Researchers develop high-efficiency carbon dioxide electroreduction system for reducing carbon footprint

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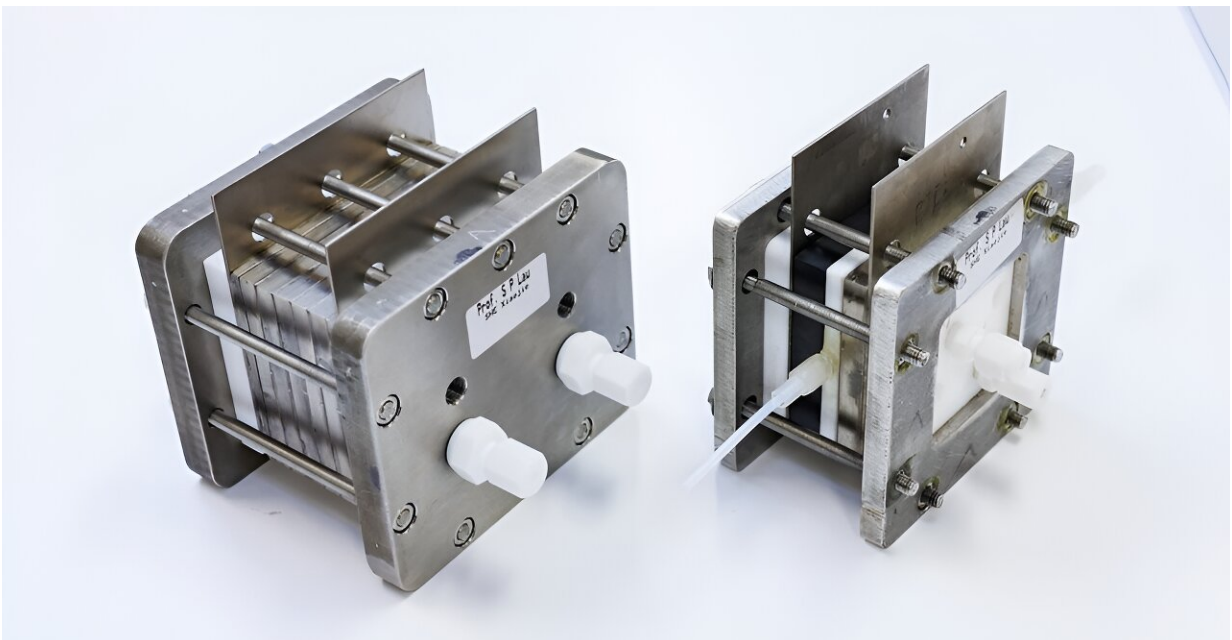

Comprising a sandwich-structured membrane electrode-assembly with a combined anion- and proton exchange membrane separating the cathode and anode, it converts CO_2 into ethylene. Credit: Hong Kong Polytechnic University

Global warming continues to pose a threat to human society and ecological systems, and carbon dioxide accounts for the largest proportion of the greenhouse gases that dominate climate warming.

To combat climate change and move towards the goal of carbon neutrality, researchers from The Hong Kong Polytechnic University (PolyU) have developed a durable, highly selective and energy-efficient carbon dioxide (CO_2) electroreduction system that can convert CO_2 into ethylene for industrial purposes to provide an effective solution for reducing CO_2 emissions.

The research was published in *Nature Energy* and won a Gold Medal at the 48th International Exhibition of Inventions Geneva in Switzerland.

Ethylene (C_2H_4) is one of the most in-demand chemicals globally and is mainly used in the manufacture of polymers such as polyethylene, which, in turn, can be used to make plastics and chemical fibers commonly used in daily life. However, it is still mostly obtained from petrochemical sources and the production process involves the creation of a very significant carbon footprint.

Led by Prof. Daniel Lau, Chair Professor of Nanomaterials and Head of the Department of Applied Physics, the research team adopted the method of electrocatalytic CO_2 reduction—using green electricity to convert carbon dioxide into ethylene, providing a more environmentally-friendly alternative and stable ethylene production.

The research team is working to promote this emerging technology to bring it closer to mass production, closing the carbon loop and ultimately achieving carbon neutrality.

Prof. Lau's innovation is to dispense with the alkali-metal electrolyte and use pure water as a metal-free anolyte to prevent carbonate formation and salt deposition. The research team calls their design the APMA system, where A stands for anion-exchange membrane (AEM), P represents the proton-exchange membrane (PEM), and MA indicates the resulting membrane assembly.

When an alkali-metal-free cell stack containing the APMA and a copper electrocatalyst was constructed, it produced ethylene with a high specificity of 50%. It was also able to operate for over 1,000 hours at an industrial-level current of 10A—a very significant increase in lifespan over existing systems, meaning the system can be easily expanded to an industrial scale.

Further tests showed that the formation of carbonates and salts was suppressed, while there was no loss of CO_2 or electrolyte. This is crucial, as previous cells using bipolar membranes instead of APMA suffered from electrolyte loss due to the diffusion of alkali-metal ions from the anolyte. The formation of hydrogen in competition with ethylene, another problem affecting earlier systems that used acidic cathode environments, was also minimized.

Another key feature of the process is the specialized electrocatalyst. Copper is used to catalyze a wide range of reactions across the chemical industry. However, the specific catalyst used by the research team took advantage of some distinctive features.

The millions of nano-scale copper spheres had richly textured surfaces, with steps, stacking faults and grain boundaries. These "defects"—relative to an ideal metal structure—provided a favorable environment for the reaction to proceed.

Prof. Lau said, "We will work on further improvements to enhance the product selectivity and seek for collaboration opportunities with the industry. It is clear that this APMA cell design underpins a transition to green production of ethylene and other valuable chemicals and can contribute to reducing carbon emissions and achieving the goal of carbon neutrality."

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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