

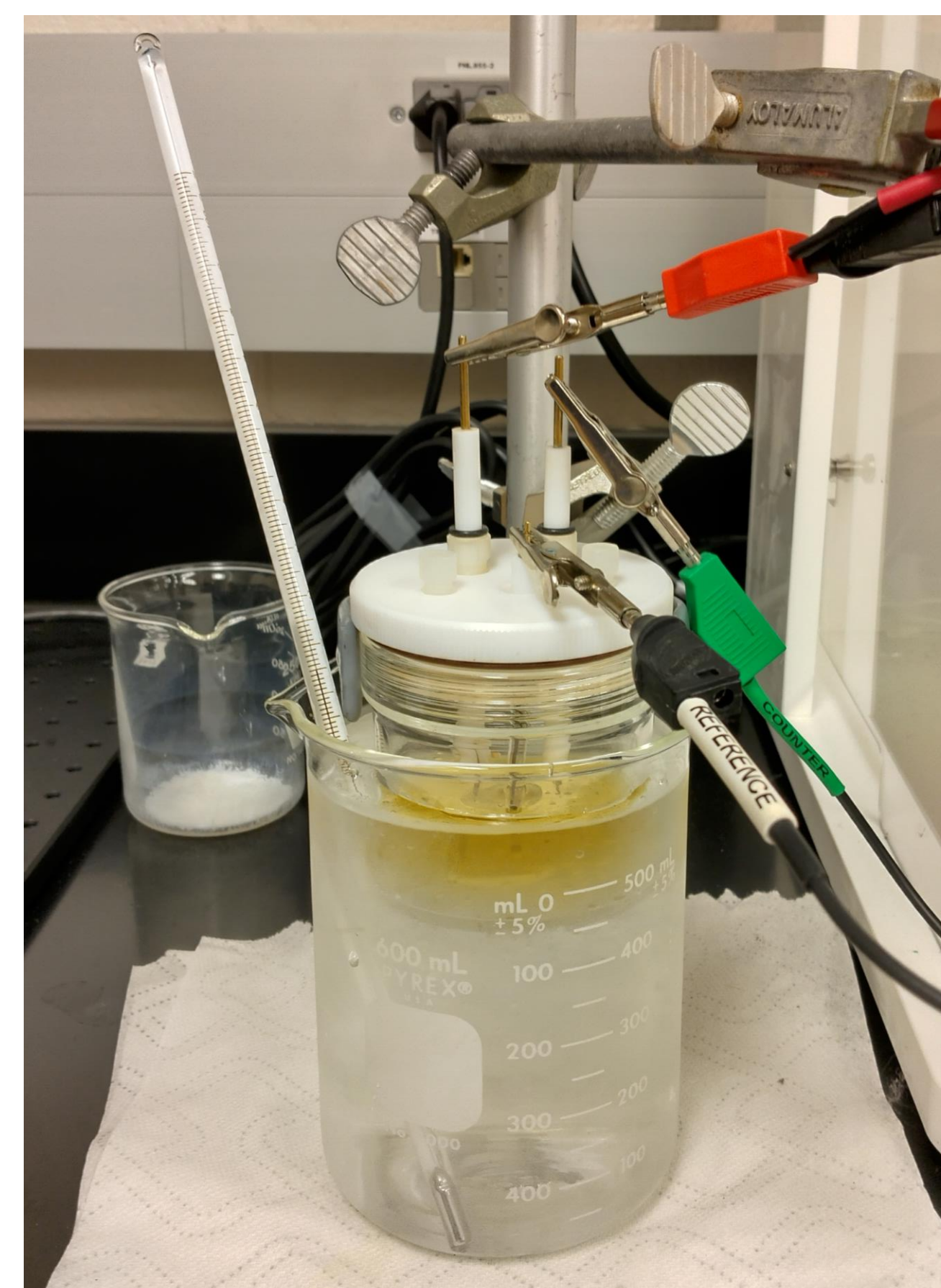
## Introduction

In today's age of growing concern for the environment and sustainability of resources, there is high demand for clean fuels that can produce energy on a large scale while having little to no effect on the atmosphere or environment. One solution is to burn hydrogen, which has no byproduct other than water. However, hydrogen production is a process that requires expensive precious metal catalysts like platinum to be efficient. We seek to make this process more inexpensive by producing electrocatalysts comparable to platinum but made from significantly cheaper materials such as iron and stainless steel. The goal is to produce a catalyst that produces high current density at low voltages, is very stable to be reused, and is cost-effective.

## Background

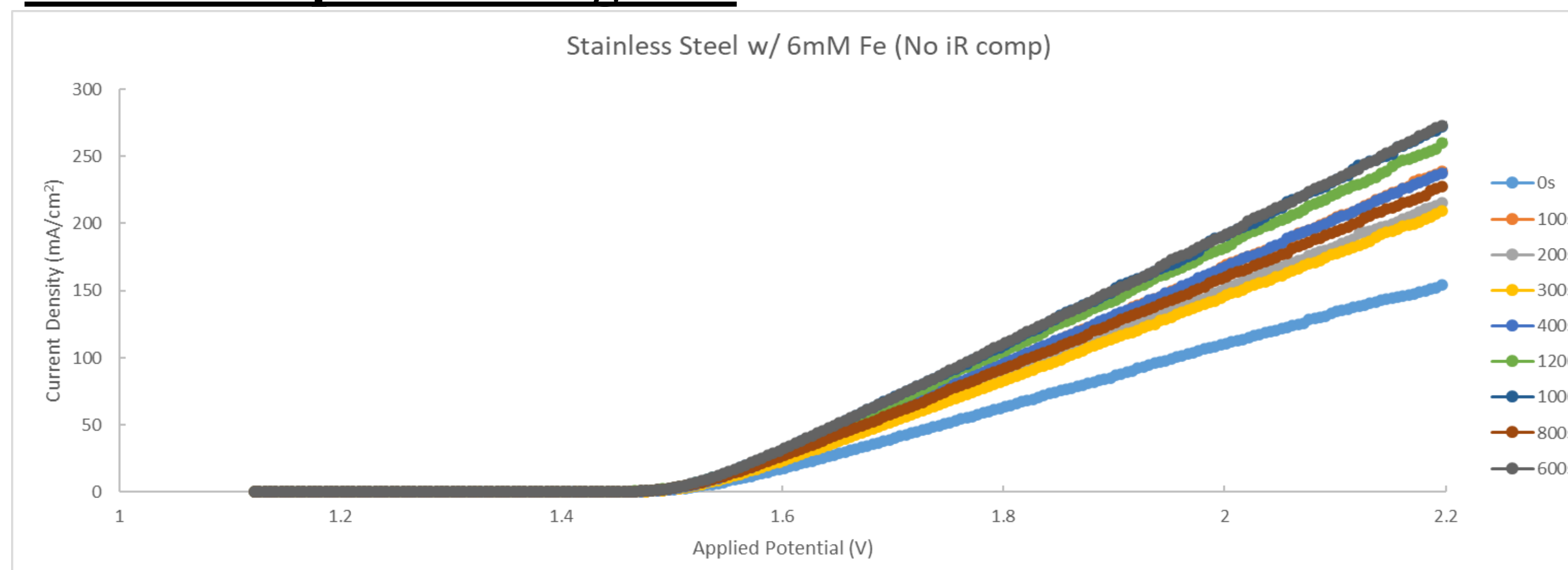
To test the properties of our electrocatalysts, we use a three-electrode cell. The three electrodes each serve an important role in scanning the materials. The working electrode (WE) is the electrode we have attached to our electrocatalyst and typically will have a specific voltage applied to it and it will in turn measure an outputted current. The counter electrode (CE) completes the electrical circuit and serves as a destination for electrons moving away from the WE. Lastly is the reference electrode (RE), which has various types, but we use an Ag/AgCl RE. Its purpose is to tell the potentiostat, which is the measurement tool and power supply to the cell, what potential it is inputting due to the constant nature of the Ag/AgCl solution when affected by electricity.

We use the program AfterMath by Pine Research Instrumentation to run our potentiostat and perform many processes related to the synthesis of our electrocatalysts and testing their efficiency and stability. The main process we use is linear sweep voltammetry (LSV) which is a program in which the potentiostat sweeps a predetermined range of potentials and then measures the current generated within the cell and displays it in the form of a graph.

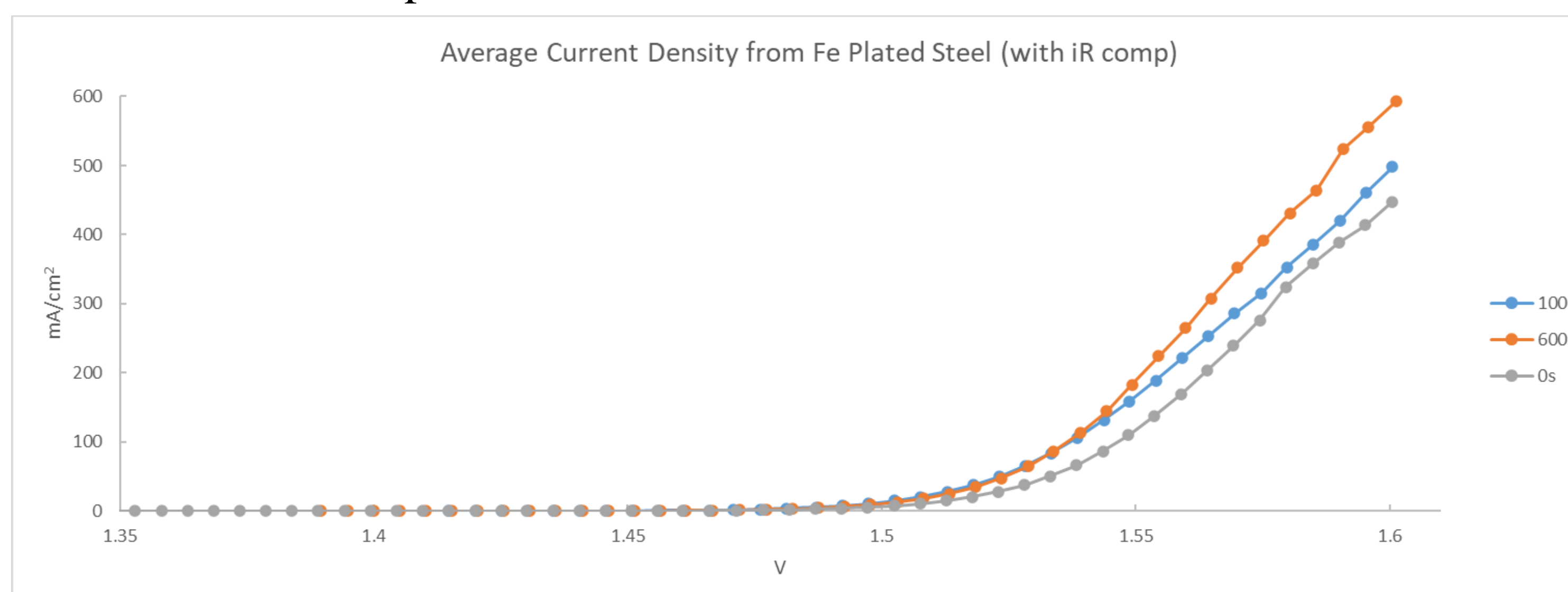


Above are the two cell setups we used this summer; the left shows the cell with its three electrodes and a solution of 1M KOH ready to test the electrocatalyst on the WE through cyclic voltammetry or linear sweep voltammetry. The Right shows the electrocatalyst deposition setup involving a solution of 6mM Fe(NO<sub>3</sub>)<sub>3</sub> and a stainless-steel substrate for the iron in the solution to plate. There is an ice bath because the electrocatalyst produces a more even distribution of iron when at lower temperatures.

## Linear Sweep Voltammograms



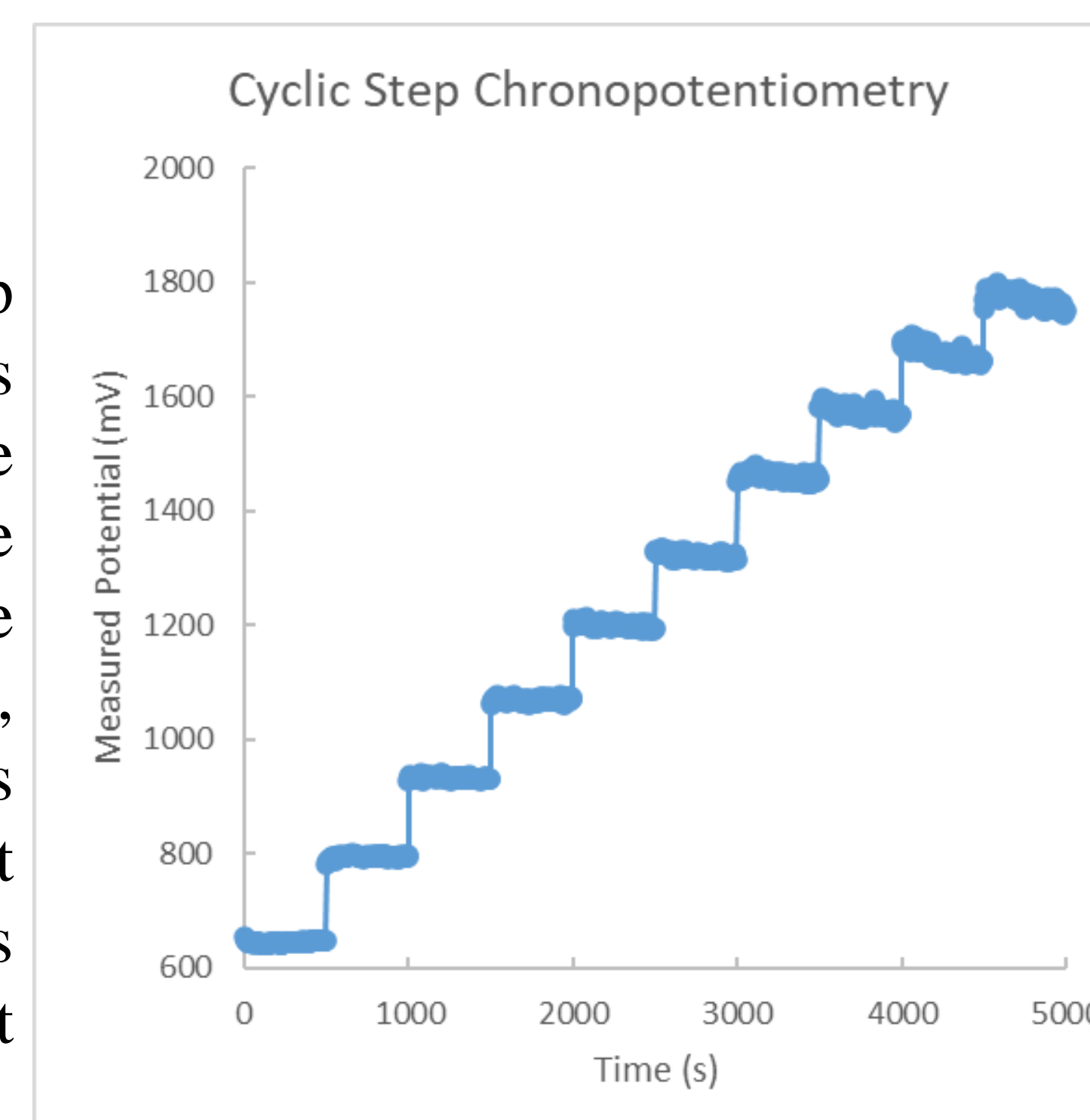
Using what we learned from last summer about the superior efficiency of iron catalysts over nickel-iron mixtures we set about testing different electrodeposition times of the iron catalyst on our stainless-steel mesh substrate. The electrocatalyst deposition process involves running a negative potential through the WE to attract the positively charged metal ions in the solution, like a magnet's poles. By changing the amount of time, we observed different levels of efficiency and found that 600s of electrodeposition was the optimal electrodeposition time, although 1000s was also comparable.



We then ran further tests to determine the reproducibility of our best electrocatalysts and found that using our procedure of electrodeposition resulted in results consistent with those of our first samples. In the above LSV, each labeled curve represents an average of 3 catalysts we produced using our procedure of electrodeposition. It also accounts for uncompensated resistance, unlike the top LSV, meaning the current density displayed here is more accurate to the true current density of the electrocatalysts. The range is also different, in the top LSV we could scan to 2.2 volts, because of the resistance present in the cell, but when we compensated for it, the current exceeded the 1-amp limit of our potentiostat at a voltage above 1.8 volts.

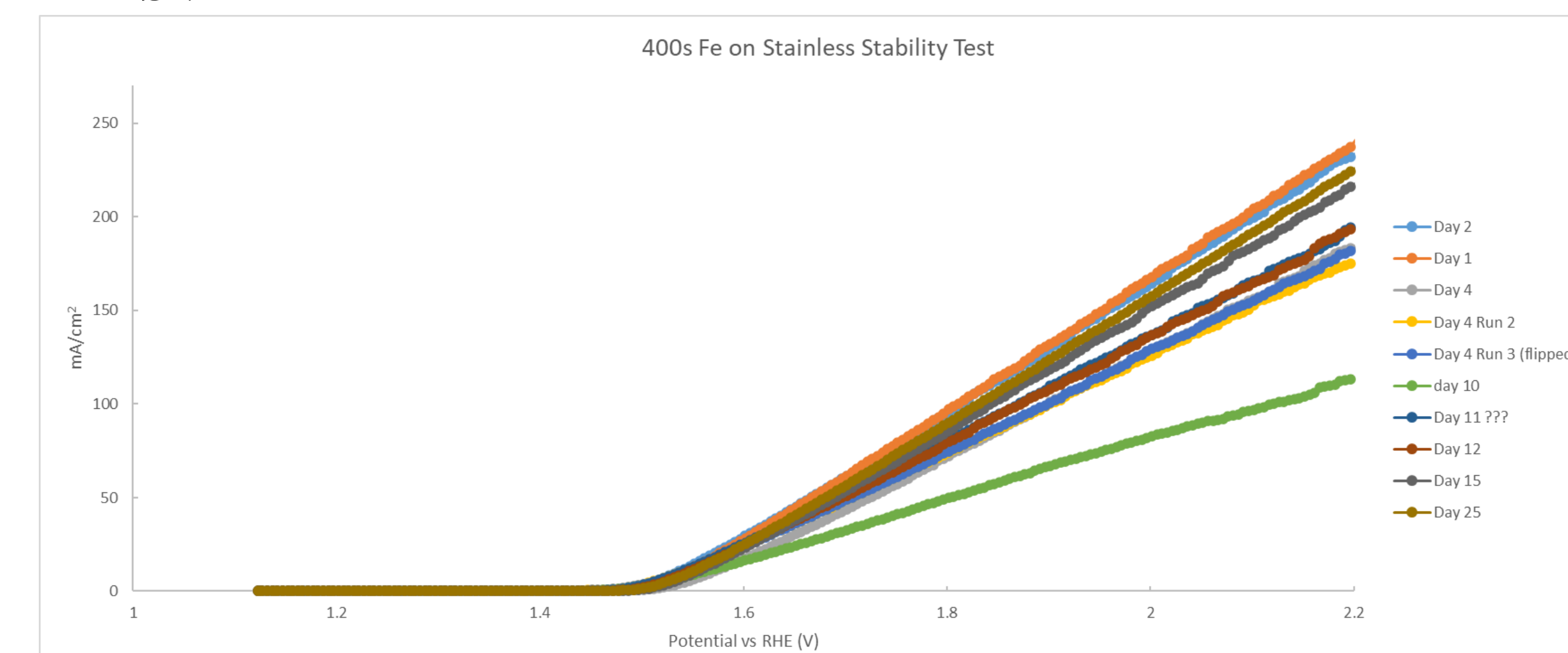
## Cyclic Step Chronopotentiometry

We also ran a cyclic step chronoamperogram, which involves inputting current rather than voltage through the WE and measuring the potential at that current. Over time, the current will jump up a specified amount, in this case 50mA/cm<sup>2</sup> per step. This graph demonstrates that as our catalyst approaches higher current densities, less potential is needed to achieve the next "step".



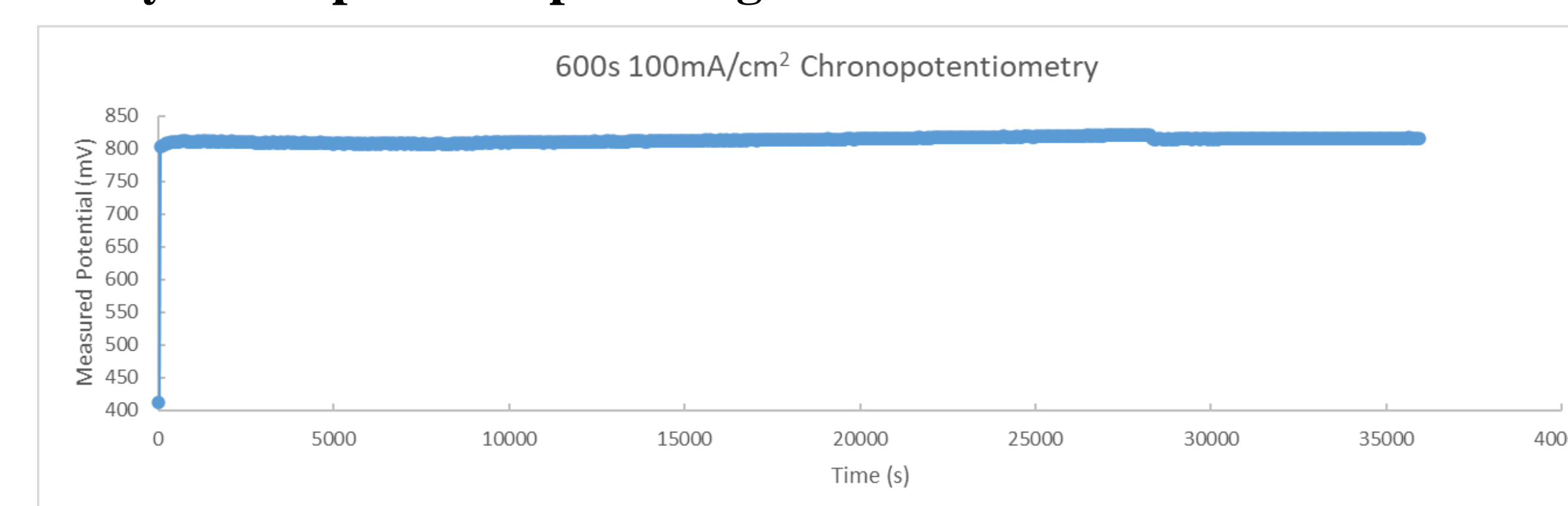
## Stability Tests

### • LSV



We ran LSVs of our 400s iron/stainless steel electrode about a month and determined that it was not deteriorating from scans or being exposed to the atmosphere. As shown above, by day 25, our results were still comparable to day 1.

### • Cyclic Step Chronopotentiogram



We also ran a 10-hour-long chronopotentiogram to demonstrate the stability of our catalyst even when used non-stop for long periods of time.

## Conclusion

By using a variety of electrochemical scans, our group was able to gather substantial data on Fe electrocatalysts electrodeposited onto stainless steel mesh substrates. We demonstrated they were very stable even when stored in the open atmosphere and likely showed comparable current density to other leading platinum electrocatalyst alternatives. By testing a wide range of electrodeposition times, we determined 600s electrodeposition to produce the most efficient Fe stainless steel electrodes.

## Acknowledgments

We are grateful for SURE 2023 for providing both funding and an invaluable hands-on research experience. We would also like to give special thanks to Pine Research Instrumentation and Dr. Li Sun for their assistance with the potentiostat software.

## References

- Elgrishi, N., Rountree, K. J., McCarthy, B. D., Rountree, E. S., Eisenhart, T. T., Dempsey, J. L. *Journal of chemical education* **2018**, 95, 197-206
- Lu, X., Zhao, C. *Nature communications* **2015**, 6, 1-7.