Efficient NiFe Electrocatalysts for Oxygen Evolution Reactions

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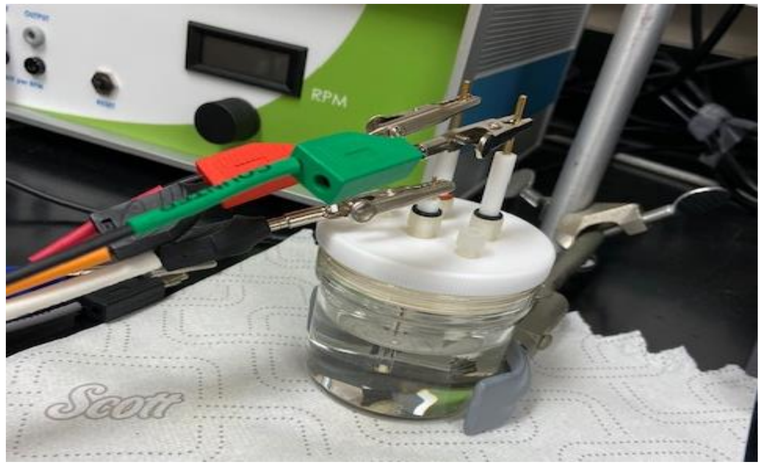
Introduction

With the growing amount of CO_2 emissions from the consumption of fossil fuels, the search for cleaner energy sources is becoming more urgent than ever. One of the most promising clean energy sources is H_2 gas since its only product after combustion is H_2O. Scientists are searching for cheaper catalysts to replace expensive noble metals, such as platinum, to generate H_2 gas from water splitting. The major challenge is meeting all the requirements for an optimal catalyst: high efficiency, low cost, and excellent stability. The ideal catalyst will produce high currents at low applied voltages with little to no overpotential. We find these requirements are affected by the synthetic conditions, including composition, pH, concentration, and deposition time.

Background

We use a three-electrode electrochemical cell in order to synthesize and test our catalysts. This cell consists of a counter, a working, and an Ag/AgCl reference electrode. The counter acts as our anode while the working electrode is the cathode. These two electrodes allow for readings on current and applied potential. The reference electrode controls the potential applied to our working electrode. Our catalysts are developed on nickel foam due to nickel acting as a strong conductor and having a lower overpotential for oxygen gas production. Nickle is also much cheaper compared to known electrocatalysts made from precious metal, such as platinum.

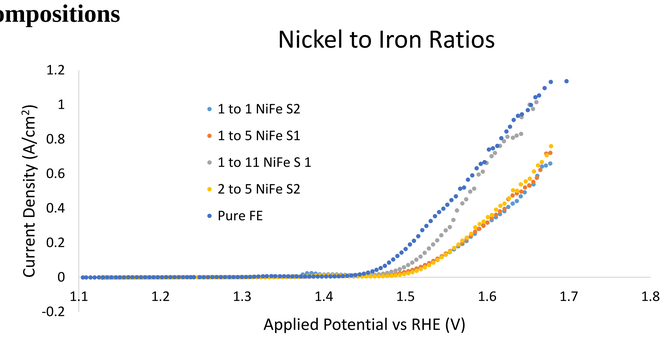
We utilize a potentiostat to test our catalysts. The potentiostat allows us to send and read precise electrical potentials and currents. We use cyclic voltammetry (CV) methods in order to test each catalyst we synthesize by comparing the amount of current produced vs the amount of voltage applied.



Shown above is our three-electrode electrochemical cell. Each electrode is connected to the potentiostat through its corresponding wire. The desired information from the potentiostat is run through Aftermath software and displayed on a computer.

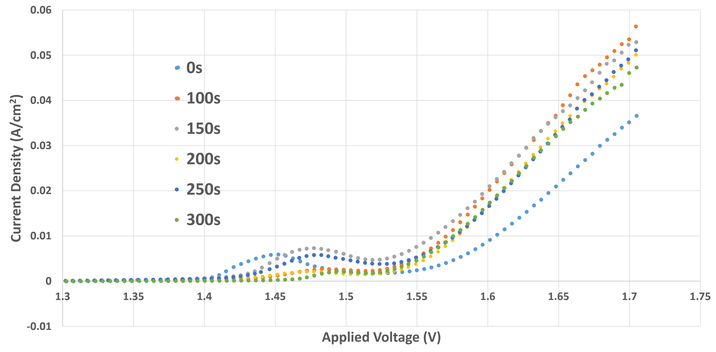
Synthesis Conditions

- **Compositions**

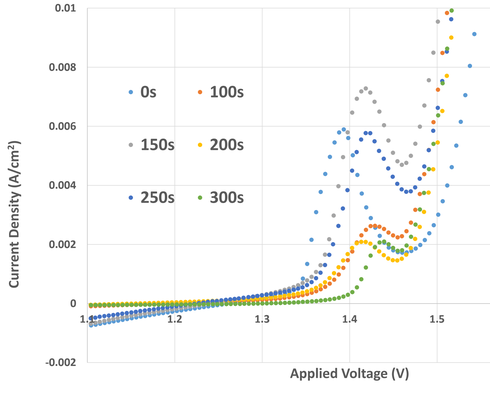


We began our research by identifying a relationship between the ratio of nickel to iron in the electrolyte solution during electrodeposition.
A series of efficiency tests demonstrated a strong positive correlation between the amount of iron in solution during synthesis and the efficiency of the catalysts.

- **All Disposition Times**



All samples were synthesized in 12mM $Fe(NO_3)_3$ at 10°C. The Fe ions were then deposited onto different samples in 50s increments. By using plain nickel foam as our control (0s sample), we were able to compare 5 different samples of various disposition times. The 100s deposited sample proved to be the most efficient catalyst as it produced the highest current density at the same applied voltage.



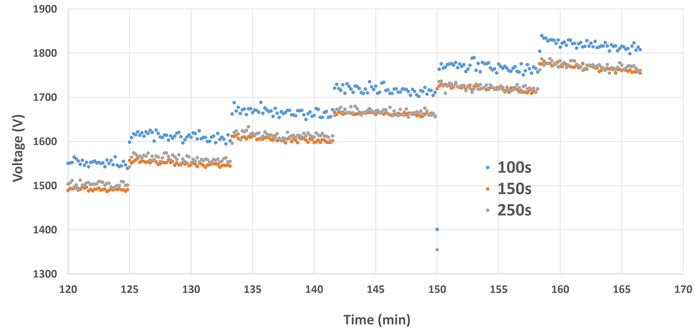
Sample ID	Overpotential (at 10mA/cm²)
0s	0.318 V
100s	0.281V
150s	0.276 V
200s	0.291 V
250s	0.291 V
300s	0.287 V
Co_3O_4	0.328 V
Co_3O_4\Graphene	0.310 V
20 wt% Ir/C	0.380 V
20 wt% Ru/C	0.390 V

Overpotential is the difference between the theoretical cell voltage and the observed voltage necessary to complete a reaction. The lower the overpotential the more effective the catalyst due to less work being wasted. The 150s disposition sample produced the lowest overpotential compared to our other catalysts. However, all our NiFe catalysts displayed a lower overpotential value then reported catalysts.

Stability Tests

In order to test the stability of our catalysts, we preformed a cyclic step chronopotentiogram. This 80-minute test records the amount of voltage required to hold the current at the working electrode at a constant level. Ideally these graphs will display a consistent stairstep pattern with little variation. The lower the applied potential, the less work is required to maintain the current density.

- **Cyclic Step Chronopotentiogram**



This cyclic-step chronopotentiogram shows all disposition times tested were consistent and created stable catalysts at high current densities. The catalyst synthesized with a 150s disposition time required the least amount of potential making it more effective than the other two catalysts.

Conclusion

By utilizing various electrochemical methods, our group has managed to collect a wide variety of data regarding the synthesis of NiFe based catalysts. Through our findings we can say that a pure Fe catalyst appears to be the optimal composition. We found that catalysts synthesized for 100 and 150 seconds in 12mM $Fe(NO_3)_3$ were proven to be the most effective. The 100s catalyst produced the highest current making it most efficient at high voltages. Inversely, the 150s catalyst produced the lowest overpotential and is the most efficient at low voltages.

Acknowledgements

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