

CONTENTS

<i>a. Abstract</i>	<i>i</i>
<i>b. Declaration</i>	<i>x</i>
<i>c. Certificate</i>	<i>xi</i>
<i>d. Report of Examiners of ODEC</i>	<i>xii</i>
<i>e. Dedication</i>	<i>xiii</i>
<i>f. Acknowledgements</i>	<i>xiv</i>
<i>g. Contents</i>	<i>xvii</i>
<i>h. List of tables</i>	<i>xxiii</i>
<i>i. List of figures</i>	<i>xxvi</i>
<i>j. List of abbreviations</i>	<i>xxxvi</i>
<i>k. List of symbols</i>	<i>xxxviii</i>
CHAPTER 1: Introduction	[1-42]
1.1 Overview of electrochemical energy storage devices	1
1.1.1 Conventional capacitors	2
1.1.2 Electrolytic capacitors	3
1.1.3 Electrochemical supercapacitors	4
1.1.4 Batteries	4
1.1.5 Fuel cells	6
1.2 Comparison of electrochemical energy storage devices	7
1.3 Historical background of supercapacitors	9
1.4 Classification of supercapacitors	9
1.4.1 Electric double layer capacitors	10
1.4.2 Pseudocapacitors	11
1.4.3 Hybrid capacitors	13
1.5 Application of supercapacitors	15
1.6 Electrode materials for supercapacitors	17
1.6.1 Electrode materials for electric double layer capacitors	17
1.6.1.1 Activated carbon	17
1.6.1.2 Carbon aerogel	18
1.6.1.3 Carbon nanotubes	19

Halenda (BJH) method	
2.10 Determination of surface energy using contact angle measurements	65
2.11 Theories governing the interaction of swift heavy ions with solid target material	67
CHAPTER 3: Experimental Techniques	[70-96]
3.1 Materials	70
3.2 Synthesis of polypyrrole nanotubes, reduced graphene oxide and nanocomposites	72
3.2.1 Synthesis of polypyrrole nanotubes	72
3.2.2 Synthesis of reduced graphene oxide	73
3.2.3 Synthesis of reduced graphene oxide–polypyrrole nanotubes nanocomposites	74
3.3 Synthesis of polyaniline nanotubes and nanocomposites	75
3.3.1 Synthesis of polyaniline nanotubes	75
3.3.2 Synthesis of reduced graphene oxide–polyaniline nanotubes nanocomposites	76
3.4 Preparation of nanocomposite electrodes	77
3.5 Swift heavy ion (SHI) irradiation of nanocomposites	78
3.5.1 Parameters related to SHI irradiation	81
3.5.1.1 Fluence (φ)	81
3.5.1.2 Beam energy	82
3.6 Characterization techniques	83
3.6.1 High resolution transmission electron microscopy	83
3.6.2 Scanning electron microscopy	84
3.6.3 X-ray diffraction	85
3.6.3.1 Calculation of crystallinity percentage	86
3.6.4 FTIR spectroscopy	88
3.6.5 Micro-Raman spectroscopy	89
3.6.6 Thermogravimetric analysis	90
3.6.7 Current-voltage characteristics	91
3.6.8 N ₂ adsorption-desorption measurements	92

3.6.9	Contact angle measurements	94
3.6.10	Measurements of electrochemical properties	95
(i)	Cyclic voltammetry	95
(ii)	Galvanostatic charge-discharge measurements	96
(iii)	Electrochemical impedance spectroscopy	96
(iv)	Cyclic stability study	96
CHAPTER 4: Reduced Graphene Oxide-Polypyrrole		[97-118]
Nanotubes Nanocomposite Electrode System		
4.1	Introduction	97
4.2	Structural characterization	99
4.2.1	Morphological analysis	99
4.2.2	X-ray diffraction analysis	101
4.3	Vibrational spectroscopy	102
4.3.1	Fourier transform infrared spectroscopy	102
4.3.2	Micro-Raman spectroscopy	104
4.4	Thermogravimetric analysis	106
4.5	Current-voltage (I-V) characteristics	108
4.6	Conductivity measurements	109
4.7	Electrochemical properties	110
4.7.1	Cyclic voltammetry	110
4.7.2	Galvanostatic charge-discharge measurements	111
4.7.3	Electrochemical impedance spectroscopy	113
4.7.4	Cyclic stability study	115
4.8	Summary	116
CHAPTER 5: Swift Heavy Ion Irradiation of Reduced		[119-146]
Graphene Oxide-Polypyrrole Nanotubes		
Nanocomposite Electrode System		
5.1	Introduction	119
5.2	Structural characterization	121
5.2.1	Morphological analysis	121
5.2.2	X-ray diffraction analysis	124
5.3	Vibrational spectroscopy	125

5.3.1	Fourier transform infrared spectroscopy	125
5.3.2	Micro-Raman spectroscopy	127
5.4	Thermogravimetric analysis	129
5.5	Current-voltage (I-V) characteristics	131
5.6	Conductivity measurements	132
5.7	Surface area and pore size analysis	133
5.8	Contact angle measurements	135
5.9	Electrochemical properties	136
5.9.1	Cyclic voltammetry	136
5.9.2	Galvanostatic charge-discharge measurements	138
5.9.3	Electrochemical impedance spectroscopy	141
5.9.4	Cyclic stability study	142
5.10	Summary	143
CHAPTER 6: Reduced Graphene Oxide-Polyaniline		[147-167]
Nanotubes Nanocomposite Electrode System		
6.1	Introduction	147
6.2	Structural characterization	148
6.2.1	Morphological analysis	148
6.2.2	X-ray diffraction analysis	150
6.3	Vibrational spectroscopy	151
6.3.1	Fourier transform infrared spectroscopy	151
6.3.2	Micro-Raman spectroscopy	153
6.4	Thermogravimetric analysis	155
6.5	Current-voltage (I-V) characteristics	157
6.6	Conductivity measurements	158
6.7	Electrochemical properties	159
6.7.1	Cyclic voltammetry	159
6.7.2	Galvanostatic charge-discharge measurements	160
6.7.3	Electrochemical impedance spectroscopy	163
6.7.4	Cyclic stability study	164
6.8	Summary	165

CHAPTER 7: Swift Heavy Ion Irradiation of Reduced Graphene Oxide-Polyaniline Nanotubes Nanocomposite Electrode System	[168-192]
7.1 Introduction	168
7.2 Structural characterization	170
7.2.1 Morphological analysis	170
7.2.2 X-ray diffraction analysis	172
7.3 Vibrational spectroscopy	173
7.3.1 Fourier transform infrared spectroscopy	173
7.3.2 Micro-Raman spectroscopy	175
7.4 Thermogravimetric analysis	177
7.5 Current-voltage (I-V) characteristics	178
7.6 Conductivity measurements	180
7.7 Surface area and pore size analysis	181
7.8 Contact angle measurements	182
7.9 Electrochemical properties	184
7.9.1 Cyclic voltammetry	184
7.9.2 Galvanostatic charge-discharge measurements	186
7.9.3 Electrochemical impedance spectroscopy	188
7.9.4 Cyclic stability study	189
7.10 Summary	190
CHAPTER 8: Conclusions and Future Prospects	[193-204]
8.1 Conclusions	193
8.2 Future prospects	203
REFERENCES	[205-242]
LIST OF PUBLICATIONS	[243-244]