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PNNL-32934

High-performing Electrocatalysts for Oxygen Reduction and Evolution for Energy Storage

June 2022

Litao Yan
Xiaohong Xie
Yuyan Shao
David Reed

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
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Abstract

In this project, we developed multi-transition metal and nitrogen co-doped electrocatalysts for potential applications in rechargeable Zn-air batteries, reversible fuel cells.

Summary

The objective of this project is to develop and demonstrate proof of principle for a new technology concept of multi-transition-metals-enabled, high-performing electrocatalysts for oxygen reduction reaction (ORR) catalyst for energy storage devices like rechargeable Zn-air batteries. There are two tasks in this project: Task 1. The development of molten NaCl-Assisted method for porous ORR catalyst synthesis; Task 2. Electrochemical performance test of new developed ORR catalysts.

Acknowledgments

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Acronyms and Abbreviations

ORR: oxygen reduction reaction

OER: oxygen evolution reaction

PEI: polyethyleneimine

EDTA: ethylenediaminetetraacetic acid

BET: Brunauer, Emmett and Teller

TEM: Transmission electron microscope

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1.0 Introduction

ORR and OER are key reactions in many energy devices, e.g., Zn/air batteries, fuel cells/electrolyzers, electrochemical reduction of CO_2, N_2, organic molecules from biomass. Electrocatalysts play a crucial role for the device efficiency and lifetime. Usually precious metals, e.g., Pt, Ir, Ru, are used due to the harsh working environment, but are limited by their limited resource and high price. To meet global demand of these energy technologies (for renewable energy storage and renewable electrochemical manufacturing), nonprecious metals-based catalysts have to be developed. Existing research have demonstrated good progress on either ORR or OER; but bifunctional catalysts that work for both ORR and OER is still a grand challenge. Here we developed a concept of using multi-transition metals to boost both ORR and OER, building on the knowledge we have produced in previous research.

2.0 Results and discussion

Task 1. ORR catalyst synthesis

We take advantage of coordination chemistry between transition metal cations and polymers to synthesis ORR catalysts. We first mixed transition metal salts, such as FeCl3 with polymer, e.g., polyethyleneimine (PEI) and ethylenediaminetetraacetic acid (EDTA), NaCl. After water evaporation process, the powder-formed precursor was ball-milled to form ultra-fine powder. Finally, the ultra-fine powder was treated at 1000 °C under Ar gas. The NaCl hard template could be easily washed away by D.I water. The iron content and composition in the carbon-based catalyst plays a critical role on ORR performance. The ORR performance of as-synthesized ORR catalyst could be optimized by tuning the iron content and composition. Fig. 1 shows BET surface area of one exemplar catalyst PEI-EDTA-Fe-0.4 catalyst. Fig. 2 shows the TEM image.

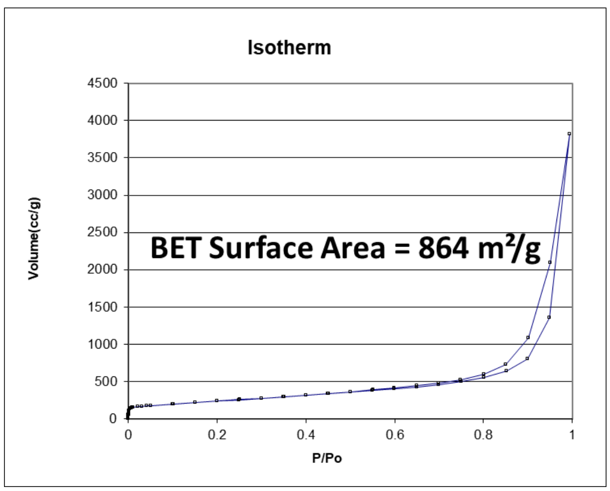

Figure 1. BET surface area of PEI-EDTA-Fe-0.4 catalyst.

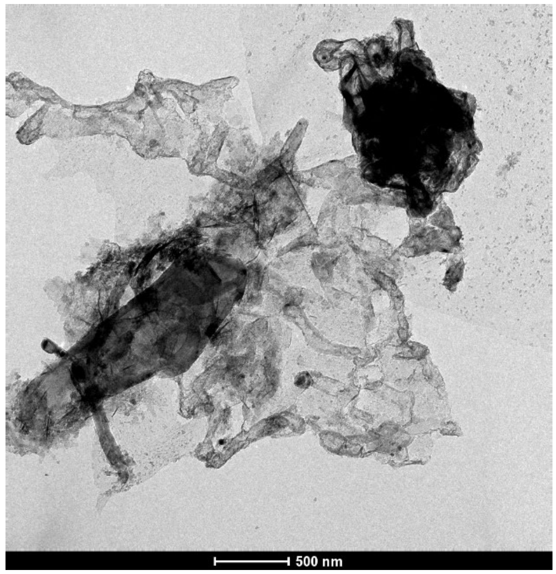

Figure 2. TEM image of PEI-EDTA-Fe-0.4 catalyst.

Task 2. Electrochemical performance test of as-synthesized ORR catalysts

Figure 3 shows the ORR performance of as-synthesized ORR catalysts with different iron content. The half wave potential increases from 0.8 V vs RHE (iron content:0.2g) to 0.93V vs RHE (iron content: 0.8g), but further increasing iron content to 1.0 g can significantly lower the half-wave potential. Specifically, the onset potential of PEI-EDTA-Fe-0.8 catalyst is ~1.075 V, higher than most of reported carbon-based ORR catalysts.

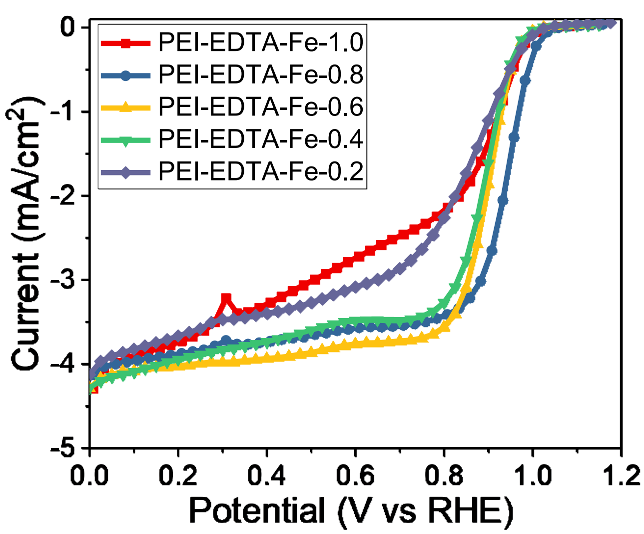

Figure. 3. ORR performance of as-synthesized ORR catalyst with different iron content.

Pacific Northwest National Laboratory

902 Battelle Boulevard
P.O. Box 999
Richland, WA 99354

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