DEVELOPMENT OF 3D PRINTED FALLING THIN FILM LIQUID PHASE ELECTROLYZER PROTOYPE FOR CO_2 REDUCTION REACTION

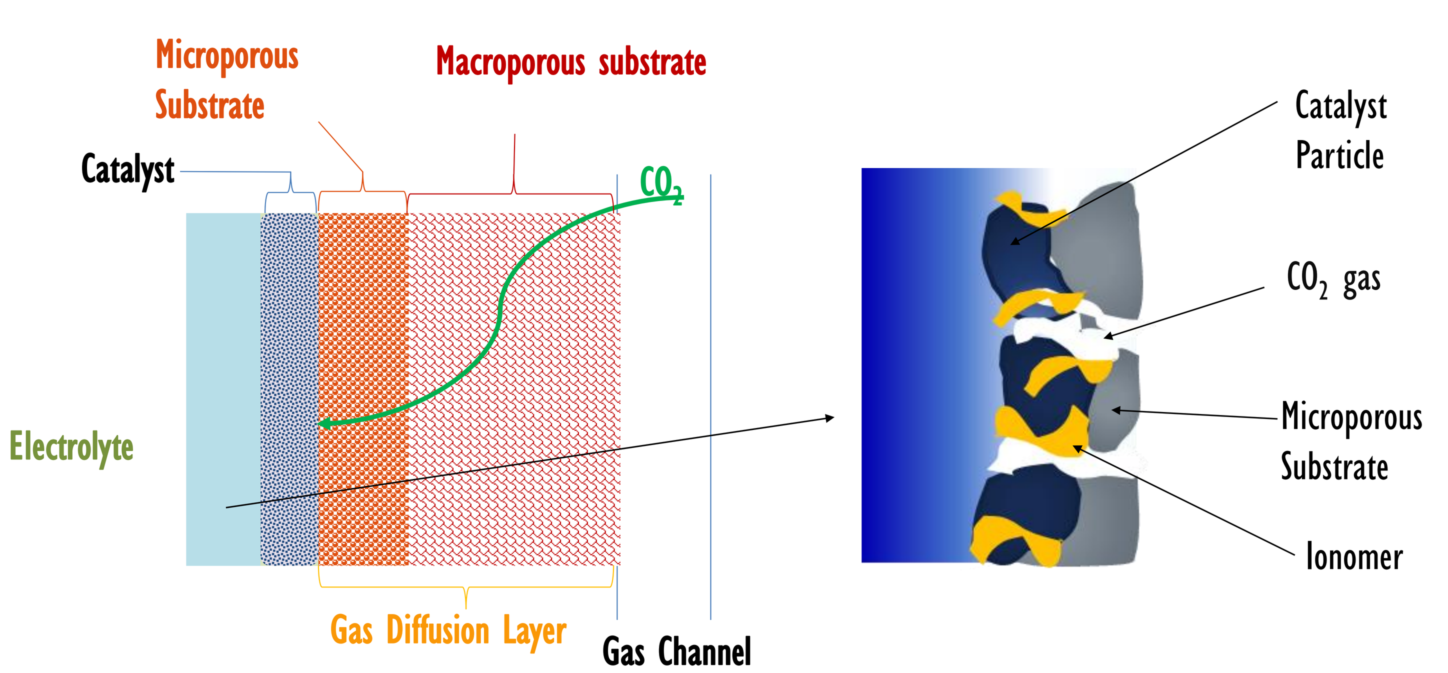
Anika F. Jalil[1], Karin U.D. Calvinho[2], Anders B. Laursen[2] and Charles G. Dismukes[2,3], (1) School of Engineering, Rutgers, the State University of New Jersey, Piscataway, NJ, (2) Department of Chemistry and Chemical Biology, Rutgers, the State University of New Jersey, Piscataway, NJ, (3) Waksman Institute, Rutgers, the State University of New Jersey, Piscataway, NJ

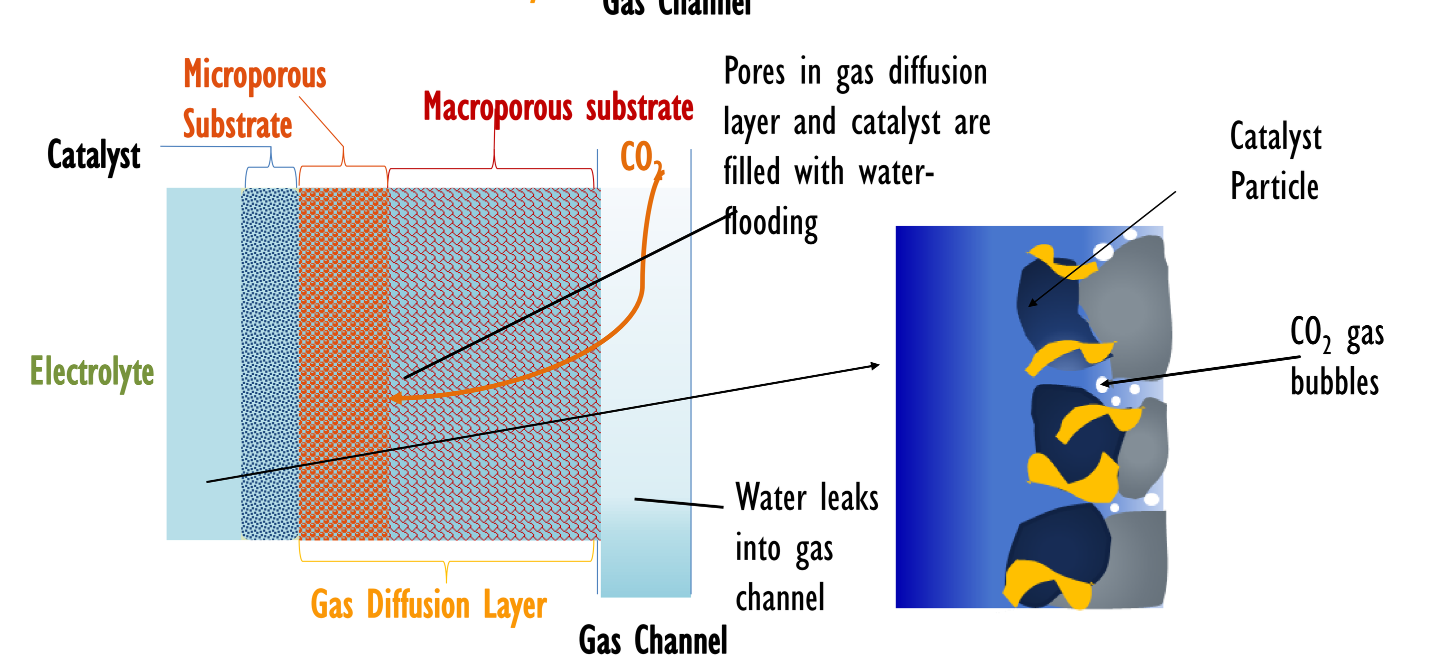
Introduction

Electrochemical CO_2 reduction offers a promising solution to reduce industrial CO_2 emissions by enabling the production of carbon-negative and profitable industrial chemicals. For electrochemical reduction to be feasible, on a large scale the electrolyzer needs to achieve several figures of merit: low cost, high current density, high energy efficiency and stability. Liquid Phase Electrolyzers (LPEs) can produce a wide variety of value-added carbon products such as plastic monomers provided that a selective and active catalyst can be discovered; our group has developed Ni-P catalysts that confer exceptional faradaic efficiencies for C_{1-3} products[1]. The primary barrier to industrially scaling up LPEs is the occurrence of liquid flooding of gas channels that impairs the mass transport of CO_2 to the catalyst. However, the chlor-alkali industry has developed falling film electrolyzers to circumvent the pressure differential at the root of the flooding problem. This technology is considered the state-of-the-art in large scale electrolyzers. Drawing from this established configuration, we created an electrolyzer prototype using 3D printing that does not suffer from flooding. Using 3D printing, we also created a proprietary percolator design which increases electrolyte mixing while optimizing the ionic conductivity. The design ensures continuous wetting of the entire electrode surface with minimal blocking of catalyst surface area. The architecture of the cell prevented fluid flooding of the catalyst and reduced cell resistances; thereby indicating that this design is advantageous for scaling to industrial dimensions for CO_2 electrolysis.

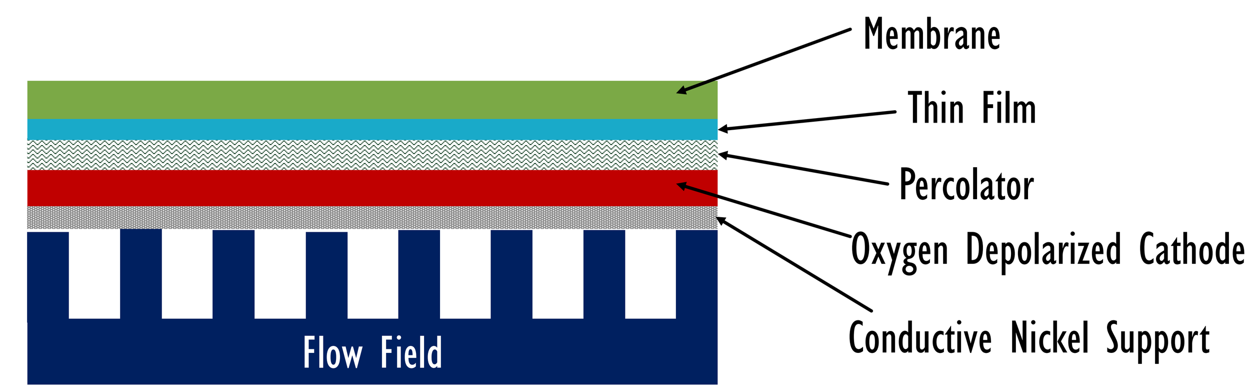
CO_2RR for C_{1-3} products → Chlor-Alkali Technology translated to CO_2RR → Rapid prototyping with 3D printing → Falling film technology for CO_2RR

Flooding in Liquid Phase Electrolyzers





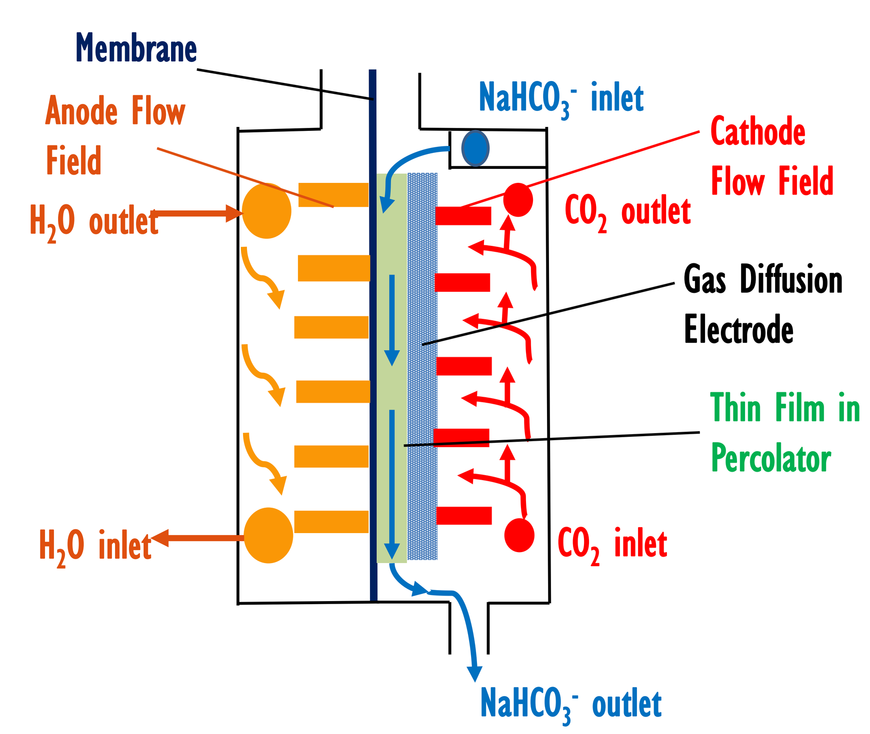
CholroAlkali Oxygen Depolarized Cathode (ODC) Technology



ODC technology is state-of-the-art in the ChlorAlkali industry. ODC electrodes consist of electrocatalyst that thermodynamically favor the production of NaOH and Cl_2. The large scale implementation of the ODC electrode calls for an electrolyzer architecture that would enable maximum catalyst activity while minimizing cell overpotential.

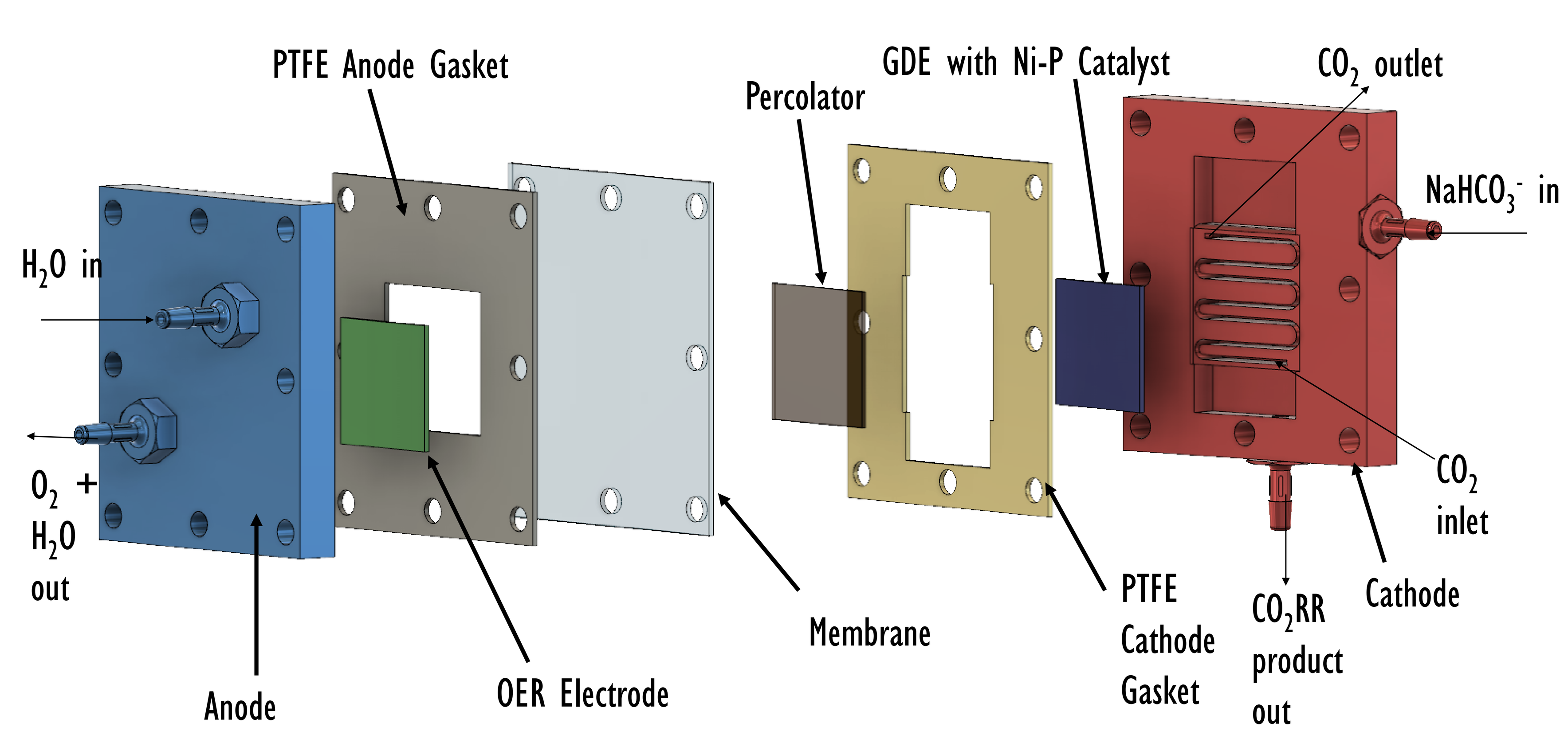
- Percolator: porous, hydrophilic structure enabling film formation
- Conductive nickel adds additional support to the electrode and improves current flow
- Thin film of electrolyte prevents development of large pressure differential that can lead to flooding.

Translating ODC Technology to CO_2RR Electrolyzers



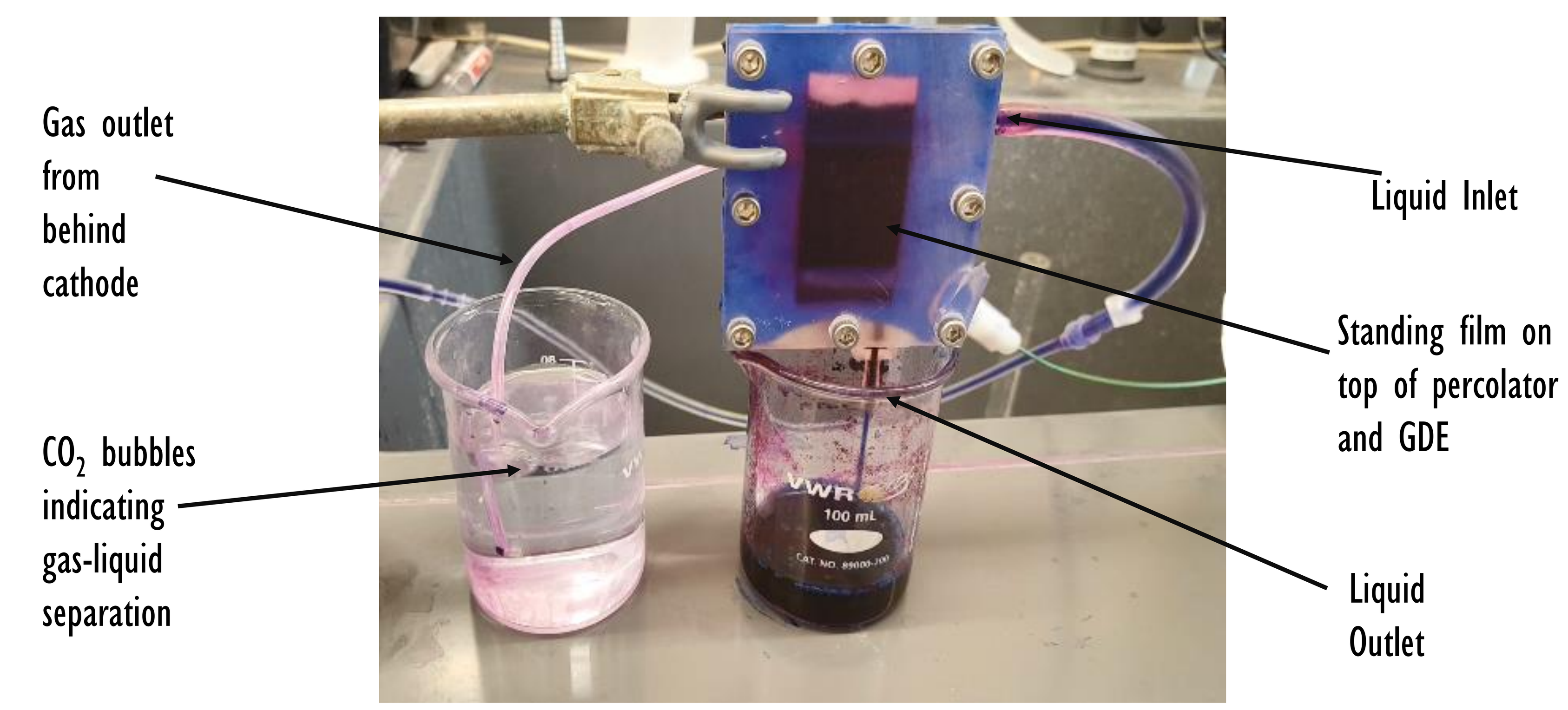
- Falling film of electrolyte evenly distributes hydrostatic pressure across entire GDE to prevent flooding
- Small volume of liquid minimizes hydrostatic pressure
- Film formation across GDE ensures maximum surface area of catalyst on GDE is involved in electrolysis
- Percolator pushes against GDE to ensure compact placement of all components- zero gap configuration implying low electrical contact resistances
- Percolator ensures both membrane and hydrophilic side of GDE remain hydrated

Electrolyzer Stack Assembly

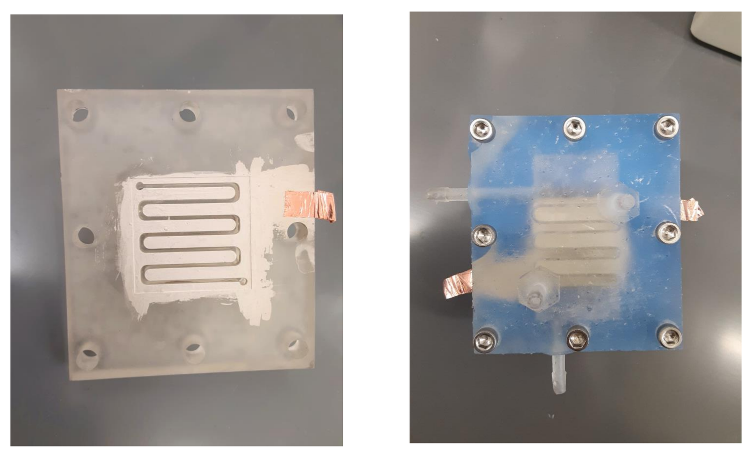


3D Printed Cathode

Computer Aided Design (CAD) software was used to design the cathode, anode and percolator. Formlabs Form 2 Stereolithography (SLA) 3D printer was used in clear resin to print these designs. Colored fluid was used to monitor the flow of liquid from the cathode inlet across the GDE. With the falling film configuration, gas and liquid separation was achieved. A standing film of liquid was also achieved across the entire GDE.

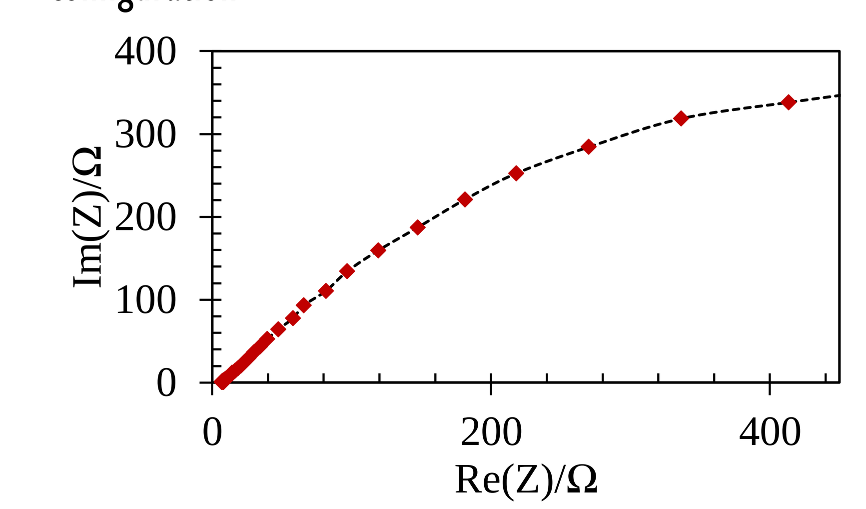


Electrochemical Impedance Spectroscopy (EIS)



- 3D printed anode and cathode flow fields with coated with conductive silver paint.
- Copper tape was added to the silver coating to create external electric contact

- EIS of the assembled 3D printed electrolyzer with 0.5M $KHCO_3$ as the electrolyte showed 1.29Ω uncompensated resistance compared to 6.75Ω with round cell configuration[1]



Future Work

- Computationally modelling pressure across catalytic area of GDE to better understand the role of fluid pressure differential.
- Faradaic efficiencies of CO_2RR products will be measured
- Current densities achieved by the electrolyzer will be monitored over extended time
- Variation of film thickness and its effect on cell performance
- Determination of electrolyzer stability

References

1. K. U. D. Calvinho et al., *Energy & Environmental Science*, 11, 2550–2559 (2018).

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