Improving Hydrogen Production Efficiency from Electrode Surface Modifications

Nick Samuel: Department of Mechanical Engineering, College of Engineering and Mines, UAF

Mentor: Dr. Sunwoo Kim

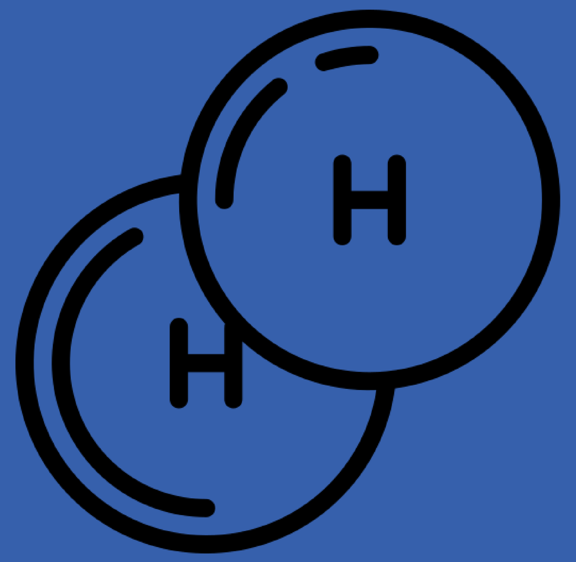


Image: Flaticon.com

Background

Hydrogen gas is one of the most promising energy sources in the modern age. Green energy such as solar, wind, or hydroelectric can be used to produce hydrogen gas, creating a sustainable way to store energy long term compared to traditional electric batteries. On top of being a solution for long-term energy storage, hydrogen gas is also an answer to the ever-growing carbon emissions crisis. When traditional hydrocarbons such as gasoline are burned, CO_2 is released into the atmosphere, which is the main contributor to climate change. However, when hydrogen gas is burned, the only byproduct produced is water, meaning that it is a 100% clean burning fuel. The main method of producing hydrogen gas sustainably is the process of water electrolysis. While this technology is not new, it has a long way to go until it can become a viable option for large-scale power usage due to the electrodes causing inefficiencies from bubble formation, which was the focus of this research.

Traditional Hydrocarbons

[fuel can] + O_2

↓

Energy + H_2O + CO_2

Hydrogen Gas

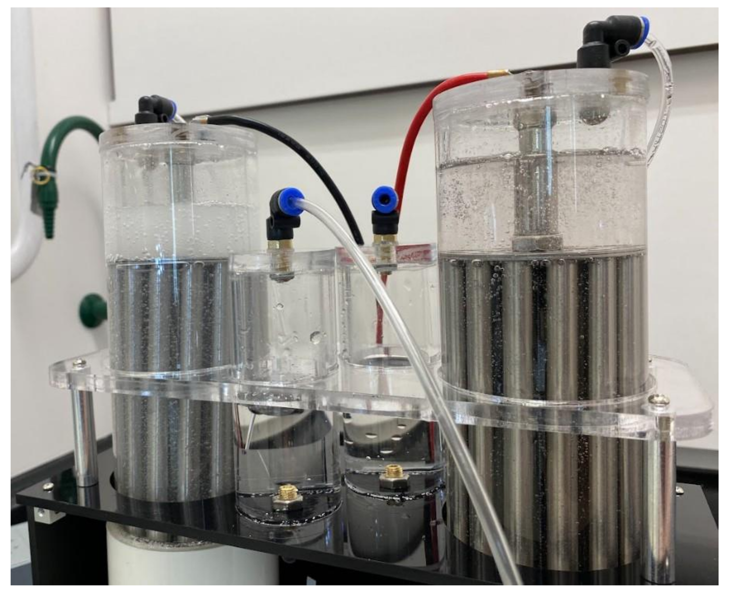
$H_2 + \frac{1}{2}O_2$

↓

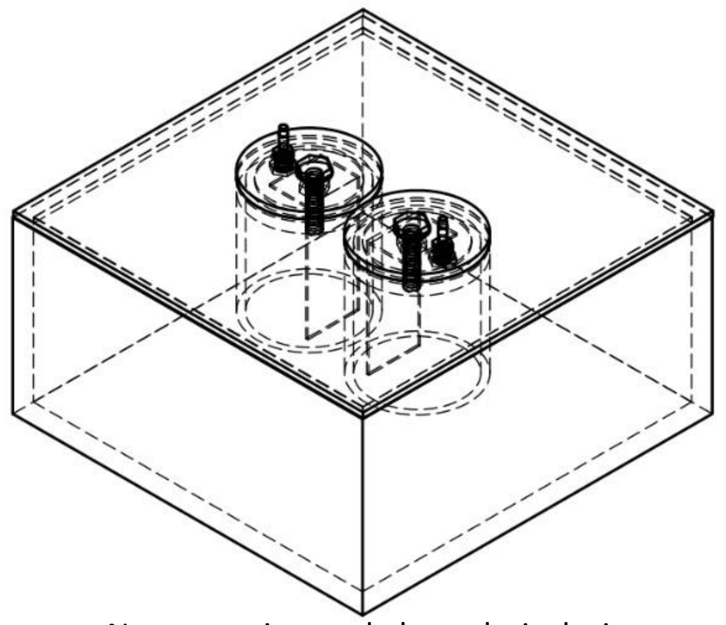
Energy + H_2O

Introduction

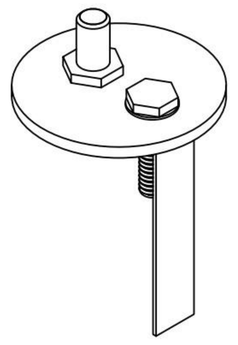
Electrolysis is the method of splitting H_2O atoms into separate gaseous hydrogen and oxygen atoms based on the chemical reaction: $\mathbf{2H_2O \rightarrow 2H_2 + O_2}$
This process utilizes water, an electrolyte to aid in electron transfer, typically NaOH or KOH, and electrodes. The electrodes are put into the aqueous electrolyte solution with a current sent through them. The OH^- and H^+ ions are attracted to the positive and negative electrodes respectively and react with the KOH to form O_2 and H_2. Since O_2 and H_2 are in a gaseous state, gas bubbles form on the surface of the electrodes and eventually detach and rise to the surface due to buoyancy effect.



Originally purchased electrolysis kit



New experimental electrolysis design

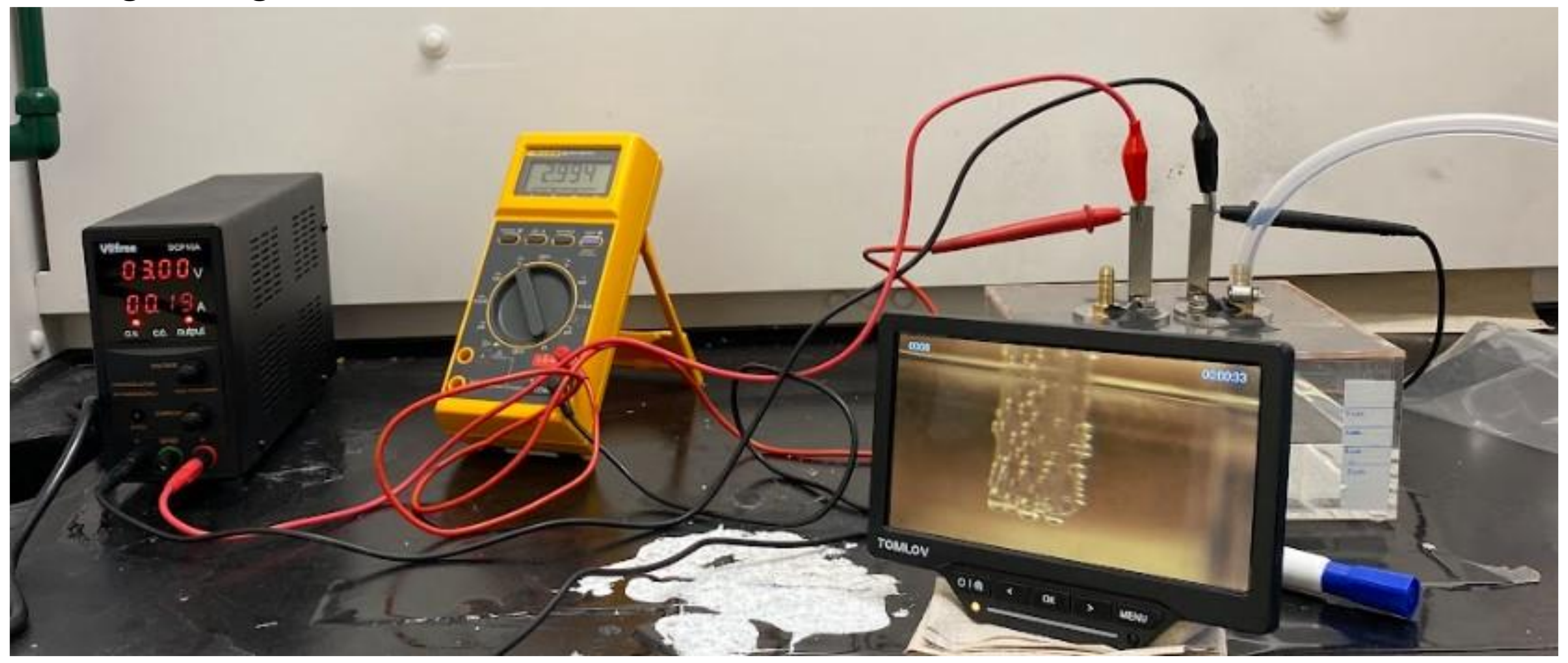


Electrode system to allow for easy changing of electrodes

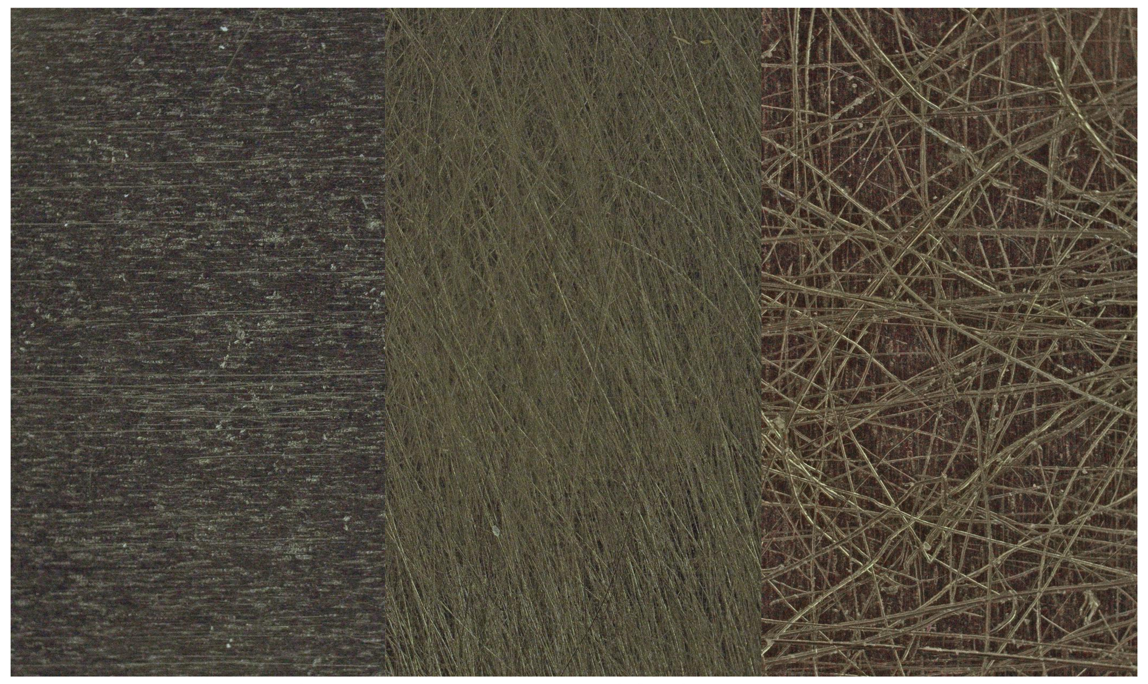
The goal of this research was to investigate improvements of efficiency and H_2 bubble generation during electrolysis utilizing modified electrode surfaces. By modifying the surface morphology of the electrodes, it can promote higher surface areas and gas bubble nucleation sites when compared to an unmodified electrode.

Experimental Setup

Electrolysis System: The electrolysis kit that was originally purchased for this research was not suitable for visualizing bubble generation, so it was decided that it would be better to design and build a new system to meet our needs, which is what the final system is. The experimental setup used 99.96% pure nickel electrodes in a 1M KOH solution and utilized a variable power supply to modulate voltage or current to the desired amount. A digital multimeter was used to accurately measure supplied voltage, and a microscope camera was used to get close images of the electrodes during testing.



The testing setup used to experiment and collect data



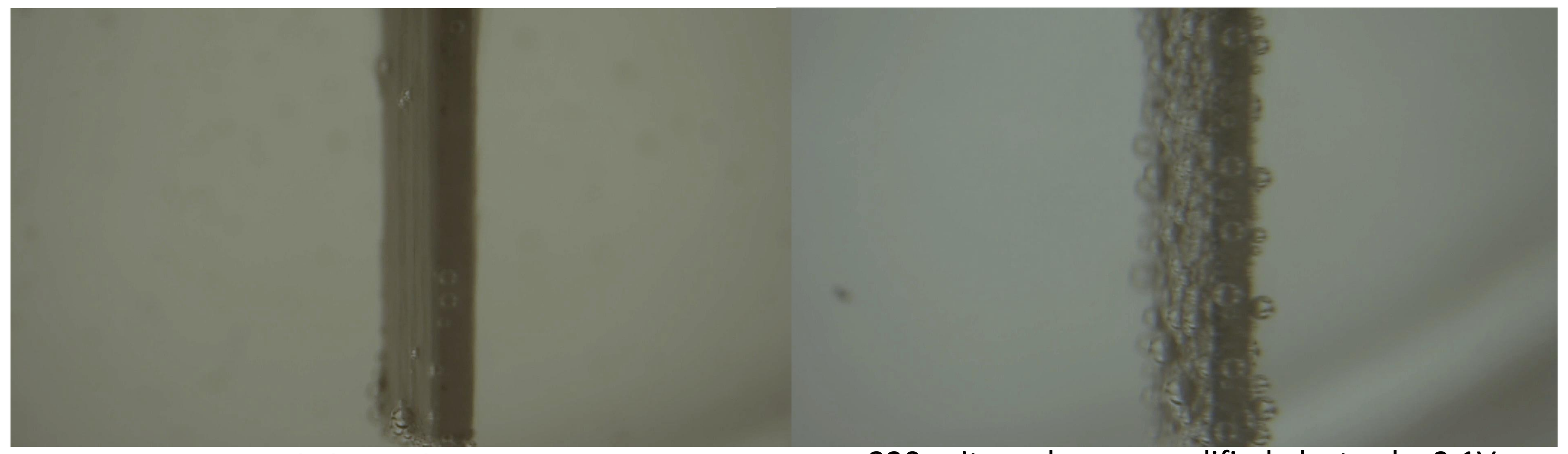
Control electrode | 320-grit modified | 80-grit modified

Electrodes were modified with different roughness sandpapers, using 320, 220, 120, and 80 grit. These were tested and compared to an unmodified, control electrode to see visual differences. A microscope camera at 1300x magnification captured the surfaces of each electrode.

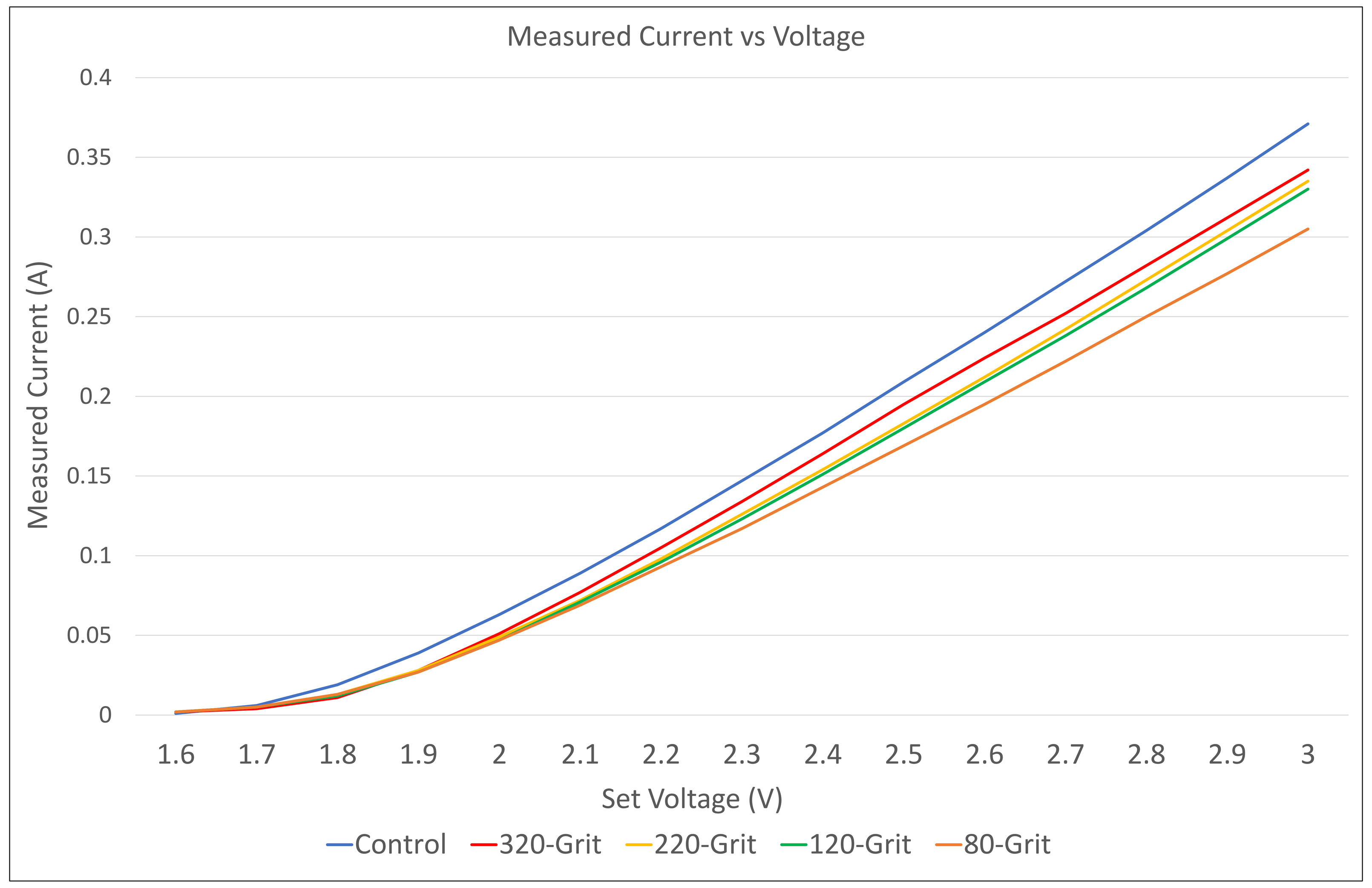
Results

The objective of this research revolved around visual analysis of electrodes during electrolysis. Although quantitative data such as voltage and current were collected during test, the qualitative aspects of the testing were the main point of interest and analysis. When looking at the electrodes at lower voltages of 1.7V, it is obvious that the modified electrodes produced much more bubbles than the control electrode. At higher voltages of 2.1V, a film of gas begins to form over the control electrode preventing large bubbles and limiting bubble production. The modified electrodes handle higher voltages better, allowing for larger bubbles to continue to form and suffering less from a gas film layer. The sandpaper modification creates more imperfections in the electrode surface, which promotes bubble generation by creating more gas nucleation sites, as well as having the effect of increasing electrode surface area.

Control electrode, 1.7V | 320-grit sandpaper modified electrode, 1.7V



Control electrode, 2.1V | 320-grit sandpaper modified electrode, 2.1V



When looking at current measurements, a clear pattern emerges. Coarser grit sandpapers resulted in lower current draw when compared to other electrodes at the same voltage, with the control electrode drawing the most current. This shows the electrodes modified by coarser grit sandpaper had lower power draw at the same voltage.

Conclusion

When comparing visual changes as well as power draw between the control and modified electrodes, it's evident that the surface modifications directly impacted gas production. This is promising because it shows that we can make electrolysis more efficient through surface modifications. Additional tests could be done to explore this further such as investigating other surface modification patterns and techniques, measuring gas flow rate, or exploring how gas bubbles form and travel in a small electrode gap.

Acknowledgments: I would like to thank Dr. Sunwoo Kim for mentorship of this project, as well as URSA for funding and the opportunity to pursue this research.