Efficiency at Scale: High-Capacity High-Throughput

Electrochemical Carbon Capture Using Sediment Flow and Pulsed Electrolysis

Hyowon Seo; Department of Materials Science and Chemical Engineering; Stony Brook University
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Overview/Abstract

This proposal outlines an innovative approach to electrochemical carbon capture, aiming to **significantly enhance both the capacity and throughput of CO_2 separation from various gas mixtures**, including biogas and natural gas. Positioned within an isothermal and modular framework, electrochemical carbon capture systems seek to address the inherent limitations of traditional amine-based thermal-swing systems, which are notably cost-intensive and degrade thermally over time. Our preliminary electrochemical carbon capture system utilizing air-stable neutral red/leuco neutral red cycle, tested at lab scale, demonstrated the capability for 0.6 L of CO_2 separation per day from simulated flue gas, identifying critical challenges in scaling capacity and throughput to meet pilot-scale demands of 170 L of CO_2 separation per day.

To surmount these challenges, we propose two novel interventions: (1) **Sediment Flow**: To achieve high capacity in aqueous electrolytes, we will decouple hydrophobic redox-active mediators from hydroxide ions, which capture CO_2 in electrochemical systems. By leveraging sediment flow, we aim to maintain the solution's low viscosity for smoother flow and significantly boost the system's capacity. (2) **Pulsed Electrolysis**: Primarily studied in the context of electrochemical deposition, pulsed electrolysis will be adapted to enhance the transport of molecular redox-active materials, thereby improving throughput within our system.

The urgency for such advancements aligns with global decarbonization efforts escalating in response to climate change. Our preliminary systems have shown potential for scalable operations that meet the stringent requirements set by the DOE EERE FOA DE-FOA-0003206, specifically aiming to handle 170 L of CO_2 per day—a substantial increase from the initial 0.6 L per day. This project **targets a 20-fold enhancement in both capacity and throughput**, adhering to DOE's standards for technological readiness and operational scale.

Moreover, the research conducted through this proposal is expected to extend its impact beyond the specific setup of methane/CO_2 mixtures to other dispersed CO_2 sources such as flue gas and air, thereby contributing broadly to the field of carbon capture and storage. With a robust strategy in place to transition **from lab-scale demonstrations to pilot-scale operations**, this project stands poised to deliver **substantial advancements in carbon capture technologies**, supporting broader societal efforts towards achieving a net-zero future.