Title: Electrochemical Carbon Capture: Technological Advancements and Economic Outlook

Abstract:

Climate change mitigation necessitates the development of effective carbon capture technologies, which include separation and concentration of CO_2. Today's maturing thermochemical technologies have exceedingly high energy requirements and rigid form factors that restrict their versatility. Using renewable electricity, rather than heat, as the energy input to drive CO_2 separation and concentration provides a compelling alternative to surpass these limitations. A wide range of electrochemical processes was recently developed for carbon capture from various sources, including high-concentration streams such as power plant flue gas and dilute streams like air and seawater. Electrochemical carbon capture (ECC) processes rely on redox reactions to desorb CO_2 through an electro-swing mechanism. Due to this unique desorption mechanism, ECCs offer several advantages, including lower energy requirements, eliminating the need to operate at elevated temperatures, and minimizing the rate of absorbent degradation. Additionally, ECCs offer the inherent advantages of electrochemical systems, such as modularity, scalability, and ease of retrofitting. In this presentation, I describe the emerging science and research progress underlying ECC processes and assess their current maturity and trajectory for carbon capture from various sources. An electrochemically mediated amine regeneration process and a pH-mediated method, inspired by vanadium redox flow batteries, will be discussed in further detail. These systems have demonstrated efficient and continuous CO_2 separation from various sources, paving the way for sustainable carbon capture technologies.

A Short Bio:

Dr. Mim Rahimi is an Assistant Professor of Environmental Engineering at the University of Houston (UH), where he also holds an affiliate appointment with the Materials Science and Engineering Program. Before joining UH, Dr. Rahimi was a postdoctoral associate at MIT (2018–2021), working with Prof. Alan Hatton. Dr. Rahimi earned his Ph.D. in Chemical Engineering from Penn State University in 2017 under the supervision of Prof. Bruce Logan. Dr. Rahimi's research group at UH focuses on developing electrochemical processes for climate change mitigation. His work has been recognized through the 2024 NSF CAREER Award, the DOE's National EnergyTech University Prize, and the UH-Chevron Energy Transition Innovation Challenge. He was also recently selected for the American Academy of Environmental Engineers and Scientists (AAEES) 40 Under 40 Recognition Program 2025.

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