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Electrochemical conversion of high-pressure CO_2 to value-added products

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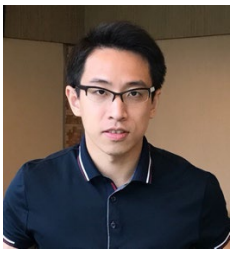
Abstract:
The electrochemical reduction of carbon dioxide, abbreviated as CO_2R, is a strategic approach aimed at completing the carbon cycle within chemical production. Traditionally, this field primarily focused on performing electrolysis on CO_2 under standard atmospheric pressure. However, in industrial settings, CO_2 is typically pressurized during its capture, transportation, and storage, often existing in a dissolved state. Our research has made a significant discovery: subjecting aqueous CO_2 to a pressure of 50 bar alters the CO_2R pathways, leading to a greater formation of formate. This phenomenon consistently occurs across commonly used CO_2R catalysts. We have achieved this by developing effective techniques for operating under high pressures, including utilizing measurable Raman spectroscopy to monitor the ongoing reaction. This approach has allowed us to establish a clear connection between the increased preference for formate and the heightened coverage of CO_2 on the cathode surface. This collaboration between theoretical models and experimental data provides robust support for this mechanism. It has also led us to enhance the cathode surface of a copper electrode with a proton-resistant layer, further amplifying the selective impact caused by pressure. Furthermore, our research has unveiled the potential to convert high-pressure gas-phase CO_2 into ethylene (C_2H_4) through CO_2R. To achieve this, we conducted density functional theory calculations to identify a range of copper alloys that promote C-C dimerization under high pressure. This dimerization step is crucial for C_2H_4 production and represents the rate-limiting step. Our theoretical predictions were rigorously validated through a combination of electrochemical measurements and operando observations, which guided us in designing a copper-based catalyst for the efficient and active conversion of high-pressure gas-phase CO_2 into C_2H_4.

Keywords:
electrochemistry, CO_2 reduction, high pressure, hydrocarbon production

Photo of invited speaker



Short Bios of invited speaker

Dr. Xu Lu obtained his B.S. and Ph.D. degrees from Department of Mechanical Engineering, University of Hong Kong in 2012 and 2017, respectively. He was then trained as a postdoctoral fellow in the Department of Chemistry, Yale University. Dr. Lu joined KAUST in March, 2021 as an Assistant Professor of Mechanical Engineering. Dr. Lu's lab, and his spin-off company, HAdrogen Tech, focus on electrochemical conversion of high-pressure CO2 conversion. So far, the Lu Lab has generated 2 U.S. provisional patents and research articles in Nature Communications (3), Journal of the American Chemical Society, Angewandte Chemie, Chemical Engineering Journal, Joule, Journal of Materials Chemistry A etc. Dr. Xu Lu is also developing cutting-edge pilot-scale showcases with industrial partners such as ACWA Power and Aramco.