The Anhydrous Electrolysis of Hydrogen Chloride to Hydrogen and Chlorine Gas

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Introduction

Chlorine plays a significant role in manufacturing many product that one depends on every day. Examples include water disinfection, sewage treatment, crop protection chemicals, cosmetics, and even pharmaceuticals. Hydrogen chloride gas can also be a byproduct from a chemical process and converting hydrogen chloride back to chlorine gas and hydrogen gas allows for a more valuable feedstock.

Electrolysis is the use of current to drive a non-spontaneous chemical reaction. The proposed reactions occurring within the electrolyzer are shown below.

Overall reaction: $2HCl \rightarrow Cl_2 + H_2$

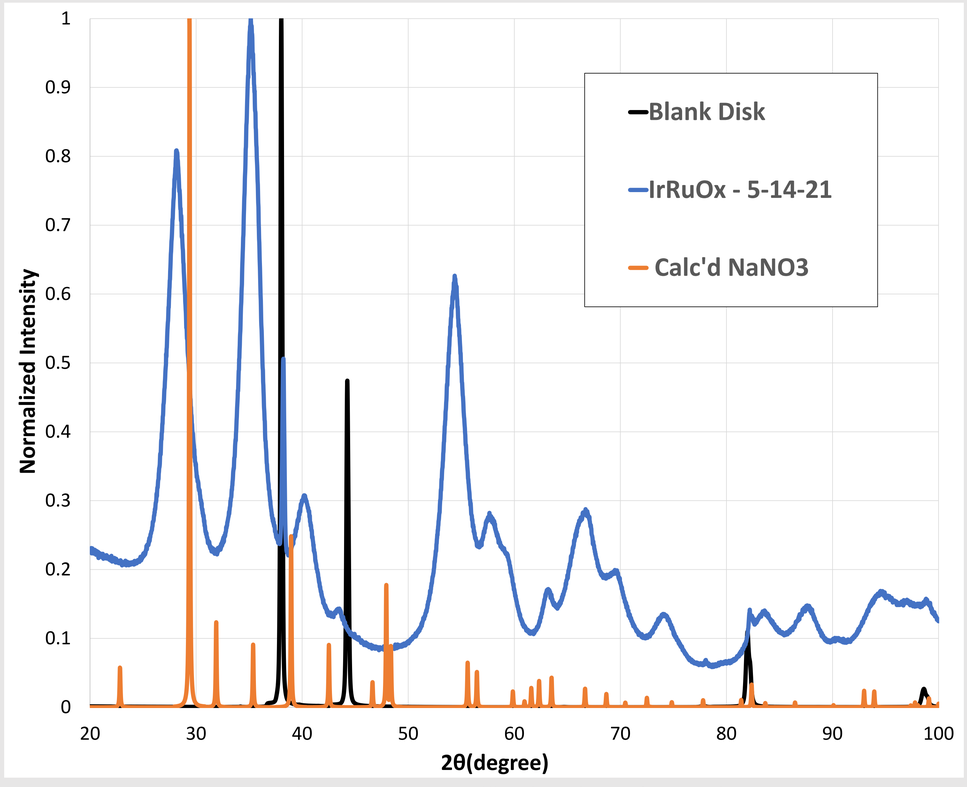
Anode reaction: $2HCl \rightarrow Cl_2 + 2H^+ + 2e^-$

Cathode reaction: $2H^+ + 2e^- \rightarrow H_2$

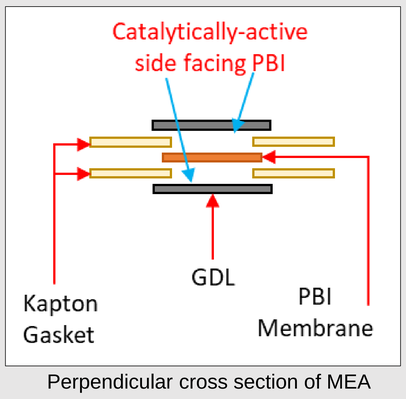
Membrane Electrode Assembly (MEA)

Traditionally, a nafion membrane would be used in eletrolyzers. For the hydrogen chloride process, a polybenzimidazole (PBI) membrane is used because the system is operating under anhydrous and acidic conditions. Nafion needs to be hydrated to have proper performance.

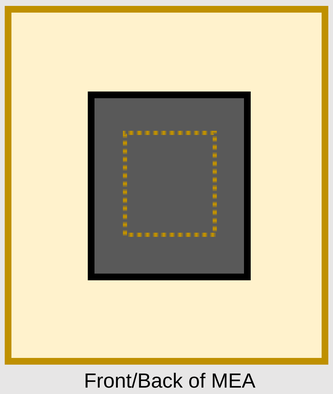
The cathode contains catalyst with a weight loading of 1 mg Pt/cm ^{2}. The catalyst used for the anode is iridium ruthenium oxide (IrRuOx). The preparation of the IrRuOx includes a synthesis is done at 500°C. Afterwards, includes a water and a perchloric acid wash treatment is performed. X-ray diffraction is performed to give details about the crystallographic structure to see if nitrates are removed from IrRuOx. The weight loading is 3 mg IrRuOx/cm^2.



2 hour 500°C X-Ray Diffraction After HClO4 Wash



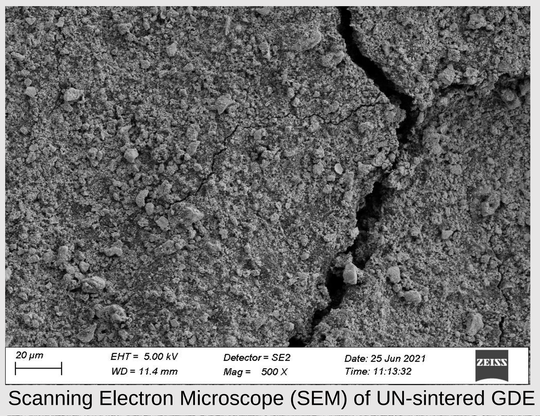
Perpendicular cross section of MEA



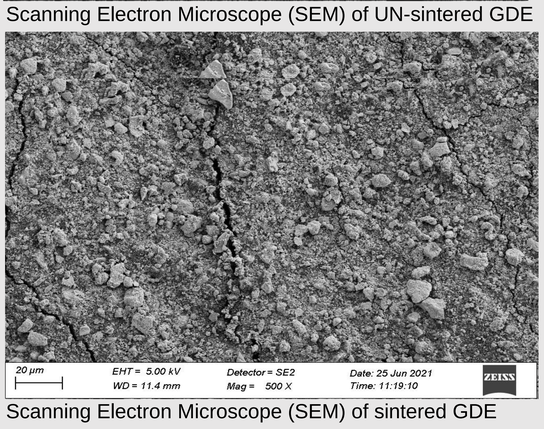
Front/Back of MEA

Sintering GDE

The MEA is pressed using a heat press. Sintering the gas diffusion electrode (GDE) material allows for the shim compression and actual compression to have a percent difference of less than 2%. Unsintered GDE tend to get over compressed by 7%. The reasoning for this is because the GDE has a polytetrafluoroethylene (PTFE) coating, and sintering allows for the PTFE to "melt" allowing for an even compression for the membrane, sub-gaskets, and GDE.



Scanning Electron Microscope (SEM) of UN-sintered GDE

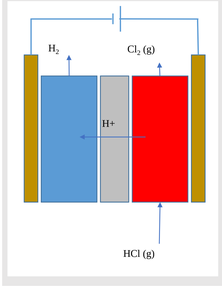


Scanning Electron Microscope (SEM) of sintered GDE

Experimental Conditions and Apparatus

Cell Activation Area:	10 cm^2
Cell Temperature:	30-160 °C
Cathode Flow Rate:	0.1 L N_2/min
Anode Flow Rate:	0.1 L HCl(g)/min
Cathode Catalyst:	1 mg Pt/cm ^{2}
Anode Catalyst:	3 mg IrRuOx/cm^2
Membrane:	PBI Membrane

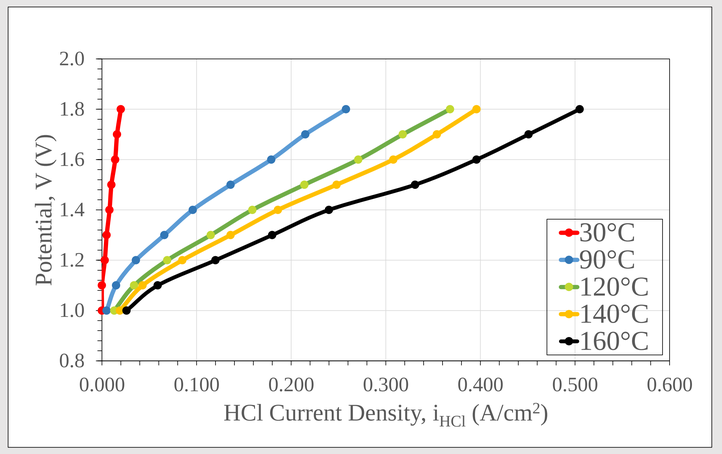
Overall Apparatus



Proton Exchange

Cell Close Up

Results



Performance of PBI Membrane for Increasing Temperature

Conclusion

- Water and acid wash removed the nitrates as shown in the XRD chart
- Sintering the GDE before heat pressing allows for a better compression
- Increasing the temperature of the cell increases the performance of the electrolyzer

Future Work

- Testing the reproducibility and performing a durability test
- Testing a broader range of temperatures
- Adding back pressure to the system to increase residence time
- Perform more tests in galvanostatic conditions

References

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2. (2020, February 14) X-ray Powder Diffraction (XRD). *Techniques*.

3. Xiao, L., Zhang, H., Scanlon, E., Ramanathan, L. S., Choe, E.-W., Rogers, D., Apple, T., & Benicewicz, B. C. (2005). High-Temperature Polybenzimidazole Fuel Cell Membranes via a Sol−Gel Process. *Chemistry of Materials*, *17*(21), 5328–5333.

Acknowledgments

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