Turning Pollution into Fuel with Record-Breaking CO_2-to-CO Conversion Rates

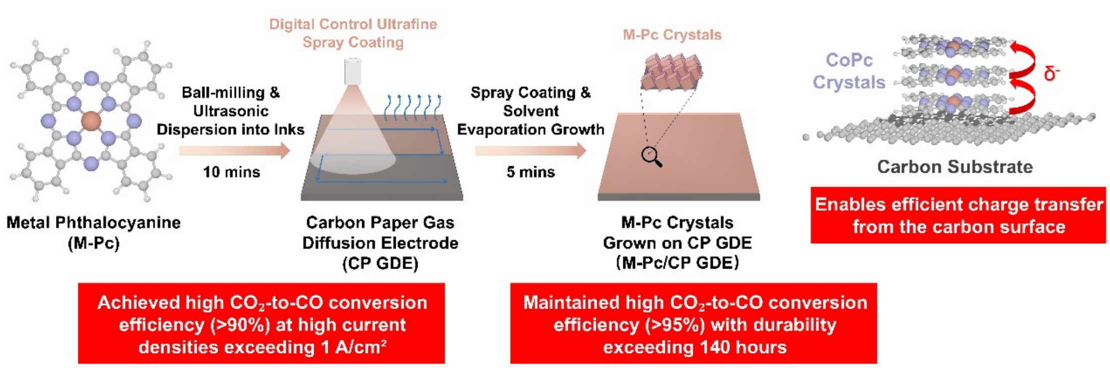
Joint press release by the Advanced Institute of Materials Research (WPI-AIMR), Tohoku University, and Hokkaido University.

From harmful to helpful: researchers have developed a record-breaking method to convert carbon dioxide into fuel.

What if we could transform harmful pollution into a helpful energy source? As we strive towards carbon neutrality, researching energy innovations that reduce pollution is crucial. Researchers at Tohoku University, Hokkaido University, and AZUL Energy, Inc. developed a streamlined process for converting carbon dioxide (CO_2) into carbon monoxide (CO) — a key precursor for synthetic fuels. Their method achieved record-breaking efficiency, cutting down the required time from 24 hours to just 15 minutes.

"CO_2-to-CO conversion is currently a hot topic to address climate change, but the conventional techniques had major pitfalls that we wanted to address," remarks Liu Tengyi (WPI-AIMR at Tohoku University). "The materials were expensive, unstable, had limited selectivity, and took long to prepare. It just wouldn't be feasible to use them in an actual industrial setting."

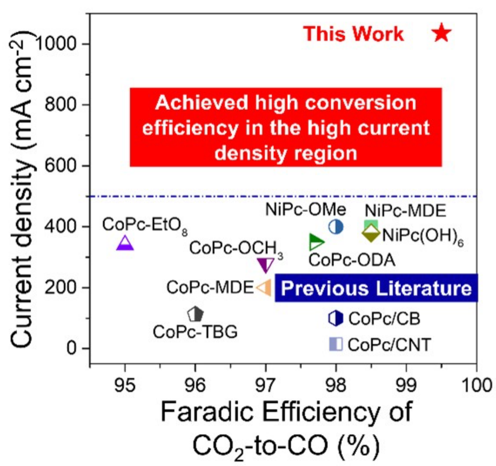
With industrial standards in mind, the researchers selected various phthalocyanines (Pc) expected to improve performance [metal-free (H_2Pc), iron (FePc), cobalt (CoPc), nickel (NiPc), and copper (CuPc)]. These were sprayed onto gas diffusion electrodes to directly form crystalline layers of the phthalocyanines on the electrode surface. Ultimately, CoPc—a low-cost pigment and metal complex—showed the highest efficiency in converting CO_2 to CO.



Fabrication method of gas diffusion electrodes modified with metal phthalocyanine crystals, and the characteristics and performance when using cobalt phthalocyanine (CoPc) crystals. ©Hiroshi Yabu et al.

This graffiti-like method of simply spraying the catalyst on a surface reduces the typical processing time down to a mere 15 minutes. Conventional methods required a tedious process of mixing conductive carbon and binders, drying, and heat treatment over 24 hours. Furthermore, under a current density of 150 mA/cm², the new system maintained stable performance for 144 hours. Using the DigCat Database (the largest experimental electrocatalysis database to date), the researchers confirmed that their catalyst surpassed all previously reported Pc-based catalysts.

"Not only is this the best Pc-based catalyst for producing CO to date, but it successfully exceeds the industrial standard thresholds for its reaction rate and stability," remarks Liu "It's the first ever to make the cut."



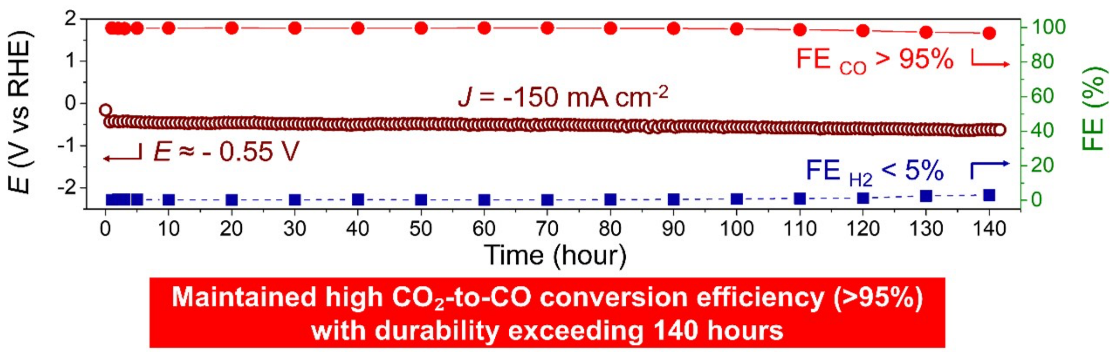
Comparison of CO_2-to-CO conversion performance between the CoPc crystal-modified gas diffusion electrode and previously reported results. © Hiroshi Yabu et al.

To investigate the reasons behind this high performance, the team conducted structural analysis using synchrotron radiation at the NanoTerasu facility, along with theoretical calculations. The results suggested that the crystallization led to densely packed molecules, which facilitated efficient electron transfer to the surface. These findings highlight that direct crystallization is an effective strategy for fabricating metal complex-based catalyst electrodes for CO_2 electroreduction.

The gas diffusion electrode fabrication method developed in this study, along with the CO_2 electrolysis technology, offers a promising pathway for synthesizing carbon monoxide

(CO), an important intermediate for synthetic fuels, from CO_2 with high efficiency using low-cost pigment-based catalysts. This approach addresses one of the key bottlenecks in synthetic fuel production by improving energy efficiency and reducing costs associated with CO_2 utilization. As such, it holds great potential as a next-generation technology for Carbon Dioxide Capture and Utilization (CCU).

The full details were published in the journal *Advanced Science* on 04 April 2025.



Durability evaluation of the CoPc crystal-modified gas diffusion electrode. ©Hiroshi Yabu et al.

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