

Contents

Abstract	page
Acknowledgements	i
Contents	iii
List of Figures	v
List of Tables	ix
List of Symbols	xiii
List of Abbreviations	xv
	xvii

Chapter 1: Introduction

1.1	Definition	1
1.2	Short History of Gas Sensors	1
1.3	Need of Gas Sensors	2
1.4	Classification of Gas Sensors	3
	1.4.1 Electrochemical	3
	1.4.2 Acoustic Wave	4
	1.4.3 Optical	4
	1.4.4 Capacitance	5
	1.4.5 Calorimetric	5
	1.4.6 Metal Oxide (MO_x)	6
1.5	Brief Comparison of Gas Sensors	6
1.6	Gas Sensor Characteristics	8
	1.6.1 Sensitivity	8
	1.6.2 Selectivity	8
	1.6.3 Response and Recovery Time	8
	1.6.4 Detection Limit	8
	1.6.5 Reproducibility	8
	1.6.6 Long-Term Stability	8
1.7	Structure of Gas Sensors	9
1.8	Types of MO_x Gas Sensors	10
1.9	Gas Sensing Mechanism	10
1.10	Key Factors of MO_x Gas Sensors	11
	1.10.1 Grain Size Effect	11
	1.10.2 Operating Temperature	13
	1.10.3 Humidity Effect	13
1.11	Factor Involved in Improvement in Sensitivity	13
	1.11.1 Metal doping	13
	1.11.2 Functionalization of noble metal nanoparticles	15
	1.11.3 Inclusion of carbon-based nanomaterials	17
	1.11.4 Nanocomposites with different MO_x	19
	1.11.5 UV activation	20
	1.11.6 High energy irradiation	23
1.12	Motivation	25
1.13	Objectives	25
1.14	Layout of the Thesis	26

Chapter 2: Materials and Experimental Techniques

2.1	Materials for MO_x Based Gas Sensors	29
	2.1.1 TiO_2	29
	2.1.2 ZnO	29
	2.1.3 V_2O_5	30
	2.1.4 Reduced Graphene Oxide (rGO)	30
	2.1.5 Carbon Nanofibers (CNF)	31

2.1.6 Doping of Transition Metals Elements	31
2.2 Deposition Techniques	31
2.2.1 RF Sputtering	31
2.2.2 Photolithography	33
2.2.3 Drop Casting	33
2.2.4 Thermal Evaporation	34
2.3 Characterization Techniques	35
2.3.1 X-Ray Diffraction (XRD)	35
2.3.2 Field Emission Scanning Electron Microscopy (FESEM)	36
2.3.3 Atomic Force Microscopy (AFM)	38
2.3.4 Ultraviolet-Visible (UV) Spectroscopy	38
2.3.5 Raman Spectroscopy	39
2.3.6 X-Ray Photoelectron Spectroscopy (XPS)	40
2.3.7 Fourier Transform Infrared Spectroscopy (FTIR)	41
2.3.8 Kelvin Probe force Microscopy (KPFM)	42
2.3.9 Electrical Characterization	42
2.3.10 Gas Sensing Measurement	43

Chapter 3: Study of Schottky Barrier Height using Metal/TiO₂ nanoplates for Hydrogen Gas Sensing

3.1 Introduction	45
3.2 Experimental Setup	46
3.3 Structural Properties of TiO ₂ Nanoplates	46
3.4 Surface Morphology of TiO ₂ Nanoplates	47
3.5 Electrical Characterization of M/TiO ₂ Nanoplates	47
3.6 Hydrogen Gas Sensing Studies of M/TiO ₂ Nanoplates	50
3.7 Proposed Hydrogen Gas Sensing Mechanism for M/TiO ₂ Nanoplates	53
3.8 Conclusion	54

Chapter 4: Effect of Ni Doping into ZnO Nanostructures for Structural, Morphological, Electrical, and Gas Sensing Properties

4.1 Introduction	55
4.2 Experimental Setup	56
4.3 Structural Characterization	57
4.4 Film Morphology	57
4.5 Optical Properties	59
4.6 Electrical Characterization	60
4.7 Hydrogen sensing measurement	61
4.8 Calculation of Activation Energy	63
4.9 Gas Sensing Mechanism	66
4.10 Conclusion	67

Chapter 5: Study of Decoration of Reduced Graphene Oxide on Metal Oxide Based Gas Sensors

5.1 Decoration of Reduced Graphene Oxide on Ni-doped ZnO for the detection of hydrogen gas	69
5.1.1 Experimental Setup	70
5.1.2 Structural Properties of rGO Decorated Ni-Doped ZnO Nanostructures	71
5.1.3 Morphological Analysis of rGO Decorated Ni-doped ZnO Nanostructures	72
5.1.4 Electrical Characterization of rGO Decorated Ni-doped ZnO Nanostructures	73
5.1.5 Gas Sensing Studies of rGO Decorated Ni-doped ZnO Nanostructures	74
5.1.6 Gas Sensing Mechanism	77
5.2 rGO Decorated V ₂ O ₅ Thin Film for NO ₂ Detection	79
5.2.1 Experimental Setup	79
5.2.2 Structural Characterization	81

5.2.3	<i>Chemical Composition of rGO Decorated V₂O₅ Thin Film</i>	81
5.2.4	<i>Topography Analysis</i>	82
5.2.5	<i>Work Function Analysis</i>	82
5.2.6	<i>Electrical Characterization</i>	83
5.2.7	<i>Gas Sensing Measurement</i>	84
5.2.8	<i>Gas Sensing Mechanism</i>	88
5.3	Conclusion	90
Chapter 6: Effect of Decoration of Carbon Nanofibers on ZnO Nanostructures for Hydrogen Detection		
6.1	Introduction	91
6.2	Experimental Setup	92
6.3	Structural Analysis	93
6.4	Surface Morphology Analysis	94
6.5	FTIR Analysis	96
6.6	Electrical Measurement	96
6.7	Gas Sensing Measurement	97
6.8	Gas Sensing Mechanism	100
6.9	Conclusion	102
Chapter 7: Conclusion and Future Work		105
Publications		109
References		111

