Electrochemically-Driven Carbon Dioxide Separation

DE-FE0031955

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U.S. Department of Energy

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Direct Air Capture Kickoff Meeting

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Program Overview

Funding: \$800,000 federal + \$200,000 cost share

Period of Performance: 10/1/2020 – 3/31/2022

Participants: University of Delaware

Project Objectives:

- Develop electrochemically-driven CO_2 separator with 0.4 mol/m^2-hr air capture at <235 kJ/mol_{CO2} (1.5 MWh/t)
- Characterize poly(aryl piperidinium) (PAP) properties to support future development

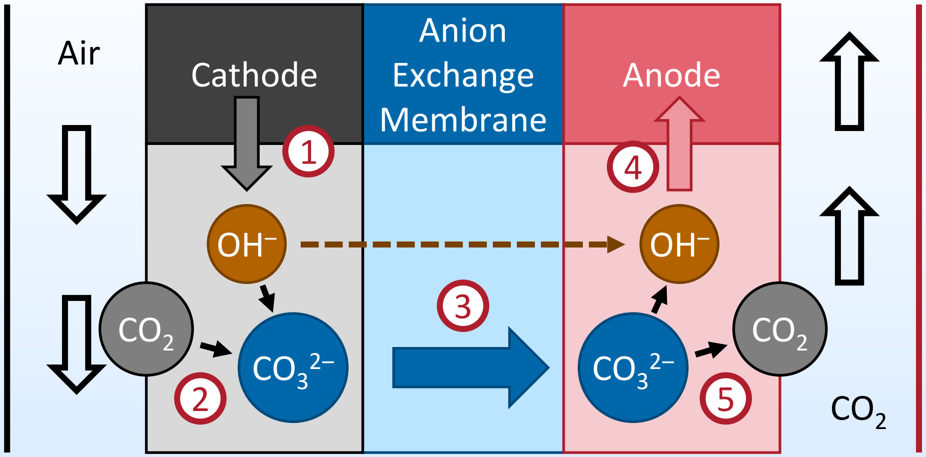
Technology Background

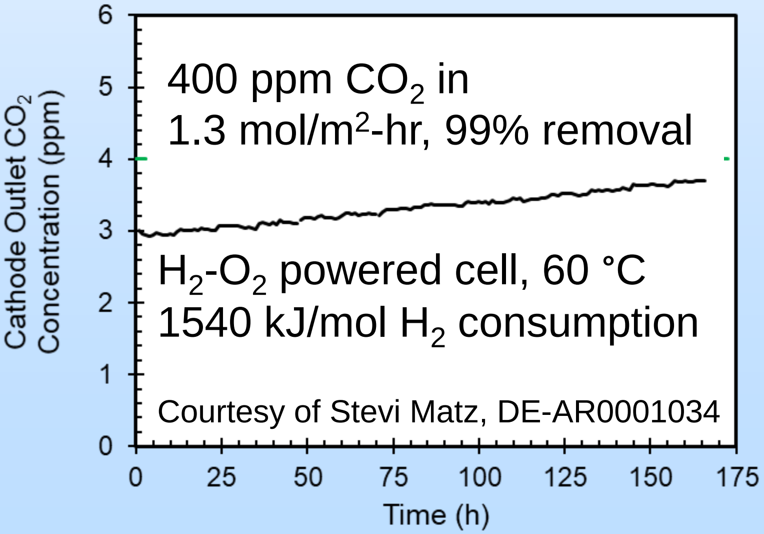
Principles of operation

1. Generate OH^-
2. Scrub CO_2 as CO_3^{2-}
3. Transport CO_3^{2-}
4. Consume OH^-
5. Release CO_2

Technical advantages

- Continuous separation
- Strong binding by OH^-
- Electrically driven
- Ambient temperature





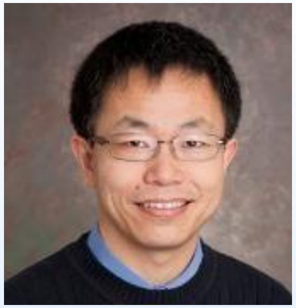
Technical Approach/Project Scope

1. **Project management and planning**
2. **Membrane fabrication –** Make flow-through PAP porous absorbers
3. **Polymer/membrane characterization –** Characterize dense and porous PAP polymer properties necessary to predict EDCS performance
4. **Membrane electrode assembly testing –** Integrate absorber, membranes, and electrodes in small single cells (25 cm^2) and test EDCS performance
5. **Process development –** High-level process design and analysis

Mile-stone	Sub-task	Milestone Description	Planned Completion
4	3.1	**Membrane anion transport:** Establish operating window where conductivity is ≥ 5 mS/cm.	3/31/2021
5	3.2	**Membrane CO_2 capture and release:** Establish operating window where first-order rate constant is ≥1000 s^{-1} and where thick-film mass transfer coefficient is ≥1 mm/s.	9/30/2021
6	4.3	**Initial cell testing and performance:** Demonstrate basic level of performance: ≤320 kJ/mol (2 MWh/t_{CO2}), 0.1 mol/m^2-hr CO_2 production (25 cm^2)	9/30/2021
7	4.3	**Final cell performance:** Characterize wide range of operating parameters. Final targets: ≤235 kJ/mol (1.5 MWh/t_{CO2}), 0.4 mol/m^2-hr CO_2 production (25 cm^2)	3/31/2022
8	5.1	**Process flowsheet:** Complete flowsheet showing high-level process design and calculate mass and energy flows	3/31/2022

Success criteria:
- Characterize PAP properties to enable modeling and analysis
- Demonstrate technical feasibility at moderate performance level

Team and Facilities



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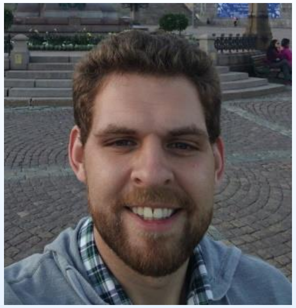

James Buchen

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Thank you to our many colleagues whose foundational work made this project possible:

- Junhua Wang
- Yun Zhao
- Teng Wang
- Stevi Matz
- Lin Shi
- David Yan
- Rohan Razdan
- Catherine Weiss
- Santiago Rojas-Carbonell
- Junwu Xiao

Membrane and cell test stations

Progress and Current Status of Project

<u>Equipment constructed / adapted</u>

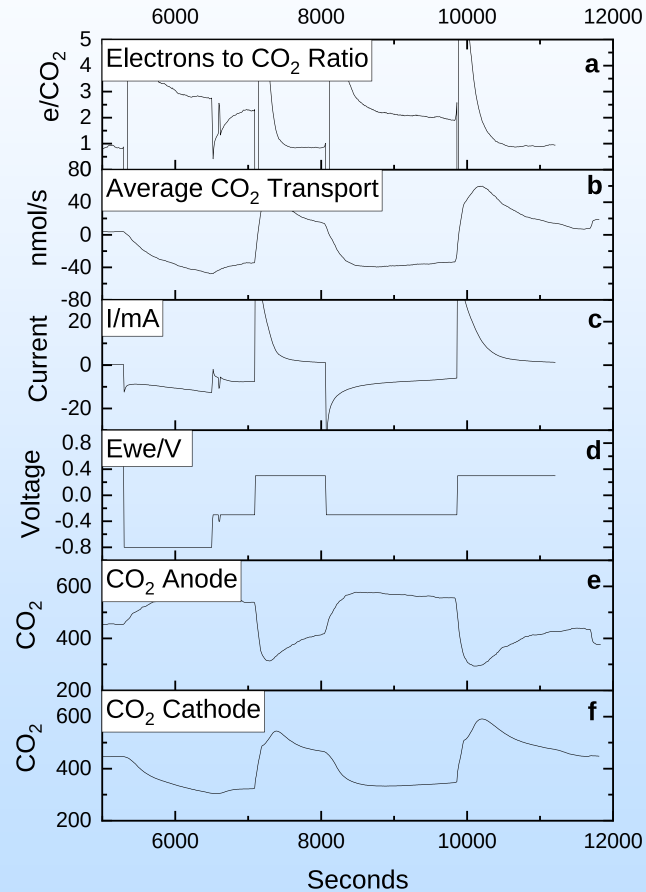
- Polymer conductivity apparatus controlling temperature, humidity, and CO_2 concentration

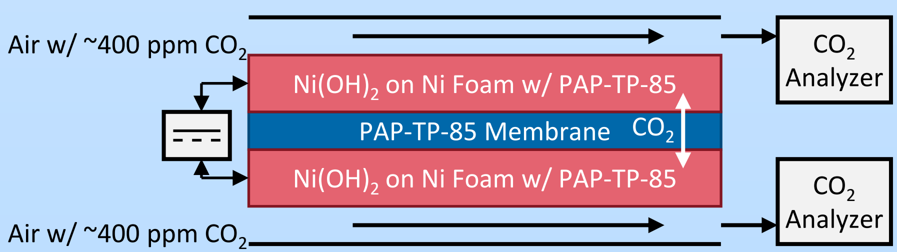
<u>Accomplishments</u>

- Fabricated porous absorbers
- $Ni(OH)_2$ electrodes with polymer electrolyte

<u>Performance achieved</u>

- Electrodes (affect cell voltage and reversal losses): 0.32 V full cycle overpotential, 100 mAh/g
- Cell: 0.05 mol/m^2-hr at 100 kJ/mol (0.6 MWh/t)
- Target: 0.40 mol/m^2-hr at 235 kJ/mol (1.5 MWh/t)





- 25 cm^2 cell
- 500 sccm gas flows
- 60 °C cell temperature
- 90% RH

Opportunities for Collaboration

- Standardization of methods to characterize kinetics and thermodynamics of CO_2 in anion exchange polymers
- Fabrication of porous polymer films
  - Structural properties are critical to device performance
  - Project will cover only a small fraction of the possible fabrication methods
- Development of CO_2 hydration catalysts
  - Accelerate CO_2 capture
  - Lower energy consumption (smaller pH swing)
- Technoeconomic analysis and manufacturing cost estimates