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A new strategy for the optimal electroreduction of CO2 to high-value products

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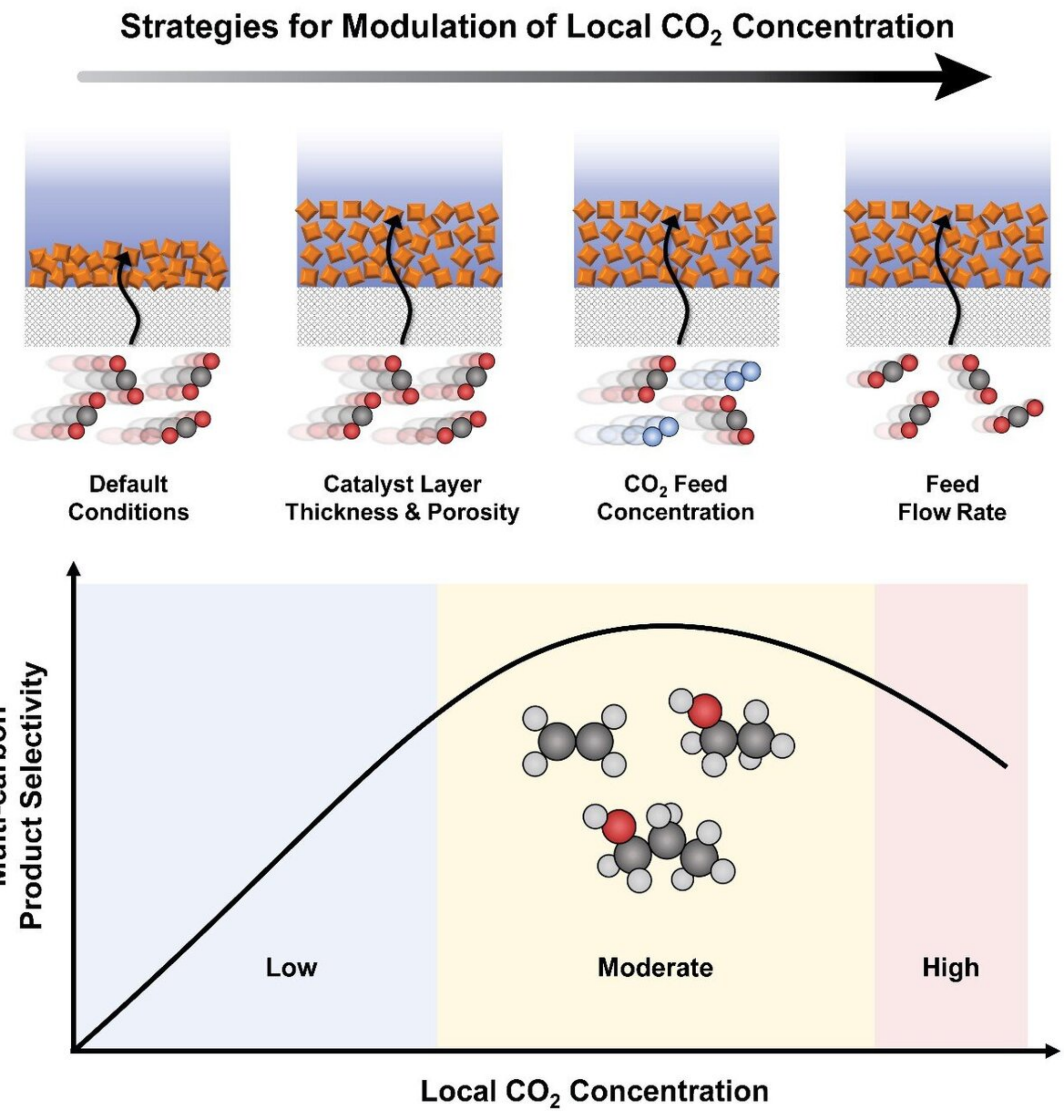

Three strategies employed in this study to modulate local CO2 concentration in a catalyst layer (top) and the relationship between local CO2 concentration and the selectivity for multi-carbon products (bottom). Note that maximum selectivity is achieved at a moderate local CO2 concentration. Credit: The Korea Advanced Institute of Science and Technology (KAIST)

A KAIST research team presented three novel approaches for modulating local carbon dioxide (CO_2) concentration in gas-diffusion electrode (GDE)-based flow electrolyzers. Their study also empirically demonstrated that providing a moderate local CO_2 concentration is effective in promoting Carbon–Carbon (C–C) coupling reactions toward the production of multi-carbon molecules. This work, featured in the May 20th issue of Joule, serves as a rational guide to tune CO_2 mass transport for the optimal production of valuable multi-carbon products.

Amid global efforts to reduce and recycle anthropogenic CO_2 emissions, CO_2 electrolysis holds great promise for converting CO_2 into useful chemicals that were traditionally derived from fossil fuels. Many researches have been attempting to improve the selectivity of CO_2 for commercially and industrially high-value multi-carbon products such as ethylene, ethanol, and 1-propanol, due to their high energy density and large market size.

In order to achieve the highly-selective conversion of CO_2 into valuable multi-carbon products, past studies have focused on the design of catalysts and the tuning of local environment related to pH, cations, and molecular additives.

Conventional CO_2 electrolytic systems relied heavily on an alkaline electrolyte that is often consumed in large quantities when reacting with CO_2, and thus led to an increase in the operational costs. Moreover, the life span of a catalyst electrode was short, due to its inherent chemical reactivity.

In their recent study, a group of KAIST researchers led by Professor Jihun Oh from the Department of Materials Science and Engineering reported that the local CO_2 concentration has been an overlooked factor that largely affects the selectivity toward multi-carbon products.

Professor Oh and his researchers Dr. Ying Chuan Tan, Hakhyeon Song, and Kelvin Berm Lee proposed that there is an intimate relation between local CO_2 and multi-carbon product selectivity during electrochemical CO_2 reduction reactions. The team employed the mass-transport modeling of a GDE-based flow electrolyzer that utilizes copper oxide (Cu2O) nanoparticles as model catalysts. They then identified and applied three approaches to modulate the local CO_2 concentration within a GDE-based electrolytic system, including 1) controlling the catalyst layer structure, 2) CO_2 feed concentration, and 3) feed flow rate.

Contrary to common intuition, the study showed that providing a maximum CO_2 transport leads to suboptimal multi-carbon product faradaic efficiency. Instead, by restricting and providing a moderate local CO_2 concentration, C–C coupling can be significantly enhanced.

The researchers demonstrated experimentally that the selectivity rate increased from 25.4% to 61.9%, and from 5.9% to 22.6% for the CO_2 conversion rate. When a cheap milder near-neutral electrolyte was used, the stability of the CO_2 electrolytic system improved to a great extent, allowing over 10 hours of steady selective production of multi-carbon products.

Dr. Tan, the lead author of the paper, said, "Our research clearly revealed that the optimization of the local CO_2 concentration is the key to maximizing the efficiency of converting CO_2 into high-value multi-carbon products."

Professor Oh added, "This finding is expected to deliver new insights to the research community that variables affecting local CO_2 concentration are also influential factors in the electrochemical CO_2 reduction reaction performance. My colleagues and I hope that our study becomes a cornerstone for related technologies and their industrial applications."

More information: Ying Chuan Tan et al. Modulating Local CO2 Concentration as a General Strategy for Enhancing C−C Coupling in CO2 Electroreduction, *Joule* (2020). DOI: 10.1016/j.joule.2020.03.013

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