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

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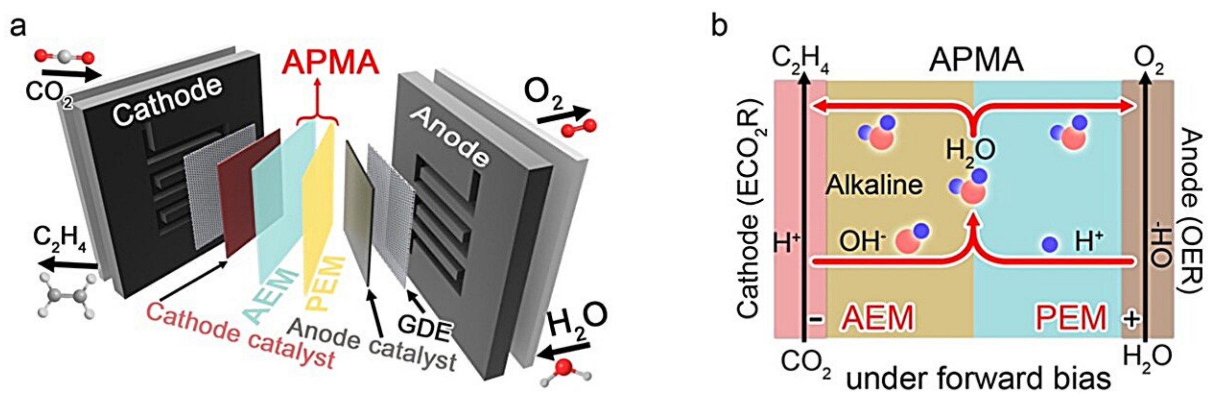


(a) The schematic of the APMA MEA system architecture for ECO_2R. (b) The schematic diagram of the ECO_2R reaction mechanism in the APMA system with an alkaline cathode environment under forward bias mode. Credit: She et al

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.

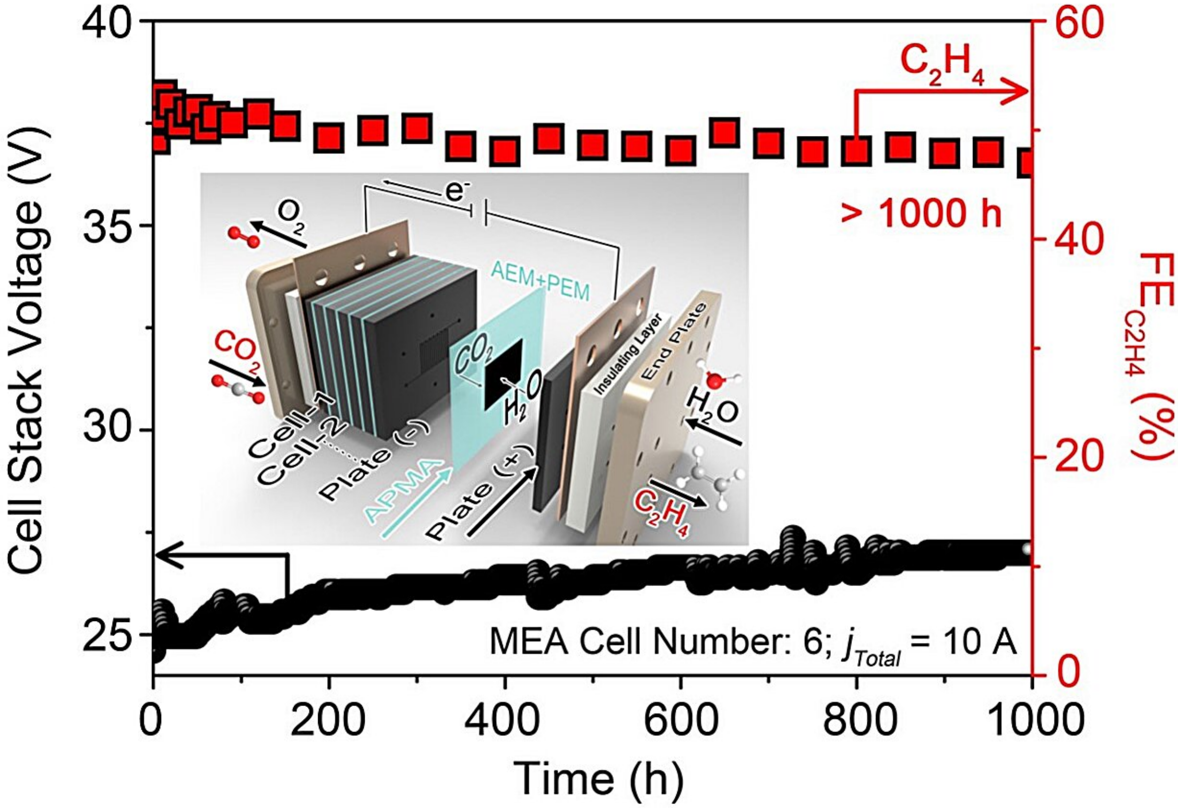
Researchers at Hong Kong Polytechnic University, University of Oxford and the National Synchrotron Radiation Research Center recently introduced a new membrane-electrode-assembly system that could facilitate the stable electrocatalytic reduction of CO_2.

Notably, their proposed system, which was first introduced in a paper published 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 CO_2 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 CO_2 into the carbon cycle by using electrocatalytic CO_2 reduction (ECO_2R) technology to combat this. However, previous research has shown that the stability of the ECO_2R system is a major challenge, with current systems lasting less than 200 hours for ECO_2R-to-ethylene (C_2H_4)."

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 H_2O as the anolyte," Lau explained. "In our APMA MEA ECO_2R system, we've created a way for CO_2 to react with H_2O to produce C_2H_4 and OH^- at the cathode, while H_2O is oxidized into O_2 and H^+ at the anode. The resulting OH^- and H^+ then combine to form H_2O 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 ECO_2R, extending, the stability of CO_2 reduction to the hydrocarbon C_2H_4 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 current density 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