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Using bifunctional ionomers as electrolytes to synthesize ethylene from carbon dioxide

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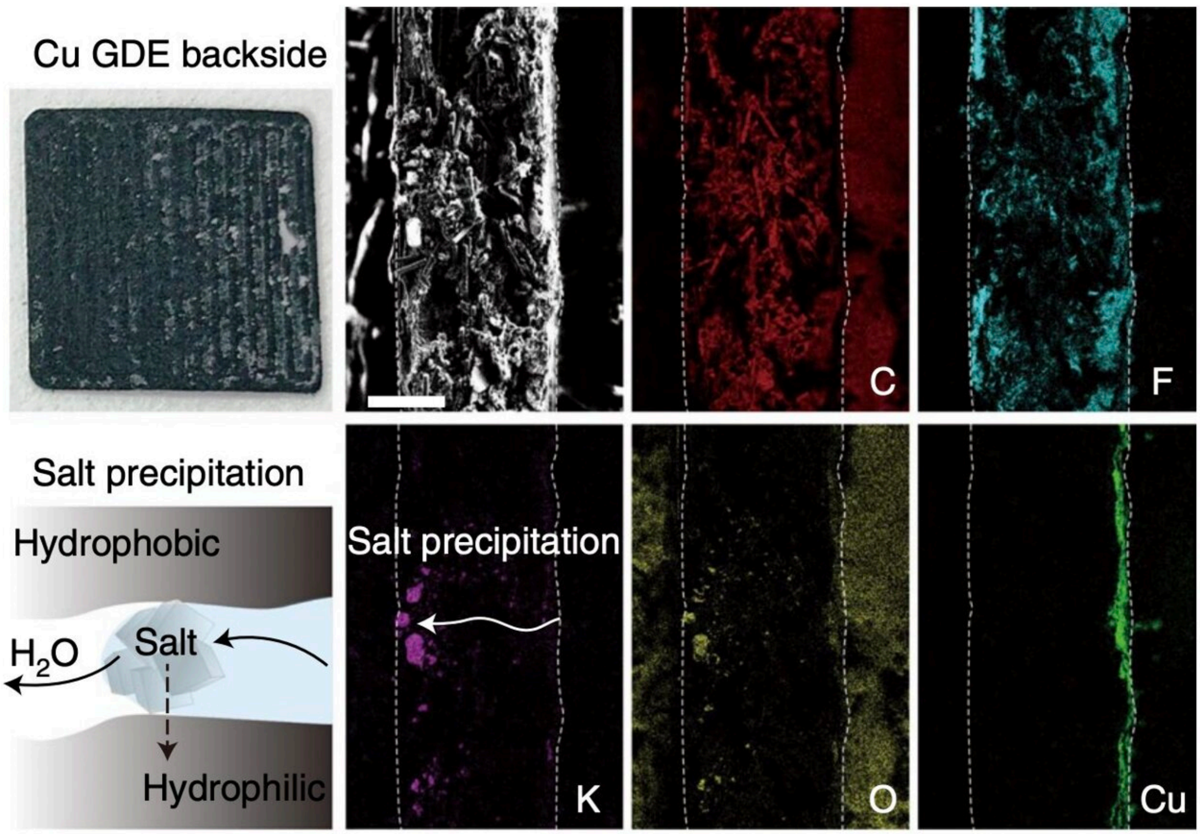

Cross-sectional scanning electron microscopy and energy-dispersive X-ray spectroscopy elemental mapping images of the Cu GDE after electrolysis, indicating the severe salt precipitation occurring in the hydrophobic pores of Cu GDE. Scale bar, 100 μm. Credit: Li et al. (*Nature Energy*, 2022)

Over the past century or so, human activities have led to the rapid deterioration of the environment on Earth, with detrimental effects such as climate change and a rise in atmospheric CO_2. Many scientists worldwide have thus been trying to devise new technologies and solutions that could help to tackle these existing environmental issues.

A possible way of reducing the presence of CO_2 in the atmosphere is to devise effective strategies to recycle CO_2 and convert it into liquid fuels or other industrial materials, ideally using sustainably produced electricity. To do this, however, researchers should be able to produce highly valuable products from CO_2 at industrial-scale current densities using a low amount of electrical energy.

Researchers at Wuhan University have recently introduced a new strategy that could be used to synthesize ethylene, a flammable hydrocarbon gas, from CO_2 and pure water. This strategy, introduced in a paper published in *Nature Energy*, entails the use of bifunctional ionomers, a reactive polymer, as polymer electrolytes to activate CO_2 and enable its efficient co-electrolysis with water to produce ethylene.

"Many CO_2 electrolyzers under development use liquid electrolytes (KOH solutions, for example), yet using solid-state polymer electrolytes can in principle improve efficiency and realize co-electrolysis of CO_2 and pure water, avoiding corrosion and electrolyte consumption issues," Wenzheng Li and his colleagues wrote in their paper. "However, a key challenge in these systems is how to favor production of multicarbon molecules, such as ethylene, which typically necessitates a strong alkaline environment."

To synthesize ethylene from $CO_{2,}$ Li and his colleagues used an alkaline polymer electrolyte (APE), which can bring the gap between cathodes and anodes down to less than tens of micrometers in membrane electrode assembly architectures (MEAs). This can in turn reduce the socalled internal ohmic loss (i.e., drop in voltage caused by the transfer of electrons in circuits or movement of ions through electrolytes and membranes), improving the technology's energy conversion efficiency at high current densities.

"We use bifunctional ionomers as polymer electrolytes that are not only ionically conductive but can also activate CO_2 at the catalyst–electrolyte interface and favor ethylene synthesis, while running on pure water," Li and his colleagues wrote in their paper. "Specifically, we use quaternary ammonia poly(ether ether ketone) (QAPEEK), which contains carbonyl groups in the polymer chain, as the bifunctional electrolyte."

The polymer electrolyte proposed by Li and his colleagues could significantly outperform liquid electrolytes, which are integrated in most existing CO_2 electrolyzers, as it could improve the devices' energy efficiency. Most notably, the team was able to render the ionomer they used bifunctional, so that it would be ionically conductive and activate $CO_{2,}$ interfering with the reaction necessary to reduce it down to ethylene.

The researchers evaluated their electrolyte by integrating it in an electrolyzer running on CO_2 and pure water. In these tests, they found that their polymer electrolyte increased the selectivity of ethylene to 50%, even in the absence of a strong alkaline environment.

"The electrolyzer running on CO_2 and pure water exhibits a total current density of 1,000 mA cm^{-2} at cell voltages as low as 3.73 V. At 3.54 V," Li and his colleagues wrote in their paper. "Ethylene is produced with the industrial-scale partial current density of 420 mA cm^{-2} without any electrolyte consumption."

The recent work by this team of researchers opens new possibilities for the conversion of CO_2 into ethylene on an industrial scale. In the future, it could inspire similar approaches for synthesizing hydrocarbons or other industrial gases from CO_2 using alkaline polymer electrolytes.

More information: Wenzheng Li et al, Bifunctional ionomers for efficient co-electrolysis of CO2 and pure water towards ethylene production at industrial-scale current densities, *Nature Energy* (2022). DOI: 10.1038/s41560-022-01092-9