Electrochemically Modulated CO$_2$ Removal from Ocean Waters

Project Number: DE-AR0001409

T. Alan Hatton and Kripa K. Varanasi
Massachusetts Institute of Technology

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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  • Released CO₂ nucleated on and withdrawn through nanoengineered surfaces.
  • CO₂-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 K₂CO₃ carbon capture process
    M. Rahimi, G. Catalina, M. Puccini and T. Hatton, RSC Advances, 10 (29) 16832-16843 (2020)
  • Aerophilic surfaces for bubble nucleation and removal

• 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
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% CO₂ in feed
- Performance fade <5% over 10,000 cycles
- Electron utilization 0.8-1 electron/mol CO₂
- Electrical energy usage <100 kJ/mol CO₂
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