# Preface

The reduced graphite oxide (rGO) and Molybdenum disulfide ($MoS_2$) are layered structures, which possess some attractive properties such as, high conductivity, high-surface area, flexibility, and good stability in acidic/basic medium. These characteristics allow rGO and $MoS_2$ nanostructures to be used in next generation energy devices. This thesis entitled **"Reduced Graphite Oxide and $MoS_2$ based Electrodes for Hydrogen Generation and Supercapacitor Applications"** is focused on the synthesis of rGO, different morphologies for 2H $MoS_2$ nanostructures and $MoS_2$-rGO heterostructure via hydrothermal technique for hydrogen evolution reaction (HER) and supercapacitor applications. We have synthesized two rGO samples using different reducing agents (hydrazine hydrate and urea) and three different morphologies of $MoS_2$ nanostructures (nanoclusters, nanoflowers and nanosheets) and $MoS_2$-rGO heterostructure. We have characterized as synthesized samples by scanning electron microscopy (SEM) and transmission electron microscopy (TEM) to confirm the morphology and structure of the samples. To confirm the phase and purity of prepared samples, we have performed X-ray diffraction (XRD) and Raman spectroscopy techniques. We have also investigated the Fourier transform infrared (FTIR) study to examine the functional groups, present in the prepared samples. We have further studied electrochemical activity of prepared samples for HER and supercapacitor applications.

In the present work, $MoS_2$ nanoflowers electrode shows the best HER activity with Tafel slope of 69 mV $dec^{-1}$ at voltage sweep rate of 5 mV $s^{-1}$ among studied materials, which can be associated with 3D architecture and higher accessibility of active sites due to arranged petal formation. Further, we have utilized $MoS_2$ nanoflowers as cathode material and investigated real time hydrogen generation using a prototype electrochemical cell. Further, we also observe capacitive behaviour of prepared samples in neutral (1M $Na_2SO_4$)

and acidic (1M $H_2SO_4$) electrolytes. Among the studied materials, $MoS_2$ nanoflowers electrode shows best capacitive performance of 382 F $g^{-1}$ at 1 A $g^{-1}$ in neutral (1M $Na_2SO_4$) electrolyte. The higher value of specific capacitance can be attributed to the accessible surface area between well separated petals of flower structure and functional groups which may increase the wettability of electrode for easy transport of electrolyte. Further, solid-state supercapacitor devices with synthesized samples as electrodes have been investigated with neutral (PVA-$Na_2SO_4$) and acidic (PVA-$H_2SO_4$) electrolytes. Among the studied SSC devices, $MoS_2$ nanosheets based SSC device shows maximum specific capacitance of 101 F $g^{-1}$ at 0.2 A $g^{-1}$ and high energy density 36.1 Wh $kg^{-1}$ with neutral (PVA-$Na_2SO_4$) electrolyte. This high performance can be due to the enhanced wettability, accessible surface area and better interface formation between nanosheet structure and solid electrolyte membrane.

The present thesis has been organized into six chapters. The consecutive chapters are organized as follows-

**Chapter 1** gives a brief introduction of rGO and $MoS_2$ nanostructure along with an overview of the current literature on HER and supercapacitor applications.

**Chapter 2** describes the synthesis process of rGO using different reducing agents (hydrazine hydrate and urea), three different morphologies of $MoS_2$ nanostructures (nanoclusters, nanoflowers and nanosheets) and $MoS_2$-rGO heterostructure. A concise overview of the characterization instruments like XRD, SEM, TEM, Raman, FTIR is provided for structural, morphological and functional group studies of samples. This chapter also describes different electrochemical characterization methods for HER and supercapacitor applications.

**Chapter 3** discusses the characterisation and HER activity of prepared rGO, $MoS_2$ nanostructures and $MoS_2$-rGO heterostructure in acidic medium. Different HER parameters have been obtained and fundamentals related to HER have been discussed in this chapter.

**Chapter 4** discusses the capacitive behaviour of prepared rGO, $MoS_2$ nanostructures and $MoS_2$-rGO heterostructure in neutral and acidic electrolytes. Specific capacitance obtained via different electrochemical technique has been discussed in this chapter.

**Chapter 5** describes the performance of prepared different rGO, $MoS_2$-nanostructures and $MoS_2$-rGO heterostructure based SSC devices with neutral (PVA-$Na_2SO_4$) and acidic (PVA-$H_2SO_4$) electrolytes. Different device parameters like capacitance, energy density and power density have been discussed in this chapter.

**Chapter 6** summarises the thesis work and highlights the scope for the future work related to this field.