

The Effect of Electrode Material on the Performance of the Ferri-Ferrocyanide Reaction for Reverse Electrodialysis (RED) Power Generation

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INTRODUCTION

Climate change is one of the greatest challenges currently threatening the world. There is an immediate need for renewable energy sources such as solar and wind, but this urgency has led to other potential sources of energy to be explored as well. One such resource is salinity gradients in bodies of water, i.e., where a freshwater river meets the brine of a sea.

Energy can be generated from these naturally occurring salinity gradients through a process known as reverse electrodialysis (RED) [1]. Several studies are being conducted to determine how catalysts and flow rates could be modified to improve the performance of these systems. This project examined how different catalysts aided the performance of the ferricyanide-ferrocyanide redox couple.

Figure 1 shows a single RED cell using the ferricyanide-ferrocyanide redox couple solution.

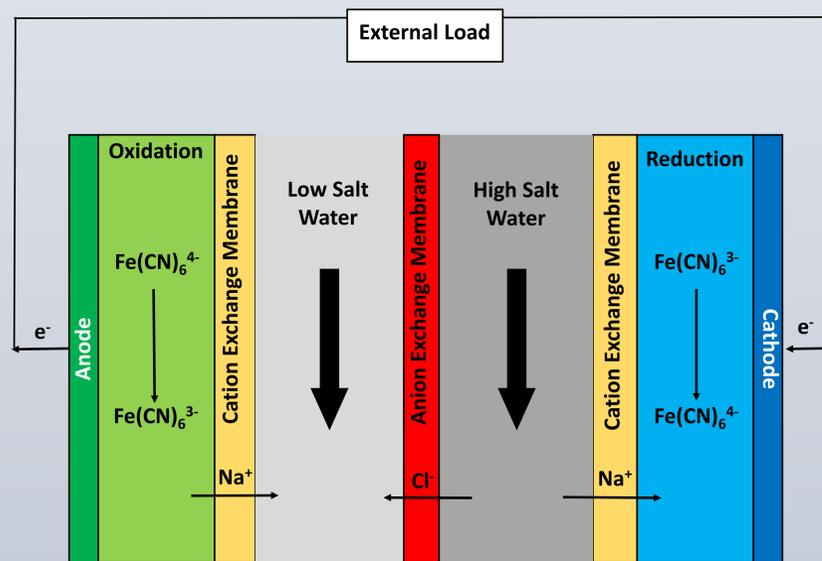


Figure 1. Single RED Cell

OBJECTIVES

- Examine the electrochemical kinetics of the ferricyanide-ferrocyanide reaction with the following electrodes:
 - Pyrolytic Graphite Basal Plane (PGB)
 - Pyrolytic Graphite Edge Plane (PGE)
 - Platinum (Pt)
- Quantify key performance indicators of the reaction with the different electrodes.
- Determine if further catalytic studies are warranted.

MATERIALS AND METHODS

A three-electrode cell with a rotating disk electrode (RDE) and potentiostat was used to perform electrochemical impedance spectroscopy (EIS). The solution tested was 20 mmol L⁻¹ of ferricyanide and ferrocyanide in 1 M KCl. Electrode materials each had an area of 0.19 cm².

Figure 2 shows the equivalent circuit used in analyzing the EIS data. The presence of mass transfer and charge transfer regions necessitated the use of a Warburg element (WS1), solution resistance (Rs) in addition to a constant phase element (CPE1) for a best fit line to determine charge-transfer resistance values (R_{ct}) [2].

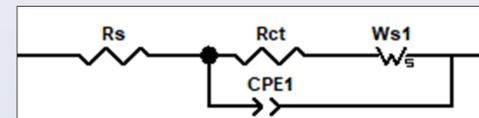


Figure 2. Equivalent Circuit

RESULTS

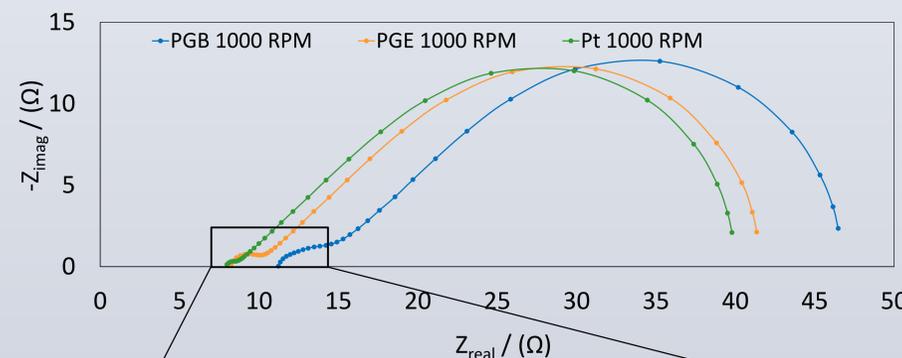


Figure 3. EIS Plot of Electrode Materials

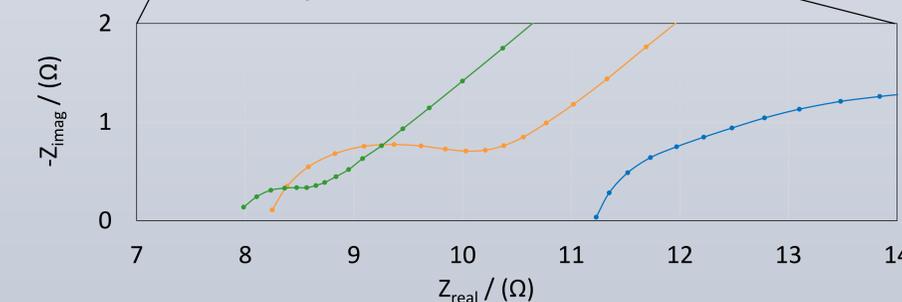


Figure 4. Charge Transfer Region of Figure 3 EIS Plot

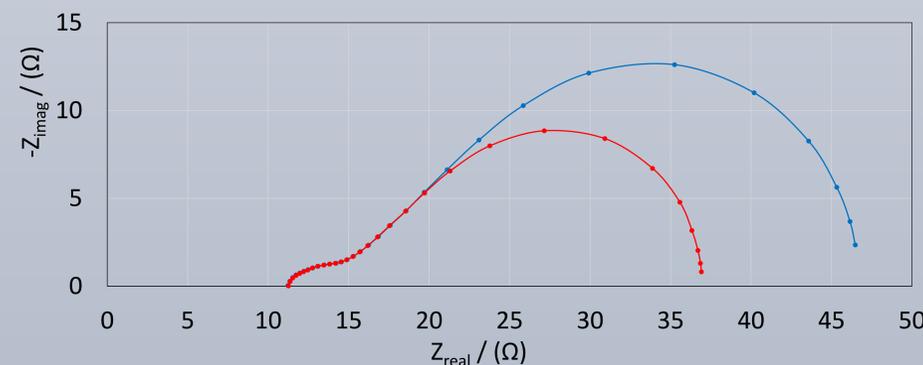


Figure 5. EIS Plot of PGB Electrode at 1000 and 2000 RPM

Table 1. Electrochemical Parameters

	R _{ct} (Ω)	J ₀ (A/cm ²)
PGB 1000	4.680	0.029
PGE 1000	3.099	0.044
Pt 1000	1.017	0.133
PGB 2000	4.320	0.031
PGE 2000	2.998	0.045
Pt 2000	1.147	0.118

The large semi-circle in figure 3 indicates a strong dependency of the reaction rate on mass transfer while still experiencing some dependency on charge transfer mechanisms as seen in figure 4. The mass transfer of this reaction was most impacted by rotation rate as shown in figure 5, while charge transfer was most impacted by electrode material as seen in figure 4.

CONCLUSIONS

We learned from these tests that both rotation rate and electrode material show a clear impact on the electrochemical parameters of the ferri-ferrocyanide reaction. This redox reaction is shown to be relatively fast and dependent on mass transfer [3]. The system is dependent on charge transfer as well, but noticeably less than mass transfer. While improving mass transport and catalyst can both improve the performance, improving mass transport may provide larger gains in performance. The charge transfer resistance of the system is also dependent on the electrode material. Though the platinum electrode had the best performance, carbon-based electrodes showed promise. As such, functionalized carbon materials may improve the performance of the ferri-ferrocyanide reaction as part of an energy generation system in the salinity gradient RED cell.

REFERENCES

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