

***...Dedicated to my beloved  
Parents, Sisters  
& Grand-Parents***

## PREFACE

The research work illustrated in this thesis comprises the literature review, research objectives, experimental work, data analysis and interpretation, and preparation of this dissertation. The selective content of dissertation has been structured as manuscript of research articles, review article and book chapters, which has been published in peer-reviewed journals and book publishing house. Two research articles, one review article, two book chapters along with five conference presentations are accomplished by Bhugendra Chutia under the direct supervision of Dr. Pankaj Bharali of Department of Chemical Sciences, Tezpur University.

The following publications and presentations are developed from the work presented in this thesis.

Selected portions of Chapter 1 were published as one review article and two book chapters, and one book chapter has been submitted for publication:

1. Patowary, S., Chetry, R., Goswami, C., **Chutia, B.** and Bharali, P. Oxygen reduction reaction catalysed by supported nanoparticles: Advancements and challenges. *ChemCatChem*, 14(7):202101472, 2022.
2. Patowary, S., **Chutia, B.**, Hazarika, K.K. and Bharali, P. Hybrid electrocatalysts with oxide/oxide and oxide/hydroxide interfaces for oxygen electrode reactions, *In heterogeneous nanocatalysis for energy and environmental sustainability*, Volume 1: Energy Applications, Wiley, 2022, Chap 4, ISBN:1119771994, 9781119771999.
3. Goswami, C., **Chutia, B.**, and Bharali, P. Metal and metal oxide-based nanomaterials for electrochemical applications, *In emerging nanostructured materials for energy and environmental science*, Springer Cham, 2019, Chap 12, ISBN:978-3-030-04473-2, eBook ISBN:978-3-030-04474-9, 499–530
4. **Chutia, B.**, Goswami, C., and Bharali, P. Metal oxide-based electrocatalysts for metal-air batteries, *In metal-air batteries: Principles, progresses and perspective (Submitted to CRC press/July 2022)*.

A version of Chapter 3 (Section 3A) was published as a research article and was presented at a conference:

1. **Chutia, B.**, Patowary, S., Misra, A., Rao, K. N., and Bharali, P. Morphology effect of  $\text{Co}_3\text{O}_4$  nanooctahedron in boosting oxygen reduction and oxygen evolution reactions. *Energy & Fuels*. (Under Revision)
2. **Poster presentation**,  $\text{Co}_3\text{O}_4$  nano-octahedron anchored on carbon as morphology-controlled bifunctional electrode for oxygen electrocatalysis, National conference on “sustainability, medicine and clean energy” at Department of Chemical Sciences, Tezpur University on 1<sup>st</sup> March 2022.

A version of Chapter 3 (Section 3B) is submitted for publication:

1. **Chutia, B.**, Chetry, R., Rao, K. N., Singh, N., Sudarsanam, P., and Bharali, P. Insight into the structure-activity relationship of sponge-like structured  $\text{Co}_3\text{O}_4/\text{C}$  electrocatalyst. (Communicated/October 2022)

A version of Chapter 4 is submitted for publication and was presented at a conference:

1. **Chutia, B.**, Bhuyan, P. S., Saikia, S., Deka, R. C., and Bharali, P. Decoding the role of  $\text{CeO}_2$  in enhancing oxygen reduction activity of  $\text{CuO}/\text{C}$  nanostructures (to be submitted)
2. **Poster presentation**, Decoding the Role of  $\text{CeO}_2$  in Enhancing Oxygen Reduction Activity of  $\text{CuO}/\text{C}$  Nanostructures, “National Conference on Research at the Interface of Chemical, Biological and Material Sciences” At Tezpur University, Tezpur, on 10<sup>th</sup> March 2023.

A version of Chapter 5 was published as a research article and was presented at a conference:

1. **Chutia, B.** and Bharali, P. Oxygen deficient interfacial effect in  $\text{CeO}_2$ -modified  $\text{Fe}_2\text{O}_3/\text{C}$  for oxygen reduction reaction in alkaline electrolyte. *Catalysis Communications*, 164: 106432, 2022.
2. **Poster presentation**, Design of  $\text{Fe}_x\text{O}_y\text{-CeO}_2/\text{C}$  nanohybrids with rich oxide-oxide interface toward bifunctional oxygen electrocatalysis, International conference on “materials chemistry and catalysis” (Virtual Mode) organized

by Department of Chemical Sciences, Tezpur University, on 4<sup>th</sup> and 5<sup>th</sup> March 2021.

A version of Chapter 6 was published as a research article and was presented in conference:

1. **Chutia, B.**, Hussain, N., Puzari, P., Jampaiah, D., Bhargava, S.K., Matus, E.V., Ismagilov, I.Z., Kerzhentsev, M. and Bharali, P. Unraveling the role of CeO<sub>2</sub> in stabilization of multivalent Mn species on  $\alpha$ -MnO<sub>2</sub>/Mn<sub>3</sub>O<sub>4</sub>/CeO<sub>2</sub>/C surface for enhanced electrocatalysis. *Energy & Fuels*, 35(13):10756-10769, 2021.
2. **Oral presentation**, Bifunctional oxygen electrocatalysis over CeO<sub>2</sub> modified  $\alpha$ -MnO<sub>2</sub>/Mn<sub>3</sub>O<sub>4</sub>/C hybrid hetero-nanostructures, “1<sup>st</sup> International e-Conference on Current Trends in Chemical Research” at Nowgong College, on 22<sup>nd</sup> August 2020.
3. **Poster presentation**, Unification of electro-catalytic oxygen reduction reactions and water oxidation: CeO<sub>2</sub> promoted spinel Mn<sub>3</sub>O<sub>4</sub> nanostructures on carbon, “National Conference on Recent Advances in Applied Sciences” at Gauhati University, Guwahati, on 17<sup>th</sup>-18<sup>th</sup> May 2019.
4. **Poster presentation**, Enhanced Oxygen Electrocatalysis Over Mn<sub>3</sub>O<sub>4</sub>/CeO<sub>2</sub>/C Nanohybrid Composite, “Organix-2018” at Tezpur University, Tezpur, on 20<sup>th</sup>-21<sup>st</sup> December 2018.

## DECLARATION

This thesis entitled “**Non-Precious Hybrid Metal Oxide-Based Electrocatalysts for Energy Applications**” being submitted to the Department of Chemical Sciences, Tezpur University, is a presentation of the original research work carried out by me. Any contribution (texts, figures, results or designs) of others, wherever involved, is appropriately referenced in order to give credit to the original author(s). All sources of assistance have been duly acknowledged. I affirm that neither this work as a whole nor a part of it has been submitted to any other university or institute for any other degree, diploma or award.

Date: 20-03-2023

Place: Tezpur



(Bhugendra Chutia)



## TEZPUR UNIVERSITY

(A Central University)

Napaam, Tezpur – 784 028, INDIA

Tel (O): +91-3712-275064

Fax: (O): +91-3712-267005/6

E-mail: [pankajb@tezu.ernet.in](mailto:pankajb@tezu.ernet.in)

Website: [www.tezu.ernet.in](http://www.tezu.ernet.in)

### Dr. Pankaj Bharali

Assistant Professor

Department of Chemical Sciences

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### CERTIFICATE FROM THE SUPERVISOR

This is to certify that the thesis entitled “**Non-Precious Hybrid Metal Oxide-Based Electrocatalysts for Energy Applications**” submitted to the School of Sciences, Tezpur University in part fulfillment for the award of the degree of Doctor of Philosophy in Chemical Sciences is a record of research work carried out by **Mr. Bhugendra Chutia** under my supervision and guidance. All help received by him from various sources have been duly acknowledged. No part of this thesis has been submitted elsewhere for award of any other degree.

Dr. Pankaj Bharali

Designation: Assistant Professor

School: Sciences

Department: Chemical Sciences

Date: 20-03-2023

Place: Tezpur

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Place: Tezpur University

(Bhugendra Chutia)

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