Efficient carbon dioxide reduction under visible light with a novel, inexpensive catalyst

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The carbon dioxide (CO$_2$) released into the atmosphere during fossil fuel burning is a leading cause of global warming. One way to address this growing threat is to develop CO$_2$ reduction technologies, which convert CO$_2$ into useful chemicals, such as CO and formic acid (HCOOH). In particular, photocatalytic CO$_2$ reduction systems use visible or ultraviolet light to drive CO$_2$ reduction, much like how plants use sunlight to conduct photosynthesis. Over the past few years, scientists have reported many sophisticated photocatalysts based on metal-organic frameworks and coordination polymers (CPs). Unfortunately, most of them either require complex post-synthesis treatment and modifications or are made from precious metals.

In a recent study published in ACS Catalysis, a research team from Japan found a way to overcome these challenges. Led by Specially Appointed Assistant Professor Yoshinobu Kamakura and Professor Kazuhiko Maeda from Tokyo Institute of Technology (Tokyo Tech), the team developed a new kind of photocatalyst for CO$_2$ reduction based on a CP containing lead–sulfur (Pb–S) bonds. Known as KGF-9, the novel CP consists of an infinite (–Pb–S–)$_n$ structure with properties unlike any other known photocatalyst.

A novel coordination polymer-based photocatalyst for CO$_2$ reduction exhibits unprecedented performance, giving scientists at Tokyo Tech hope in the fight against global warming. Made from abundant elements and requiring no complex post-synthesis treatment or modifications, this promising photocatalyst could pave the way for a new class of photocatalysts for efficiently converting CO$_2$ into useful chemicals.

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For instance, KGF-9 has no pores or voids, meaning that it has a low surface area. Despite this, however, it achieved a spectacular photoreduction performance. Under visible-light irradiation at 400 nm, KGF-9 demonstrated an apparent quantum yield (product yield per photon absorbed) of 2.6% and a selectivity of over 99% in the reduction of CO$_2$ to formate (HCOO$^-$). "These values are the highest yet reported for a precious-metal-free, single-component photocatalyst-driven reduction of CO$_2$ to HCOO$^-$," says Prof. Maeda. "Our work could shed light on the potential of nonporous CPs as building units for photocatalytic CO$_2$ conversion systems."

In addition to its remarkable performance, KGF-9 is easier to synthesize and use compared to other photocatalysts. Since the active Pb sites (where CO$_2$ reduction occurs) are already "installed" on its surface, KGF-9 does not require the presence of a cocatalyst, such as metal nanoparticles or metal complexes. Moreover, it requires no other post-synthesis modifications to operate at room temperature and under visible light illumination.

The team at Tokyo Tech is already exploring new strategies to increase the surface area of KGF-9 and boost its performance further. As the first photocatalyst with Pb(II) as an active center, there is a good chance that KGF-9 will pave the way to a more economically feasible CO$_2$ reduction. In this regard, the research team says, "We believe that our study provides an unprecedented opportunity for developing a new class of inexpensive photocatalysts for CO$_2$ reduction consisting of earth-abundant elements."


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