Researchers develop new technology to recycle greenhouse gas into energy, materials

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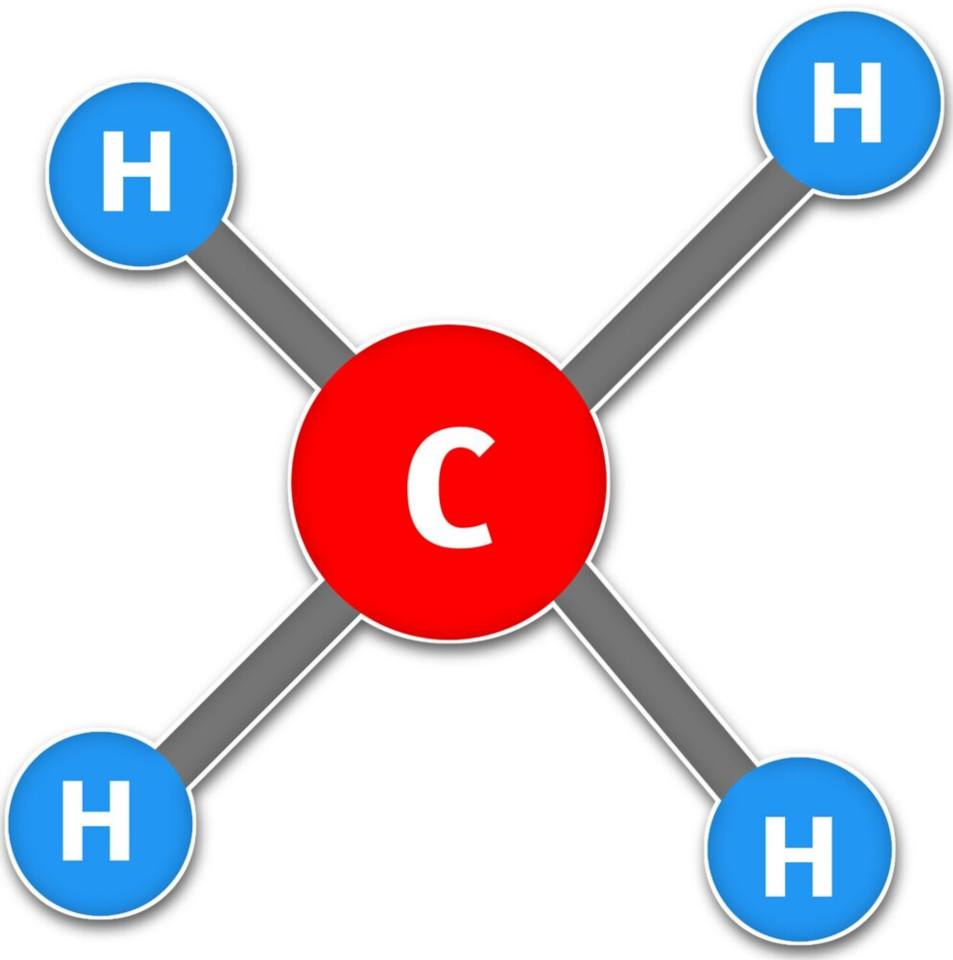

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A pair of University of Central Florida researchers has developed new methods to produce energy and materials from the harmful greenhouse gas, methane.

Pound-for-pound, the comparative impact of methane on the Earth's atmosphere is 28 times greater than carbon dioxide—another major greenhouse gas—over a 100-year period, according to the U.S. Environmental Protection Agency.

This is because methane is more efficient at trapping radiations, despite having a shorter lifetime in the atmosphere than carbon dioxide.

Major sources of methane emissions include energy and industry, agriculture and landfills.

The new UCF innovations enable methane to be used in green energy production and to create high-performance materials for smart devices, biotechnology, solar cells and more.

The inventions come from nanotechnologist Laurene Tetard and catalysis expert Richard Blair, who have been research collaborators at UCF for the past 10 years.

Tetard is an associate professor and associate chair of UCF's Department of Physics and a researcher with the NanoScience Technology Center, and Blair is a research professor at UCF's Florida Space Institute.

A better, cleaner technology for producing hydrogen

The first invention is a method to produce hydrogen from hydrocarbons, such as methane, without releasing carbon gas.

By using visible light—such as a laser, lamp or solar source—and defect-engineered boron-rich photocatalysts, the innovation highlights a new functionality of nanoscale materials for visible light-assisted capture and the conversion of hydrocarbons like methane. Defect engineering refers to creating irregularly structured materials.

The UCF invention produces hydrogen that is free from contaminants, such as higher polyaromatic compounds, carbon dioxide or carbon monoxide, that are common in reactions performed at higher temperatures on conventional catalysts.

The development can potentially lower the cost of catalysts used for creating energy, allow for more photocatalytic conversion in the visible range, and enables more efficient use of solar energy for catalysis.

Market applications include possible large-scale production of hydrogen in solar farms and the capture and conversion of methane.

"That invention is actually a twofer," Blair says. "You get green hydrogen, and you remove—not really sequester—methane. You're processing methane into just hydrogen and pure carbon that can be used for things like batteries."

He says traditional hydrogen production uses high temperatures with methane and water, but in addition to hydrogen, that process also generates carbon dioxide.

"Our process takes a greenhouse gas, methane and converts it into something that's not a greenhouse gas and two things that are valuable products, hydrogen and carbon," Blair says. "And we've removed methane from the cycle."

He noted that at UCF's Exolith Lab they were able to generate hydrogen from methane gas using sunlight by putting the system on a large solar concentrator.

Knowing this, he says countries that don't have abundant sources of power could use the invention since all they would need is methane and sunlight.

Besides oil and natural gas systems, methane exists in landfills, industrial and agricultural areas, and wastewater treatment sites.

Growing contaminant-free carbon nano/microstructures

This technology developed by Tetard and Blair is a method for producing carbon nanoscale and microscale structures with controlled dimensions. It uses light and a defect-engineered photocatalyst to make patterned, well-defined nanoscale and microscale structures from numerous carbon sources. Examples include methane, ethane, propane, propene and carbon monoxide.

"It's like having a carbon 3D printer instead of a polymer 3D printer," Tetard says. "If we have a tool like this, then maybe there are even some carbon scaffolding designs we can come up with that are impossible today."

Blair says the dream is to make high-performance carbon materials from methane, which is currently not done very well right now, he says.

"So, this invention would be a way to make such materials from methane in a sustainable manner on a large industrial scale," Blair says.

The carbon structures produced are small but well structured, and can be arranged precisely, with precise sizes and patterns.

"Now you're talking high-dollar applications, perhaps for medical devices or new chemical sensors," Blair says. "This becomes a platform for developing all sorts of products. The application is only limited by the imagination."

Since the growth process is tunable at different wavelengths, design methods could incorporate various lasers or solar illumination.

Tetard's lab, which works at the nanoscale, is now trying to reduce the size.

"We're trying to think of a way to learn from the process and see how we could make it work at even the smaller scales—control the light in a tiny volume," she says.

"Right now, the size of the structures is microscale because the light focal volume we create is microsize," she says. "So, if we can control the light in a tiny volume, maybe we can grow nano-sized objects for patterned nanostructures a thousand times smaller. That's something we're thinking of implementing in the future. And then, if that becomes possible, there are many things we can do with that."

A better, cleaner technology for producing carbon

The researchers' better, cleaner technology for producing hydrogen was actually inspired by an earlier innovative method of theirs that makes carbon from defect-engineered boron-nitride using visible light.

They discovered a new way to produce carbon and hydrogen through a chemical cracking of hydrocarbons with energy supplied by visible light coupling with a metal-free catalyst, defect-engineered boron-nitride.

Compared to other methods, it's better because it doesn't require significant energy, time, or special reagents or precursors that leave impurities.

All that's left is carbon and some traces of boron and nitrogen, none of which are toxic to humans or the environment.

The photochemical transformation technology lends itself to many applications, including sensors or new components for nanoelectronics, energy storage, quantum devices and green hydrogen production.

Strong collaboration

As longtime research collaborators Tetard and Blair are all too familiar with the old saying, "If at first you don't succeed, try, try again."

"It took a while to get some really exciting results," Tetard says. "In the beginning, a lot of the characterization that we tried to do was not working the way we wanted. We sat down to discuss puzzling observations so many times."

Yet, they plowed forward, and their perseverance paid off with their new inventions.

"Richard has a million different ideas on how to fix problems," Tetard says. "So eventually, we would find something that works."

She and Blair joined forces shortly after meeting in 2013 at UCF's physics department. Blair had just discovered catalytic properties in the chemical compound boron nitride that were "unheard of" and wanted to publish the information and do more research.

He had a collaborator for theoretical modeling, Talat Rahman, a distinguished Pegasus Professor in the Department of Physics, but he needed someone to help characterize the findings.

"At the characterization level, that's not where my strength is," he says. "I have strengths that complement Laurene's strengths. It made sense to see if we could do something together and if she could add some insight to what we were seeing."

So, in collaboration with Rahman and the U.S. National Science Foundation, they hoped to gain a molecular understanding of the catalytic properties defect-laden, hexagonal (crystal structured) boron nitride, a metal-free catalyst.

Typical catalysts often consist of metals, and boron nitride, sometimes called "white graphite," has had many industrial uses due to its slippery properties, but not for catalysis.

"Until we came along, that kind of boron nitride was considered just inert," Blair says. "Maybe a lubricant, maybe for cosmetics. But it didn't have any chemical use. However, with defect engineering, the research team found that the compound had great potential for producing carbon and green hydrogen, possibly in large volumes."

The technology the team developed for making carbon from defect-engineered boron-nitride using visible light came unexpectedly.

Blair says that to analyze the catalyst's surface, they would place it in a small container, pressurize it with a hydrocarbon gas, such as propene, and then expose it to laser light.

"Each time, it did two things that were frustrating," he says. "The catalyst itself emitted light that obscured any data we needed, and the student kept saying, 'it's getting burned' and I would say that's impossible. There's no carbon on the catalyst."

"And there was no oxygen," adds Tetard. They were stumped.

"If we wanted to study that burning spot, it needed to be bigger," she says.

Once they managed to produce a larger sample, they put it under the electron microscope.

"We started seeing some lines, but it's a loose, messy powder, so it shouldn't be ordered," Tetard said. "But when we zoomed in some more, we saw some carbon and lots of it, with the defect-engineered boron-nitride powder clinging to the top of it."

What was seen as a problem was actually serendipitous, as the discovery would allow hydrogen production at low temperatures and the production of carbon as a by-product with no release of greenhouse gases or pollutants.

Provided by University of Central Florida

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