NEBRASKA CENTER FOR ENERGY SCIENCES RESEARCH

Cycle 19
January 2025

Principal Investigator: Dr. Yongfeng Lu
Position Title: Professor
Department: Electrical & Computer Engineering

Email: ylu2@unl.edu
Phone: 402-472-3771
Webpage: https://engineering.unl.edu/ece/faculty/yongfeng-lu/

Enhanced Hydrogen Generation and Utilization using Femtosecond Laser-Nanostructured NiCo2O4 Electrocatalysts

Abstract.

To date, low-temperature unified electrochemical energy conversion devices, known as unified regenerative fuel cells (URFCs), have been the focus of intensive research and development. In these devices, the same pair of electrodes is used for both electrolysis and electricity generation, with oxygen evolution reaction (OER)/oxygen reduction reaction (ORR) occurring at one electrode and hydrogen evolution reaction (HER)/ hydrogen reduction reaction (HOR) occurring at the other one. URFCs offer significant advantages in terms of construction costs, mobility, and cost-effectiveness in energy production and storage, especially for applications in the hydrogen energy/economy. However, the biggest challenge is to find and design efficient OER/ORR catalysts. Due to kinetic hindrances, OER/ORR reactions present a much greater technological challenge than their hydrogen electrode counterparts.

In this proposal, we aim to significantly enhance OER/ORR performances by increasing the electrocatalytically active areas and enhancing local electric fields using femtosecond (fs) laser-nanostructured NiCo2O4/Ni. Fs laser surface nanostructuring precisely alters Nickel (Ni) surfaces at nanoscale, creating unique and repeatable nanostructures, such as nanospikes. When combined with NiCo2O4 electrocatalyst, which has been identified by our team as a promising electrocatalyst for enhancing hydrogen-involved reactions, we expect significant improvements. Specifically, for OER, the overpotential of nanostructured NiCo2O4/Ni will be lowered to approximately 240 mV at 100 mA/cm², which is only 55% and 27% of the overpotential of untreated NiCo2O4 and platinum (Pt), respectively.

Co-Ni oxides have been identified as a potential electrocatalyst for H_2 utilization in fuel cells. Its good catalytic performance can also be attributed to its porous structure, high specific surface area, and abundant Co^{3+} active sites. Therefore, this project will also explore and extend the evaluation of the proposed nanostructured $NiCo_2O_4$/Ni for ORR. If successful, our proposed electrocatalyst system will be an efficient and cost-effective bifunctional OER/ORR electrocatalyst for both H_2 production and utilization.