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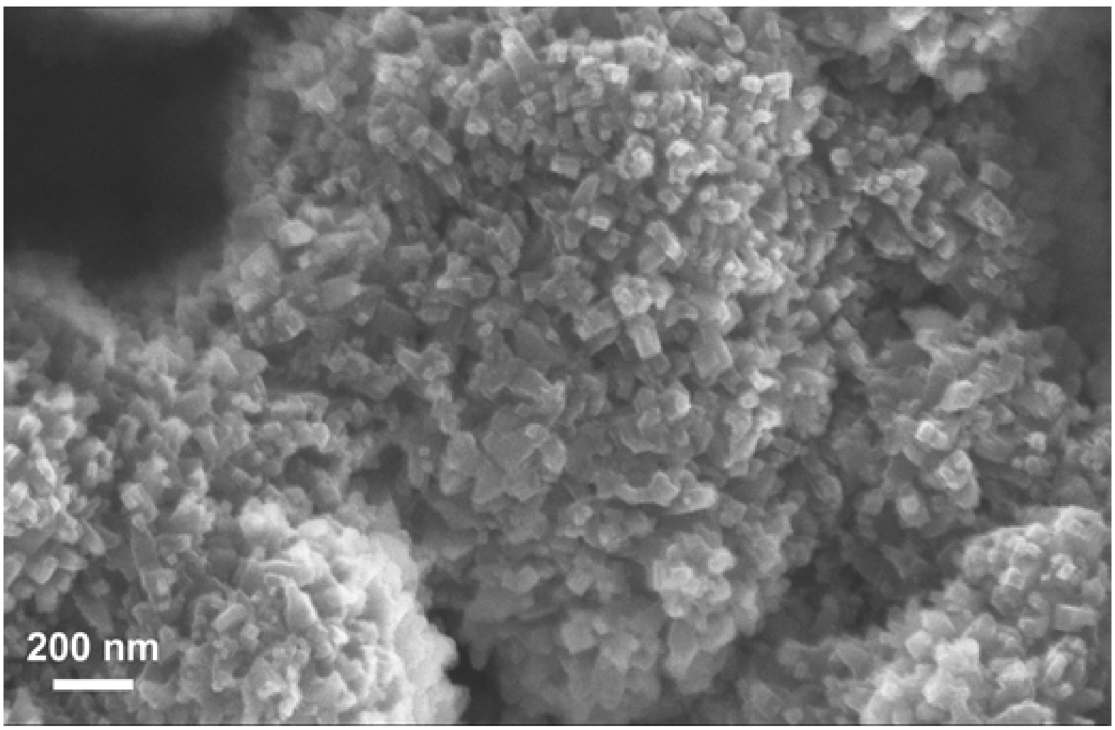
Materials Could Capture CO2 and Make It Useful

Novel molecular structures are a first step toward economical carbon capture at a wide scale.

By Richard Martin on September 24, 2015



The intricate, highly porous structure of covalent organic frameworks makes them uniquely suited for capturing carbon dioxide.

Although progress has been made in limiting carbon emissions in some countries, particularly in Europe and North America, it's clear that finding ways to capture carbon dioxide from smokestacks – or from the atmosphere – is becoming increasingly imperative. Available systems dramatically increase the cost of electricity from plants equipped with the technology. And what to do with all that carbon dioxide after it's separated remains problematic.

Now a team of scientists at Lawrence Berkeley National Laboratory and the University of California, Berkeley, have devised a method that uses super-porous molecular structures known as covalent organic frameworks, with catalysts to convert the carbon dioxide to carbon monoxide, which can be used in making a range of materials including fuels, plastics, and even pharmaceuticals.

The new materials, says Chris Chang, a chemist with Berkeley Lab's Chemical Sciences Division and one of the co-leaders of the research team, are based on "a highly stable, porous structure that's decorated with all of these catalysts." Though it's early stage research and nowhere near ready to scale up to power plant levels, it's an important step toward finding practical ways to absorb and use carbon dioxide in both waste streams and the air.

First developed in the mid-2000s by Omar Yaghi, now a professor of chemistry at UC Berkeley and the co-director of the Kavli Energy NanoSciences Institute, covalent organic frameworks are intricate, highly porous crystals that have a range of potential applications in gas storage, photonics, and various chemical processes. They are especially valuable as carbon capture materials because they function in the presence of water, which means you can eliminate the toxic organic solvents that are used in other forms of carbon capture; you're no longer "fixing one problem and creating another," as Yaghi puts it.

Capturing the carbon is half of the solution; turning it into usable materials is the second half. "The challenge has always been, could you convert it into some starting material that can be used as feedstocks for useful chemicals?" says Yaghi. "This work is the first step toward that challenge."

Work on carbon capture from the waste streams of power plants has stalled in recent years (see "What Carbon Capture Can't Do"). Current approaches center on postcombustion capture, generally using amine-based solvents; precombustion methods, such as gasifying coal before burning it; and oxy-combustion, which burns coal in pure oxygen rather than air. All are effective, but they're expensive and inefficient. And none will work for removing carbon from the atmosphere (see "Can Sucking CO2 Out of the Atmosphere Really Work?").

Work on novel techniques, like the research of Yaghi and Chang and their team, could open up new avenues to make carbon capture more feasible. One limitation is that the catalysis requires energy: thus, the system to capture and convert carbon dioxide would itself consume electricity. Chang says one goal is to link devices for carbon capture and conversion with solar panels.

"Capturing carbon selectively is a daunting challenge," says Yaghi. "And converting it into a useful material adds to that. Five years ago we couldn't have said we could do it. Now I wouldn't say we've solved it, but we're now in a position to say that this is feasible."

Credit: Images by courtesy of University of California, Berkeley

Tagged: Energy, carbon capture, carbon emissions, CO2, University of California, Lawrence Berkeley National Laboratory

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COSMOS

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Carbon capture that could turn a profit

A catalyst that turns CO_2 into carbon monoxide could curb greenhouse emissions while also providing a useful commercial gas. Viviane Richter explains.

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Carbon dioxide from coal-fired power plants is the greenhouse gas most responsible for climate change.

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Carbon dioxide is a climate supervillain – hard to capture and even harder to lock away. But instead of trying to banish the greenhouse gas to an underground prison, why not reform it?

Chemists at the University of California in Berkeley have developed a catalyst that turns carbon dioxide from a costly waste product into a valuable resource. Their catalyst converts CO_2 into carbon monoxide. While that's not a gas you'd want to breathe in, it is a useful raw material industry already uses to manufacture plastics and fuels.

Matthew Hill, a material scientist at CSIRO, says he's impressed by the catalyst's "dramatic" performance. The Berkeley team published their discovery in *Science* in August.

But the world is still not relinquishing its dependence on cheap coal

Before humanity became addicted to coal a couple of hundred years ago, CO_2 levels in the atmosphere were around 280 parts per million. Today, they are nudging 400 ppm and still rising sharply. But the world is still not relinquishing its dependence on cheap coal. Carbon capture and storage (CCS) is one answer. Last year the world's first commercial carbon-capture power plant opened at Boundary Dam in Canada. The plant's flue gases are bubbled through large vats of amine solution that trap the CO_2. It's an expensive process. Costs at Boundary Dam are offset by selling the gas to a nearby oil company where it is used to drive petroleum out of the ground. But that strategy won't work everywhere. "We need an alternative," Hill says.

So Christian Diercks, joint leader of the new study, decided to convert the CO_2 into carbon monoxide (CO), a "foundation molecule" used to manufacture plastics and diesel.

Carbon monoxide, when mixed with hydrogen, can be used to make diesel fuel

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Nearly 20 years ago, chemists discovered how to use chemicals called cobalt porphyrins to convert CO_2 into CO. Known as electrocatalysts, they pluck an oxygen molecule from every passing CO_2 molecule when an electric current is applied to a solution. Unfortunately, these electrocatalysts are only stable in organic solvents that are environmentally harmful. In water they tend to clump, making them slow and inefficient.

So Diercks used some chemical wizardry to make the electrocatalysts soluble and stable in water. He reinforced the cobalt porphyrin molecules by loosely weaving them together to form tall, interlocked stacks.

Locked in this scaffold, the catalyst resists clumping while channels between the loose weave leave room for CO_2 to slip in. When the team coated the interwoven chemical on to an electrode, then dipped it in water, each porphyrin turned CO_2 to CO at the rate of 290,000 molecules a second. That's a 26-fold improvement over the previous catalyst. The material was also very stable, powering on undiminished for the full 140 hours it was tested.

Diercks has only made milligram quantities of the catalyst so far, and says at this point it is impossible to calculate what the scale-up costs would be for a power plant.

But Hill remains optimistic about the catalyst's potential to limit CO_2 emissions. "If you can turn that CO_2 into a commodity that has value associated with it – that could be the tipping point," he says.

Viviane Richter is a staff writer at COSMOS.