

Exploring the Influence of Magnetite Surface Area on Electrolytic Current

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Motivation

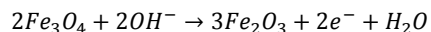
To use hydrogen gas as an energy storage medium for renewable energy applications, the efficiency with which electrolysis creates hydrogen must be increased.

Previous work has explored the use of sacrificial magnetite anodes to facilitate hydrogen production at lower potentials than otherwise needed [1]. However, these experiments have also demonstrated that the hydrogen production is far too slow for industrial purposes [1].

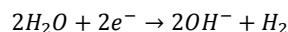
In this project, we compare several electrodes to investigate the dependence of the reaction rate on anodal surface area.

Background Theory

In a NaOH solution, the reactions believed to be occurring are



at the magnetite anode, and



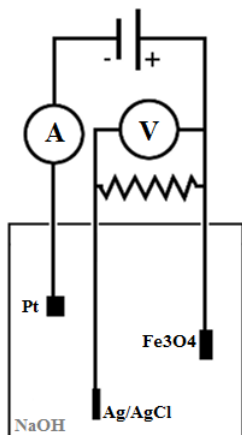
at a platinum cathode [1].

After the initial surface magnetite oxidizes, the reaction rate will depend dominantly on the slow diffusion of fresh magnetite to the surface of the anode. Assuming a linear diffusion gradient and constant reaction rates across the entire surface, the resulting current should follow a typical diffusion model [2]:

$$I(t) \sim \frac{A\sqrt{D}}{\sqrt{\pi t}}$$

Thus, there should be a linear dependence between the surface area of the anode and the reaction rate. In addition, a super linear dependence on surface area might also be observed in the current, opening up the possibility for improved performance at higher surface area.

Electrolysis Setup



A simplified diagram of the potentiostat⁺ used for electrochemical measurements.

The reference Ag/AgCl electrode maintains a stable potential against which the voltage of the magnetite anode can be measured against consistently.

We perform cyclic voltammetry and chronoamperometry to study the reactions at the anode and cathode.

Sodium Hydroxide (pH 14) is used as the electrolyte.

Progress

Electrode Preparation

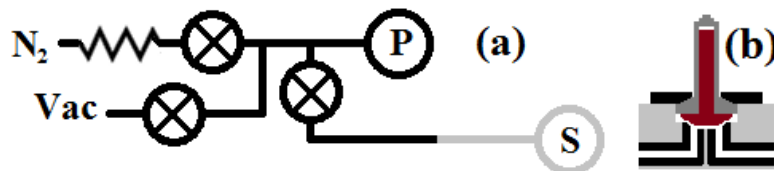
Four groups of electrodes were created by taking magnetite powder, with grain diameters on the order of 1 micrometer, and pulverizing it in a ball mill at different intensities and durations.

This powder was then compressed using ceramic molds, an arbor press and taper dowel pins – producing cylindrical pellets with greater stability at larger radii than previously obtained.

BET Manifold and Valve Pins

Surface areas will be measured using a BET device comprised of a gas handling system that has been machined from raw aluminum (see **a**), and valve casings and pins that have been machined from aluminum and steel as to minimize dead volume and increase accuracy (see **b**).

The device allows a comparison between initial and equilibrium pressure as to determine the amount of nitrogen that adsorbs to the sample. By plotting this quantity against initial pressure, the surface area of the sample can be inferred [3].



Remaining Objectives

Current Objectives

- Repair the degassing heater thermostat
- Obtain surface area measurements for samples from the four separate preparation groups.

Future Objectives

- Perform a cyclic voltammogram for each sample to confirm the redox reaction against previous results and locate current peaks.
- Perform a chronoamperometry for each sample to examine current dependence on time and obtain steady state information.
- Compare steady state currents for the prepared samples and infer surface area dependence.

Acknowledgements

⁺The Wheestat potentiostat is the product of Professor Jack Summers of The Georgia Institute of Technology.

This project is a continuation of the work of Professor Woods Halley and the students who have worked with him.

This project has been supported by the UMN Undergraduate Research Opportunities Program (UROP)

References

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3. Brunauer, Stephen, Paul Hugh Emmett, and Edward Teller. "Adsorption of gases in multimolecular layers." *Journal of the American Chemical Society* 60.2 (1938): 309-319.