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Experimental Insights for CO_2 Conversion to High-Value Products

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The electrochemical reduction of CO_2 provides a promising route for the sustainable production of value-added chemicals and fuels. However, developing cost-effective and efficient electrocatalysts with high selectivity for a specific product remains a major challenge. Different families of electrocatalytic materials designed to selectively promote the formation of specific CO_2RR products, including metal oxides, metal sulfides, and bimetallic systems, will be introduced.
Among these materials, CuO_x and Ag–Cu bimetallic catalysts exhibited promising selectivity toward ethylene production, an important industrial building block widely used in plastics manufacturing. Our results demonstrate that the initial oxidation state of Cu plays a key role in determining ethylene selectivity. Furthermore, the incorporation of Ag can enhance ethylene selectivity when an optimal Ag content is employed. To gain deeper insight into the structure–performance relationships of these catalysts under operating conditions, operando X-ray absorption spectroscopy (XAS) measurements were performed, enabling us to correlate the evolution of the catalyst structure with its electrocatalytic performance.
Bismuth- and tin-based catalysts such as Bi_2S_3 and Cu-Sn nanomaterials showed excellent selectivity for formate/formic acid production in alkaline and acidic media in a flow cell [1-2]. The outstanding CO_2RR performance was further demonstrated in a three-compartment electrolyzer containing a solid-state electrolyte (SSE) layer, which enables the production of pure formic acid solution. In addition, the synthesis route was successfully scaled up, enabling catalyst production to increase from the milligram to the gram scale. Combining excellent CO_2RR performance and the low-cost, scalable production of the catalysts, this approach shows strong potential for future industrial implementation.

References:

[1] Huang, L.; Di Costola, F.; Allione, M.; Bianco, S.; Sacco, A.; Pirri, C. F.; Zeng, J. Nanoscale Copper–Tin Dioxide Interfaces for Efficient CO_2 Electroreduction to Formic Acid and Formate at High Rates. *ChemSusChem* 2025, *18* (24), e202501686.
[2] Monti, N. B. D.; Chen, T.; Huang, L.; Wang, J.; Fontana, M.; Pirri, C. F.; Ju, W.; Zeng, J. Unveiling the Origin of pH-Dependent Catalytic Performance of Bi_2O_3 Nanostructure for Electrochemical CO_2 Reduction. *J Phys Chem Lett* 2025, *16* (15), 3761–3768.

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Lan Huang received her BSc in Chemistry and MSc in Analytical Chemistry from China West Normal University in 2015 and 2018, respectively. During her master's studies, she focused on the design and development of high-performance electrocatalysts with tailored structures and compositions for water splitting. In 2018, she joined Chongqing Technology and Business University as a research assistant and was promoted to research associate in 2020. Since 2023, she has been conducting doctoral research funded by the Marie Skłodowska-Curie Actions Doctoral Networks programme (MSCA-DN). Her work primarily focuses on the green and scalable synthesis of high-performance electrocatalysts for CO_2 reduction.