

Table of Contents

CHAPTER 1: Introduction	23-48
1.1. Necessity of energy storage devices.....	24
1.2. Kinds of energy storage devices.....	24
1.2.1. Battery.....	26
1.2.2. Fuel cell.....	27
1.2.3. Capacitor.....	28
1.2.4. Supercapacitor.....	31
1.3. Supercapacitors' fundamental working mechanism.....	31
1.4. Classification of supercapacitors.....	35
1.4.1. EDLC.....	36
1.4.2. Pseudocapacitor.....	38
1.4.3. Hybrid supercapacitors.....	39
1.5. Components of supercapacitors.....	41
1.5.1. Electrode.....	41
1.5.1.1. Carbon based.....	42
1.5.1.2. Conducting polymer based.....	42
1.5.1.3. Metal oxide based.....	43
1.5.2. Electrolyte, separator, current collector, and sealants.....	43
1.6. Challenges with supercapacitor.....	45
1.7. Applications.....	46
CHAPTER 2: Literature review	49-80
2.1. Carbon-based materials.....	50
2.1.1. Graphene.....	50
2.1.2. Graphene structure.....	52
2.1.3. Graphene derivatization.....	53
2.1.3.1. Graphene oxide (GO).....	53

2.1.3.2. Reduced graphene oxide (rGO).....	54
2.2. Conducting polymers.....	59
2.2.1. Polyaniline (PANI).....	61
2.3. Metal oxides.....	67
2.4. Composites.....	69
2.5. Benefits of the ternary composite system.....	78
2.6. Research gap.....	79
2.7. Objectives.....	79
CHAPTER 3: Materials, methods, and characterization techniques	81-110
3.1. Materials.....	83
3.2. Synthesis procedure.....	84
3.2.1. Synthesis of graphene oxide.....	84
3.2.2. Synthesis of polyaniline.....	85
3.2.3. Synthesis of metal oxides.....	89
3.2.4. Synthesis of graphene oxide and polyaniline based binary composite.....	92
3.2.5. Synthesis of ternary composites.....	94
3.2.6. Fabrication of electrodes and supercapacitor.....	95
3.2.7. Characterization techniques.....	97
3.2.8. Material characterization.....	98
3.2.8.1. XRD.....	98
3.2.8.2. FTIR.....	99
3.2.8.3. FESEM and EDS.....	99
3.2.8.4. Electrochemical characterization and performance evalution of the fabricated systems.....	100
3.2.8.4.1. Cyclic voltammetry (CV).....	102
3.2.8.4.2. Charge-discharge (CD).....	104
3.2.8.4.3. Electrochemical impedance spectroscopy (EIS).....	106

CHAPTER 4: Synthesis of graphene oxide-polyaniline-copper cobaltite (GO/PANI/CuCo₂O₄) based hybrid composite system and its use in supercapacitor electrodes **111-138**

4.1. Introduction.....	112
4.2. Results and discussion.....	113
4.2.1. Raman spectra.....	113
4.2.2. XRD analysis.....	113
4.2.3. FTIR analysis.....	116
4.2.4. FESEM.....	117
4.2.5. Compositional analysis for surface morphology.....	119
4.2.6. Electrochemical characterization.....	121
4.3. Conclusion.....	138

CHAPTER 5: Comparison of graphene oxide based hybrid composite system, and their use as supercapacitor electrodes **139-166**

5.1. Introduction.....	140
5.2. Results and discussion.....	140
5.2.1. XRD.....	140
5.2.2. FTIR.....	144
5.2.3. FESEM.....	146
5.2.4. Elemental analysis from the morphology.....	147
5.2.5. Elemental mapping.....	148
5.2.6. Electrochemical nature.....	149
5.3. Conclusion.....	165

CHAPTER 6: Summary & future perspectives **167-171**

REFERENCES **172-209**

APPENDIX **210-215**