Review of technologies that boost potential for carbon dioxide conversion to useful products

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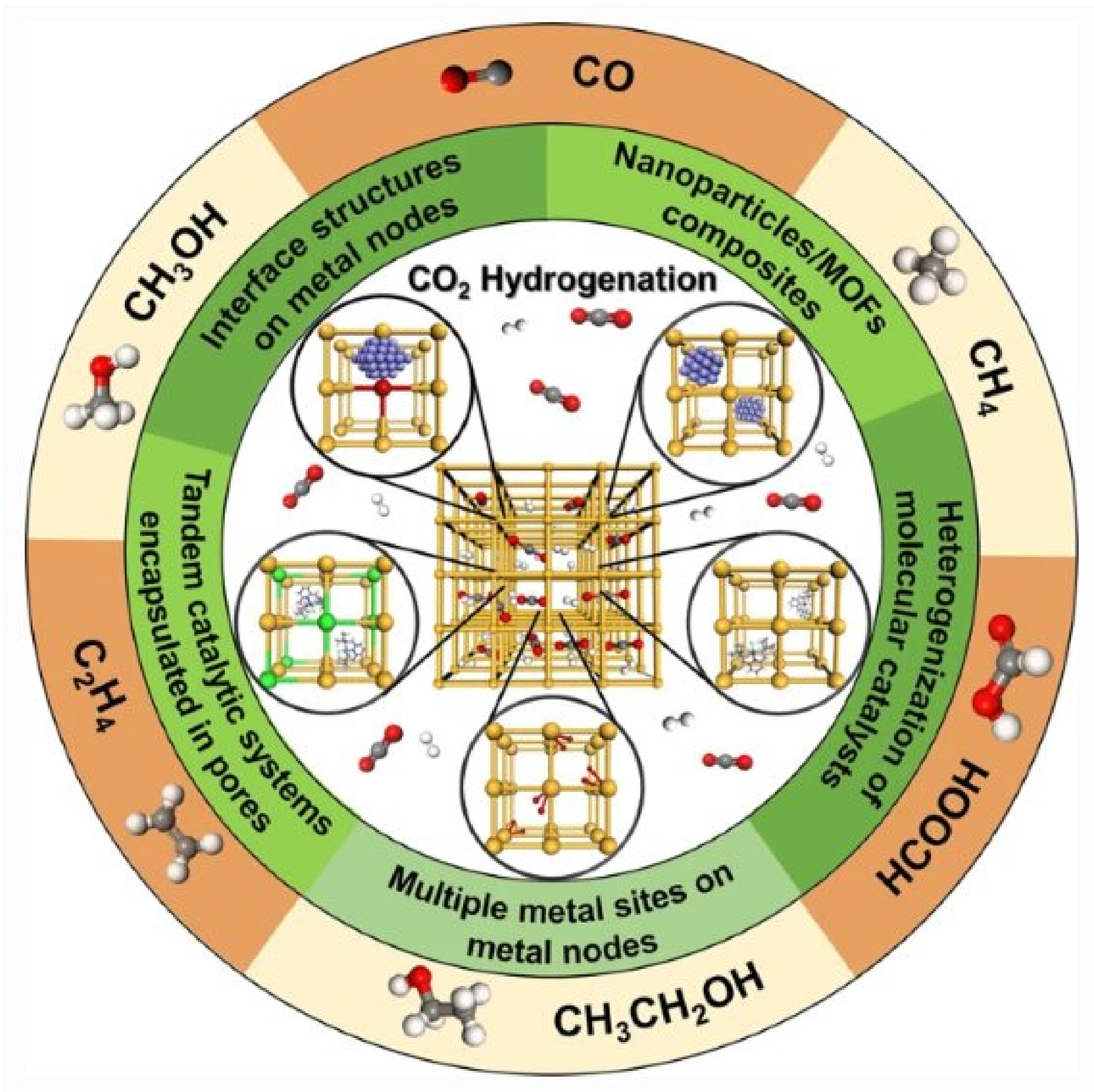

With the well-defined reticular frameworks and flexible modifiability, metal-organic frameworks (MOFs) can be the ideal platform to construct the enabled catalysts for carbon dioxide hydrogenation with the enhancement of catalytic activity and precise control of selectivity. Credit: Tsinghua University Press

The excessive emission of greenhouse gases, especially carbon dioxide, is rapidly raising the average global temperature. Capturing the carbon dioxide and converting it to useful fuels and chemicals can be an ideal way to reduce carbon dioxide concentration and ease this serious environmental problem.

Among the technologies that hold promise for carbon dioxide conversion is the hydrogenation of carbon dioxide. The interest is strong because hydrogen is a green and sustainable energy which can be continually produced. In working to advance the technology, various researchers have tested a range of catalysts for carbon dioxide hydrogenation, but there are still challenges in applying these catalysts in industrial settings. Metal-organic frameworks based catalysts offer an alternative to traditional catalysts for these technologies. Thus, the team of researchers has systematically reviewed metal-organic frameworks based catalysts for selective hydrogenation of carbon dioxide with a goal of developing catalysts that have great potential in future applications of carbon dioxide hydrogenation.

The team published their findings in *Nano Research*.

Capturing carbon dioxide has become an important way to ease the negative impacts it has on the environment. But once the carbon dioxide is captured, researchers then face the challenge of what to do with the captured carbon dioxide because in the past there have not been industrial uses for such a large volume of carbon dioxide. Knowing that natural carbon hydrogenation has produced fossil energy sources, such as oil, coal, and natural gas, during photosynthesis, researchers have determined that synthetic carbon dioxide hydrogenation holds great potential as a method for reusing the captured carbon dioxide.

But finding the right catalyst to use in the hydrogenation of carbon dioxide has been a challenge because traditional catalysts require a high temperature in order to convert the carbon dioxide. These harsh conditions of heat increase the carbon emissions and cause the fast sintering of the active substances. And the limited catalytic activity and selectivity for hydrogenation of carbon dioxide on traditional catalysts still constraint the development in industry setting. The researchers wanted to construct novel catalysts for hydrogenation of carbon dioxide with the higher catalytic performance in the milder conditions, especially for avoiding the high temperature.

The researchers turned their attention to metal-organic frameworks based catalysts. The metal-organic frameworks, a class of crystalline materials, can provide an ideal platform to construct novel catalysts for carbon dioxide hydrogenation under mild conditions. The metal-organic frameworks offer the advantage of being tunable frameworks with well-defined pores that encourage the construction of diverse catalytic sites. These catalytic structures can be used toward different products, such as carbon monoxide, methane, formic acid, methanol and C_{2+} products. In their research, the team conducted a detailed, systematic review of a variety of metal-organic frameworks based catalysts for potential use in the selective hydrogenation of carbon dioxide.

Although much progress has been made in developing metal-organic frameworks based catalysts, the researchers note that several challenges remain. More in-depth research is needed to address these issues.

Looking ahead to future research in the area of metal-organic frameworks based catalysts, the researchers make four recommendations for possible future studies.

First, they suggest that more extensive design and accurate synthesis are needed in constructing the interface structures in the metal-organic frameworks. Next, the researchers suggest that the carbon dioxide conversion at low temperatures can be improved by introducing functional sites within the metal-organic frameworks to assist in the activation of the carbon dioxide. Their third recommendation is that more in-depth design of catalytic sites within the metal-organic frameworks is needed to reduce the dependence of target product selectivity on the intrinsic properties of metals. Their final recommendation is to develop high pressure in situ characterization technologies, such as high pressure in situ X-ray absorption spectroscopy, X-ray diffraction analysis, and Raman spectroscopy, to characterize the dynamic structural change of metal-organic frameworks based catalysts during carbon dioxide hydrogenation at high pressure.

"We hope that our discussion about metal-organic frameworks based catalysts for selective hydrogenation of carbon dioxide can provide some insights for developing the enabled catalysts to achieve high activity, excellent selectivity, and good stability. We believe that metal-organic frameworks based catalysts have the great development prospects and application potential in carbon dioxide hydrogenation under mild conditions in the future," said Guodong Li, a professor at the National Center for Nanoscience and Technology.

More information: Shengxian Shao et al, Recent advances in metal-organic frameworks for catalytic CO2 hydrogenation to diverse products, *Nano Research* (2022). DOI: 10.1007/s12274-022-4576-z

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