Inexpensive blue pigment enables efficient one-step conversion of carbon dioxide to methane

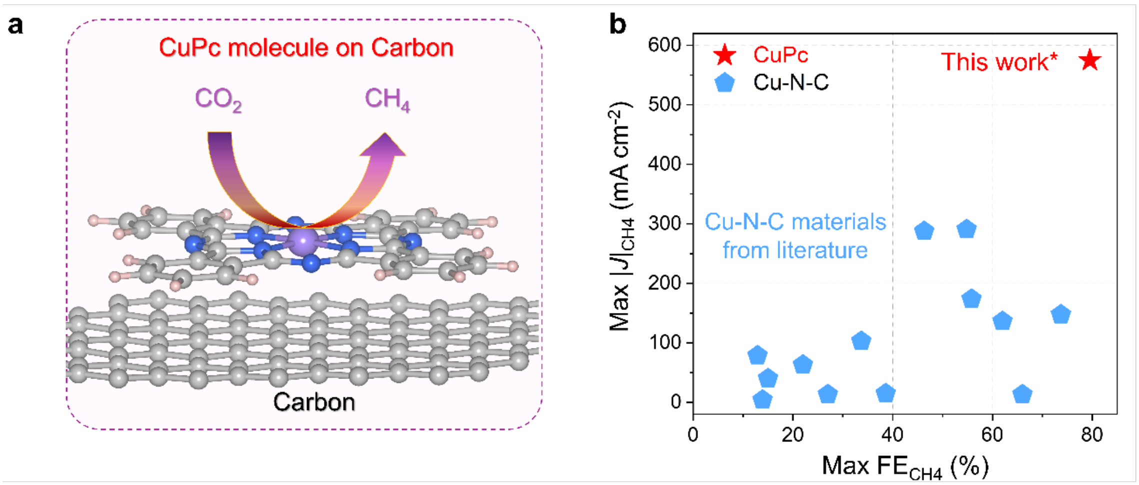
A common blue pigment could help turn carbon dioxide (CO_2) from an industrial waste product into a useful fuel. A joint research team led by Tohoku University's Advanced Institute for Materials Research (WPI-AIMR), in collaboration with Hokkaido University and startup AZUL Energy, has developed a catalyst that converts CO_2 directly into methane (CH_4) with high efficiency using copper phthalocyanine, an inexpensive and readily available blue pigment.

Details were published in the journal *Small* on August 2, 2026.

The researchers applied the copper phthalocyanine catalyst to a gas diffusion electrode, enabling CO_2 to be reduced to methane in a single electrochemical step. The system achieved a maximum current density of 575 mA cm^{-2} and a maximum Faradaic efficiency of 79.5% for methane production, demonstrating that the catalyst can selectively convert CO_2 into methane at high rates.

The catalyst also showed stable performance during long-term operation. At a current density of 150 mA cm^{-2}, the system maintained methane selectivity above 60% for approximately 80 hours. This durability and selectivity represent an improvement over conventional copper nanoparticle catalysts, which can produce a mixture of different products and make subsequent gas separation more difficult.

Converting CO_2 into useful chemicals and fuels using electricity generated from renewable energy is known as electrochemical CO_2 reduction (ECR). The approach has attracted attention as a potential means of recycling carbon while reducing reliance on fossil resources. Methane is particularly attractive as a target product because it is a widely used gaseous fuel and can potentially be integrated into existing gas infrastructure.

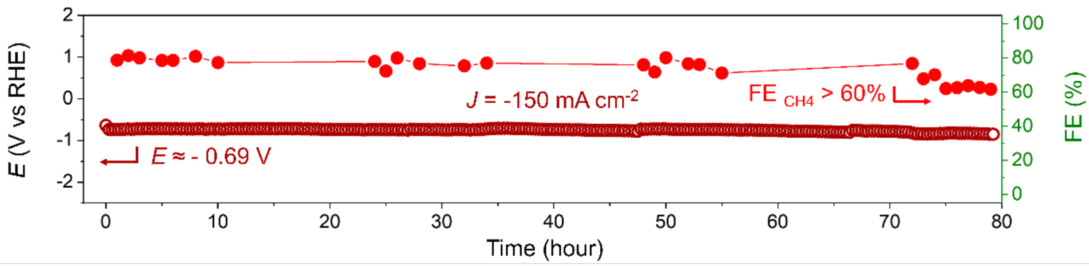


Schematic illustration of copper phthalocyanine supported on carbon (a) and catalytic performance for CO2-to-CH4 conversion (b), showing the maximum current density and maximum Faradaic efficiency. (Hiroshi Yabu et al. 2026)

However, producing methane directly from CO_2 is challenging. Electrochemical reduction involves a complex network of reaction pathways, and conventional catalysts can produce several different carbon-containing products alongside methane. Separating and purifying these products adds complexity and energy requirements to the overall process.

To understand why the new catalyst favors methane production, the researchers performed theoretical calculations of the reaction pathways. The calculations showed that the pathway leading to methane formation has a lower energy barrier on the copper phthalocyanine catalyst than pathways leading to other one-carbon products. This suggests that the catalyst can steer the reaction toward methane by favoring a more energetically accessible pathway.

“Converting CO_2 directly into CH_4 in a single, high-efficiency step has been a significant hurdle in carbon recycling,” says Professor Hiroshi Yabu of WPI-AIMR, Tohoku University, one of the lead researchers. “By using a low-cost and readily available blue pigment, we have developed an approach that could make this process more practical and scalable. We hope this work will contribute to technologies that convert carbon emissions into useful fuels.”

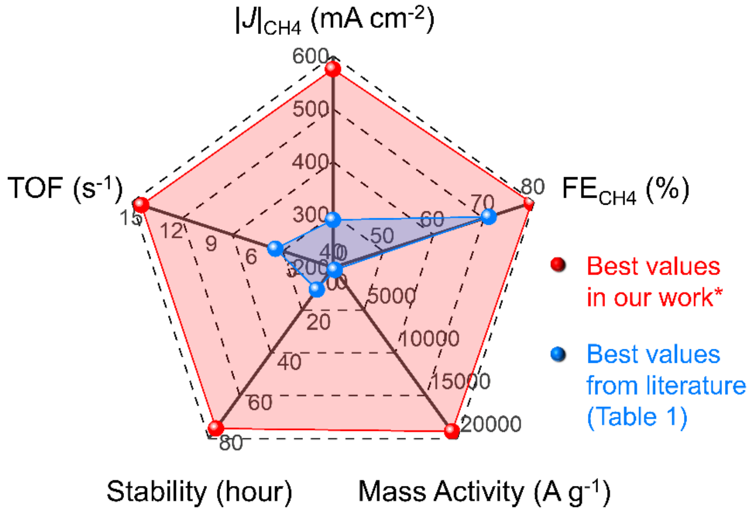


Evaluation of catalyst durability. (Hiroshi Yabu et al. 2026)

The findings could contribute to the development of next-generation carbon capture and utilization (CCU) technologies. In particular, producing methane directly from CO_2 could reduce the need for downstream separation and purification compared with systems that generate mixtures of gaseous products.

The researchers' next step is to test the catalyst in an electrolyzer using CO_2 captured from actual industrial emissions. They also plan to investigate its use with CO_2 recovered directly from the atmosphere through direct air capture (DAC) technologies. These efforts will help establish the scientific and technological foundations needed to evaluate the catalyst for larger-scale CO_2 utilization.

By combining an inexpensive catalyst with an electrochemical process powered by renewable electricity, the research provides a potential route for converting captured CO_2 into methane in a single step. Further development of the catalyst and electrolyzer system will be needed to determine its performance under practical operating conditions and its potential for integration into carbon recycling technologies.



Comparison of catalytic performance with previously reported catalysts. (Hiroshi Yabu et al. 2026)

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