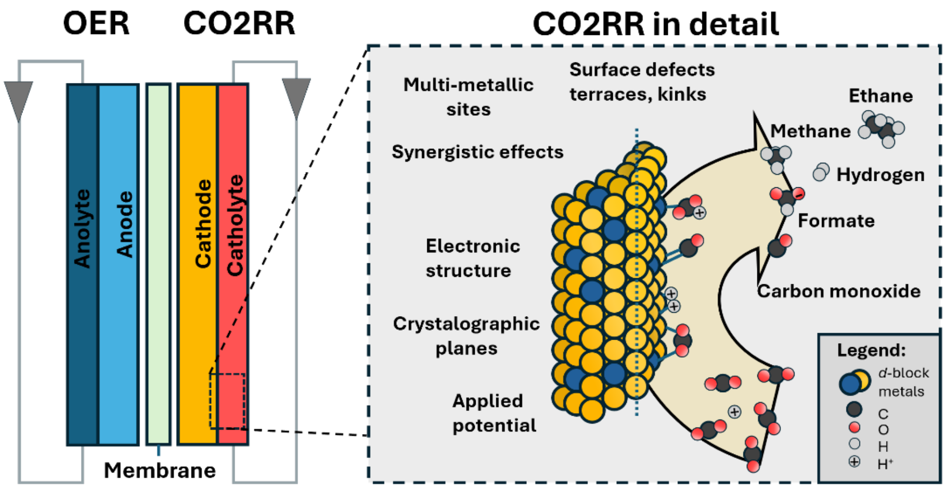
Effect of Cu, Zn, and Te modification on the activity and selectivity of transition metal selenides in electrochemical CO_2 reduction

Carbon dioxide (CO_2) is one of the most frequently discussed molecules in today's world—and for good reason. Its undeniable role in climate change, coupled with rising atmospheric concentrations, is closely linked to global warming. But what if we stopped seeing CO_2 as waste, and started treating it as a resource? Increasingly, CO_2 is being treated as a raw material—a carbon source for the production of fuels, chemicals, and materials. One of the most promising ways to achieve this is through electrochemical CO_2 reduction (**CO_2RR**).

Put simply, this technology mimics photosynthesis—but instead of using sunlight and plants, it relies on electricity and specialized catalytic materials. In an electrolyzer, CO_2 is bubbled through an electrolyte (e.g., potassium bicarbonate solution), where—under an applied voltage—it is broken down and transformed into new compounds such as **carbon monoxide** (CO), **formate** ($HCOO^-$), or **hydrocarbons** like methane or ethylene, depending on the reaction conditions and the catalyst used.



A major advantage of this technology is its versatility: by selecting the right catalyst and tuning the parameters, the reaction can be "steered" toward specific products. While **copper** is the most widely studied catalyst, it is by no means the only candidate. **Transition-metal chalcogenides**, particularly **monoclinic selenides**, are drawing increasing attention.

Although selenides as a class have been extensively studied for CO_2RR, monoclinic selenide compounds remain relatively unexplored. These materials, typically composed of metals like **Fe**, **Ni**, and **Se**, show promising activity in CO_2 reduction. Their unique crystal structures make them excellent candidates for catalysis. Moreover, cationic and anionic doping can further improve their selectivity or suppress unwanted side reactions. These materials combine good electrical conductivity, high surface reactivity, and chemical stability. Although their mechanisms are still not fully understood, advances in computational methods and *in situ* experimental techniques are helping to shed light on their behavior.

So how can such materials be studied? Key techniques include electrochemical measurements, such as cyclic voltammetry and electrochemical impedance spectroscopy, which provide insights into how the catalyst behaves under different voltage conditions and which reactions dominate its surface. To determine selectivity, gas chromatography (GC) will be employed. This highly sensitive technique allows for the detection and quantification of gas-phase products such as hydrogen, carbon monoxide, or methane. By combining electrochemical and analytical approaches, researchers will be able to evaluate both material's **efficiency** andits **selectivity**.

Ultimately, **electrochemical CO_2 reduction** represents a step toward a circular carbon economy, where emissions are not only reduced but **transformed into something valuable**. And if selenide-based catalysts meet expectations, they may play a key role in turning the vision of sustainable development into reality.