Benchmarking Iron Nickel Carbide Nanomaterials as Electrocatalysts for the Oxygen Evolution Reaction

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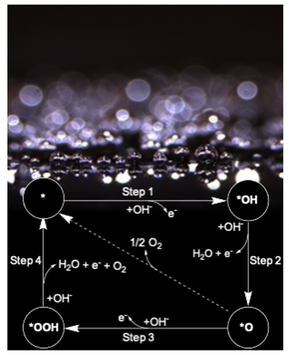
Oxygen Evolution Reaction

- Molecular Oxygen Formation at electrode surface



❖Four electron mechanism for OER.

Oxygen Evolution Reaction (OER) is the kinetically rate limited step of Water Splitting Reactions (WSRs).

Low-Cost electrocatalyst

State of the art Ru / Ir electrocatalysts are high in price & have low earth abundance.

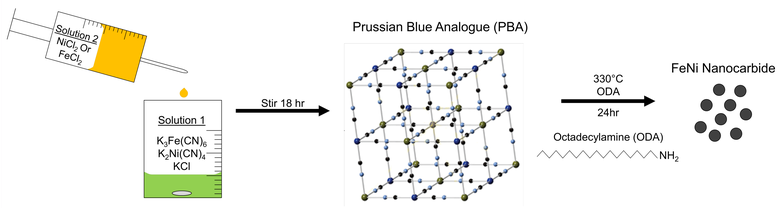
			
Ir	Ru	Ni	Fe
$141.50[2]	$19.610[2]	$0.043[1]	$0.0000921[1]

Water Splitting Applications

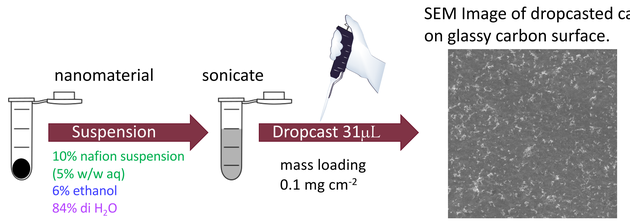
- ❖ New electrocatalytic OER materials serve as useful energy conversion and storage applications.
- ❖ Hydrogen fuel cells utilize electricity generated in OER.
- ❖ Fuels for solar cells utilize electrocatalytic OER materials.

Experimental Methods

Synthesis of FeNi Nanocarbides

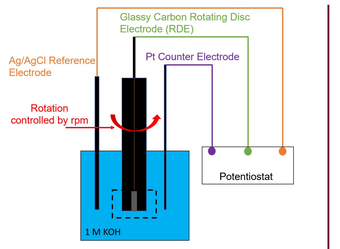


Electrode Surface Modification

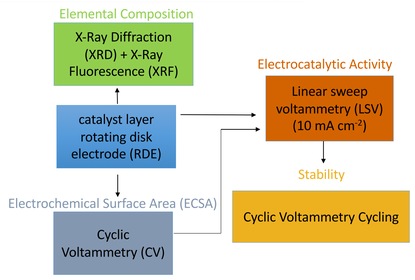


SEM Image of dropcasted catalyst on glassy carbon surface.

Benchmarking Protocol for an OER electrocatalyst



Rotating Disk Electrode (RDE) Setup

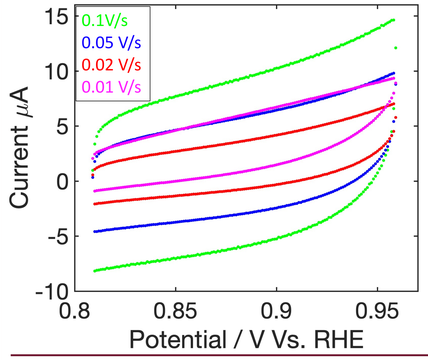


References: 1. Business Insider. (n.d.). *Nickel price today* from https://markets.businessinsider.com/commodities/nickel-price
2. Daily metal Price: Ruthenium Price (USD / Kilogram) for the Last Day https://www.dailymetalprice.com/metalprices.php?c=ru&u=kg&d=1

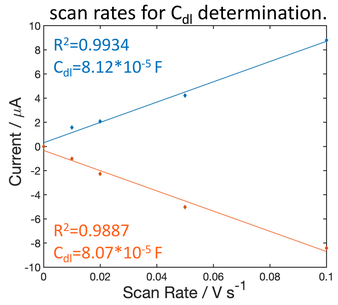
Electrochemical Performance of $Fe_xNi_{1-x}C_y$

❖ Electrochemical Surface Area (ECSA)

Cyclic Voltammograms (CVs) were run at several scan rates vs Ag/AgCl in 1M KOH to determine the electrochemical surface area.



Current values measured at varying scan rates for C_{dl} determination.

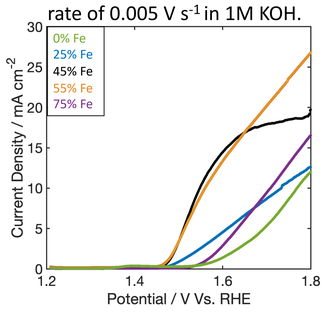


❖ $ECSA = \frac{C_{dl}}{C_s}$; $i_c = vC_{dl}$

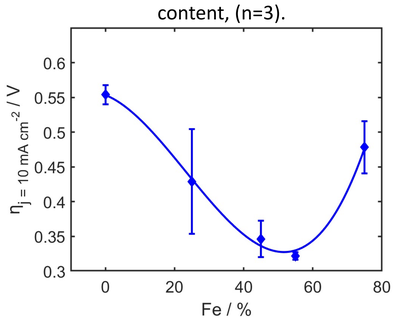
❖ Electrocatalytic OER Activity

Overpotentials were extracted from Linear Sweep Voltammograms (LSVs) at a current density of 10 mA cm^{-2}. under alkaline conditions.

LSV curves for the electrocatalytic OER at a scan rate of 0.005 V s^{-1} in 1M KOH.



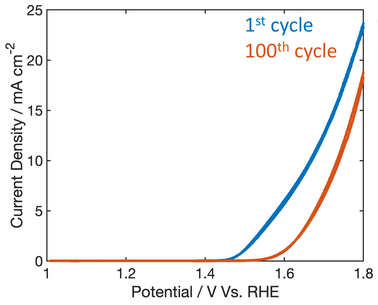
Extracted overpotentials at 10 mA cm^{-2} from LSV curves of varying Fe content, (n=3).



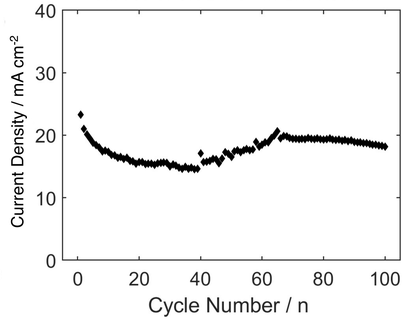
❖Stability Measurements

Electrochemical stability for the 55% Fe doped FeNi nanocarbide electrocatalyst was assessed over 100 CV cycles with a potential range of 0-0.8V for 4.5hrs.

CV curves for the OER at a scan rate of 0.01 V s^{-1} in 1M KOH.



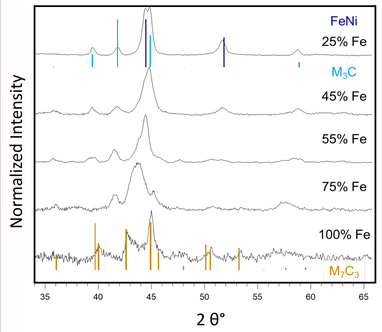
Current Density at 1.8 V for 100 CV curves of 0.01 V s^{-1} in 1M KOH.



Structural Characterization

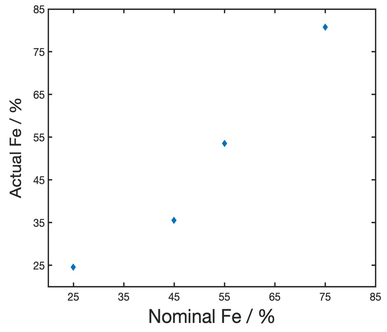
Powder X-Ray Diffraction (pXRD) was utilized to determine structural characterization by examining crystalline phase changes resulting from Fe incorporation into the Ni nanocarbide lattice.

pXRD of $Fe_xNi_{1-x}C_y$



X-Ray Fluorescence (XRF) measurements confirmed that the stochiometric amount of Fe incorporated into the Ni nanocarbide resulted in the actual amount of Fe.

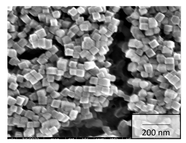
Actual Vs. Nominal Percentages of Fe



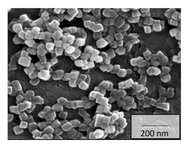
Scanning Electron Microscope (SEM) images demonstrate relative nanoparticle size and morphology for 25%, 45%, 55%, and 75% Fe doped FeNi nanocarbide. Nanoparticle size and morphology can be important descriptor OER activity and stability.

SEM Images of FeNi Nanocarbides

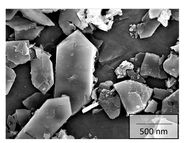
25% Fe



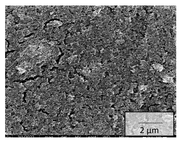
45% Fe



55% Fe



75% Fe



Conclusions and Future Work

Conclusions

- ❖ Present data findings indicate 55% Fe content exhibited the greatest activity as a result of having the lowest overpotential.
- ❖ Present stability measurements indicate that the 55% Fe catalyst is a potential low-cost electrocatalyst for the Oxygen Evolution Reaction.

Future Work

- ❖ Further stability measurements on varying Fe % content.
- ❖ Electrocatalytic OER activity measurements on other varying Fe % content.
- ❖ Tafel plot analysis for the rate determining steps of OER.
- ❖ XPS Data for measuring oxidative state changes in Fe.

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