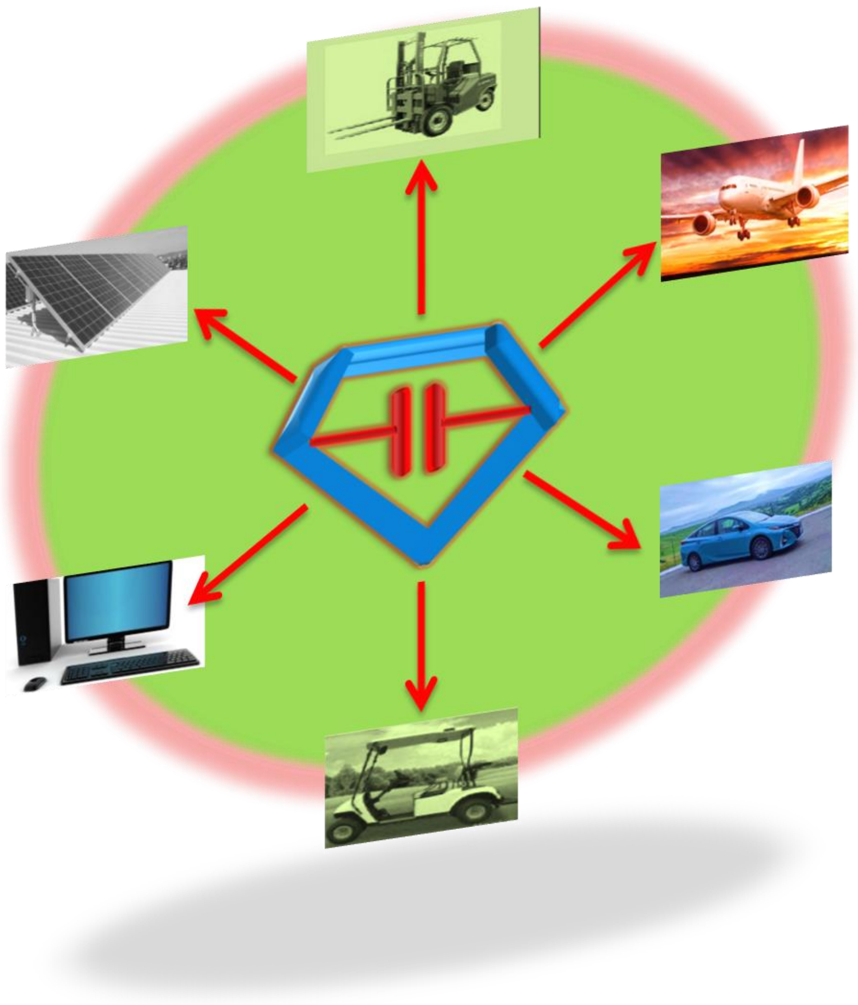
Chapter 1

Introduction



1. Introduction

Electrochemical capacitors or Supercapacitors is an electrochemical energy storage device which converts electrochemical energy in to the electrical energy. Two electrode supercapacitor consist two high specific surface area based electrodes, situated both sides of a separator that contain the electrolyte whereas in three electrode supercapacitor active material, Ag/AgCl or $Hg/HgCl_2$ and platinum wire are acts as working electrode, reference and counter electrode respectively.[1]Depending on the charge storage mechanisms supercapacitors can be classified into three types.[2]Most common type of SCs are electrochemical double layer capacitor (EDLC), which can store energy using ion adsorption and use carbon based active material like Graphene ,carbon nanotubes.[3-7]In transition metal oxides (TMOs),[8-16] transition metal dichalcogenides (TMDCs),[17] hydroxides[18-20] and conductive polymer[21-24]based supercapacitor energy is stored due to fast and reversible surface redox reaction occurring at the surface of the active electrode materials, which are known as pseudocapacitor (PSCs). Advanced approaches to increase the specific capacitance and energy density are to develop hybrid electrode materials for supercapacitor by adding electrochemically active materials with carbonaceous materials. This kind of SCs knows as Hybrid supercapacitors (HSCs).

1.1 Motivation

Now a day, it is next to impossible to imagine our lives without wearable and portable electronic devices such as smartphones, laptops, e-papers, cameras, displays, transplantable medical devices, smart watch and many more, which play an effective role to change new generation’s life style. With the decreasing availability of fossil fue1, increasing pollution associated with their use and ever growing demand of energy consumption of these kinds of smart electronics requires superior energy storage devices. According to Ragone chessboard, though supercapacitors (SCs) and batteries are the most successful players but due to the higher power density, cycle efficiency and charging-discharging rate supercapacitors play leading role over other energy storage devices like lithium ion battery (LIB).[1] Yet, a number of nano structured pseudocapacitive electrode materials such as nano particles, nanorods, nanospheres, nanosheets etc. have attracted for supercapacitor applications. Among them two dimensional (2-D) graphene analogues (GA) are the best for the highly flexible ultrathin-film supercapacitor in all-solid-state with higher energy density and excellent mechanical flexibility.[17,18,25]Two-dimensional (2-D) nanomaterials offer exciting prospects for both fundamental studies and several technological applications due to their unique and intriguing properties.[26-30] Materials with intrinsic layered structure provide scope for the production of 2-D systems with a very broad range of properties. In their 2-D structure, inorganic layered materials such as transition metal oxides (MnO_2, RuO_2, MoO_3, TiO_2 etc.) and transition metal dichalcogenides (MoS_2, WS_2, VS_2, etc.) for their unique properties becomes promising candidates for topological insulators, energy harvesters, thermal conductors, and transistors. [31-36]

1.2 Objective

The main focus of this dissertation is to get a better understanding about the electrochemical behaviour of the 2-D nano materials to fabricate of hybrid SCs with the carbonaceous electrode materials using aqueous and solid (gel electrolyte) electrolytes for two electrode and three electrode supercapacitor applications.

The objectives of this thesis are:

1. Large scale production of 2-D nano materials by facial low cost environmental friendly mixed solvent exfoliation, hydrothermal or solvothermal process.
2. Fabrication of hybrids or composite flexible supercapacitors based on 2-D nano materials with high energy density.
3. High performance of supercapacitor with excellent cycle stability.

1.3 Novelty

Present work reported large scale production of 2-D materials using mixed solvent exfoliation from their bulk forms and Hydro (or solvo) thermally synthesized layered materials also exfoliated by liquid phase exfoliation by suitable solvents. These well dispersed stable solutions were used to make thin films which can be readily transferred on wide range of substrates for flexible supercapacitor electrode applications with high energy density. The performance of the composite electrode materials by varying compositions also included in the present work. The specific novelty claims in this thesis are listed below

- Mixed solvent exfoliation of 2-D nano materials.
- Few layered 2-D materials and their hybrids or composites with graphene and CNTs thin films on different substrates for flexible supercapacitor application

- An investigation the performance of 2-D materials based solid state supercapacitor varying compositions and optimised the best composition endowed with high energy density.

1.4 Thesis structure

The chapter1 contains the introduction of this research. The literature review of electrochemical capacitors is given in the chapter 2, containing a picture of the growth of supercapacitors from conventional capacitors, selection of electrode materials, electrolytes and synthesis of 2-D nano materials respectively. The chapter3 presents different measurement and characterization tools and the electrochemical performance measurement techniques for supercapacitors. Chapter 4 provides a novel mixed solvent exfoliation process to prepare transition metal oxide nanosheets for thin film flexible supercapacitor application. The chapter5 presents $BiVO_4$/rGO hybrid electrode material with optimised weight percentage of $BiVO_4$ for superior electrochemical performance. The chapter6 provides highly crystalline 2-D BiOCl nanoplate and their composites with MWCNT for flexible supercapacitor with excellent cycle stability. We have reported we have used SWCNT network as a current collector instead of gold which will be helpful to make transparent flexible supercapacitor. The chapter7 presents large scale production of MoS_2 and MoS_2/rGO hybrid by simple hydrothermal route followed by liquid phase exfoliation to get the nanosheets. These MoS_2 nanosheets in presence of rGO exhibit excellent electrochemical performances. The chapter 8 contains $VOPO_4$ and MWCNT composite electrode material fabrication and the electrochemical. The chapter 9 provides overall conclusions and future work.

1.5 References

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