CONTENTS

Title Page No.

Acknowledgement VI
Synopsis VIII
List of Figures XV
List of Tables XXV
List of Abbreviation XXVI

CHAPTER 1

INTRODUCTION 1

1.1 Promising Wide Band Gap Material 3
1.1.1 Gallium Nitride (GaN) 3
1.1.2 Progress and Prospects of 1D GaN Nanostructures 6
1.2 Overview of the Thesis 8
1.3 References 10

CHAPTER 2

EXPERIMENTAL AND CHARACTERIZATION TECHNIQUES 13

2.1 Growth Techniques 13
2.1.1 Introduction 13
2.1.2 Thermal Chemical Vapor Deposition 14
2.1.3 Thermal Physical Vapor Deposition 17
2.1.4 DC Sputtering 18
2.2 Structural and Morphological Characterization 19
2.2.1 Electron Microscopes 19
2.2.1.1 Transmission Electron Microscope (TEM) 20
2.2.1.2 Scanning Electron Microscope (SEM) 24
2.3 Optical and Electronic Properties 25
2.3.1 Raman Scattering Spectroscopy 25
2.3.1.1 Major Components of micro-Raman Spectrometer 27
2.3.1.2 Raman Imaging and Mapping Study 28
2.3.2 Photoluminescence Spectroscopy 29
2.3.3 Kelvin Probe Force Microscopy (KPFM) 31
2.4 Electrochemical Impedance Spectroscopy (EIS) 33
2.5 Gas Sensor Measurement System 35
2.6 Summary 36
2.7 References 36

CHAPTER 3
GENERAL ROUTE OF SYNTHESIS FOR 1D GaN NANOSTRUCTURES, CHARACTERIZATION, AND GROWTH DYNAMICS 38

3.1 Introduction 38
3.2 Surface Polarity in GaN vs Morphology 40
3.3 Vapor-Liquid-Solid Growth: GaN Nanowires 42
   3.3.1 Synthesis of GaN Nanowire 42
   3.3.2 Morphological and Structural Variation 43
      3.3.2.1 Hexagonal GaN Nanowires 45
      3.3.2.2 Triangular GaN Nanowires 46
      3.3.2.3 Wurtzite/Zinc-blende Biphase Homostructure in Triangular GaN Nanowires 48
      3.3.2.4 Square Shaped GaN Nanowires 50
   3.3.3 Steady State Growth of Nanowires 51
   3.3.4 Optical Properties 53
      3.3.4.1 Raman Scattering Study 54
      3.3.4.2 Photoluminescence Study 59
3.4 Vapor-Solid Growth: GaN Nanotips and GaN Nanoparticles 61
   3.4.1 Materials and Methodology 62
   3.4.2 Characterization 63
      3.4.2.1 Morphological and Structural Properties 63
      3.4.2.2 Raman Scattering Study 67
      3.4.2.3 Stress Analysis 68
      3.4.2.4 Photoluminescence Study 69
   3.4.3 Polarity Driven Growth Mechanism 71
3.5 Summary 75
3.6 References 76
CHAPTER 4

SINGLE-STEP GROWTH DYNAMICS AND PHYSICOCHEMICAL PROPERTIES OF CORE–SHELL Ga2O3@GaN MICROBELTS

4.1 Introduction

4.2 Growth of Core–Shell Ga2O3@GaN Microbelts
   4.2.1 Materials and Methodology
   4.2.2 Morphological and Structural Studies
   4.2.3 Optical Properties
      4.2.3.1 Raman Scattering Study
      4.2.3.1 Raman Phase Mapping
      4.2.3.1 Photoluminescence Study
   4.2.4 Single Step Growth Mechanism

4.3 Physicochemical Properties of Core–Shell Ga2O3@GaN Microbelts
   4.3.1 Study of Surface Potential on Single GaN Microbelt by Kelvin probe force microscope (KPFM)
      4.3.1.1 Importance of the Study
      4.3.1.2 Methodology
      4.3.1.3 Surface Potential Variation
      4.3.1.4 Enhanced Variation of Surface Potential with Humidity Levels
      4.3.1.5 Molecular Mechanism of Surface Potential Variation in the GaN Microbelts
   4.3.2 Superhydrophobicity in Single GaN Microbelt
      4.3.2.1 Introduction
      4.3.2.2 Materials and Methodology
      4.3.2.3 Wetting Properties of a Single Microbelt
      4.3.2.4 Mechanism of Superhydrophobicity

4.4 Summary

4.5 References

CHAPTER 5

GROWTH AND FUNCTIONALIZATION OF GaN NANOTUBES FOR CATALYTIC AND GAS SENSING APPLICATION

5.1 Introduction
5.2 Quasi Vapor-Solid Growth of GaN Nanotube
   5.2.1 Materials and Methodology
   5.2.2 Morphological and Structural Properties
   5.2.3 Growth Mechanism
5.3 Functionalization of GaN Nanotube with Platinum Nanoclusters
   5.3.1 Materials and Methodology
   5.3.2 Morphological and Structural Properties
5.4 Optical Properties
5.5 Laser Assisted Catalysis
   5.5.1 Laser Induced Localized Oxidation and Photofragmentation of GaN Nanotube
   5.5.2 Mechanism of Photocatalyzed Oxidation in Pt-GaN Nanotube
5.6 Hydrogen Sensing Properties of GaN Nanotube
   5.6.1 Materials and Methodology
   5.6.2 Pt Catalyzed Hydrogen Sensing Properties of GaN Nanotube
   5.6.3 Mechanism of Hydrogen Sensing in GaN Nanotube
5.7 Summary
5.7 References

CHAPTER 6

IN-SITU LABEL FREE IMPEDIMETRIC NANOWIRE BASED DNA BIOSENSOR

6.1 Introduction
   6.1.1 Impedimetric Biosensor
   6.1.2 Electrochemical Impedance Spectroscopic (EIS) Technique for Label-free DNA Biosensor
   6.1.3 Progress and Prospects of Nanowire Based DNA Biosensor
6.2 Experimental Protocols and Methodology
   6.2.1 Chemicals and Reagents
   6.2.2 Surface Functionalization of Nanowires
   6.2.3 DNA Probe Immobilization
   6.2.4 In-Situ Detection of DNA Hybridization
   6.2.5 Methodologies
6.3 Characterization
6.4 GaN Nanowire based Impedimetric DNA Biosensor
6.4.1 In-Situ Detection of H1N1 DNA Hybridization 148
6.4.2 Selectivity and Specificity 151
6.5 Mechanism of DNA Sensing using EIS 153
6.6 Summary 156
6.7 References 157

CHAPTER 7
PROBING DYNAMICS OF BIOPHYSICOCHEMICAL PROCESSES AT THE NANO-BIO INTERFACE 159

7.1 Introduction 159
7.2 Materials and Methodology 161
  7.2.1 Synthesis, Functionalization and Characterization of GaN Nanoparticles 161
  7.2.2 Bacterial Strains and Culture Conditions 162
  7.2.3 Planktonic and Biofilm Inhibition Assays 163
  7.2.4 Methodology for the Study of Nanoparticle-Bacterial Cell Interaction 164
    7.2.4.1 Sample Preparation for FESEM Study 164
    7.2.4.2 Confocal Laser micro-Raman Spectroscopic (CLRS) Analysis 164
7.3 Tracing the Toxic Effect of GaN Nanoparticles 165
  7.3.1 Effect of GaN Nanoparticles on Inhibition of Biofilm Formation 165
  7.3.2 Destruction of Bacterial Membrane 167
    7.3.2.1 Morphological Study 167
    7.3.2.2 Confocal Raman Study 168
    7.3.2.3 Raman Mapping of Protein Exudation Site 171
    7.3.2.4 Single Cell Analysis 173
7.4 Molecular Mechanism at the Nano-Bio Interface 176
7.5 Summary 177
7.8 References 178

CHAPTER 8
BRIEF SUMMARY OF THE THESIS WORK AND FUTURE PROSPECTIVES 180

Journal Publication, Book and Conference Proceedings 183