Electrocatalysis for Hydrogen Evolution Reactions (HER) and Oxygen Reduction Reactions (ORR)

Zach Tracy, **Bryce Currey**, & Dr. Fan Zuo
Department of Chemistry and Physics, Indiana State University, Terre Haute, IN

Introduction to Electrocatalysis

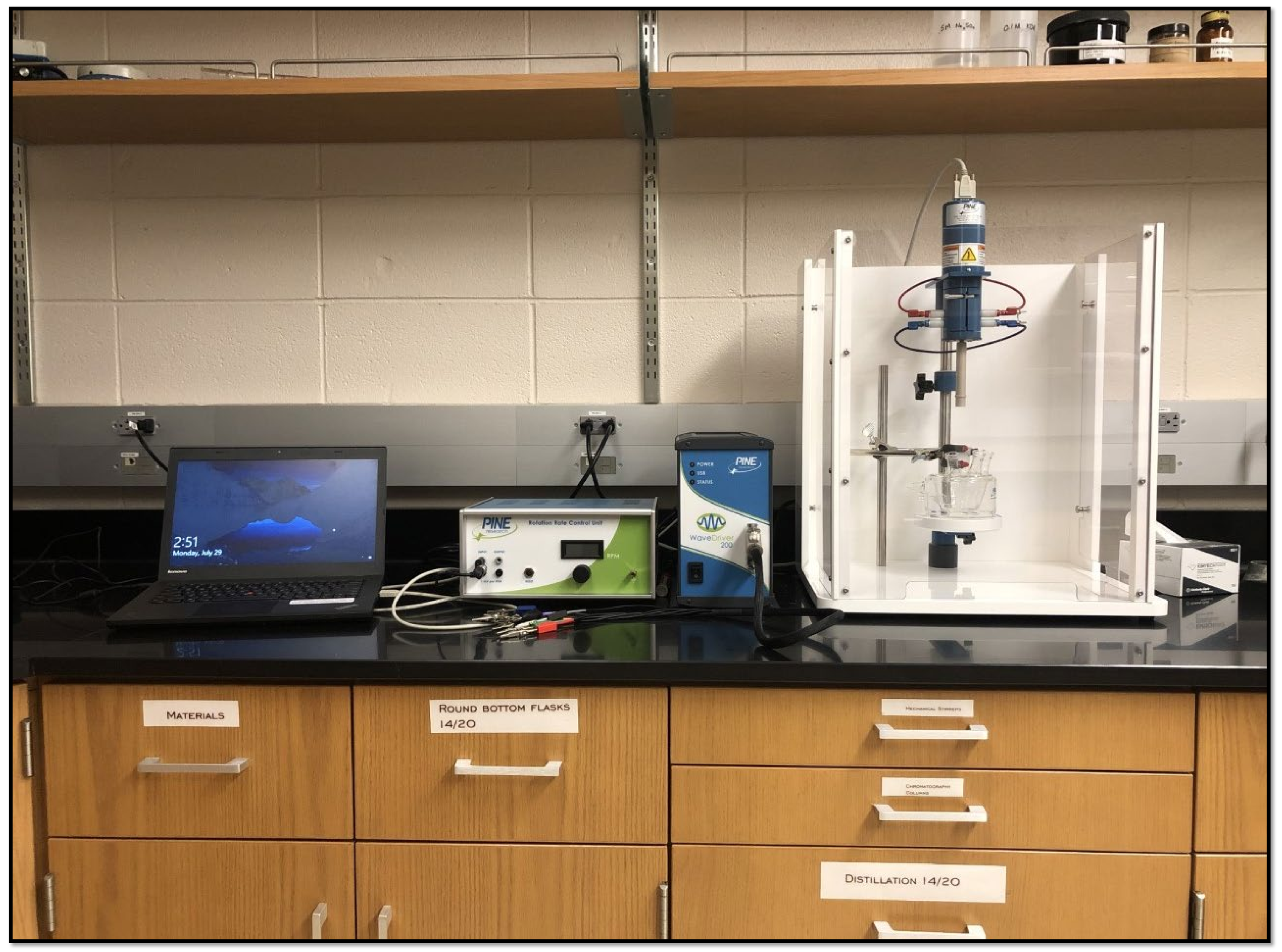
Electrochemistry has been a well-developed branch of science since the 1800's. This field has been revived by cutting-edge testing equipment and emerging demand in alternative renewable energy sources. We focus on a rapid developing area known as electrocatalysis, combining electrochemistry with catalysts. Precise study of electron behavior is a crucial step to understand reaction mechanism and design efficient catalysts for energy application.

Our goals

Platinum and other noble metals are widely considered to be the best catalysts for many electrocatalytic processes. However, the high price limits their large scale implementation . Our motivation is to discover electrocatalysts that have comparable efficiency to platinum, but at a fraction of the cost.

Our setup

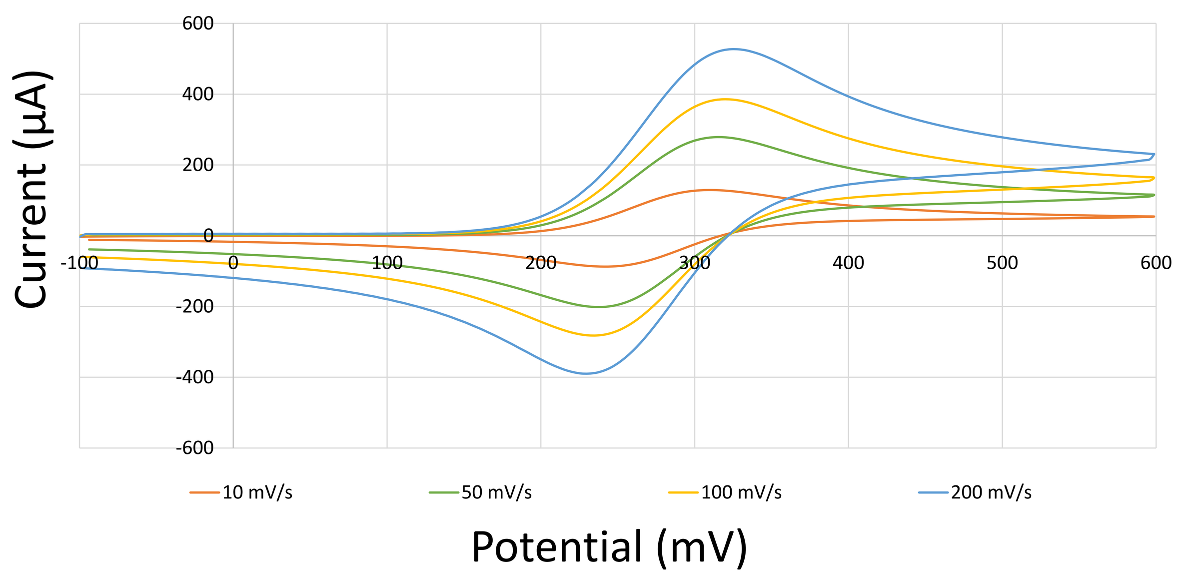
We use a potentiostat and a rotating electrode setup. Our potentiostat allows us to send and read electrical currents, and the rotating electrode allows us to manipulate the mass transfer process. We also use a three electrode setup, as opposed to the traditional two, which consists of a working electrode, 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.



From left to right we have our laptop containing all of the software. Past that is the motor that controls the rotation rate of the spinning electrode. Further to the right we have the potentiostat, and lastly followed by the mount for the rotator electrode.

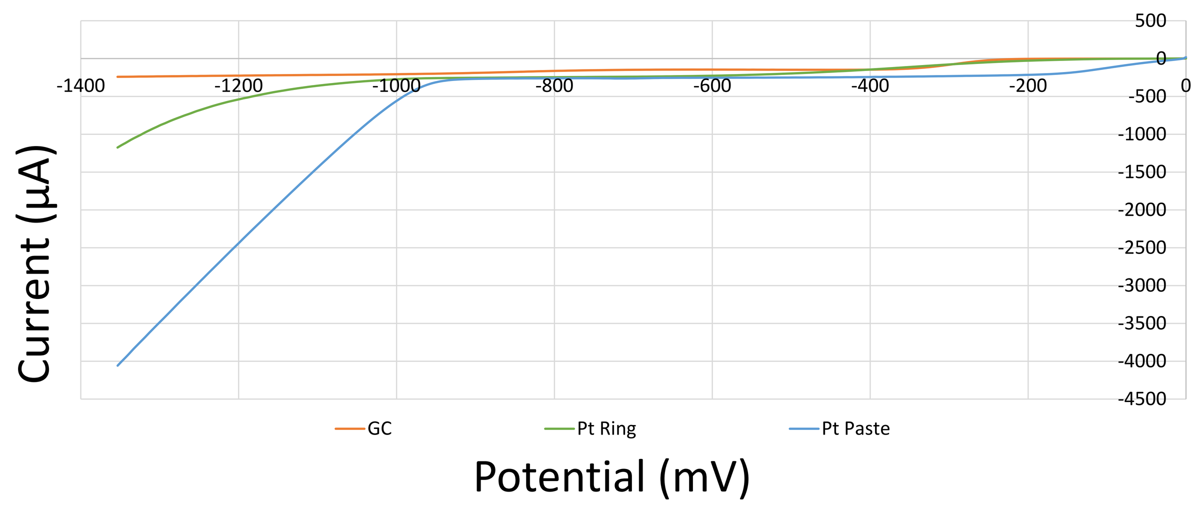
Parameter Effects

Sweep Rate Effect



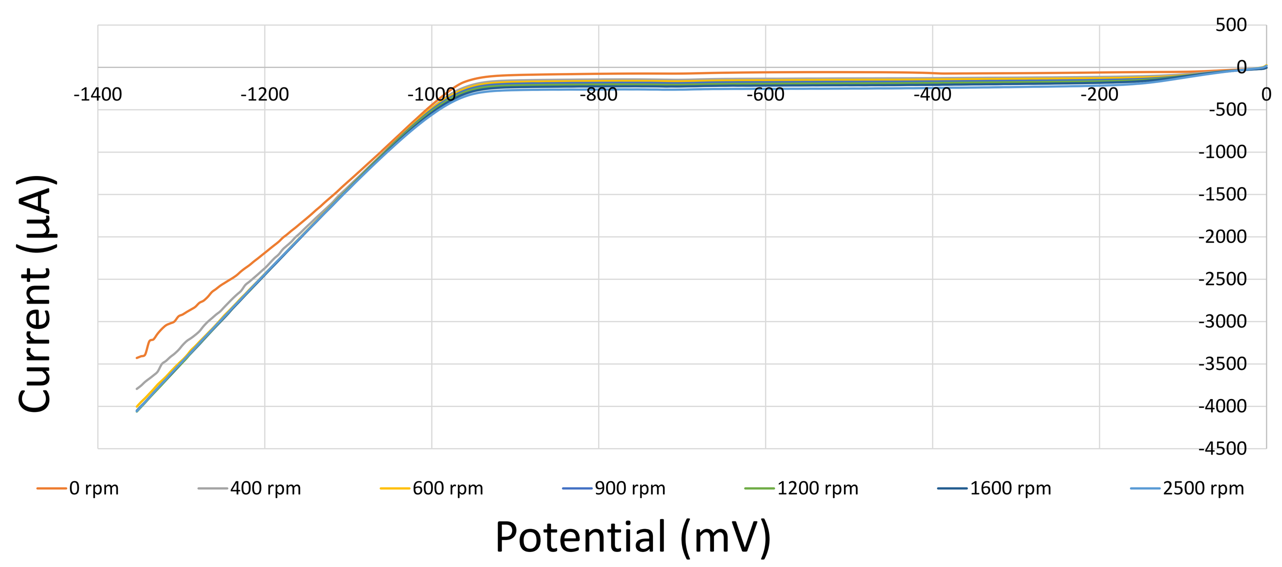
The solution used was 0.1 mM $K_4Fe(CN)_6$ solution mixed in 1.0 M KNO_3 solution. We ran four tests, each at a different sweep rate. It was shown that as sweep rates went up, the peaks of the CV chart also went up. This can be explained with the Randles-Sevcik equation. ($i_{pc}=2.69\text{x}10^8 n^{3/2} A D^{1/2} v^{1/2} C$)

Catalytic Effect



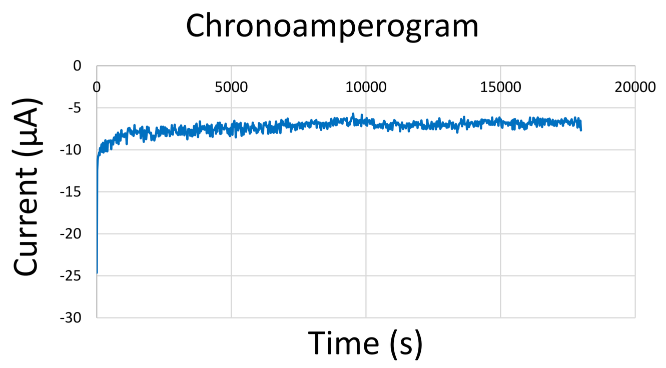
This test was a LV scan (in 0.1 M KOH) ran to compare pre-established catalysts. We ran electrodes with a glassy carbon insert, a platinum ring, and one which was a glassy carbon coated in a platinum paste. The glassy carbon had no catalytic effect, where as the other two electrodes did. It is worth noting that Pt paste show much higher current than Pt ring which is expected.

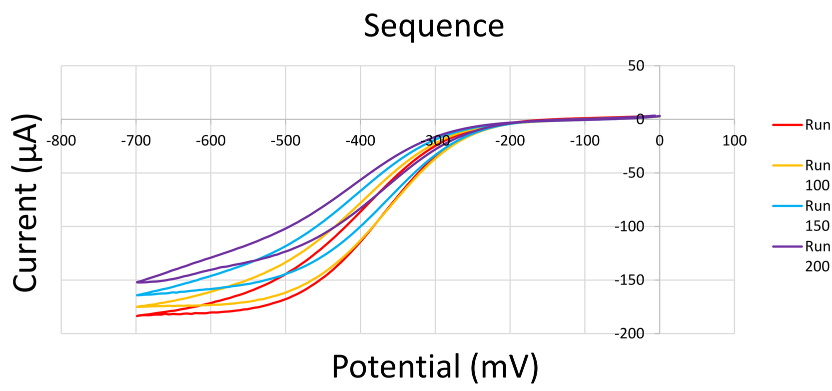
Rotation Speed Effect



This test was a series ran with the platinum paste electron in the 0.1 M KOH solution. This showed that as you increase the spin speeds of your electrodes, your catalyst can reach larger currents. This is because the spin of the electrode causes new solution to constantly come in contact with the electrode.

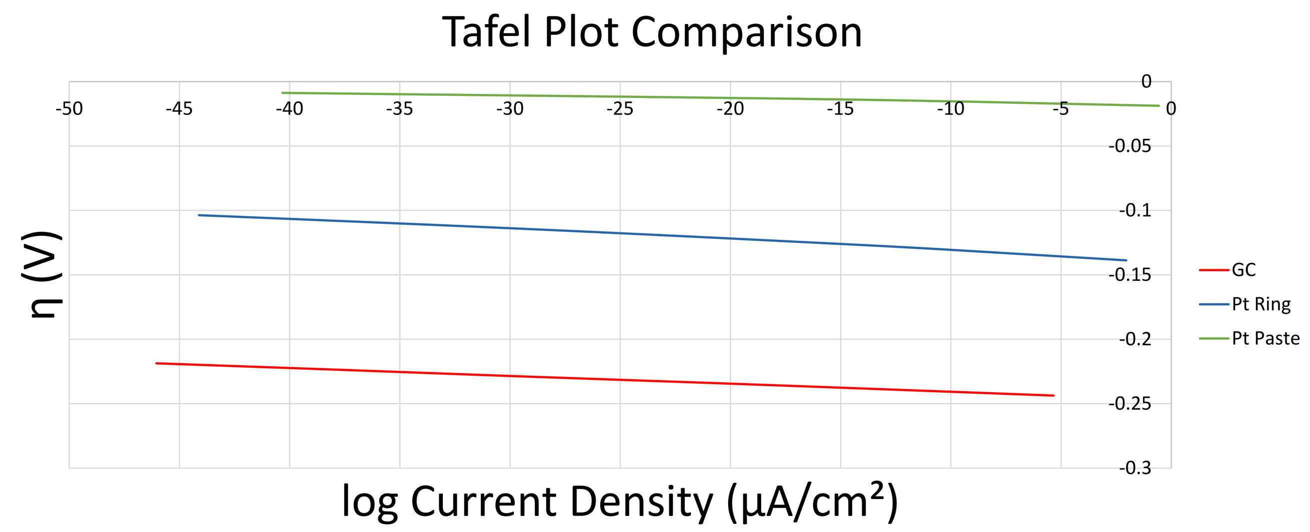
Durability Tests





Both of these charts are different examples of durability tests in a 0.1 M KOH solution. The chronoamperogram is a test where the electrode is held at a specific voltage for an extended amount of time. The chart on the right is a sequence of 200 CV tests ran in succession. Durability tests show the catalyst is stable for extended working time.

Tafel Plot



Tafel plots are the best way to compare electrodes. Instead of just showing the curve, one could use this chart to compare the over-potential, corrosion potential, and open circuit potential. It clearly exhibits that among the glassy carbon, Pt ring, and Pt paste, the Pt paste is the most effective catalyst as it has the lowest overpotential.

Conclusion

Through the set up of out equipment, troubleshooting of our software, and collecting data, our group has set a very strong foundation for future electrochemical research. Through our experimentation we have collected data for various effects that helped us understand the intricate workings of electrocatalysis, and will help us format our experiments in future trials. Along with this, our group collected numerous data sets for platinum catalysts. Future teams can use this data to compare new catalytic compounds against the well known platinum catalysts.

Acknowledgements

Our group would like to acknowledge Dr. Fan Zuo, Dr. Ryan Van Hovelyn, 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.

Indiana State University