

# Abstract

The depleting natural resources and ever-increasing needs of energy led to environmental issues which attract immense attention of the researchers for future technology advancement in the field of energy conversion and storage. The electrochemical supercapacitors (SCs), also known as “ultra-supercapacitors” being a part of the electrochemical energy storage devices, attracted great attention owing to its high power delivery > 100 times higher than battery, long cyclic life >10<sup>5</sup> and high efficiency. In recent years some flexible wearable electronics have evolved in leaps and bounds and emerged as a new market of portable and wearable electronics. To meet the requirement of this new market, fiber shaped SCs have been considered among flexible and stretchable solutions. This dissertation presents the fabrication, electrochemical performance testing and performance optimization of different flexible substrates for fiber shaped SCs. Nanoscale materials offer advanced and exciting fabrication techniques of SC electrodes for high-performance electrochemical energy storage devices. In material science, a major challenge is to synthesize the nanomaterials with desirable chemical properties and to engineer the nanostructures in an appropriate way.

This thesis exhibits the successful fabrication and applications of very promising materials in electrochemical SCs for energy storage, including ZnO/Graphite composite, manganese dioxide deposition on carbon fibers (CFs), Fe<sub>2</sub>O<sub>3</sub> composite with rGO aerogel and MoS<sub>2</sub>. The prime objective is to understand their synthesis processes and electrochemical performance in supercapacitor devices. First of all, two parallel electrode configuration devices were assembled in gel-polymer electrolyte using ZnO/graphite as active material dip-coated on copper wire. The assembled device exhibits excellent performance as compared to bare graphite powder-based electrode in terms of specific capacitance, energy and power density. The cyclic and bending stability has also been evaluated. Moving towards flexibility, other flexible substrates, transition metal oxides and their composites are investigated as electrode material for SCs. Here, I have selected CFs as flexible substrate and MnO<sub>2</sub> as active material. MnO<sub>2</sub> is electrodeposited (ED) on CFs using both potentiostatic and galvanostatic techniques. After comparing electrochemical performance, the best performing deposition technique (galvanostatic deposition) was optimized by tuning deposition parameters such as, time and current density. The morphology of the

nanostructures and their electrochemical performance (specific capacitance, cycling effects and bending stability) which contribute to the understanding of the energy storage mechanism of  $\text{MnO}_2$  based SCs is thoroughly investigated. In addition to single step deposition, the performance of  $\text{MnO}_2$  on CFs ( $\text{MnO}_2/\text{CF}$ ) electrode is further improved using 2-step ED of  $\text{MnO}_x$  by achieving the full coverage of the substrate and connectivity of the nanostructured material. The performance of the material was also improved by introducing oxygen vacancies on the  $\text{MnO}_x$  surface by hydrogenation process (obtaining  $\text{Mn}_3\text{O}_4$ ) and subsequently optimized by electrochemical conversion of this spinel structure into Sodium Birnessite. Electrochemical performance and energy density of the supercapacitor is also enhanced by exploiting asymmetric configuration of the device in PVA based gel-polymer electrolytes. In this dissertation two asymmetric devices are assembled: i)  $\text{MnO}_x/\text{CF}$  and  $\text{Fe}_2\text{O}_3/\text{rGO}$ , ii) H- $\text{MnO}_x$  and  $\text{MoS}_2$  with former as cathodes and later as anodes material respectively. Both the devices have shown excellent electrochemical performance along with wide voltage windows 1.2 V and 1.8 V respectively which is fundamental for high energy density devices. The synthesis of electrodes described in this thesis exploiting electrodeposition technique is simple, cost effective, and environmental friendly approach. It possesses great potential to fabricate low-cost and high specific energy density SCs.