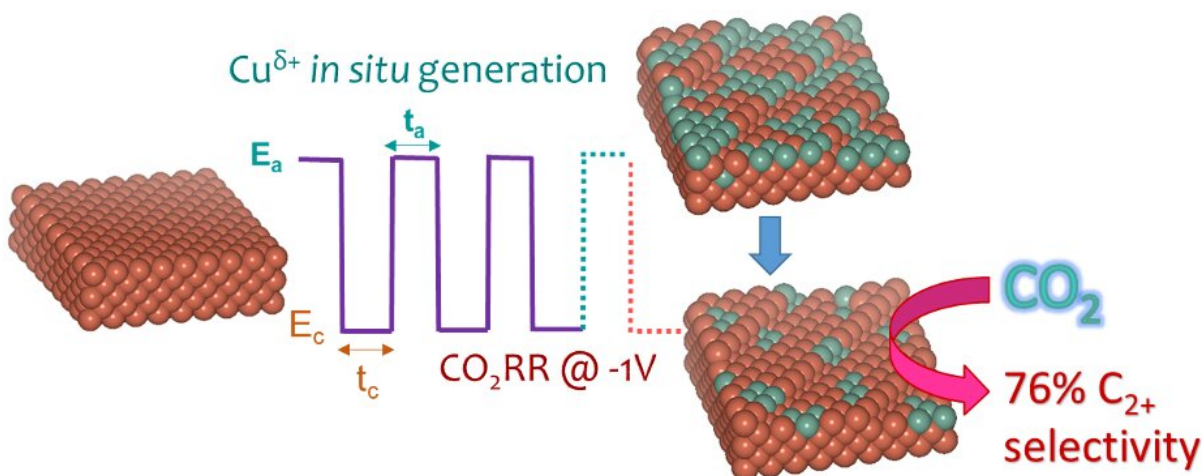


# Simultaneously tuning the surface structure and oxidation state of copper catalysts

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Credit: Arán-Ais et al.

Electrical energy derived from renewable sources could be used to rearrange bonds in carbon dioxide ( $\text{CO}_2$ ) and water molecules into complex hydrocarbons, which can then be burnt to produce new energy and  $\text{CO}_2$ , ultimately enabling a carbon cycle. Copper is a catalytic material that has been found to be promising for enabling this process and facilitating the  $\text{CO}_2$  electroreduction reaction ( $\text{CO}_2\text{RR}$ ).

Two key elements when trying to understand the parameters controlling the  $\text{CO}_2\text{RR}$  reaction are a well-defined [surface structure](#) and known

material composition. Past theoretical and experimental studies have shown that the C—C coupling pathway for generating ethylene is favored on the Cu(100) surface.

More recently, researchers noticed the key catalytic role played by  $\text{Cu}^{\delta+}$  and sub-surface oxygen for the production of C2-C3 hydrocarbons and alcohol. However, stabilizing copper under the conditions necessary for the  $\text{CO}_2$  electroreduction reaction ( $\text{CO}_2\text{RR}$ ) to take place has so far proved to be very challenging.

Researchers at the Fritz-Haber Institute, part of the Max-Planck Society in Berlin, have carried out a study aimed at stabilizing Cu(I), copper in the 1+ [oxidation state](#), in order to better understand its role in the  $\text{CO}_2\text{RR}$  reaction. In a recent paper, [published in \*Nature Energy\*](#), they reported an enhanced efficiency in producing ethanol using copper, attained by tuning the structure and oxidation state of Cu (I) catalysts.

"So far, the stabilization of Cu(I) species under  $\text{CO}_2$  reduction conditions has proved to be very difficult," Beatriz Roldan Cuenya, one of the researchers who carried out the study, told TechXplore. "The main goal of our study was to be able to generate Cu(I) species and transiently stabilize them on a well-defined surface, to then study their impact on the  $\text{CO}_2\text{RR}$  product selectivity."

In their study, Roldan Cuenya and her colleagues tuned the structure and oxidation state of copper catalysts using a technique known as pulsed electrolysis. This technique allowed them to design a pulsed potential sequence, which enabled the simultaneous tuning of both the surface structure and composition of Cu catalysts during the  $\text{CO}_2\text{RR}$  reaction.

The researchers monitored changes in the catalyst's structure as well as the chemical state of its surface. This ultimately led to interesting new findings about the mechanisms through which copper catalysts enable

the generation of hydrocarbons via the CO<sub>2</sub>RR reaction.

"Our findings suggest that the combination of (100) domains, defect sites, and surface Cu<sub>2</sub>O is the best configuration to enhance the CO<sub>2</sub>RR reaction pathway leading to C<sub>2+</sub> products," Roldan Cuenya explained. "In particular, an increased ethanol selectivity could be linked to the coexistence of Cu(I) and Cu<sup>0</sup> species, while the ethylene yield was dominated by the length of the Cu(100) terraces."

The recent study carried out by this team of researchers gathered new interesting findings that shed some light on the role of [copper](#) catalysts in facilitating the electrochemical conversion of CO<sub>2</sub>. In the future, the technique used by Roldan Cuenya and her colleagues could be used to tune electrochemical interfaces with constrained surface structures and compositions, so that they can be used to selectively produce C<sub>2</sub> products.

"In our next studies, would like to explore the effect of the continuous regeneration of Cu(I) species on other [surface](#) orientations and finally apply this pulsed protocol to other nanoparticulated systems aiming more practical applications in real electrolyzers," Roldan Cuenya said.

**More information:** Rosa M. Arán-Ais et al. The role of in situ generated morphological motifs and Cu(i) species in C<sub>2+</sub> product selectivity during CO<sub>2</sub> pulsed electroreduction, *Nature Energy* (2020). [DOI: 10.1038/s41560-020-0594-9](https://doi.org/10.1038/s41560-020-0594-9)

Federico Calle-Vallejo et al. Theoretical Considerations on the Electroreduction of CO to C<sub>2</sub>Species on Cu(100) Electrodes, *Angewandte Chemie International Edition* (2013). [DOI: 10.1002/anie.201301470](https://doi.org/10.1002/anie.201301470)

Javed Hussain et al. Calculations of Product Selectivity in

Electrochemical CO<sub>2</sub> Reduction, *ACS Catalysis* (2018). [DOI: 10.1021/acscatal.7b03308](https://doi.org/10.1021/acscatal.7b03308)

Yoshio Hori et al. Selective Formation of C<sub>2</sub> Compounds from Electrochemical Reduction of CO<sub>2</sub> at a Series of Copper Single Crystal Electrodes, *The Journal of Physical Chemistry B* (2002). [DOI: 10.1021/jp013478d](https://doi.org/10.1021/jp013478d)

Yun Huang et al. Electrochemical Reduction of CO<sub>2</sub> Using Copper Single-Crystal Surfaces: Effects of CO\* Coverage on the Selective Formation of Ethylene, *ACS Catalysis* (2017). [DOI: 10.1021/acscatal.6b03147](https://doi.org/10.1021/acscatal.6b03147)

Hemma Mistry et al. Highly selective plasma-activated copper catalysts for carbon dioxide reduction to ethylene, *Nature Communications* (2016). [DOI: 10.1038/ncomms12123](https://doi.org/10.1038/ncomms12123)

Hai Xiao et al. Cu metal embedded in oxidized matrix catalyst to promote CO<sub>2</sub> activation and CO dimerization for electrochemical reduction of CO<sub>2</sub>, *Proceedings of the National Academy of Sciences* (2017). [DOI: 10.1073/pnas.1702405114](https://doi.org/10.1073/pnas.1702405114)

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