

## TABLE OF CONTENTS

<b>Chapter 1</b>	<b>Introduction</b>	
1.1	Introduction	1
1.2	Research Objectives	5
1.3	Thesis Outline	5
1.4	References	7
<b>Chapter 2</b>	<b>Literature Review</b>	
2.1	Introduction	8
2.2	Introduction Carbon Nanotubes (CNTs)	8
2.2.1	Synthesis of Carbon Nanotubes	10
2.2.1(i)	Carbon Arc-Discharge Technique	10
2.2.1(ii)	Laser-Ablation Technique	12
2.2.1(iii)	Chemical Vapor Deposition (CVD) Technique	13
2.3	Properties of Carbon Nanotubes	17
2.4	Alcohol Sensor	20
2.5	Carbon Nanotube Based Sensors	22
2.6	Carbon Nanotube as Alcohol Sensor	26
2.7	Instruments for the Characterization of carbon nanotube Composites	30
2.7.1	Fourier Transform Infra-red Spectrometry (FTIR)	30
2.7.2	Fundamental Principle of X-ray Diffraction (XRD)	35
2.8	References	41
<b>Chapter 3</b>	<b>Experimental setup and MWCNT/PEO, MWCNT/PVA and MWCNT/PVA/ZnO Composites Fabrication Techniques</b>	
3.1	Introduction	46
3.2	Fabrication of Composites	47
3.2.1	MWCNT/PEO	50
3.2.2	MWCNT/PVA	54
3.2.3	MWCNT/PVA/ZnO Solution Preparation	55
3.3	Preparation of Nano-Sized ZnO by Ball Milling	55
3.4	Characterization	60
3.5	Experiment Setup Application as gas Sensor	60
3.6	Resistance Measurement	62
3.7	References	63

<b>Chapter 4</b>	<b>Results and Discussions</b>	
4.1	Introduction	64
4.2	Characterization by Fourier Transform Infra-red (FTIR)	64
4.3	Scanning Electron Microscope (SEM)	67
4.4	Application of Nanocomposites as Methanol Sensor	71
	4.4.1 MWCNT/PEO Composite	71
	4.4.2 MWCNT/PVA Composite	74
	4.4.3 MWCNT/PVA and ZnO Composite	84
4.5	References	98
<b>Chapter 5</b>	<b>Conclusion</b>	
5.1	Conclusion	99
5.2	Suggestion for Future Work	100

## List of Figures

Figure 1.1	Crystal structures of ZnO	3
Figure 2.1	Structure of SWNTs as shown in (a) and structure of MWCNTs as shown in (b).	9
Figure 2.2	Basic hexagonal bonding structures for one graphite layer (the ‘graphene sheet’). Carbon nuclei shown as filled circle, out-of-plane $\pi$ -bonds, and $\sigma$ -bonds connect the C nuclei in-plane.	18
Figure 2.3	The honeycomb lattice of graphene. The hexagonal unit cell contains two carbon atoms (A and B). The chiral vector determining the structure of a carbon nanotube is given by $L$ , and its length gives the circumference. The chiral angle is denoted by $\eta$ , with $\eta = 0$ corresponding to zigzag nanotubes and $\eta = \pi/6$ to armchair nanotubes.	18
Figure 2.4	Cross sectional structure of the FET-based sensor and the experimental geometry	26
Figure 2.5	The drain current measurements as a function of time with a source drain bias of 100 mV and a gate bias of 10 V	27
Figure 2.6	(a) Schematic diagram of experimental setup. (b) Gases used in the experiment	28
Figure 2.7	Change in sensor current upon exposure to different gases	29
Figure 2.8	The basic components of FTIR system	31
Figure 2.9	Major vibration modes for a nonlinear group	33
Figure 2.10	FTIR spectra of functionalized carbon nanotubes	34
Figure 2.11	X-ray Diffraction analysis	35
Figure 2.12	Diagram of X-ray diffractometer	37
Figure 2.13	XRD patterns of (a) $\gamma$ -Fe <sub>2</sub> O <sub>3</sub> and (b) $\gamma$ -Fe <sub>2</sub> O <sub>3</sub> –TiO <sub>2</sub> after heat treatment at a temperature of 400°C for 1 hour, (M – maghemite, H – hematite, A – anatase)	40
Figure 3.1	Schematic diagram for the preparation of two groups of composites	51
Figure 3.2	The photograph of (a) filter paper, (b) filter paper deposited with MWCNT/PEO composite.	53
Figure 3.3	MWCNT/PVA colloidal solutions at different loadings	55
Figure 3.4	XRD patterns of ZnO ball milled for (a) 10 hours (b) 20 hours (c) 30 hours	57
Figure 3.5	Peaks of XRD for ZnO at different time and show full width at half its maximum intensity.	59
Figure 3.6	Crystallite dimensions of ZnO sample with milling time	59
Figure 3.7	EDX spectrum of as-synthesized ZnO nanostructures	60
Figure 3.8	Experimental setup of the measuring system	61
Figure 3.9	Resistance change measured at 16.7 vol.% for various times	62
Figure 4.1	FTIR spectrum for MWCNT/PVA at different loading	65
Figure 4.2	FTIR spectrum for MWCNT/PVA and a) 1%, b)2%, c)3%, d)4% and e) 5% of ZnO.	66

Figure 4.3	SEM images for 5wt% of MWCNT/PVA at different magnifications (a) 20x, (b) 200x and (c) 500x.	67
Figure 4.4	SEM images for 4wt% of MWCNT/PVA at magnification of (a) 2000x (b) 5000x.	68
Figure 4.5	SEM image for 2wt% MWCNT/PVA	69
Figure 4.6	SEM images for 1wt% MWCNT/PVA at (a) 2000x and (b) 5000x	69
Figure 4.7	Shows SEM images for MWCNT/PVA/5%ZNO at (a) 20x, (b) 500x and (c) 1800x.	
Figure 4.8	The response resistance of 9 wt% MWCNT/PEO at different methanol concentration of (a) 16.67, (b) 8.3, (c) 5, (d) 3.3 and (e) 1.7.vol%.	72
Figure 4.9	The response sensitivity of MWCNT/PEO at different methanol concentrations.	73
Figure 4.10	The resistance response of 1wt% MWCNT/PVA at various methanol concentrations (a) 16.7, (b) 8.3, (c) 5 (d) 3.3 and (e) 1.7vol%.	74
Figure 4.11	The sensitivity of 1% MWCNT/PVA at different methanol concentrations.	75
Figure 4.12	The resistance response of 2% MWCNT/PVA at various methanol concentrations: (a) 16.7, (b) 8.3, (c) 5, (d) 3.3 and (e) 1.7 vol %.	76
Figure 4.13	The sensitivity response of 2wt% MWCNT at different methanol concentrations.	77
Figure 4.14	The response resistance of different methanol concentrations at: 3%wt MWCNT/PVA (a) 16.7, (b) 8.3, (c) 5 (d) 3.3 and (e) 1.7.	78
Figure 4.15	The response sensitivity 3%wt of MWCNT/PVA at different methanol concentrations.	79
Figure 4.16	The response resistance of 4wt% MWCNT/PVA at different methanol concentrations: (a) 16.7, (b) 8.3, (c) 5%, (d) 3.3 and (e) 1.7vol%.	81
Figure 4.17	The response sensitivity of 4wt% MWCNT at different methanol concentrations.	81
Figure 4.18	The response resistance of 5wt% MWCNT/PVA at different methanol concentrations: (a) 5, (b) 16.7, (c) 8.3, (d) 3.3 and (e) 1.7vol%.	82
Figure 4.19	The response sensitivity of 5wt% MWCNT/PVA at different methanol concentrations.	83
Figure 4.20	The response resistance of MWCNT/PVA/1%ZnO at different methanol concentrations: (a) 3.3, (b) 5, (c) 8.3, (d) 16.7 and (e) 1.7vol.%.	85
Figure 4.21	The sensitivity response of MWCNT/PVA/1%ZnO at different methanol concentrations.	87

Figure 4.22	The response resistance of MWCNT/PVA/2%ZnO at various methanol compositions: (a) 1.7, (b) 3.3, (c) 5, (d) 8.3, and (e) 16.7vol%.	88
Figure 4.23	The response sensitivity of MWCNT/PVA/2% ZnO at different methanol concentrations.	89
Figure 4.24	The resistance response of MWCNT/PVA/3%ZnO at different methanol composition: (a) 5, (b) 16.7, (c) 8.3, (d) 3.3 and (e) 1.7 vol.%.	90
Figure 4.25	The recorded sensitivity of MWCNT/PVA/3% ZnO at different methanol concentrations.	91
Figure 4.26	The resistance response of MWCNT/PVA/4%ZnO at different methanol composition: (a) 3.3, (b) 16.7, (c) 8.3, and (d) 1.7vol%.	93
Figure 4.27	The sensitivity of MWCNT/PVA/2% ZnO at different methanol concentrations.	94
Figure 4.28	The resistance response of MWCNT/PVA/5%ZnO at different methanol composition: (a) 3.3, (b) 8.3, (c) 5, (d) 16.7 and (e) 1.7vol%.	95
Figure 4.29	The sensitivity of MWCNT/PVA/5% ZnO at different methanol concentrations.	96

## List of Tables

Table 2.1	Phase composition, lattice constants (a, b, c), average size of the crystalline blocks (D) and micro-strains of heat treated $\gamma$ -Fe <sub>2</sub> O <sub>3</sub> and $\gamma$ -Fe <sub>2</sub> O <sub>3</sub> -TiO <sub>2</sub> samples at 400°C	39
Table 3.1	Properties of triton	49
Table 3.2	Properties of zinc oxide	49
Table 3.3	Properties of absolute Methanol	50
Table3.4	Facilities and materials for the experimental setup	52