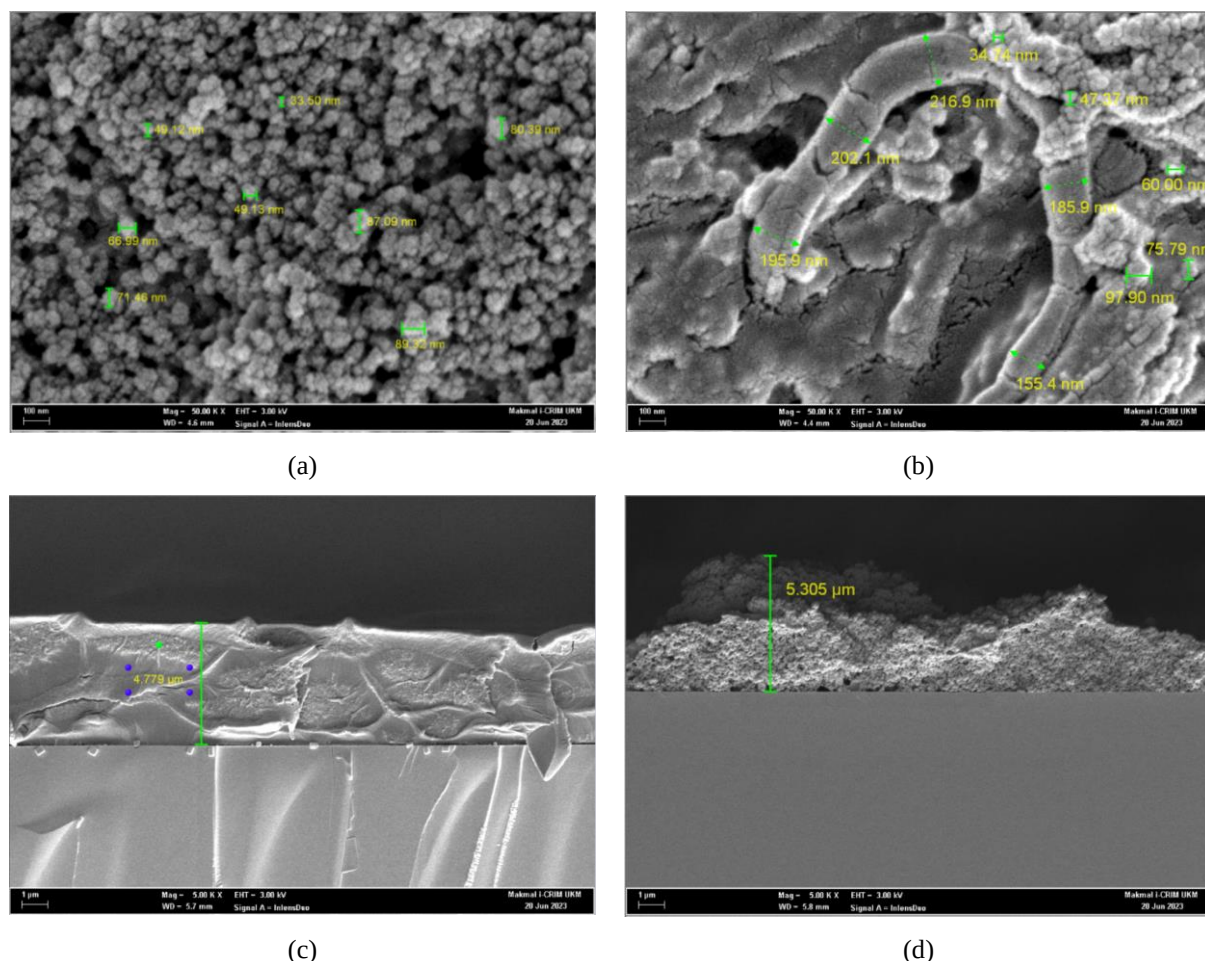


Fig. 4. FESEM morphology images of PANI-(SnO₂)_{1-x}-CNT_x nanocomposite thin films with (a) $x = 0.00$ and (b) $x = 0.03$; and the cross-sectional images of PANI-(SnO₂)_{1-x}-CNT_x nanocomposite thin films with (c) $x = 0.00$ and (d) $x = 0.03$.

Atomic Force Microscopy (AFM) analysis

Fig. 5 shows the 3D images of surface morphology from AFM analysis on PANI-SnO₂-CNT nanocomposite thin films. From the analysis, the surface roughness of the thin films can be determined. From **Fig. 5(a)**, the film surface in the image seems to be the smoothest compared to the others. The surface of the film begins to show small uneven peaks in **Fig. 5(b)** and the peaks more numerous and coarser in **Fig. 5(c)** and **Fig. 5(d)**. The roughness parameters which were obtained from AFM analysis have been shown in **Table 3**. The average roughness R_a and root-mean-squared roughness R_q of PANI-SnO₂-CNT nanocomposite thin films were found to increase when the CNT concentration increases. It can be explained with the same reason in FESEM analysis of the film thickness. The increasing of

roughness parameters with the increasing of CNT concentrations is due to the large grain size and plus the uneven agglomerations in the surface. In addition, according to Mahalingam *et. al.* (2020), the increasing roughness with the increase of CNT is due to the property of one-dimensional structure of CNTs to tangle along with the metal oxide that can provide rougher surface structure [32]. This is also in good agreement with the crystallite size from XRD analysis which is increasing with CNT concentrations. The relation between both crystallite size and average roughness has been plotted in **Fig. 6**. For sensing performance, increasing roughness will increase the current in the I - V measurement due to the role of the conductive CNT network of increasing conductivity [33].

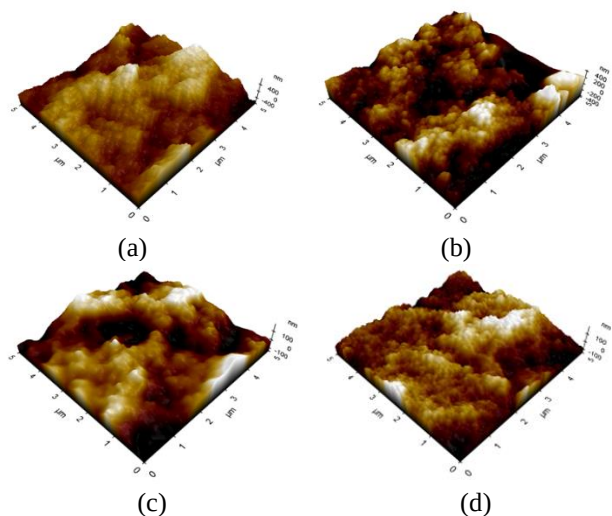


Fig. 5. AFM surface morphology images of PANI-(SnO₂)_{1-x}-CNT_x nanocomposite thin films with (a) $x = 0.00$, (b) $x = 0.01$, (c) $x = 0.02$ and (d) $x = 0.03$.

Table 3. The roughness parameters of PANI-(SnO₂)_{1-x}-CNT_x nanocomposite thin films with (a) $x = 0.00$, (b) $x = 0.01$, (c) $x = 0.02$ and (d) $x = 0.03$.

No.	CNT percentage	Average roughness, R_a (nm)	Root-mean-squared roughness, R_q (nm)
(a)	$x = 0.00$	36.857	47.2
(b)	$x = 0.01$	39.599	49.2
(c)	$x = 0.02$	86.614	110.9
(d)	$x = 0.03$	207.663	255.6

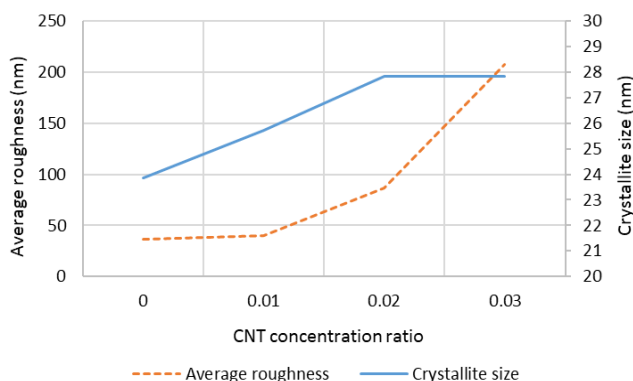


Fig. 6. The combination plots of crystallite size and average roughness against CNT concentrations.

Ultraviolet-visible (UV-Vis) spectroscopy analysis

Fig. 7 shows the absorbance bands of PANI-(SnO₂)_{1-x}-CNT_x nanocomposite thin films with CNT percentages, $x = 0.01$, 0.02 and 0.03 respectively. The absorption of the thin films has been measured in the wavelength range between 200 – 800 nm. Absorbance peaks have appeared in two locations which are at the wavelength around

270 – 300 nm and one more peak at around 370 nm. The strong absorption bands at around 270 – 300 nm are attributed to the dispersion of CNT [34]. The band become lowered and shifted from 270 nm to 290 and 300 nm with the decreasing of CNT percentage. These phenomena are due to the electronic energy transitions of nanotubes with decreasing filler percentage and the formation of charge-transfer species as the nanotubes can be covalently bonded to the PANI matrix [35]. For sample $x = 0.03$, the absorbance peak intensity is the highest, showing that carbon nanotubes are produced at high concentration. For sample $x = 0.01$, the intensity of the peak reduced, indicating that lower concentration of CNTs were formed [36]. The broad bands which are located at around 370 nm are related to the highly crystalline SnO₂ [37]. The absorbance intensity of SnO₂ peaks is gradually increasing according to the reduction of CNT percentage. The increase in absorbance intensity for SnO₂ peaks indicates that the amount of SnO₂ nanoparticles is also gradually increasing.

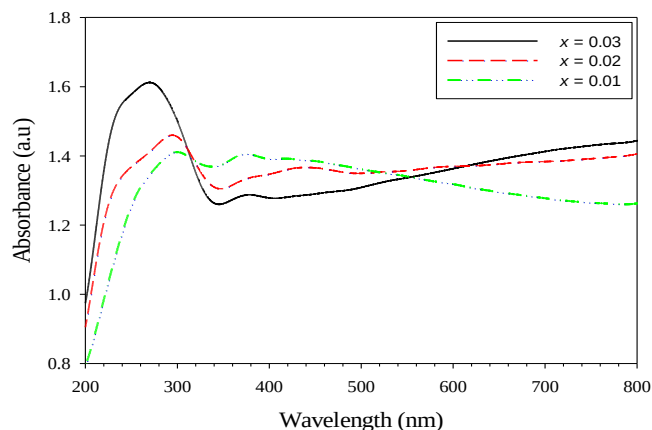


Fig. 7. UV-Vis absorbance bands for PANI-(SnO₂)_{1-x}-CNT_x nanocomposite thin films with $x = 0.01$, 0.02 and 0.03 .

Sensitivity performance of PANI-SnO₂-CNT nanocomposite thin films

The sensitivity performance test was conducted using current-voltage (I - V) measurement to investigate the changes in current and interactions resulting from the sensor thin film and *E. coli* bacterial solution. By dipping the sensor thin film into deionized water and *E. coli* solution, 4 V of voltage was applied and changes in the generated current was measured. Different sensitivities of PANI will measure varying values, allowing a comparison between different CNT concentration in PANI-SnO₂-CNT. The concentration of *E. coli* solution remains constant throughout the experiment, while various CNT concentrations are used.

Fig. 8 shows the I - V characteristic of PANI-(SnO₂)_{1-x}-CNT_x nanocomposite thin films with $x = 0.00$, 0.01 , 0.02 and 0.03 . **Fig. 8 (a)** is the result of I - V characteristic of PANI-SnO₂-CNT thin films in deionized water while **Fig. 8(b)** is the result from *E. coli* solution. For both figures,

the highest maximum current flow is obtained from CNT ratio $x = 0.03$, followed by $x = 0.02$, $x = 0.01$ and the lowest current is from $x = 0.00$. The increasing in CNT concentration causes an increase in the maximum current flow. High current provides a high conductivity environment for metal ion release, and high conductivity will perform high sensitivity of the thin film sensor [13,38]. As the comparison between Fig. 8(a) and Fig. 8(b), the current range measured in *E. coli* solution is higher than the current range measured in deionized water. The higher range of current flow in *E. coli* solution proved the presence of interaction between microbe and metal particles in the PANI-SnO₂-CNT matrix [39]. The metabolism from microbe produces more acidic environment for the metal ion release and the metal ion interacts with bacteria cell wall [40].

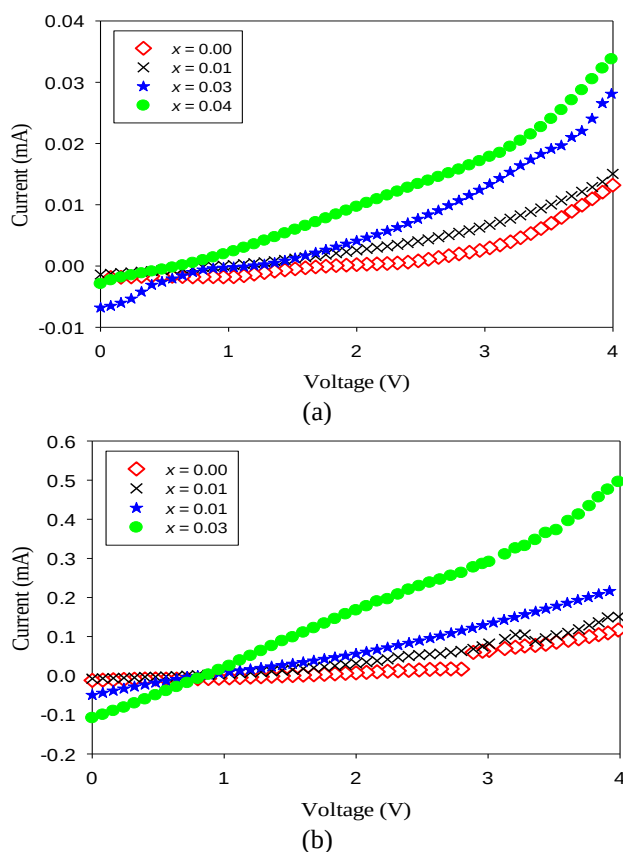


Fig. 8. I-V characteristics of PANI-(SnO₂)_{1-x}-CNT_x nanocomposite thin films with $x = 0.00, 0.01, 0.02$ and 0.03 in (a) deionized water and (b) *E. coli* solution.

The sensitivity of the sensor is described as the ratio of the current upon sensor electrode exposed to the *E. coli* solution (I_e) to that of without exposed to the *E. coli* which is in deionized water (I_o). Fig. 9 shows the graph of sensitivity (S) on *E. coli* against the percentage of CNT concentrations which are calculated using the formula [41]:

$$S = \frac{I_e - I_o}{I_o} \quad (1)$$

where S is the sensitivity of sensor electrode on *E. coli*, I_e is the current when the sensor electrode is exposed to a medium with *E. coli*, and I_o is the current when the sensor electrode is exposed to the same medium but without *E. coli*. From Fig. 9, it can be observed that the sample with the highest sensitivity towards *E. coli* is the PANI-(SnO₂)_{1-x}-CNT_x thin film with $x = 0.03$ and the sensitivity value is $S = 16.32$. It is followed by PANI-(SnO₂)_{1-x}-CNT_x thin film with $x = 0.02$ ($S = 12.34$), $x = 0.01$ ($S = 10.41$) and the lowest sensitivity is performed by PANI-SnO₂ without CNT ($S = 9.47$). We can conclude that the increasing in CNT concentration has a potential to increase the sensitivity performance of PANI-(SnO₂)_{1-x}-CNT_x nanocomposite thin films [42]. This finding also proves that this electrochemical sensor has a good ability to detect the presence of *E. coli* bacteria with different concentrations on the doping material which is CNT.

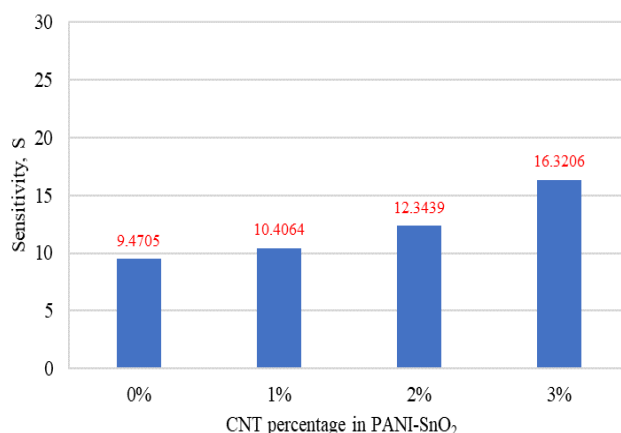


Fig. 9. Sensitivity of PANI-SnO₂-CNT nanocomposite thin films against CNT percentages.

CONCLUSION

Based on the results obtained and from previous research that have been studied, the fabricated electrochemical sensor based on PANI-SnO₂-CNT has a good potential to detect the presence of *E. coli* bacteria in water. PANI-(SnO₂)_{1-x}-CNT_x nanocomposite thin films with $x = 0.00, 0.01, 0.02$ and 0.03 were synthesized and fabricated using sol-gel method and spin-coating technique. From XRD and FESEM analysis, the crystallite and particle size increase with the increasing of CNT concentration. From AFM the surface roughness of PANI-SnO₂-CNT thin film increases with the increasing of CNT concentration. The highest sensitivity value is $S = 16.32$ which is performed by PANI-(SnO₂)_{1-x}-CNT_x thin film with $x = 0.03$ while the lowest sensitivity is $S = 9.47$, performed by PANI-SnO₂ thin film without CNT. This indicates the increasing in CNT concentration has a potential to increase the sensitivity performance of PANI-(SnO₂)_{1-x}-CNT_x nanocomposite thin films towards *E. coli*.

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AUTHOR'S CONTRIBUTIONS

The plan was conceived by Huda Abdullah, Norshafadzila Mohammad Naim, Iskandar Yahya, Noorfazila Kamal, Norazreen Abdul Aziz, A. Atiqah, Noraziah Mohamad Zin, Mohd Hafiz Dzarfan Othman and Wing Fen Yap, the experiments were performed by Mohamad Aiman Arif Awang Omar and Jian Xian Kang, data analysis by Mohamad Aiman Arif Awang Omar and Jian Xian Kang, and the paper was written by Norshafadzila Mohammad Naim and Mohamad Aiman Arif Awang Omar. Authors have no competing financial interest.

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