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Reducing CO₂ with common elements and sunlight New rare-metal-free photocatalyst turns CO₂ into carbon resource

(Tokyo, June 22) An international collaborative research group including Tokyo Institute of Technology, Université PARIS DIDEROT and CNRS has discovered that CO₂ is selectively reduced to **CO**^[1] when a **photocatalyst**^[2] composed of an organic semiconductor material and an iron complex is exposed to visible light. They have made clear that it is possible to convert CO₂, the major factor of global warming, into a valuable carbon resource using visible light as the energy source, even with a photocatalyst composed of only commonly occurring elements.

In recent years, technologies to reduce CO₂ into a resource using metal complexes and semiconductors as photocatalysts are being developed worldwide. If this technology called artificial photosynthesis can be applied, scientists would be able to convert CO₂, which is considered the major factor of global warming and is being treated as a villain, into a valuable carbon resource using sunlight as the energy source.

Complexes and inorganic semiconductors containing precious and rare metals such as ruthenium, rhenium, and tantalum have been used in highly active photocatalysts reported so far. However, considering the tremendous amount of CO₂, there was a need to create new photocatalysts made only with elements widely available on Earth.

Professor Osamu Ishitani, Associate Professor Kazuhiko Maeda, research staff Ryo Kuriki and others of Tokyo Tech, with the support of JST (Japan Science and Technology Agency)'s Strategic Basic Research Programs (CREST Establishment of Molecular Technology towards the Creation of New Functions) for international collaborative research projects, performed collaborative research with the research group of Professor Marc Robert of Université PARIS DIDEROT and CNRS. As a result, by fusing carbon nitride, an organic semiconductor, with a complex made of iron and organic materials and using it as a photocatalyst, they succeeded in turning CO₂ into a resource at high efficiency under the condition of exposure to visible light at ordinary temperature and pressure.

By combining the organic semiconductor **carbon nitride**^[3], made of carbon and nitrogen, with an

iron complex and using it as a photocatalyst, they found that they could reduce carbon dioxide (CO_2) to carbon monoxide (CO) at high efficiency. This photocatalytic reaction progresses when exposed to visible light, which is the major component in the wavelength band of sunlight. The carbon nitride absorbs visible light and drives the migration of electrons from the reducing agent to the iron complex, the catalyst. The iron complex uses that electrons to reduce CO_2 to CO . The **turnover number**^[4], the **external quantum efficiency**^[5], and the **selectivity**^[6] of CO_2 reduction—performance indicators for the formation of CO —reached 155, 4.2%, and 99%, respectively. These values are almost the same as when precious metal or rare metal complexes are used, and about ten times more than photocatalysts reported so far using base metals or organic molecules.

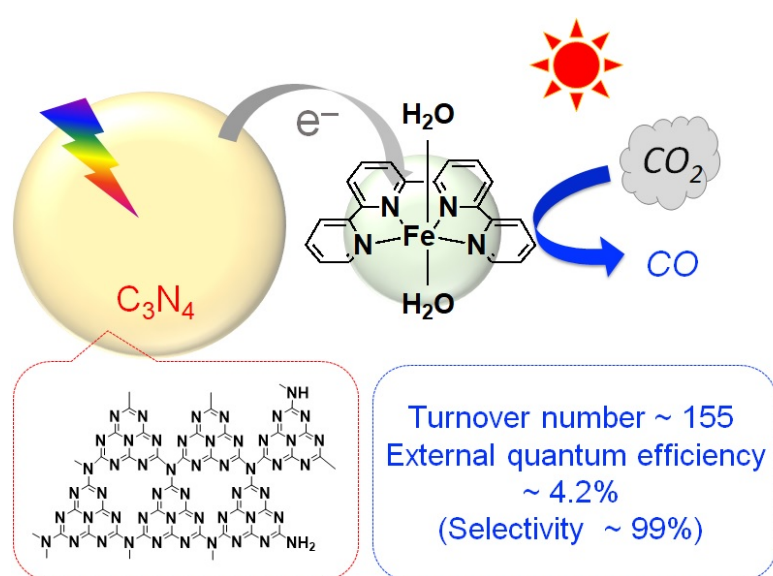


Figure 1. CO_2 reduction using a photocatalyst combining carbon nitride and an iron complex

This research was the first to demonstrate that CO_2 can be reduced into a resource efficiently using sunlight as the energy source, even by using materials which exist abundantly on Earth, such as carbon, nitrogen, and iron. Tasks remaining are to further improve their function as a photocatalyst and to succeed in fusing them with oxidation photocatalysts which can use water, which exists abundantly on Earth and is inexpensive, as a reducing agent.

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Technical Terms

- [1] **CO:** It is receiving attention as a valuable carbon resource, since hydrocarbon can be synthesized from it using methods such as the Fischer-Tropsch process.
- [2] **Photocatalyst:** Molecules or substances which promote reaction as a catalyst by absorbing light.
- [3] **Carbon nitride:** An organic semiconductor made of only carbon and nitrogen. Its structure is shown in Figure 1.
- [4] **Turnover number:** An indicator of the number of times an active site functioned in a catalytic reaction. For example, if there were 100 active sites and 10,000 product materials were produced, the turnover number is 100.
- [5] **External quantum efficiency:** The ratio of the amount of light which was used in the reaction to the amount of light exposed. For example, if the object was exposed to 10,000 photons and 100 photons took part in the reaction, the external quantum efficiency is 1%.
- [6] **Selectivity:** The ratio of the desired product to the total product formed by a chemical reaction.

Reference

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