Researcher probes how to convert carbon dioxide into the building blocks for fuel

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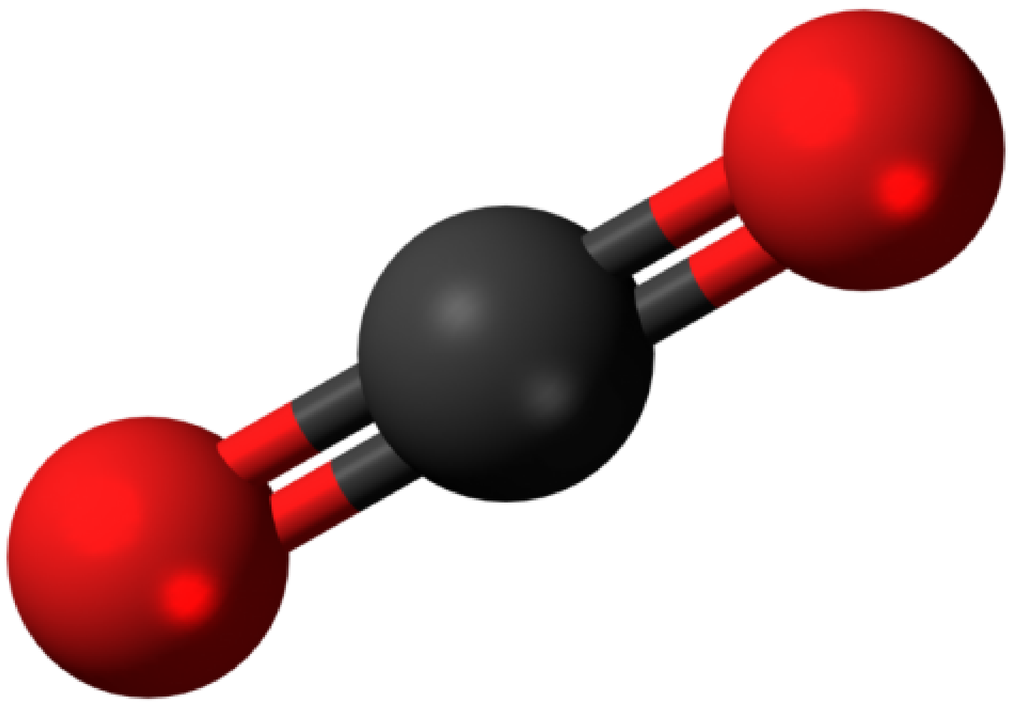

Ball-and-stick model of carbon dioxide. Credit: Wikipedia

To split the chemical bonds in CO_2 molecules, heat is needed. One way to get this heat is from plasmas, and it's been long known that plasmas can efficiently split CO_2, thanks to 40-year-old research from the Soviet Union.

"Issues with the climate and greenhouse gases have led to this old research [that has] been explored by many scientists," says Alex van de Steeg, researcher in the Elementary Processes in Gas Discharges group in the department of Applied Physics.

While the old research has left its mark on scientists, it's also confused them. "It's been hard to reproduce past results," notes Van de Steeg. "For example, recent experiments with CO_2 plasmas have shown that higher temperatures are needed, above 3000 kelvin (K) in fact. But the old research indicates that splitting can take place at lower temperatures."

Motivation for new methods

Disagreement between the past results and recent attempts to replicate them proved a great motivation for Van de Steeg's research, which he carried out at DIFFER under the supervision of Gerard van Rooij and Richard van de Sanden and in collaboration with Maastricht University and Shell.

"To gain a better understanding of how CO_2 dissociates or splits in a plasma, we developed new ways to study CO_2 plasmas generated in a microwave using so-called laser scattering diagnostics," says Van de Steeg. "This involves focusing an intense laser beam into the plasma and then measuring the light scattered. In this way, we can gather time and spatial information on the temperature and composition of the plasma."

Measurements of the CO_2 plasma provided information on the chemical and physical processes that occur during splitting of the molecules. Added to that, the researchers gained a new appreciation for the extreme conditions in CO_2 plasmas. "The plasma temperature exceeds 6000 K, which is hotter than the surface of the sun," notes Van de Steeg.

Probing the plasma also helped Van de Steeg and the researchers to create a map of the plasma, which they then combined with a numerical model. "This helped us to identify reaction rates and the molecules involved in those reactions in different parts of the plasma, and it showed that chemical reactivity is dependent on very high temperatures, which contradicts the past results. Before we didn't have this information, so having this information is significant."

Reactions count

What's more, Van de Steeg's research revealed the chemical reactions that produced the most CO, which would of course increase the potential to produce more fuels afterwards.

"Two reactions lead to almost all splitting: collisions of CO_2 molecules with other molecules in the plasma, and the aggregation of O and CO_2 (known as association) that eventually leads to CO and O_2," says Van de Steeg.

And it's the second of these reactions that might lead to an increased (or larger) energy efficiency of thermal CO_2 reactors. "Maximum efficiency without O-CO_2 association is just above 50%, which increases to 70% when they are included. And this is close to the efficiencies reached in experiments 40 years ago."

One thing to note is that a lot of energy is needed to initiate the plasma reactions, but this energy can be more than balanced thanks to the potential of using the CO molecules to make sustainable fuels. "So, instead of taking oil from wells to produce fossil fuels, we can make fuels using the CO_2 already in the atmosphere from combusting fuels in the past. It's a circular process of sort."

Future fuels

Van de Steeg's research indicates that high energy efficiencies of CO_2 splitting are within reach, and he's very optimistic about where these findings could go. "With these findings and careful reactor design, high energy efficiencies are within reach, which means that plasma splitting approaches could be an attractive technology for the energy transition."

And what makes it even more attractive is the availability of large-scale microwave radiation equipment that can be used to split CO_2 using plasmas. With plenty of CO_2 in the atmosphere and the technology in place, it seems like it's only a matter of time until research like that of Van de Steeg helps to establish reactors to produce future fuels from CO_2.

More information: Please click on the link to read the PhD-thesis, titled "Insight into CO_2 dissociation kinetics in microwave plasma using laser scattering."

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