ACKNOWLEDGEMENT

*I owe my sincere thanks to the **Lord Almighty** and my parents for showering me with their generous blessings in all my endeavors.*

*I express my gratitude and wish to place on record my sincere thanks to **Sri. G. Rangaswamy,** Managing Trustee, PSGR Krishnammal College for Women, whose untiring zeal and perseverance has laid the foundation to build this paramount masterpiece which is a temple of learning and has inspired many.*

*I wish to express my deep sense of reverential gratitude to **Smt. R. Nandini,** Chair Person, PSGR Krishnammal College for Women, for providing the facilities to conduct this study.*

*I record my thanks to **Dr. (Mrs.) N. Yesodha Devi** M.Com., Ph.D., Secretary, PSGR Krishnammal College for Women, for granting me permission to undertake this project work.*

*I record my deep sense of gratitude and indebtedness to **Dr. (Mrs.) S. Nirmala** M.B.A., M.Phll, Ph.D., Principal, PSGR Krishnammal College for Women, Coimbatore, for providing help towards the completion of this study.*

*I wholeheartedly thank **Dr. (Mrs.) P.Meena** M.Sc., M.Phil., Ph.D., Associate Professor and Head of the Department of Physics, PSGR Krishnammal College for Women, Coimbatore, for her encouragement and generous help which Was of great value.*

*I am very much indebted to my guide **Dr. (Mrs.) J. Balavijayalakshmi** M.Sc., M.Phill. (Phy.), Ph.D., MCA., M.Phil. (Comp.Sci). Assistant Professor, Department of Physics, PSGR Krishnammal College for Women, Coimbatore, for her excellent, outstanding guidance,*

constructive criticism, motivation, valuable advice untiring support, timely suggestions, constant encouragement and inspiration throughout the study, holding me strong in all the places I faltered.

I have a great pleasure in thanking my doctoral committee member, ***Dr. N.Suriyanarayanan*** *M.Sc, M.Phil, M.S(IT), Ph.D Professor and Head of the department of Physics, Government College of Technology, Coimbatore for his valuable guidelines, feedback and recommendations that have enhanced the quality of my research work.*

I Sincerely thank all the ***staff members*** *of the* ***Department of Physics,*** *PSGR Krishnammal College for Women, Coimbatore, for being supportive and understanding.*

I thank my ***Parents, Sister and friends*** *for their support, understanding and co-operation for the successful completion of the study.*

I would specially like to thank my husband ***K. Kannan*** *for his encouragement and support throughout my study.*

S.YUVASHREE

CONTENTS

CHAPTER NO.	TITLE	PAGE NO.
	Abstract	i
	List of Figures	v
	List of Tables	vii
	List of abbreviations	viii
	CHAPTER I INTRODUCTION	
1.1	**INTRODUCTION TO NANOTECHNOLOGY**	01
1.2	**NANO MATERIALS**	02
	1.2.1. Classification of Nanomaterials	02
1.3	**SYNTHESIS OF NANOPARTICLES**	04
	1.3.1 Top-down approach	05
	1.3.2. Bottom-up approach	06
1.4	**Properties of nanomaterials**	06
	1.4.1 Structural properties	06
	1.4.2 Optical properties	07
	1.4.3 Chemical properties	07
	1.4.4 Mechanical properties	08
	1.4.5 Electronic properties	08
	1.4.6 Thermal properties	09
	1.4.7 Magnetic properties	09
1.5	**APPLICATIONS OF NANOTECHNOLOGY**	10
	1.5.1 Nanoclays	10
	1.5.2 Nanocoatings and nanostructured surfaces	10
	1.5.3 Drug Delivery	11
	1.5.4 Energy storage	11
1.6.	**REVIEW OF LITERATURE**	11
1.7	**MATERIAL INTRODUCTION**	21
	1.7.1 Carbon nanostructures	21
	1.7.2 Graphene	23

1.7.3 Structure of Graphene 24
1.7.4 Properties of Graphene 25
1.7.4.1 Electronic properties 25
1.7.4.2 Optical properties 26
1.7.4.3 Thermal properties 26
1.7.4.4 Mechanical properties 26
1.7.5 Reduced graphene oxide 27
1.7.6 Graphene Based Nanocomposites 28
1.7.6.1 Functionalization of graphene oxide 28
1.7.6.2 Applications of graphene based nanocomposites 29
1.7.7 Polymer **30**
1.7.7.1 Chitosan 31
1.7.7.2 Chitin to chitosan 32
1.7.7.3 Physiochemical Characteristics 32
1.7.7.4 Biological properties 33
1.7.8 Metallic nanoparticles **33**
1.7.9 Zinc oxide **34**
1.7.9.1 Crystal structures of ZnO 34
1.7.9.2 Mechanical properties 35
1.7.9.3 Electronic properties 35
1.7.10 Copper oxide 35
1.7.10.1 Structure of CuO 36
1.7.10.2 Physiochemical properties of CuO 36
1.7.11 Silver 37
1.7.11.1 Structure of Ag 37
1.7.11.2 Physiochemical properties of Ag 37
1.7.12 Gold 38
1.7.12.1 Structure of Gold 38
1.7.12.2 Physiochemical properties of Au 39
1.7.13 p-Aminophenol 39
1.8 CHARACTERIZATION TECHNIQUES 40
1.8.1 Fourier transform infrared spectroscope (FT-IR) 40

1.8.2 X-Ray diffraction (XRD) 41
1.8.3. Scanning electron microscopy 42
1.8.4. Energy Dispersive X-ray Analysis 44
1.8.5 High-resolution transmission electron microscope 45
1.8.6 Electrochemical sensors 46
1.8.6.1 Experimental set up and instrumentation 48
1.8.6.2 Cyclic voltammetry 50
1.9 SCOPE OF THE WORK 52
1.10 ORGANIZATION OF THESIS 53
References 56

CHAPTER –II

INFLUENCE OF CHITOSAN BLENDED REDUCED GRAPHENE OXIDE NANOSHEETS FOR THE ELECTROCHEMICAL DETERMINATION OF p-AMINOPHENOL

2.1 INTRODUCTION 73
2.2 EXPERIMENTAL PROCEDURE 74
2.2.1 Reagents 74
2.2.2 Synthesis of Graphene oxide 74
2.2.3 Synthesis of reduced graphene oxide/ chitosan nanocomposites 76
2.3 RESULTS AND DISCUSSION 76
2.3.1 FT-IR Spectral Analysis 76
2.3.2 XRD Structural Analysis 78
2.3.3 SEM analysis 79
2.3.4 Energy-Dispersive X-ray Analysis 81
2.4 ELECTROCHEMICAL RESPONSE OF p-AMINOPHENOL 82
2.5 CONCLUSION 83
References 84

CHAPTER-III

ELECTROCHEMICAL INVESTIGATION OF POLYMER FUNCTIONALIZED REDUCED GRAPHENE OXIDE/ ZINC OXIDE NANOCOMPOSITES FOR THE DETECTION OF p-AMINOPHENOL

3.1	**INTRODUCTION**	88
3.2.	**EXPERIMENTAL PROCEDURE**	89
	3.2.1 Reagents	89
	3.2.2 Synthesis of reduced graphene oxide/ chitosan/Zinc oxide nanocomposites	89
3.3	**RESULTS AND DISCUSSION**	90
	3.3.1 FT-IR Spectral Analysis	90
	3.3.2 XRD Structural Analysis	92
	3.3.3 SEM Analysis	94
	3.3.4 EDAX Analysis	96
	3.3.5 HR-TEM and SAED Analysis	97
3.4.	**ELECTROCHEMICAL INVESTIGATION OF p-AMINOPHENOL**	98
	3.4.1 Electrochemical behaviour of modified electrodes	99
	3.4.2 Effect of pH	100
	3.4.3 Effect of Scan Rate	101
	3.4.4 Effect of Analyte Concentration	102
3.5	**CONCLUSION**	103
	References	104

CHAPTER – IV

INFLUENCE OF COPPER OXIDE NANOPARTICLES ENSEMBLED ON CHITOSAN BLENDED REDUCED GRAPHENE OXIDE NANOSHEETS FOR THE ELECTROCHEMICAL DETECTION OF p-AMINOPHENOL

4.1	**INTRODUCTION**	108
4.2	**EXPERIMENTAL PROCEDURE**	109
	4.2.1. Reagents	109
	4.2.2. Synthesis of reduced graphene oxide / chitosan / copper oxide nanocomposites	109
4.3	**RESULTS AND DISCUSSION**	110
	4.3.1 FT-IR Spectral Analysis	110
	4.3.2 XRD Structural Analysis	111
	4.3.3 SEM Analysis	113

4.3.4 EDAX Analysis 115
4.3.5 HR-TEM Analysis 116
4.4 ELECTROCHEMICAL INVESTIGATION OF p-AMINOPHENOL 117
4.4.1 Electrochemical behavior of modified electrodes 118
4.4.2 Effect of pH 119
4.4.3 Effect of scan rate 120
4.4.4 Effect of analyte concentration 121
4.5 CONCLUSION 122
References 123

CHAPTER-V

EFFECT OF SILVER NANOPARTICLES ON POLYMER BLENDED REDUCED GRAPHENE NANOHYBRIDS AS A VERSATILE ELECTROCHEMICAL SENSOR FOR THE DETECTION OF p-AMINOPHENOL

5.1 INTRODUCTION 127
5.2 EXPERIMENTAL PROCEDURE 128
5.2.1 Reagents 128
5.2.2 Synthesis of reduced graphene oxide/ chitosan/Silver nanocomposites 128
5.3 RESULTS AND DISCUSSION 129
5.3.1 FT-IR Spectral Analysis 129
5.3.2 XRD Structural Analysis 130
5.3.3 SEM analysis 132
5.3.4 Energy-Dispersive X-ray Analysis 134
5.3.5 TEM and SAED analysis 136
5.4 ELECTROCHEMICAL RESPONSE OF p-AMINOPHENOL 137
5.4.1 Electrochemical behavior of modified electrodes 138
5.4.2 Effect of pH 139
5.4.3 Effect of Scan Rate 140
5.4.4 Effect of Analyte Concentration 141
5.5 CONCLUSION 142
References 143

CHAPTER- VI

EMBELLISHMENT OF GOLD NANOPARTICLES ON THE SURFACE OF CHITOSAN BLENDED REDUCED GRAPHENE OXIDE FOR THE ELECTROCHEMICAL INVESTIGATION OF p-AMINOPHENOL

6.1.	**INTRODUCTION**	147
6.2.	**EXPERIMENTAL PROCEDURE**	148
	6.2.1. Reagents	148
	6.2.2. Synthesis of reduced graphene oxide / chitosan / Gold nanocomposites	148
6.3.	**RESULTS AND DISCUSSION**	149
	6.3.1 FT-IR Spectral Analysis	149
	6.3.2 XRD Structural Analysis	150
	6.3.3 Scanning Electron Microscopy Analysis	152
	6.3.4 EDAX Analysis	154
	6.3.5 HR-TEM Analysis	156
6.4	**ELECTROCHEMICAL INVESTIGATION OF p-AMINOPHENOL**	157
	6.4.1 Electrochemical Response of p-Aminophenol	157
	6.4.2 Effect of pH	158
	6.4.3 Effect of scan rate	159
	6.4.4 Effect of Analyte Concentration	160
6.5	**CONCLUSION**	161
	References	162

CHAPTER - VII

ANTIBACTERIAL AND ANTICANCER ACTIVITIES OF THE rGO/CS/ METAL OXIDES (ZnO, CuO), METAL (Ag, Au) NANOCOMPOSITES

7.1	**INTRODUCTION**	166
7.2	**CLASSIFICATION OF BACTERIA**	168
	7.2.1 Gram Positive Bacteria	168
	7.2.2 Gram Negative Bacteria	168
7.3	**FEATURES OF THE TEST ORGANISMS**	169
	7.3.1 Staphyloccocus Aureus	169
	7.3.2 Bacillus Subtilis	170
	7.3.3 Escherichia Coli	171
	7.3.4 Klebsiella Pneumonia	172

7.4	**DETERMINATION OF ANTIBACTERIAL ACTIVITY**	173
7.5	**MATERIALS AND METHODS**	173
	7.5.1 Reagents	173
	7.5.2 Preparation Of Inoculum	173
	7.5.3 Sterilization Of Forceps And Cotton Swabs	173
	7.5.4 Experimental Procedure	173
7.6	**RESULTS AND DISCUSSION**	174
	7.6.1 Antibacterial Activity of rGO/CS/ZnO nanocomposites against Gram Positive and Gram-Negative Bacteria	174
	7.6.2 Antibacterial Activity of rGO/CS/CuO nanocomposites against Gram Positive and Gram-Negative Bacteria	177
	7.6.3 Antibacterial Activity of rGO/CS/Ag nanocomposites against Gram Positive and Gram-Negative Bacteria	180
	7.6.4 Antibacterial Activity of rGO/CS/Ag nanocomposites against Gram Positive and Gram-Negative Bacteria	183
7.7	**DETERMINATION OF ANTICANCER ACTIVITY**	185
	7.7.1 Materials	185
	7.7.2 Cell Line Culture	185
	7.7.3 Cytotoxicity Assay	186
7.8	**RESULTS AND DISCUSSION**	187
	7.8.1 Anticancer Activity of rGO/CS/ ZnOnanocomposites	187
	7.8.2 Anticancer Activity of rGO/CS/ CuOnanocomposites	190
	7.8.3 Anticancer Activity of rGO/CS/Ag nanocomposites	193
	7.8.4 Anticancer Activity of rGO/CS/Au nanocomposites	196
7.9	**CONCLUSION**	198
	References	200

CHAPTER VIII
SUMMARY OF RESULTS AND CONCLUSION

8.1	**INTRODUCTION**	205
8.2	**INFLUENCE OF CHITOSAN BLENDED REDUCED GRAPHENE OXIDE NANOSHEETS FOR THE ELECTROCHEMICAL DETERMINATION OF p-AMINOPHENOL**	205
8.3	**ELECTROCHEMICAL INVESTIGATION OF POLYMER FUNCTIONALIZED REDUCED GRAPHENE OXIDE / ZINC OXIDE NANOCOMPOSITES FOR THE DETECTION OF p-AMINOPHENOL**	206
8.4	**INFLUENCE OF COPPER OXIDE NANOPARTICLES ENSEMBLED ON CHITOSAN BLENDED REDUCED GRAPHENE OXIDE NANOSHEETS FOR THE ELECTROCHEMICAL DETECTION OF p-AMINOPHENOL**	206
8.5	**EFFECT OF SILVER NANOPARTICLES ON POLYMER BLENDED REDUCED GRAPHENE NANOHYBRIDS AS A VERSATILE ELECTROCHEMICAL SENSOR FOR THE DETECTION OF p-AMINOPHENOL**	207
8.6	**EMBELLISHMENT OF GOLD NANOPARTICLES ON THE SURFACE OF CHITOSAN BLENDED REDUCED GRAPHENE OXIDE FOR THE ELECTROCHEMICAL INVESTIGATION OF p-AMINOPHENOL**	208
8.7	**ANTIBACTERIAL AND ANTICANCER ACTIVITIES OF THE rGO/CS/METAL OXIDES (ZnO, CuO), METAL (Ag, Au) NANOCOMPOSITES**	209
8.8	**CONCLUSION**	210
	LIST OF PUBLICATIONS	
	PAPER PRESENTED IN INTERNATIONAL CONFERENCE	

ABSTRACT

Graphene, a thin planar sheet of sp^2 hybridized carbon atoms has created a revolution over the past few decades in materials science and technology since from its invention. Owing to its excellent mixture of physical and chemical properties, it becomes a potential candidate in many interesting research areas such as supercapacitors, batteries, solar cells, nanoelectronics, metal oxides, functional nanocomposites, sensing, catalysis etc. Recently, efforts have been made to develop technologically feasible graphene-based devices. The development of composite materials based on graphene and natural polymers provide an ideal material in the biomedical field. However, the lack of good mechanical and thermal properties limits its applications. This drawback could be overcome by the reduction of graphene oxide into reduced graphene oxide (rGO). The rGO combined with the polymer helps to increase the adsorption of nanocomposites which thereby enhances the properties of the material to suit commercial applications. In addition to these, metal and metal oxide nanoparticles are decorated on the surface of polymer blended reduced graphene oxide that enhances the conductivity of hybrid nanocomposites. This present research is focused on the development of simple hybrid nanocomposites for the electrochemical determination of p-Aminophenol and biological applications. The metal and metal oxides nanoparticles ensembled on chitosan blended reduced graphene oide nanocomposites are synthesized by chemical reduction method. The as synthesized nanocomposites are analyzed through an assortment of characterization to investigate their structural, morphological, and electrocatalytic properties along with their biological applications.

The graphene oxide is synthesized by modified Hummer's method and the chitosan functionalized reduced graphene oxide is synthesized by chemical reduction method. The structural, spectral, morphological and elemental studies of the synthesized nanocomposites are characterized by X-ray powder diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), Scanning Electron Microscopy (SEM) and Energy Dispersive X-Ray Analysis (EDAX). XRD analysis reveals that the small diffraction peak at 10.3° corresponds to the plane of chitosan

and the broadening of the peak at 24 ^{o} may be due to the amorphous nature of chitosan. The band at 1640 cm^{-1} corresponds to the NHCO stretching vibrations of amine groups of chitosan. The surface morphology of rGO/CS nanocomposites reveals that the formation of white patches on the surface of flat wrinkled leaf like structure of rGO. The electro-chemical behaviour for the prepared GO and rGO/CS nanocomposites is investigated using cyclic voltammetry. The rGO/CS nanocomposites exhibits high redox peak current for p-AP compared to GO modified GCE.

The various concentrations of (0.002M, 0.004M, 0.006M, 0.008M and 0.01M) zinc nanoparticles embedded on chitosan blened reduced graphene oxide nanocomposites are synthesized by chemical reduction method. The nanocomposites are characterized using XRD, FT-IR, SEM, EDAX, HR-TEM and SAED analysis. The XRD pattern of rGO/CS/ZnO nanocomposites shows the hexagonal wurtzite phase of ZnO and the crystallite size is found to be about 27.3 nm, 33.4 nm and 34.9 nm. The surface morphological analysis reveals that the rod shaped ZnO nanoparticles found to be homogeneously distributed on the surface of rough, thin, wrinkled reduced graphene oxide/chitosan nanosheets. EDAX analysis reveals the presence of carbon, oxygen and zinc without any impurities that further confirms the formation of rGO/CS/ZnO nanocomposites. The electrochemical behaviour of rGO/CS/ZnO nanocomposite towards the detection of p-AP at the modified glassy carbon electrode is studied using cyclic voltammetry. The maximum redox peak current is observed to be 0.06µA for pH 7 of 0.008M of rGO/CS/ZnO nanocomposite with a wide linear range of detection about 10µM to 180µM. This is due to its uniform dispersion of ZnO nanoparticles on the large surface area of rGO/CS, leads to good electron transfer rate between p-AP and rGO/CS/ZnO nanocomposite modified GCE.

The various concentrations of (0.002M, 0.004M, 0.006M, 0.008M and 0.01M) copper oxide decorated chitosan blended reduced graphene oxide are synthesized by a facile chemical reduction method. The prepared nanocomposites are characterized by XRD, FT-IR, SEM, EDAX, HR-TEM and SAED analysis. The XRD analysis reveals that the crystallite size of copper oxide nanoparticles is in the

range from 9.16 nm to 18.5 nm. SEM and HR-TEM analysis reveals that the spherical shaped copper oxide nanoparticles well dispersed on to the chitosan blended rGO nanosheets. Elemental analysis reveals the presence of carbon, oxygen and copper without any impurities. Under optimized conditions, the maximum redox peak current is 0.18µA for pH 5 of 0.008M of rGO/CS/CuO nanocomposite and the linear range of detection about 60µM to 150µM.

The incorporation of silver nanoparticles onto the chitosan blened reduced graphene oxide nanocomposites are synthesized by chemical reduction method. The influence of various concentrations of (0.002 M, 0.004 M, 0.006 M, 0.008 M and 0.01 M) of silver nanoparticles on the surface of rGO/CS nanocomposites is investigated using FT-IR, XRD, SEM, HR-TEM and SAED analysis. XRD analysis reveals that the rGO/CS/Ag nanocomposites are well crystallized and the crystallite size is found to be about 23.6 nm. The band formed around 596 cm^{-1}confirms the formation of Ag nanoparticles on the surface of rGO/CS. The surface morphology analysis reveals that the spherical shaped Ag nanopartices are well dispersed on the surface of rGO/CS sheets. The electrochemical property of prepared rGO/CS/Ag nanocomposites is investigated using cyclic voltammetry. The electrochemical behaviour reveals that the large effective surface area of the prepared nanocomposites allows it to function as an electron transfer medium and enhances the charge transfer rate.

The decoration of various concentrations of (0.002 M, 0.004 M, 0.006 M, 0.008 M and 0.01 M) of gold nanoparticles on the surface of rGO/CS/Au nanocomposites synthesized by chemical reduction method and investigated using FT-IR, XRD, SEM, HR-TEM and SAED analysis. The interaction of functional groups between rGO, CS and Au is confirmed using FT-IR analysis. It reveals that the band formed around 586 cm^{-1} corresponds to the stretching of metallic vibrations. XRD reveals that the nanocomposites are of high crystalline in nature with the crystallite size of about 8.9 nm to 16.5 nm. SEM and HRTEM analysis confirms that the spherical shaped gold nanoparticles are closely anchored onto the surface of rGO/CS nanosheets. EDAX analysis confirms the presence of carbon, oxygen and gold in the prepared nanocomposites. The electrochemical behaviour

reveals that 0.006M of rGO/CS/Au nanocomposites has shown prominent electrochemical behavior towards the detection of p-aminophenol.

The prepared nanocomposites are tested for antibacterial and anticancer activity. The antibacterial activity is done against Gram-positive (B. subtilis and S. aureus) and Gram-negative (E.coli and K. pneumoniae) using disc diffusion technique. The cytotoxicity effect is studied against Human hepatocarcinoma (HepG–2) cell lines. The prepared nanocomposite shows the reduction in cell viability by dose-dependent manner. These results attest an efficacy as a substantial material for the treatment of HepG–2 cancer cell lines. Hence the prepared nanocomposites may be applied in biomedical field.

In summary, prepared rGO/CS/ZnO, rGO/CS/CuO, rGO/CS/Ag and rGO/CS/Au show an excellent electrocatalytic activity which acts as a good electrode material and can be applied in environment for the detection of p-Aminophenol. Moreover, the nanocomposites show outstanding bactericidal activity and antiproliferative activity that can be potentially applied in biomedical field.

LIST OF FIGURES

FIGURE NO	TITTLE	PAGE NO.
1.1	Nano scale and Nanostructures	01
1.2	Classifications of Nanomaterials	03
1.3	Top-down and bottom-up approach.	05
1.4	Applications of Nanotechnology	10
1.5	Different structural forms of Carbon: Diamond, Graphene, Graphite, Fullerenes and Carbon nanotubes	22
1.6	Structure of Graphene	24
1.7	Structure of Reduced graphene oxide	27
1.8	Functionalization of graphene oxide	28
1.9	Applications of graphene based nanocomposites	29
1.10	Structure of chitosan	31
1.11	Chitin to chitosan	32
1.12	Crystal structures of ZnO	34
1.13	Crystal structures of CuO	36
1.14	Structure of Ag	37
1.15	Structure of Au	38
1.16	Schematic representation of X-ray diffraction	41
1.17	Schematic diagram of Scanning electron microscope	43
1.18	Schematic diagram of EDAX	44
1.19	Schematic diagram of HR-TEM	45
1.20	Electrochemicl set up	48
1.21	Working electrode	48
1.22	Counter electrode	49
1.23	Reference electrode	50
1.24	Cyclic voltagramm curve	50
1.25	Methodology	53
2.1	Schematic representation for synthesis of Graphene oxide	74

2.2	Flowchart for synthesis of graphene oxide	75
2.3	FT-IR spectra of (a) GO (b) rGO (c) rGO/CS nanocomposites	76
2.4	XRD patterns for (a) GO (b) rGO (c) rGO/CS nanocomposites	78
2.5	SEM images of (a) GO (b) rGO and (c) rGO/CS nanocomposites	79
2.6	EDAX spectra for (a) GO (b) rGO and (c) rGO/CS	81
2.7	Cyclic voltagramm curve for (a) GO/GCE (b) rGO/CS/GCE in presence of 10µM of p-Aminophenol in 0.1 M Phosphate buffer solution (PBS : pH 5) at a scan rate of 20 mV s^{-1}	82
3.1	FT-IR Spectral Analysis of various concentrations (a) 0.002 M (b) 0.004 M (c) 0.006 M (d) 0.008 M and (e) 0.01 M of Zinc oxide nanopaticles on the surface of rGO/CS nanocomposites	90
3.2	XRD analysis of various concentration (a) 0.002M (b) 0.004M (c) 0.006M (d) 0.008M and (e) 0.01Mof Zinc oxide nanopaticles on the surface of rGO/CS nanocomposites	92
3.3	SEM images for various concentration (a) 0.002M (b) 0.004M (c) 0.006M (d) 0.008M and (e) 0.01M of Zinc oxide nanoparticles incorporated on rGO/CS nanocomposites.	94
3.4	EDAX analysis of various concentrations (a) 0.002M (b) 0.004M (c) 0.006M (d)0.008M and (e) 0.01M of zinc oxide nanoparticles incorporated on rGO/CS nanocomposites	96
3.5	HR-TEM images with different magnifications (c) Particle size distribution histogram of rGO/CS/ZnO nanocomposites and (d) SAED pattern for 0.008M concentration of Zinc oxide nanoparticles incorporated on rGO/CS nanocomposites	97
3.6	Cyclic voltagramm curve for (a) GO/GCE (b) rGO/ZnO/GCE (c) rGO/CS/GCE and (d) rGO/CS/ZnO/GCE in the presence of 50µM of p-Aminophenol in 0.1 M Phosphate Buffer Solution (PBS : pH 5) at a scan rate of 20 mV s^{-1}	99
3.7	Effect of pH on the redox peak current of 170 µM of p-AP and its linearity	100
3.8	Effect of scanrate and its linear relationship for 180 µM of p-AP at pH 7 of PBS solution	101
3.9	Cyclic voltagramm curves for 0.008M of rGO/CS/ZnO/GCE towards the detection of various concentrations of p-AP in pH 7of PBS solution at 20mV/s scan rate	102

4.1	FT-IR spectral analysis for various concentrations of Copper II acetate monohydrate (a) 0.002 M (b) 0.004 M (c) 0.006 M (d) 0.008 M and (e) 0.01 M on the surface of rGO/CS nanocomposites	110
4.2	XRD pattern for various concentrations of Copper II acetate monohydrate (a) 0.002 M (b) 0.004 M (c) 0.006 M (d) 0.008 M and (e) 0.01 M on the surface of rGO/CS nanocomposites	111
4.3	SEM images for various concentration (a) 0.002M (b) 0.004M (c) 0.006M (d) 0.008M and (e) 0.01M of copper oxide nanoparticles incorporated on rGO/CS nanocomposites.	113
4.4	EDAX analysis of various concentration (a) 0.002M (b) 0.004M (c) 0.006M (d) 0.008M and (e) 0.01M of copper oxide nanoparticles incorporated on rGO/CS nanocomposites.	115
4.5	TEM images for different magnifications and (c) Particle size distribution histogram of rGO/CS/CuO nanocomposites (d) SAED pattern for 0.008M of copper oxide nanoparticles incorporated on rGO/CS nanocomposites	116
4.6	Cyclic voltagramm curve for (a) GO/GCE (b) rGO/CS/GCE (c) rGO/CuO/GCE and (d) rGO/CS/CuO/GCE in the presence of 50µM of p-Aminophenol in 0.1 M Phosphate Buffer Solution (PBS : pH 5) at a scan rate of 20 mV s^{-1}	118
4.7	Effect of pH on the redox peak current of 150 µM of p-AP and its linearity	119
4.8	Cyclic voltagramm curve for effect of scanrate and its linear relationship for 150µM of p-AP in pH 5 of PBS solution	120
4.9	Cyclic voltagramm curves for 0.008M of rGO/CS/CuO/GCE towards the detection of various concentrations of p-AP in pH 5 of PBS solution at 20mV/s scan rate	121
5.1	FT-IR spectral analysis for various concentrations of silver nitrate (a) 0.002 M (b) 0.004 M (c) 0.006 M (d) 0.008 M and (e) 0.01 M on the surface of rGO/CS	129
5.2	XRD pattern for various concentrations of Silver nitrate (a) 0.002 M (b) 0.004 M (c) 0.006 M (d) 0.008 M and (e) 0.01 M on the surface of rGO/CS nanocomposites	130
5.3	SEM images of various concentration (a) 0.002 M (b) 0.004 M (c) 0.006 M (d) 0.008 M (e) 0.01 M of silver nanoparticles incorporated on rGO/CS nanocomposites	132

5.4	EDAX spectra for various concentration of (a) 0.002 M (b) 0.004 M (c) 0.006 M (d) 0.008 M (e) 0.01 M of silver nanoparticles incorporated on rGO/CS nanocomposites.	134
5.5	TEM images for different magnifications and (c) Particle size distribution histogram of rGO/CS/Ag nanocomposites (d) SAED pattern for 0.006M of silver nanoparticles incorporated on rGO/CS nanocomposites	136
5.6	CV curve for (a) Bare GO and (b) 0.006 M of rGO/CS/Ag modified GCE in absence of p-Aminophenol.	137
5.7	Cyclic voltagramm curve for (a) GO/GCE (b) rGO/CS/GCE (c) rGO/Ag/GCE and (d) rGO/CS/Ag/GCE in presence of 50µM of p-Aminophenol in 0.1 M Phosphate buffer solution (PBS : pH 6) at a scan rate of 20 mV s^{-1}	138
5.8	Effect of pH value of PBS on the redox peak current of 50 µM of p-Aminophenol and its linearity	139
5.9	Cyclic voltagramm curves for effect of scan rate and its linear relationship for 160 µM of p-AP in 0.1 M of PBS solution (pH-6) at various scan rates.	140
5.10	Cyclic voltagramm curves for 0.006M of rGO/CS/Ag/GCE towards the detection of p-Aminophenol in 0.1 M of PBS solution (pH 6) at a sczn rate of 20 mV/s	141
6.1	FT-IR spectra for various concentrations of (a) 0.002 M (b) 0.004 M (c) 0.006 M (d) 0.008 M and (e) 0.01 M gold nanoparticles decorated on chitosan functionalized reduced graphene oxide nanocomposites	149
6.2	XRD patterns for various concentrations of (a) 0.002 M (b) 0.004 M (c) 0.006 M (d) 0.008 M and (e) 0.01 M gold nanoparticles decorated on chitosan functionalized reduced graphene oxide nanocomposites	150
6.3	SEM images for various concentrations of (a) 0.002 M (b) 0.004 M (c) 0.006 M (d) 0.008 M and (e) 0.01 M gold nanoparticles decorated on chitosan functionalized reduced graphene oxide nanocomposites	152
6.4	EDAX spectra for various concentrations of (a) 0.002 M (b) 0.004 M (c) 0.006 M (d) 0.008 M and (e) 0.01 M gold nanoparticles decorated on chitosan functionalized reduced graphene oxide nanocomposites	154

6.5	TEM images for different magnifications and (c) Particle size distribution histogram of rGO/CS/Au nanocomposites (d) SAED pattern for 0.008M of gold nanoparticles incorporated on rGO/CS nanocomposites	156
6.6	Cyclic voltagramm curve for (a) GO/GCE (b) rGO/CS/GCE (c) rGO/Au/GCE and (d) rGO/CS/Au/GCE in the presence of 50µM of p-APl in 0.1 M Phosphate Buffer Solution (PBS : pH 5) at a scan rate of 20 mV s^{-1}	157
6.7	Effect of pH value of PBS on the redox peak current of 130 µM of p-Aminophenol and its linearity graph	158
6.8	Cyclic voltagramm curves for effect of scan rate and its linear relationship for 150 µM of p-AP in 0.1 M of PBS solution (pH 7) at various scan rates.	159
6.9	Cyclic voltagramm curves for 0.006M of rGO/CS/Au/GCE towards the detection of p-Aminophenol in 0.1 M of PBS solution (pH 7)	160
7.1	Shematic diagram of gram positve and gram negative bacteria	168
7.2	S.aureus	169
7.3	Bacillus subtilis	170
7.4	Escherichia coli	171
7.5	Klebsiella Pneumonia	172
7.6	Antibacterial activity for various concentrations of rGO/CS/ZnO nanocomposites against Gram negative [(E.coli (a), K.pneumonia (b)] and Gram positive [(Bacillus subtilis (c), S.aureus (d)]	174
7.7	Antibacterial activity for various concentrations of rGO/CS/CuO nanocomposites against Gram negative [((a) E.coli (b) K.pneumonia] and Gram positive [(c) S.aureus (d) Bacillus subtilis]	175
7.8	Graphical representation of zone of inhibition (mm) of various concentrations 0.002 M, 0.004 M, 0.006 M, 0.008 M and 0.01 M of copper oxide nanoparticles incorporated on rGO/CS nanocomposites	177
7.9	Graphical representation of zone of inhibition (mm) of various concentrations 0.002M, 0.004M, 0.006M, 0.008M and 0.01M of silver nanoparticles incorporated on rGO/CS nanocomposites.	178

7.10	Antibacterial activity for various concentrations of rGO/CS/Ag nanocomposites against Gram negative [((a) E.coli (b) K.pneumonia] and Gram positive [(c) S.aureus (d) Bacillus subtilis]	180
7.11	Graphical representation of zone of inhibition (mm) of various concentrations 0.002 M, 0.004 M, 0.006 M, 0.008 M and 0.01 M of gold nanoparticles incorporated on rGO/CS nanocomposites	181
7.12	Antibacterial activity for various concentrations of rGO/CS/Au nanocomposites against Gram negative [((a) E.coli (b) K.pneumonia] and Gram positive [(c) S.aureus (d) Bacillus subtilis]	183
7.13	Graphical representation of zone of inhibition (mm) of various concentrations 0.002 M, 0.004 M, 0.006 M, 0.008 M and 0.01 M of gold nanoparticles incorporated on rGO/CS nanocomposites	184
7.14	Morphological assessment of anticancer activity for various concentrations of 0.01M of zinc oxide nanoparticles decorated on the surface of rGO/CS nanocomposite against HepG-2 cell line	187
7.15	Cytotoxic effect of various concentrations of 0.01M of ZnO nanorods decorated on the surface of rGO/CS nanocomposite against HepG-2 cell line	188
7.16	Percentage of viability vs various concentration of 0.01M of ZnO nanorods decorated on the surface of rGO/CS nanocomposite against HepG-2 cell line	189
7.17	Morphological assessment of anticancer activity for various concentrations of 0.002M of copper oxide nanoparticles decorated on the surface of rGO/CS nanocomposite against HepG-2 cell line	190
7.18	Cytotoxicity for 0.002 M of CuO nanocomposites decorated on the surface of rGO/CS nanocomposite against HepG-2 cell line	191
7.19	Percentage of viability vs various concentration of 0.002 M of CuO nanocomposites decorated on the surface of rGO/CS nanocomposite against HepG-2 cell line	192

7.20	Morphological assessment of anticancer activity for various concentrations of 0.008 M of Ag nanoparticles decorated on the surface of rGO/CS nanocomposite against HepG-2 cell line	193
7.21	cytotoxicity for 0.002 M of Ag nanocomposites decorated on the surface of rGO/CS nanocomposite against HepG-2 cell line	194
7.22	Percentage of viability vs various concentration of 0.008 M of Ag nanocomposites decorated on the surface of rGO/CS nanocomposite against HepG-2 cell line	195
7.23	Morphological assessment of anticancer activity for various concentrations of 0.01 M of Au nanoparticles decorated on the surface of rGO/CS nanocomposite against HepG-2 cell line	196
7.24	Cytotoxicity effect for various concentrations of 0.01 M of Au nanocomposites decorated on the surface of rGO/CS nanocomposite against HepG-2 cell line	197
7.25	Percentage of viability versus various concentration of 0.01 M of Au nanocomposites decorated on the surface of rGO/CS nanocomposite against HepG-2 cell line	198

LIST OF TABLES

TABLE NO.	TITLE	PAGE NO.
7.1	Antibacterial activity of various concentrations 0.002M, 0.004M, 0.006M, 0.008M and 0.01M of Zinc oxide nanorods incorporated on rGO/CS nanocomposites.	176
7.2	Antibacterial activity of various concentrations 0.002M, 0.004M, 0.006M, 0.008M and 0.01M of copper oxide nanoparticles incorporated on rGO/CS nanocomposites.	179
7.3	Antibacterial activity of various concentrations 0.002M, 0.004M, 0.006M, 0.008M and 0.01M of silver nanoparticles incorporated on rGO/CS nanocomposites.	182
7.4	Antibacterial activity of various concentrations 0.002M, 0.004M, 0.006M, 0.008M and 0.01M of gold nanoparticles incorporated on rGO/CS nanocomposites.	185

ABBREVATIONS

GO	Graphene Oxide
CNTs	Carbon nanotubes
rGO	Reduced Graphene Oxide
CS	Chitosan
$NaNO_3$	Sodium Nitrate
H_2SO_4	Sulpuric acid
$KMnO_4$	Potassium Permanganate
H_2O_2	Hydrogen Peroxide
N_2H_4	Hydrazine hydrare
NH_4OH	Ammonium hydroxide
$AgNO_3$	Silver Nitrate
$HAuCl_3.3H_2O$	Gold III chloride trihydrate
$C_4H_6O_4Zn.2H_2O$	Zinc Acetate dihydrate
$CH_3COO_2C_4.H_2O$	Copper II acetate monohydrate
$NaBH_4$	Sodiumborohydrate
Ag	Silver
Au	Gold
ZnO	Zinc oxide
CuO	Copper oxide
AgCl	Silver Chloride
KCl	Potassium Chloride
KH_2PO_4	Potassium dihydrogen phosphate
K_2HPO_4	Dipotassium hydrogen phosphate
p-AP	p-Aminophenol
PBS	Phosphate Buffer Solution
GCE	Glassy Carbon Electrode
FT-IR	Fourier Transform Infrared
XRD	X-ray Diffraction
SEM	Scanning Electron Microscope
EDAX	Energy Dispersive X-ray analysis

HRTEM	High Resolution Transmission electron microscope
SAED	Selected Area Electron Diffraction
M	Molarity
CV	Cyclic Voltammetry
E_i	Initial potential
E_p	Peak Potential
I_p	Peak current
E_{pa}	Anodic peak potential
I_{pa}	Anodic peak current
E_{pc}	Cathodic peak potential
I_{pc}	Cathodic peak current
υ	Scan rate
cm	Centimeter
mA	Microampere
µA	Microampere
mM	Millimole
µM	Micromole
IC50	Half maxima inhibitory concentration
g	Gram
µg/ml	Microgram per millilitre
DMSO	Dimethysulfoxide
MTT	3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyl tetrazolium bromide
FBS	Fetal Bovine Serum
a.u.	Arbitrary Unit
B. subtilis	Bacillus subtilis
K. pneumonia	Klebsiella pneumonia
S. aureus	Staphylococcus aureus
E.Coli	Escherichia coli
HepG-2	Liver cancer cell line