

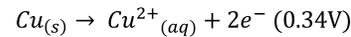
# Viscous Effects of Ethylene Glycol in the Electrodeposition of Copper in an Electrochemical System

Juan J. Juarez, Dr. Kirk Ziegler, Chun-Chieh Wang, Dr. Ranga Narayanan, Matthew Mango  
University of Florida, Department of Chemical Engineering



## Introduction

Electrodeposition is the process by which metal ions are deposited by reduction onto a cathode surface.



The research at hand seeks to investigate the effect of changing the surface tension of the electrolyte by changing its viscosity and observing changes in electrodeposition patterns.

$$\ln \gamma = \ln A + \frac{B}{\eta}$$

Through literature review, ethylene glycol confirmed to be a good solute to change the viscosity of the electrolyte solution.

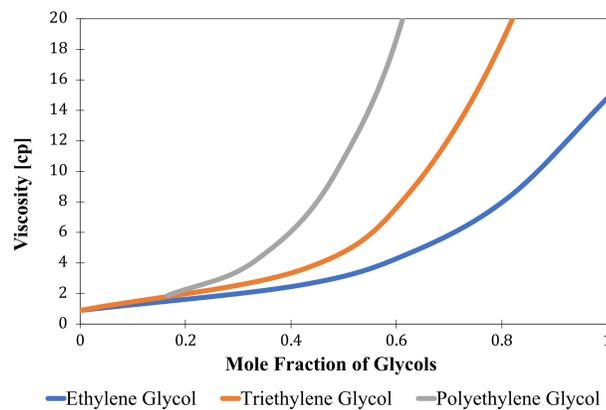


Figure 1. Viscosity vs. concentration for glycol-water systems at 25 °C

## Objective

An analysis of changes in surface tension, ion conductivity, and current behavior with the addition of ethylene glycol will be the purpose of these experiments to better understand observed changes in electrodeposition morphology.

## Electrochemical Cell Design

- I. The electrochemical cell has two pairs of nails spaced at 1 cm each.
- II. One piece of glass is placed on the substrate, held in place by polyimide tape.
- III. Two strips of copper wire were wrapped around the nails tightly, parallel to each other.
- IV. An additional glass was placed on top of the wires and held in place with polyimide tape.
- V. An electrolyte solution of 0.1M  $CuSO_4$  was injected with the corresponding weight fraction of ethylene glycol.
- VI. The cell was sealed with epoxy, and allowed to dry for 10 minutes.

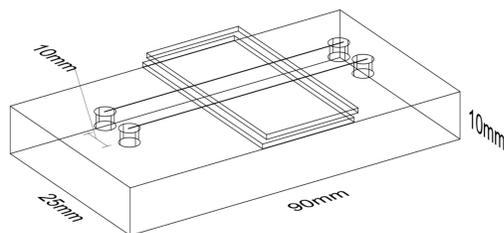


Figure 2. Schematic of the electrochemical cell

## Data Collection Procedure

- I. A potential difference of 1V was applied using DC voltage.
- II. The cell was placed under a camera-based microscope.
- III. A level was used to ensure that the cell was perpendicular to the microscope.
- IV. The camera was programmed to take pictures for different time intervals depending on the length of the experiment.
- V. Current measurements were collected over the course of the experiment, using total charge as markers of interest.

To set up a model for analysis, a control experiment with 0.1M  $CuSO_4$  and no ethylene glycol can be used. Figures 4a-4c attempt to demonstrate a qualitative model to determine when dendrite formation has occurred. Figure 4a and 4c are the extremes, and Figure 4b is the target model to look for in the experiments.

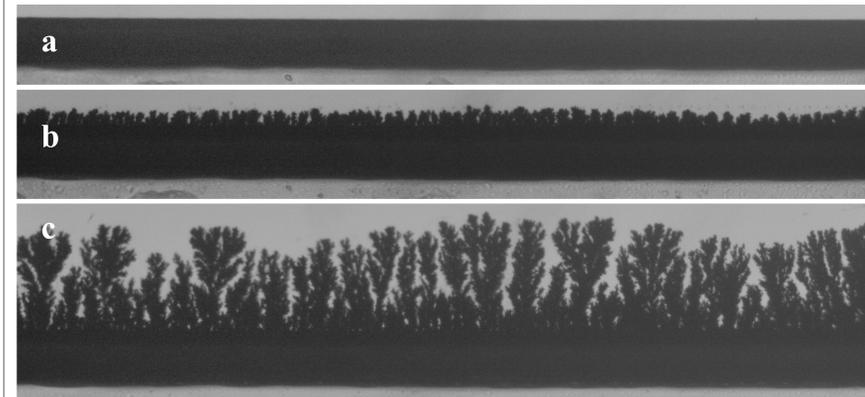


Figure 4 (a-c). Control experiment using 0.1M  $CuSO_4$  and no ethylene glycol.

## Results

The resulting dendritic patterns were obtained at a total charge marker of  $Q=0.53C$ . Figure 5a represents the 0wt% ethylene glycol electrolyte and Figure 5f represents the 50 wt% ethylene glycol electrolyte.

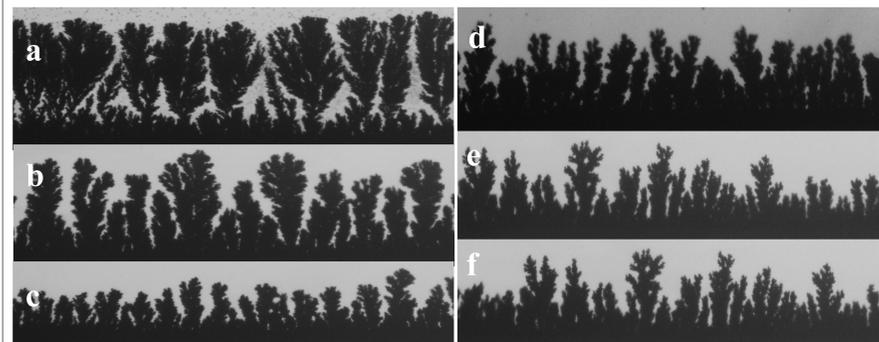


Figure 5 (a-f). Patterns formed at a total charge of  $Q=0.53 C$ . Pictures a-f show the different weight concentrations of ethylene glycol, with picture a being the control experiment of 0 wt% and picture f being 50 wt%.

Figure 6 displays the relationship between current and elapsed time. This graph provides meaningful information about the initial current and the current progression throughout the experiment.

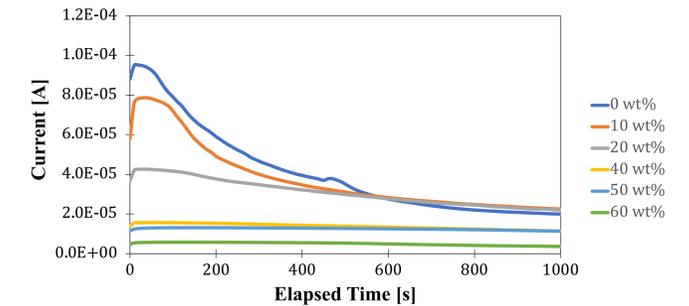


Figure 6. Current versus elapsed time.

Figure 7 demonstrates the relationship between charge and elapsed time. The graph is useful to understand how the kinetics and mass transfer are affected by addition of ethylene glycol.

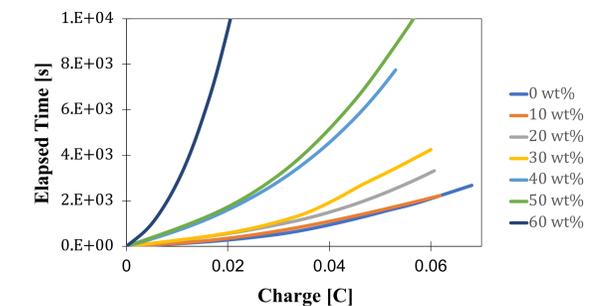


Figure 9. Elapsed time versus total charge.

## Discussion

Viscosity increased

Ion conductivity decreased due to the increased resistance from the electrolyte solution

Dendrite formation reduced due to a decrease in mass convection (Figure 5a-f)

Lower current outputs were observed (Figure 6)

Longer time intervals were required to reach the same charge marker (Figure 7)

As ethylene glycol increased in weight concentration

## References

- [1] Chun-Chieh Wang, "Verification of Electrodeposition Patterns Caused by Interfacial Instability," Ph.D. dissertation, Dept. of Chemical Eng., University of Florida, Gainesville, FL.
- [2] A.H. Pelofsky, "Surface Tension-Viscosity Relation for Liquids," J. Chem. Eng. Data, vol.11, no.3, pp.394-397, July 1966.
- [3] F.S. Jerome, J.T. Tseng, L.T. Fan, "Viscosities of aqueous glycol solutions," J. Chem. Eng. Data, vol.13, no.4, pp.496, Oct. 1968.

## Acknowledgements

I would like to thank my research team and mentors, my friend Dr. Soofi for her unconditional support, and the Center of Undergraduate Research at UF for their patronage.