Electrochemically Modulated CO_2 Removal from Ocean Waters

Project Number: DE-AR0001409

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U.S. Department of Energy

National Energy Technology Laboratory

Direct Air Capture Kickoff Meeting

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Program Overview

Funding: $650,000; No Cost Share

Project Period: 2 Years; Start date TBD

Project Participants

PIs: T. Alan Hatton and Kripa K. Varanasi

Postdoc: Seoni Kim

RAs: Jack Lake and Simon Rufer

Overall Project Objectives:

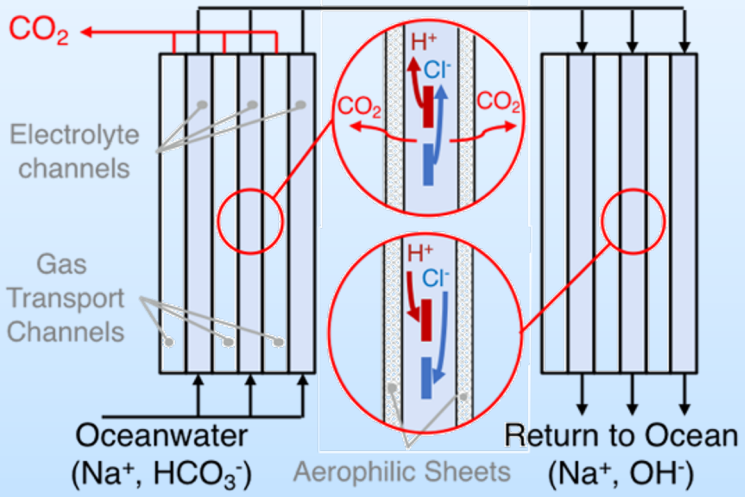
Develop membrane-free process utilizing electrochemical pH modulation to initially release CO_2 and then to re-alkalize treated water before it is returned to the ocean.

Technology Background

- **Project Concept:**
  - Ocean water acidified by release of intercalated protons with suitable cell voltage.
  - Released CO_2 nucleated on and withdrawn through nanoengineered surfaces.
  - CO_2-depleted stream alkalized and electrodes regenerated for cyclic swing operation.
- **Data that support the premise of the project:**
  - Electrode systems deployed for pH modulation in K_2CO_3 carbon capture process

    M. Rahimi, G. Catalina, M. Puccini and T. Hatton, *RSC Advances,* 1**0 (**29) 16832-16843 (2020)
  - Aerophilic surfaces for bubble nucleation and removal

    L. Rapoport, T. Emmerich and K. Varanasi, *Adv. Mater. Interfaces*, **7 (**6) 1901599 (2020)
- **Technical advantages:**
  - Easy to deploy
  - Relies on renewables (wind, solar, etc.)
  - Does not require
    - Ion exchange membranes
    - separate anolyte and catholyte streams
    - addition of chemicals
    - formation of byproducts or secondary streams.
- **Technical Challenges:**
  - Long term stability of electrodes
  - Cost of electrodes



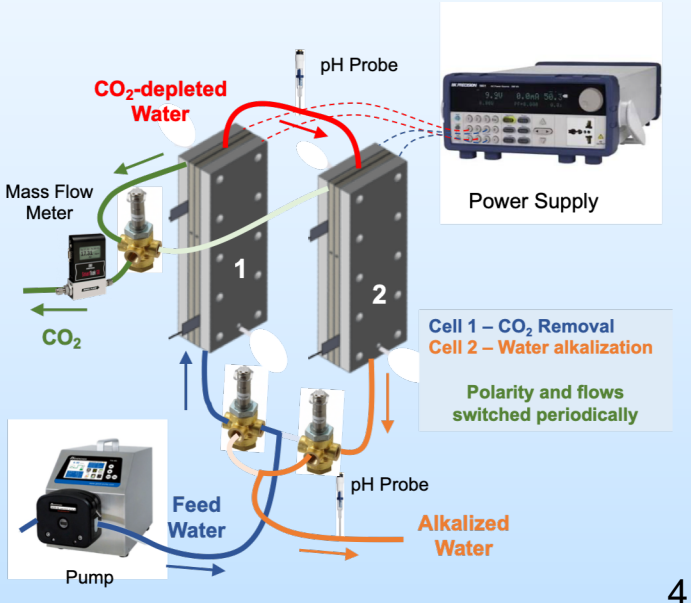
Technical Approach/Project Scope

Experimental design, work plan and Project schedule:

- Thermodynamic and transport modeling Q1-Q2
- Electrode preparation and characterization Q1-Q4
- Development of electrode fabrication technologies Q3-Q5
- Design and fabrication of aerophilic surfaces Q3-Q5
- Fabrication of integrated bench-scale units Q5-Q8
- Techno-economic analysis Q7-Q8

Project success criteria

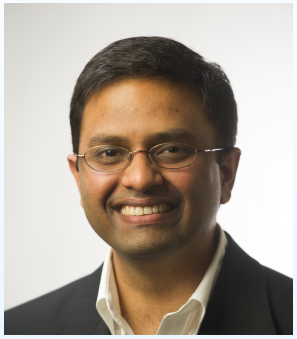
- Stable removal of 80% CO_2 in feed
- Performance fade <5% over 10,000 cycles
- Electron utilization 0.8-1 electron/mol CO_2
- Electrical energy usage <100 kJ/mol CO_2



Team and Facilities

Principal Investigators

T. Alan Hatton



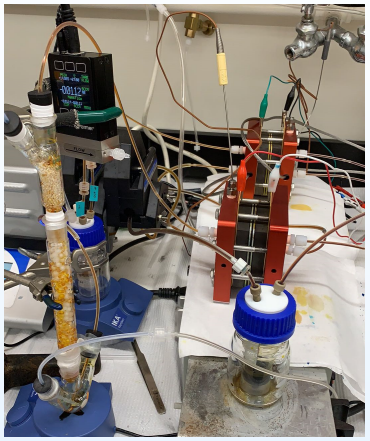
Kripa K. Varanasi

Research Team

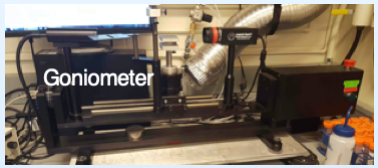
Seoni Kim

Jack Lake

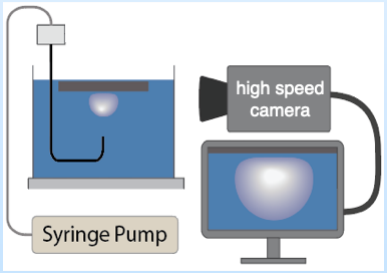
Simon Rufer

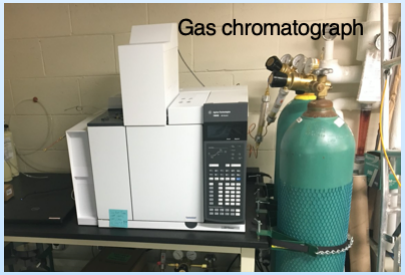


Electrochemical cell flow modules, electrode fabrication technologies, etc.



Nanoengineered surfaces, bubble capture and removal studied using goniometry, high-speed imaging, GC, etc.





Opportunities for Collaboration

Potential synergistic effects through collaboration on advancing our technologies:

- Production of specialized electrode configurations
- Understanding long-term stability and failure modes
- Collaboration with off-shore wind & energy, marine industries to understand techno-operational aspects for deployment on off-shore platforms
- National lab collaboration (in-situ XRD, advanced light source)

Potential areas of complementary work by others that may contribute to this technology:

- Techno-economic analysis
- Engineering scale-up design
- Large-scale fabrication of tailored electrodes and nanoengineered surfaces