

A pure water-fed membrane-electrodeassembly system for electrocatalytic reduction of carbon dioxide

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(a) The schematic of the APMA MEA system architecture for ECO_2R . (b) The schematic diagram of the ECO_2R reaction mechanism in the APMA system with an alkaline cathode environment under forward bias mode. Credit: She et al

The sustainably powered, electrochemical reduction of carbon dioxide (CO_2) into useful chemicals and feedstock could help to mitigate greenhouse gas emissions, allowing industries to reuse released CO_2 in beneficial ways. Most of the strategies for realizing this introduced so far, however, have notable limitations, including a poor stability over long periods of time.

Researchers at Hong Kong Polytechnic University, University of Oxford



and the National Synchrotron Radiation Research Center recently introduced a new membrane-electrode-assembly system that could facilitate the stable electrocatalytic reduction of CO_2 .

Notably, their proposed system, which was first introduced in a paper <u>published</u> in *Nature Energy*, is fed by pure water (H_2O) and thus does not rely on alkali-metal electrolyte.

"Our modern society heavily depends on fossil fuels to power our economy, but the resulting CO₂ emissions are a major threat to the climate," Shu Ping Lau, co-author of the paper, told Tech Xplore. "We are looking to harness and re-enter massive amounts of CO₂ into the carbon cycle by using electrocatalytic CO₂ reduction (ECO₂R) technology to combat this. However, previous research has shown that the stability of the ECO₂R system is a major challenge, with current systems lasting less than 200 hours for ECO₂R-to-ethylene (C₂H₄)."

In their recent work, Lau and his collaborators have been trying to overcome the limitations of existing systems for electrocatalytic CO_2 reduction. Their objective is to create a new electrolysis architecture that suppresses carbonate formation during ECO_2R and thus enables a prolonged stable operation.

"Our goal is to maintain an alkaline cathode environment without involving alkali metal cations, ultimately designing the APMA MEA (AEM+PEM assembly membrane-electrode assembly) architecture with pure H₂O as the anolyte," Lau explained. "In our APMA MEA ECO₂R system, we've created a way for CO₂ to react with H₂O to produce C₂H₄ and OH⁻ at the cathode, while H₂O is oxidized into O₂ and H⁺ at the anode. The resulting OH⁻ and H⁺ then combine to form H₂O in the middle of the membranes."



System stability performance of ECO_2R -to- C_2H_4 in a pure- H_2O -fed APMA-MEA cell stack containing 6 APMA-MEA cells at a constant current of 10 A. Inset: Schematic of the APMA-MEA cell stack containing 6 APMA-MEA cells for the ECO_2R reaction. Credit: She et al

The new system introduced by the researchers is comprised of two distinct membranes (AEM and PEM), a cathode catalyst (stepped-surface Cu), an anode catalyst (Pt/Ti) and pure water as the anolyte. One of its most remarkable advantages is that it does not require any additional chemicals to initiate reactions, and just uses pure H_2O as the electrolyte. This means that it could be easily scaled up to an industrial level.



"Even more impressive, the APMA MEA architecture overcomes the thermodynamic limitation of CO_2 reacting with the electrogenerated OH⁻ into carbonate, which extends the system's stability," Lau said. "With its durability and efficiency, our APMA MEA system has the potential to revolutionize CO_2 electrocatalysis technology and transform the modern fossil energy system."

In initial tests, the APMA MEA system introduced by this team of researchers achieved highly promising results. Using only pure H_2O as the anolyte and under the forward-bias mode, it was found to effectively suppress carbonate formation during ECO₂R, extending, the stability of CO₂ reduction to the hydrocarbon C₂H₄ to reach an impressive 1,000 hours.

"Our breakthrough in creating a stable and durable ECO_2R system is crucial to industrializing ECO_2R ," Lau said. "With the potential to move towards industrial-level rates, the APMA MEA system could pave the way for significant reductions in CO_2 emissions on an industrial scale."

The promising methods and technology introduced by Lau and his colleagues could soon be further improved and evaluated, both in laboratory and real-world industrial settings. Ultimately, it could contribute to ongoing global efforts aimed at reducing carbon emissions, by facilitating the electrocatalytic reduction of CO_2 .

"In our initial APMA MEA system, we encountered high operation voltage and low current density, resulting in a low yield of the desired product (C_2H_4) and overall low energy efficiency," Lau added. "Our next step is to concentrate on enhancing the <u>current density</u> and energy efficiency of the APMA system while reducing the system's overpotential."

More information: Xiaojie She et al, Pure-water-fed, electrocatalytic



CO2 reduction to ethylene beyond 1,000 h stability at 10 A, *Nature Energy* (2024). DOI: 10.1038/s41560-023-01415-4

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