Chapter 6 Conclusion and Future Scope of The Work

6.1 Conclusion

In conclusion, thesis work is mainly focused on the synthesis of different nanostructures of rGO, MoS_2 and MoS_2-rGO heterostructure via hydrothermal technique for HER and supercapacitor applications. We have synthesized two samples of rGO 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. The morphologies of the prepared nanostructures have been studied using SEM and TEM. Further, XRD and Raman spectroscopy studies have been performed to confirm the phase and purity of prepared samples. The FTIR study has been performed to examine the functionality present in the samples. Different electrochemical characterization techniques like LSV, CV, GCD and EIS have been performed to evaluate HER activity and supercapacitor applications for prepared materials. In case of HER application, we have successfully demonstrated real time hydrogen generation using a prototype electrochemical cell with MoS_2 nanoflowers as cathode material. In case of supercapacitor application, we have demonstrated the capacitive behaviour of prepared samples in neutral (1M Na_2SO_4) and acidic (1M H_2SO_4) aqueous electrolytes. Further, solid-state supercapacitor (SSC) devices have been fabricated using above samples as electrodes with neutral (PVA-Na_2SO_4) and acidic (PVA-H_2SO_4) solid electrolytes and their performance have been examined.

Important Finding of The Present Work

- In the present work, we have successfully demonstrated HER activity of all prepared samples. Among prepared materials, MoS_2 nanoflowers electrode shows the best HER activity with Tafel slope value of 69 mV dec^{-1} at voltage sweep rate of 5 mV s^{-1}, 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 demonstrated real time hydrogen generation using a prototype electrochemical cell.

- ❖ We have also successfully demonstrated capacitive behaviour of all prepared samples in neutral (1M Na_2SO_4) and acidic (1M H_2SO_4) aqueous electrolytes. Among studied materials, MoS_2 nanoflowers electrode shows best capacitive performance 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.
- ❖ We have successfully investigated the performance of rGO, MoS_2 nanostructures and MoS_2-rGO heterostructure based solid-state supercapacitor devices with neutral (PVA-Na_2SO_4) and acidic (PVA-H_2SO_4) solid 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. The high performance of MoS_2 nanosheets based SSC device could be due to the formation of good interface between nanosheet structure and solid electrolyte.
- ❖ The present work also illustrates the cost-effective large-scale production of rGO and MoS_2 nanostructures for energy generation and storage.

6.2 Future Scope of the Work

- ❖ In future, hydrothermal synthesis route can be explored to synthesize different carbon and 2D transition metal dichalcogenide (TMDCs) materials and heterostructures.

- ❖ The HER activity of synthesized nanostructures for sea water electrolysis can be explored and electrolyser design can be modified accordingly.
- ❖ In future, new synthesis methods can be elucidated to synthesize composite electrode materials of MoS_2 with different metals and metal oxide nanostructures for hydrogen production and SSC device for industrial requirement.
- ❖ Design of flexible supercapacitor using different flexible electrodes and solid electrolytes can also be explored.
- ❖ In situ synthesis of rGO-MoS_2 heterostructures can explored via other methods to further improve the performance of heterostructure for HER and supercapacitor applications.
- ❖ The prepared MoS_2 nanostructures can also be explored for other energy devices like batteries, solar cells, fuel cells etc.