Benchmarking Electrocatalytic Efficiency of Iron-Nickel Nanocarbides as Electrocatalysts for the Oxygen Evolution Reaction

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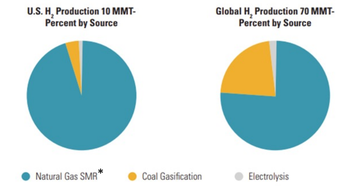
Electrocatalysts for Water Splitting

▼ The process of utilizing green hydrogen as a fossil fuel alternative



1. Wind turbines and solar panels are used to harness electrical energy.
2. Electrical energy can be utilized to produce hydrogen through electrocatalytic water-splitting.
3. Produced hydrogen can be stored and eventually be used as a clean energy source.

*SMR = steam methane reformer reactions[2]

▼ Low-cost compared to state-of-the art electrocatalysts[1].

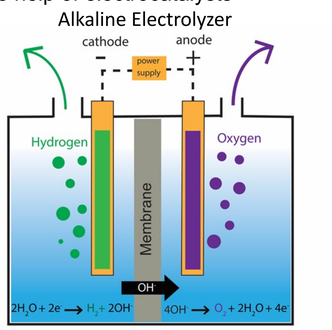
Co = $0.05650 / g

Ru = $19.80 / g

Fe = $0.000100 / g

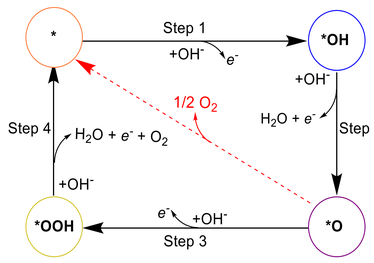
Ni = $0.02358 / g

▼ Water electrolyzers can turn electrical energy into hydrogen with the help of electrocatalysts



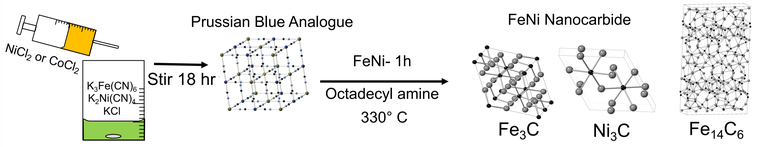
Electrical energy → chemical energy → hydrogen

▼ Four-electron oxygen evolution reaction (OER) mechanism in alkaline conditions.

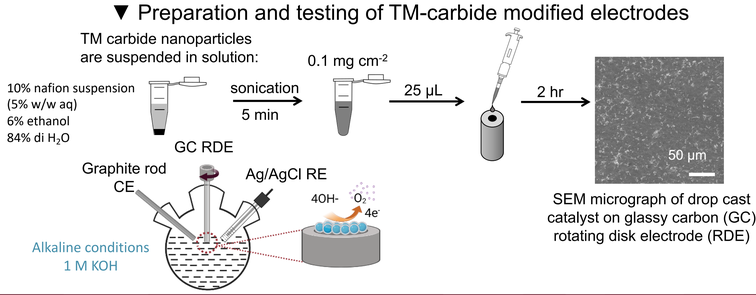


Experimental Methods

▼ Scalable, single-source precursor nanocarbide synthesis



▼ Preparation and testing of TM-carbide modified electrodes



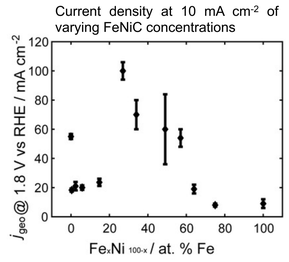
SEM micrograph of drop cast catalyst on glassy carbon (GC) rotating disk electrode (RDE)

Electrocatalytic Activity and Stability

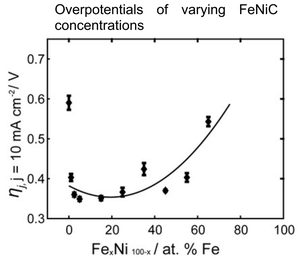
▼ Electrocatalytic OER activity

▼ **Electrocatalytic activity** was determined by analyzing linear sweep voltammograms (LSVs) of FeNiC samples of varying relative amounts of Fe and Ni, under alkaline conditions (1.0 M KOH)

Current density at 10 mA cm^{-2} of varying FeNiC concentrations

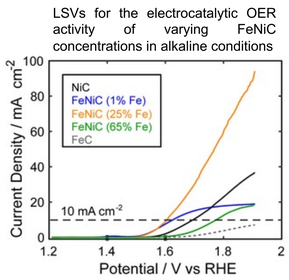


Overpotentials of varying FeNiC concentrations

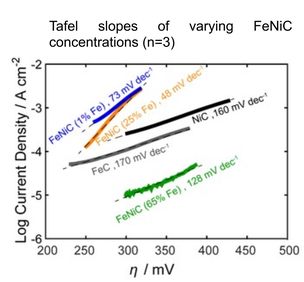


▼ Electrochemical kinetics of carbides

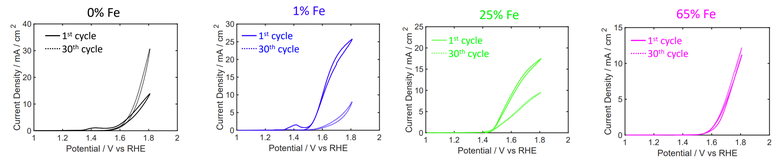
LSVs for the electrocatalytic OER activity of varying FeNiC concentrations in alkaline conditions



Tafel slopes of varying FeNiC concentrations (n=3)



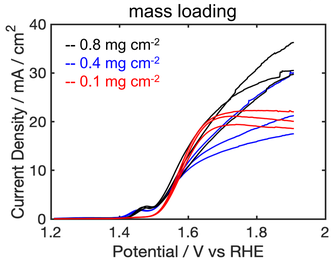
▼ **Electrochemical stability** of a variety of FeNiC samples were assessed over 30 cyclic voltammogram (CV) cycles with a potential rage of 1.0-1.8V for 1.5 hours.



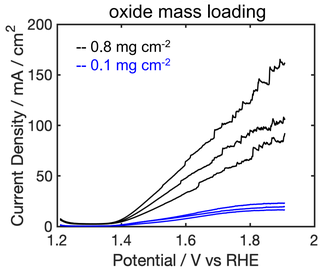
Tuning Catalytic Mass Loading

▼ **Linear sweep voltammograms** for FeNiC (5% Fe) were measured at varying mass loading amounts to investigate differences in electrochemical behavior when compared to the industry standard, ruthenium oxide.

LSVs for varying FeNiC (5% Fe) mass loading



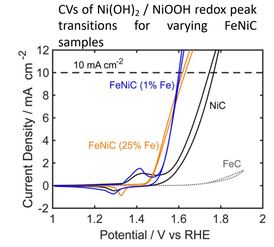
LSVs for varying ruthenium oxide mass loading



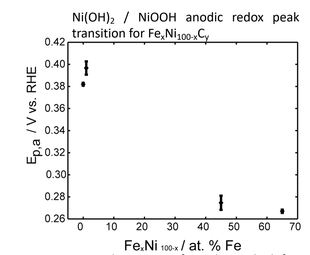
Ni(OH)$_2$ / NiOOH Redox Activity Analysis

▼ **Ni(OH)$_2$ / NiOOH redox peak transitions** upon addition of varying % Fe in FeNiC carbides under alkaline conditions.

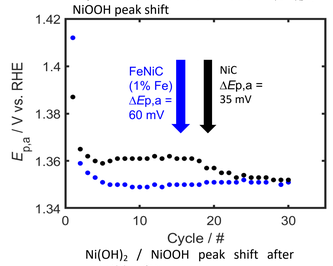
CVs of Ni(OH)$_2$ / NiOOH redox peak transitions for varying FeNiC samples



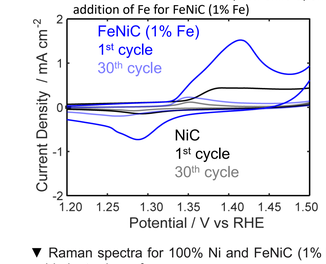
Ni(OH)$_2$ / NiOOH anodic redox peak transition for $Fe_xNi_{100-x}C_y$



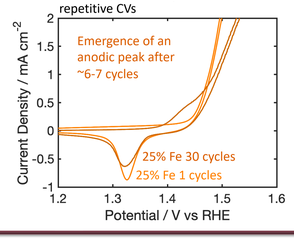
Repetitive run CVs of anodic Ni(OH)$_2$ / NiOOH peak shift



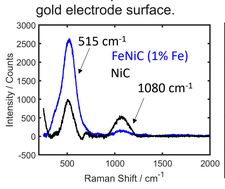
Limited view CV of anodic peak shift upon addition of Fe for FeNiC (1% Fe)



Ni(OH)$_2$ / NiOOH peak shift after repetitive CVs



▼ Raman spectra for 100% Ni and FeNiC (1% Fe) on gold electrode surface.



* Values obtained from literature.

Species	Peak shift(s) (cm^{-1})
Ni-O	900,1100
Disordered β-Ni(OH)$_2$	516
α-Ni(OH)$_2$	460,495
α-FeOOH	560

Conclusions and Future Work

Conclusions:

▼ Results indicate 25% Fe content exhibited the greatest electrocatalytic activity and lowest, most favorable tafel slope.

▼ Electrocatalytic mass loading data indicates that smaller mass loading will cause limited current to achieve at a faster rate.

▼ Voltammetric analysis indicates that a higher percentage of iron will result in an anodic peak shift towards a lower potential.

Future Work:

▼ Raman analysis of varying Fe % samples to identify active oxide species of FeNiC samples with varying Fe content.

▼ Increasing catalyst loading to better explore redox behavior in FeNiC samples.

References and Group Information

1. Daily Metal prices. https://www.dailymetalprice.com/ (accessed Feb 17, 2022).
2. *Office of Fossil Energy. HYDROGEN STRATEGY Enabling a Low-Carbon Economy*. United States Department of Energy: Washington, DC. (Accessed March 12, 2023).

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