PREFACE

A fundamental electrochemical process, the Oxygen Evolution Reaction (OER) is essential to many energy conversion and storage technologies, such as fuel cells, metal-air batteries, and water electrolysis. The effective and dependable production of oxygen using OER is essential for the advancement of green energy technology as the globe moves toward sustainable energy solutions. Specifically, electrochemical water splitting, a viable process for creating hydrogen fuel, a significant renewable energy source, is based on OER. Because of its complicated kinetics and large overpotentials, the OER is still one of the most difficult electrochemical processes to optimize, despite its significance. Protons and electrons are released as a result of the process, which oxidizes water molecules to produce oxygen gas.

In addition to being sluggish, the reaction pathway necessitates catalysts that can efficiently reduce the activation energy in order to improve performance. This is because it involves several electron transfer stages and the formation of reactive intermediates. The present knowledge of the OER, its mechanistic pathways, and the catalysts intended to increase its efficiency are all explored in this article. It also examines the advancements being made in materials science, namely the creation of catalysts for OER that are more active, stable, and economical. These catalysts range from transition metal oxides to newly developed transition metal selenides and their polypyrrole composites. In addition to enhancing energy conversion systems, a thorough knowledge of these processes is essential for maximizing the scalability and efficiency of renewable energy technologies. With this investigation, we hope to close the gap between basic electrochemical concepts and real-world applications while providing a

thorough analysis of the OER's contribution to the development of sustainable energy systems in the future. The objectives of chapters 1-7 are given as-

Chapter 1 elaborates the origin of the OER and its importance to the real-world demands. An introduction and importance of electrochemical water splitting is thoroughly discussed. We have explained the fundamental kinetic and thermodynamic parameters which are important to examine the catalytic activity of catalysts. The previously reported literatures in this field are also discussed. Further, the main objectives of the thesis are provided at the end of the chapter.

Chapter 2 includes principles and methods of characterization techniques which are used to explain the various properties and electrocatalytic activity of prepared catalysts. This chapter is divided into five categories viz; structural analysis, morphological analysis, elemental analysis, electrochemical analysis, and *operando* spectro-electrochemical analysis.

Chapter 3 provides the synthesis and characterizations of zinc ferrite particles and their electrocatalytic activity toward OER. It explains the effect of doping of metal Zn in Fe_3O_4 lattice by varying the stoichiometric amount of zinc. The optimum stoichiometric amount of Zn and the best OER catalytic activity has been investigated. Moreover, active intermediate species are elucidated by the real time *operando* UV-vis spectroscopy.

Chapter 4 explains the new class of material for OER, which is mixed metal selenides and their polypyrrole composites. In this chapter we've explored the manganese selenide and its polypyrrole composite. The elemental and morphological studies are explained. The enhanced catalytic activity after the doping of polypyrrole is explained and detailed

electrocatalytic activity is provided. For determining the species formed during OER, we've explored the *operando* UV-Vis spectroscopy.

Chapter 5 explains the effect of metal doping in the metal selenides. In this chapter we've doped Mo in the manganese selenide lattice and to further enhance the catalytic efficiency, we've made a composite by adding polypyrrole. The heterostructure is studied via various characterization methods to understand its morphology and catalytic activity. Mo doping undoubtedly increases the catalytic activity of manganese selenide which is explained well and discussed in this chapter.

Chapter 6 again explains the effect of metal doping. This time, we've doped Cu in the manganese selenide lattice and understand the structural changes. Clearly the catalytic activity is increased which is discussed and explained well in this chapter. To further enhance the catalytic activity, we again prepared a composite of the material with polypyrrole. The role of conducting polymer (ppy) is discussed and elaborated in detail.

Chapter 7 provides a summary of the findings from this research, highlighting the key insights and contributions of the thesis. It also discusses potential future directions for further improving OER catalysts and expanding the applications of electrochemical water splitting technology.