

# A tin-based tandem electrocatalyst for the synthesis of ethanol via CO<sub>2</sub> reduction

November 25 2023, by Ingrid Fadelli

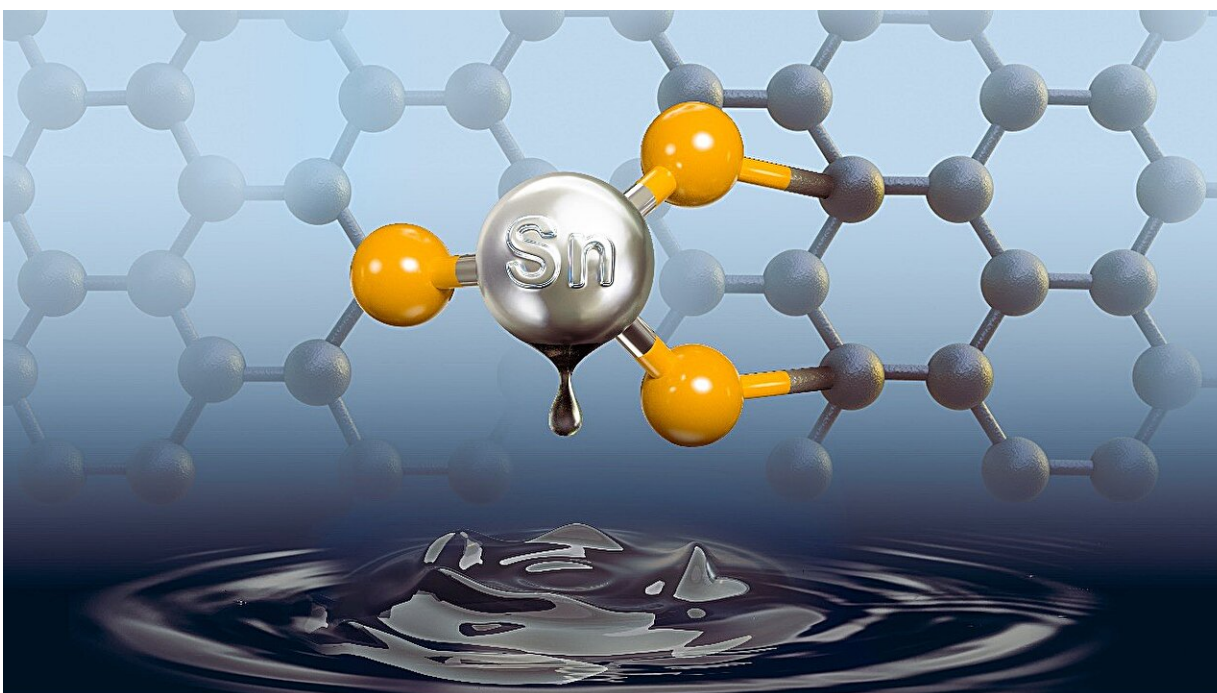


Diagram showing the C-C coupling process on Sn<sub>1</sub>-O3G to produce ethanol from CO<sub>2</sub>RR. Credit: Ding et al

The electrochemical reduction of carbon dioxide (CO<sub>2</sub>) into various multi-carbon products is highly desirable, as it could help to easily produce useful chemicals for a wide range of applications. Most existing catalysts to facilitate CO<sub>2</sub> reduction are based on copper (Cu), yet the processes underpinning their action remain poorly understood.

Researchers at the Chinese Academy of Sciences, City University of Hong Kong, and other institutes in China have recently set out to design more efficient Cu-free electrochemical catalysts for the reduction of CO<sub>2</sub>. Their paper, [published](#) in *Nature Energy*, introduces a new catalyst based on Tin (Sn), which was found to reduce CO<sub>2</sub> to ethanol (CH<sub>3</sub>CH<sub>2</sub>OH) with a selectivity of 80%.

"The discovery of C-C coupling over the Sn<sub>1</sub>-O3G catalyst was not accidental, but instead built on our earlier works on understanding the CO<sub>2</sub>RR behavior of transition metal single-atom catalysts," Prof. Bin Liu, co-author of the paper, told Tech Xplore.

"Specifically, we conducted preliminary experiments involving structural and electrochemical characterizations of various Sn-based CO<sub>2</sub>RR catalysts, including metallic Sn nanoparticles, SnS<sub>2</sub> nanosheets, SnS<sub>2</sub> on nitrogen-doped graphene, single Sn atoms on nitrogen-doped graphene (Sn-4N) and single Sn atoms on O-rich graphene (Sn<sub>1</sub>-O3G)."

In their preliminary experiments, the researchers found that both Sn<sub>1</sub>-4N and Sn<sub>1</sub>-O3G catalysts could reduce CO<sub>2</sub> to CO with KHCO<sub>3</sub>, as a proton donor in a CO<sub>2</sub>RR solution. However, these catalysts displayed different behavior in the presence of the acid formate, with only Sn<sub>1</sub>-O3G ultimately producing ethanol.

"These observations led us to believe that the difference in CO<sub>2</sub>RR between the Sn<sub>1</sub>-4N and Sn<sub>1</sub>-3OG catalysts could result from the different coordination environments of Sn," Prof. Liu said. "Thereafter, we focused our efforts on understanding the C-C coupling mechanism on O-coordinated Sn catalytic sites and constructed a tandem catalyst to realize selective CO<sub>2</sub>RR to ethanol."

Prof. Liu and his colleagues fabricated their new Sn-based electrocatalyst by eliciting a solvothermal reaction between SnBr<sub>2</sub> and

thiourea on a three-dimensional (3D) carbon foam. They subsequently examined their catalyst to characterize its structure.

Their examinations suggest that their catalyst is made up of SnS<sub>2</sub> nanosheets and atomically dispersed Sn atoms. These components are coordinated on the 3D O-rich carbon by binding with three O atoms (Sn<sub>1</sub>-O3G).

"The electrochemical performance of the SnS<sub>2</sub>/Sn<sub>1</sub>-O3G catalyst for CO<sub>2</sub>RR was evaluated using chronoamperometry in an H-type cell containing CO<sub>2</sub>-saturated 0.5-M KHCO<sub>3</sub>," Prof. Liu said. "Our catalyst can reproducibly yield ethanol with a Faradaic efficiency (FE) of up to 82.5% at -0.9 V<sub>RHE</sub> and a geometric current density of 17.8 mA cm<sup>-2</sup>. Additionally, the FE for ethanol production could be maintained at above 70% over the potential window from -0.6 to -1.1 V<sub>RHE</sub>."

In initial evaluations, the catalyst developed by the researchers achieved highly promising results, successfully producing ethanol from a CO<sub>2</sub>RR solution with a high selectivity. In addition, the catalyst was found to be stable, maintaining 97% of its initial activity after 100 h of operation.

"The dual active centers of Sn and O atoms in Sn<sub>1</sub>-O3G serve to adsorb different C-based intermediates, which effectively lowers the C-C coupling energy between \*CO(OH) and \*CHO," Prof. Liu explained. "Our tandem catalyst enables a formyl-bicarbonate coupling pathway, which not only provides a platform for C-C bond formation during ethanol synthesis and overcomes the restrictions of Cu-based catalysts but also offers a strategy for manipulating CO<sub>2</sub> reduction pathways towards desired products."

The recent work by this team of researchers introduces an alternative Cu-free catalyst for eliciting the C-C bond formation and enabling the reduction of CO<sub>2</sub> to ethanol. In the future, their proposed approach

could be used to produce ethanol more reliably and could potentially also be applied to the synthesis of other desired chemical products via the CO<sub>2</sub> reduction reaction.

"The search for more efficient catalysts with dual active sites should be pursued through high-throughput experiments and theoretical calculations," Prof. Liu added. "The rate and selectivity of a catalytic reaction are also closely related to the coverage of reaction intermediates on the [catalyst](#)'s surface.

"Therefore, an in-depth study of factors that affect the residence time of intermediates, such as the pore structure of the support for the Sn<sub>1</sub>-O<sub>3</sub>G dual-active sites, would help to deepen understanding of the C-C coupling process. We envisage that tandem catalysis based on the concept of dual-active sites could be extendable to C-X (X = N or S) coupling to prepare other chemicals, such as urea and alanine."

**More information:** Jie Ding et al, A tin-based tandem electrocatalyst for CO<sub>2</sub> reduction to ethanol with 80% selectivity, *Nature Energy* (2023). [DOI: 10.1038/s41560-023-01389-3](https://doi.org/10.1038/s41560-023-01389-3)

© 2023 Science X Network

Citation: A tin-based tandem electrocatalyst for the synthesis of ethanol via CO<sub>2</sub> reduction (2023, November 25) retrieved 3 May 2024 from <https://techxplore.com/news/2023-11-tin-based-tandem-electrocatalyst-synthesis-ethanol.html>

This document is subject to copyright. Apart from any fair dealing for the purpose of private study or research, no part may be reproduced without the written permission. The content is provided for information purposes only.