Research aims to convert greenhouse gas into valuable products with electricity

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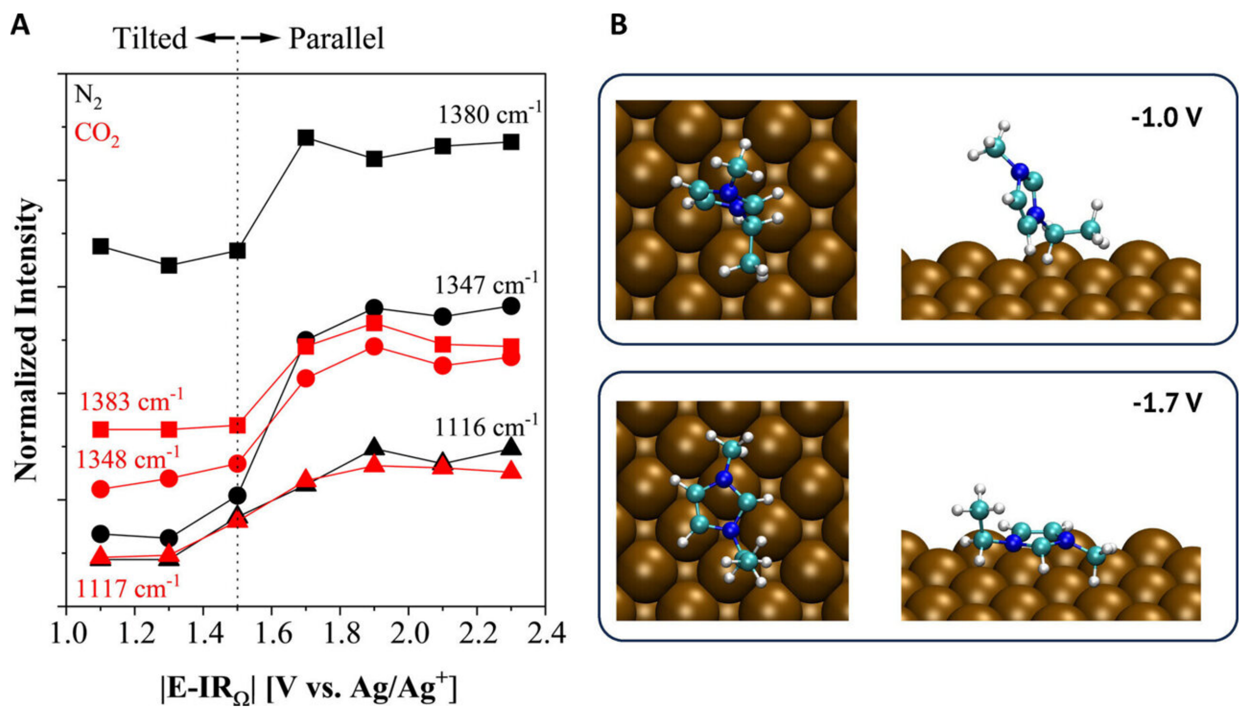

(A) SERS peak intensity as a function of absolute applied potential (|E-IR$_\Omega$|). Dotted line marks the potential of the change in the orientation of imidazolium species under N_2 (black) and CO_2 (red). Peaks: 1116 cm^{-1} (pentagons) for δ(C_4C_5–H); 1347 cm^{-1} for υ(Im ring)+υ(CH_2(N)) (spheres); 1380 cm^{-1} for υ(Im ring)+υ(CH_2(N))+υ(CH_3) (triangles). (B) Lowest energy geometries calculated for [EMIM]$^+$ at −1.0 and −1.7 V on Cu (100) (top and side views) indicating the preference of the parallel orientation at a more negative potential. Atom color code: blue=N; cyan=C; white=H. Credit: *Angewandte Chemie* (2023). DOI: 10.1002/ange.202312163

Researchers at Case Western Reserve University are developing ways to convert waste into fuels and other products, using processes that are energy efficient and powered by renewable sources.

More specifically, they're close to resolving the challenge of converting carbon dioxide (CO_2), a major greenhouse gas, into valuable chemicals using electricity.

CO_2 can be a useful raw material for making commodity chemicals and fuels. But the process of creating the necessary reaction isn't easy because it requires high pressures, high temperatures and special materials.

"Our modern society is in critical need of technologies that can capture the CO_2 from waste—or even air—and convert it to products at benign conditions," said Burcu Gurkan, professor of chemical engineering at Case School of Engineering. "Electrochemical conversion of carbon dioxide is an unresolved problem that is more than 150 years old."

Until now, research has mainly focused on developing catalyst materials and understanding the energy-intensive CO_2 conversion reaction in water-based electrolytes. Yet challenges remain because water-based systems have limited capacity for CO_2. In addition, the process includes unwanted side reactions, such as hydrogen gas emissions.

But in a study published this fall in the European journal *Angewandte Chemie*, the Case Western Reserve research team demonstrated that the ionic liquids they developed effectively capture and convert CO_2 in an electrochemical process.

Ionic liquids are salts that melt below 100°C. The ones that Gurkan's group developed are liquid at room temperature. These ionic liquids also are unique in that they have high capacity for CO_2 capture and maintain electrochemical stability. As a result, the team achieved the desired electrochemical process.

"Our approach focuses on ionic liquid electrolytes that can alter the thermodynamics and product distribution due to kinetic effects which can be further tuned, thanks to the flexibility in ionic liquid design," Gurkan said.

The study, led by Oguz Kagan Coskun, a doctoral student in Gurkan's group, combined spectroscopic and electroanalytical techniques to reveal the fundamental mechanisms necessary for ionic liquids to activate the CO_2 reduction reaction at the copper electrode surface.

The group reported needing less energy to drive the reaction and noted that it could lead to creation of a variety of industrially relevant products—without the unwanted side products found in the traditional electrolysis process.

Further, the report explains crucial aspects influencing the properties of the reaction environment for the effective use of CO_2. This additional information contributes to a deeper understanding of reaction environment, especially concerning unconventional electrolytes.

The team plans to examine the individual reaction steps further to inform subsequent electrolyte designs. The ultimate goal: better control of the chemicals from the reaction and advance the electrochemical approaches to CO_2 recycling.

More information: Oguz Kagan Coskun et al, Tailoring Electrochemical CO2 Reduction on Copper by Reactive Ionic Liquid and Native Hydrogen Bond Donors, *Angewandte Chemie* (2023). DOI: 10.1002/ange.202312163

Provided by Case Western Reserve University

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