Optimization of NiFe Electrocatalysts for Hydrolysis Reactions

Robert M. Lange & Dr. Fan Zuo

Department of Chemistry and Physics, Indiana State University, Terre Haute, IN

Introduction

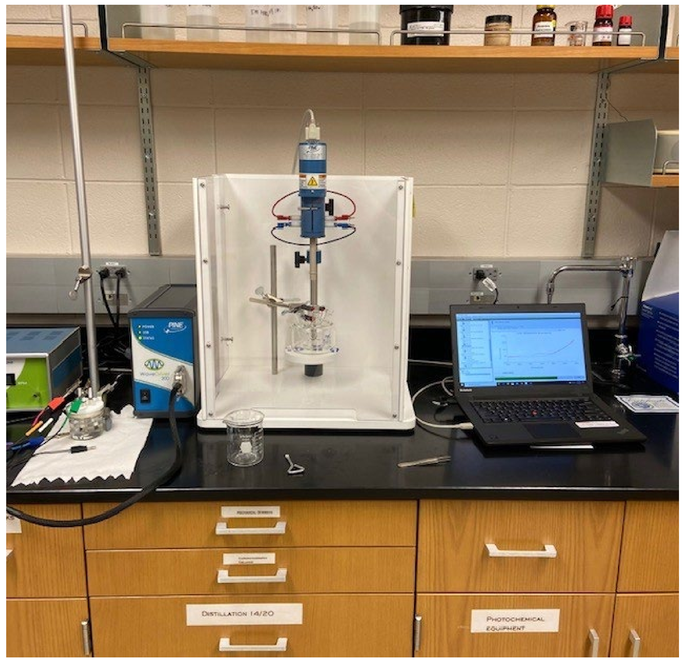
Electrocatalysis is a branch of chemistry that combines the field of electrochemistry with that of catalysis. In electrocatalysis, practitioners study catalysts that lower the activation energy of reactions that cause electrons to move from one element to another. Researchers are looking for cheap and effective catalysts for hydrolysis reactions that produce oxygen and hydrogen gas, as well as catalysts for reactions that will reduce carbon dioxide in the atmosphere. The ideal catalyst for this reaction will be cheap to manufacture and require little applied potential for a lot of current.

Our goals

Our goal is to find a cheap and efficient catalyst for hydrolysis reactions. In order to achieve this, we synthesized catalysts in varying conditions and tested their efficiency and stability. Later, we combined this information to create better, more efficient catalysts.

Our setup

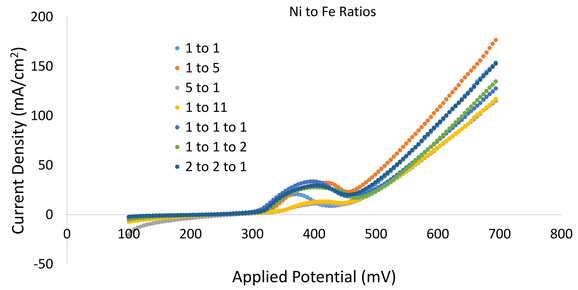
We use a potentiostat to test our catalysts. Our potentiostat allows us to send and read electrical potentials and currents down to the microvolt or picoamp. We also use a three-electrode setup, which consists of a working electrode, a counter electrode, and a reference electrode. The counter and working electrodes allow for readings on current and applying potential, while the reference electrode helps us control the potential applied to our working electrode. For these experiments we use catalysts grown on nickel foam, as they have lower overpotential for oxygen production and are cost-effective to synthesize.



From left to right we have our three-electrode electrochemical cell, which is connected to the potentiostat to its right. To the right of the potentiostat is a rotating electrode setup, and the computer to its right has Aftermath software that we use to run our cyclic voltammetry tests.

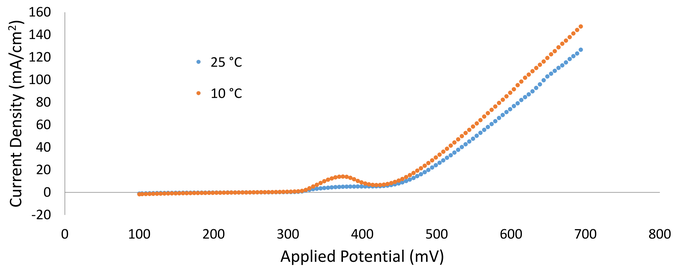
Synthesis Conditions

- **Compositions**



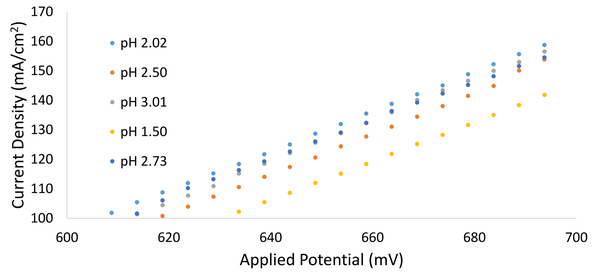
We approximated the optimal composition for $Ni_xFe_y(OH)_{(x+y)}$ catalysts by manipulating the ratios of nickel to iron at the time of synthesis, and then testing their current density (mA/cm^2)as a function of applied potential (mV). We later added copper to our catalysts and tested their current density. Our data shows that a ratio of 1:5 Ni to Fe is optimal.

- **Temperature**



We were also curious how temperature at the time of synthesis would affect the catalyst's performance. We hypothesized that a lower temperature would allow the catalyst to deposit onto the foam in a more uniform way, creating a more stable and efficient catalyst. You can see from the test that the catalyst synthesized at 10 ºC is more efficient than the one synthesized at room temperature (25 ºC).

- **pH**

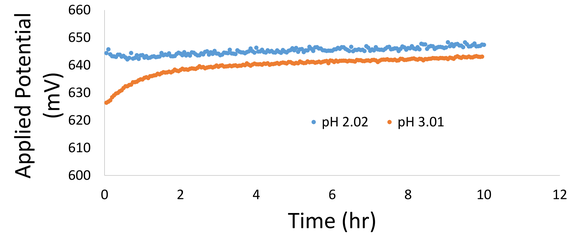


We determined the initial pH of the solution to be 2.73, and then tested our catalysts in solutions of varying pH. In the future, we would like to experiment with more basic solutions.

Stability Tests

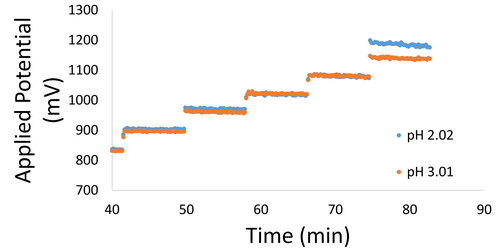
In order to test the stability of our catalysts, we conducted two stability tests. The chronopotentiogram is a 10-hour test that measures the amount of potential required to maintain a specific current density for a specified time. A cyclic step chronopotentiogram measures the amount of potential required to maintain increasing levels of current density. Ideally these graphs will have little deviation from the trendline and a lower applied potential.

- **Chronopotentiogram**



This chronopotentiogram comparison shows that the catalyst synthesized at a pH of 3.01 is more efficient than the catalyst synthesized in 2.02 solution. It also shows that these catalysts are relatively stable over long periods of time.

- **Cyclic Step Chronopotentiogram**



This cyclic-step chronopotentiogram shows that the catalyst synthesized in a solution of pH 3.01 is more efficient than the catalyst synthesized in a pH 2.02 solution. This is consistent with our findings in the regular chronopotentiogram.

Conclusion

Through using modern electrochemical methods, our group has managed to collect a wide variety of data regarding Nickel-Iron based catalysts. While this is not the end of our research journey, we can say that a 1:5 NiFe catalyst appears to be the optimal composition. We can say that catalysts synthesized at lower temperatures appear more efficient than those synthesized at room temperature, and we can say that catalysts synthesized at 3.01 pH are more stable than those synthesized in more acidic solutions.

Acknowledgements

Our group would like to acknowledge Dr. Fan Zuo, and the rest of the ISU Chemistry and Physics Department. We would also like to acknowledge the ISU Faculty Start-up Fund. Finally, we want to acknowledge the SURE program for the experience it has provided.