PREFACE

Global research on energy and energy related issues become more and more intensive, due to the significantly increased investment. This is due to the dearth of conventional energy sources and the greenhouse gas issue. Finding new sources of energy is a crucial area for research, but energy storage is equally vital. Supercapacitors are coming to light as cutting-edge energy storage technologies that provide high-power density (as of a capacitor) and high-energy density (as of a battery), filling the gap between batteries and regular capacitors. Supercapacitors' two primary methods for storing charge are electrochemical double layer and the redox process. Considerable effort is being paid to strategies that could integrate both mechanisms within a supercapacitor to improve its electrochemical characteristics.

Supercapacitors are classified based on their charge storage techniques as ELDCs (electric double-layer capacitors), pseudocapacitors, and hybrids. EDLCs use adsorption to accumulate charges on electrolyte- electrode interface; on the other hand, the pseudocapacitors utilize reversible redox (Faradaic) reactions. The hybrid supercapacitors employ a combination of EDLC and pseudocapacitance to store electrochemical energy. EDLCs are generally carbon-based materials with better power density but lack energy density as they hold less charge owing to their surface adsorption tendency. The pseudocapacitive materials, such as metal oxides and conductive polymers, offer greater energy densities with higher specific capacitance.

In the current research, different low-cost and sustainable composite materials were synthesized for supercapacitor applications. Various electrochemical parameters like specific capacitance, specific energy density, specific power density, coulombic efficiency, cycle life, charge transfer resistance, etc. were investigated after fabricating the supercapacitor electrodes.

The composite materials comprising a conducting polymer, carbon material, and a bimetal oxide have been shown to be more electroactive than pure materials and less reported.

Polyaniline (PANI) is one of the most captivating conductive polymers in numerous applications such as supercapacitors, sensors, and batteries due to its multiple redox states. Metal oxides show poor cycle stability and low-rate capability as a result of their poor inherent conductivity. By providing enough surface area for the electroactive components (in this case, bimetallic oxides and polyaniline), activated carbon served the dual purposes of protecting the structural integrity of metal oxides and polyaniline and providing enough surface area to survive mechanical distortion during redox transitions. Therefore, waste coconut-shell-derived activated carbon and binary metal oxides of XY_2O_4 type (where X, and Y are transition metals, and O is oxygen) were selected for incorporation into matrix for superior electrochemical performance.

Very limited research has been conducted on low-cost ternary composite materials for supercapacitor applications. The primary purpose of the current work is to synthesize polyaniline-activated carbon-bimetallic oxides-based hybrid ternary composites and use them as supercapacitor electrodes with a goal to improve specific capacitance, specific energy density, and cycle life. Further, optimization studies of the ternary composite materials on the basis of weight percentage on specific capacitance was also conducted with the help of response surface methodology.

The current study has been divided into **7 chapters**. **Chapter 1** discusses about the introduction of supercapacitors, classifications, advantages and disadvantages. **Chapter 2** consists of a detailed literature review on various types of materials used in supercapacitors, research gap, and objective of the research work. **Chapter 3** consists of the materials, methods, and various characterization techniques used during the research work. In **chapter 4**, part-I, a novel low-cost sustainable composite material based on polyaniline-activated-carbon copper cobaltite was successfully synthesized. Its specific capacitance was found to be 613.5 F/g at a scan rate of 1 mV/s. The ternary composite exhibited a specific energy density of 44.1 Wh/kg 1 A/g and a maximum specific power density of 5997.13 W/kg at 20 A/g. In part II, the ternary composite material was optimized to obtain the best composition towards electrochemical properties with the help of Response Surface Methodology. In **chapter 5**, part-I, another novel low-cost sustainable composite material based on polyaniline-activated-carbon cobalt ferrite was successfully synthesized, and its specific capacitance was found to be 640.8 F/g at a scan rate of 1 mV/s. It exhibited a specific energy density of 46.9 Wh/kg 1 A/g and a maximum specific power density of 5998.7 W/kg at 20 A/g. In part II, the ternary composite material was optimized to obtain the best composition towards electrochemical properties with the help of Response Surface Methodology. Similarly, in **chapter 6** part (I), electrochemical properties of polyaniline/activated carbon/ copper ferrite have been discussed. The specific capacitance of the synthesized ternary composite material was found to be 759.8 F/g at a scan rate of 1 mV/s. It exhibited a specific energy density of 49.6 Wh/kg 1 A/g and a maximum specific power density of 5996.6 W/kg at 20 A/g. The part (II) of chapter 6 deals with the optimization of constituents of ternary composite material towards best electrochemical performance. The conclusion of the present work has been discussed in **chapter 7.**