

## Engineering of Highly Active Indium-based Catalysts for the Hydrogenation of CO<sub>2</sub> to Methanol

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### Abstract

The utilization of CO<sub>2</sub> as feedstock for the chemical industry is a highly appreciated measure to control inevitable emissions. CO<sub>2</sub> generated as byproduct along the chemical value chain could be re-introduced by subsequent valorization processes to facilitate a circular economy. Of particular interest is the direct hydrogenation to hydrocarbons or methanol due to the rising strive for a hydrogen-based industry. Ideally, the CO<sub>2</sub> is captured from the earth atmosphere and combined with hydrogen from sustainable power sources. Methanol is a crucial building block for the chemical industry, especially as intermediate for the fabrication of formaldehyde or acidic acid. Furthermore, it is employed in methanol fuel cells and serves as propellant in combustion engines.

Nowadays, methanol is industrially synthesized from mixed syngas (CO, CO<sub>2</sub>, H<sub>2</sub>) over a copper-zinc catalyst at 50-100 bars and 200-300°C. Typically, the CO<sub>2</sub> content is minimized as the selectivity for the reversed water gas shift reaction (RWGS) intensifies with a rising partial pressure of CO<sub>2</sub>. The resulting water leads to hydrothermal conditions causing severe changes of the copper-zinc interface and reduction of the hydrogenation activity.<sup>[1,2]</sup> Yet, in order to utilize CO<sub>2</sub> as a feedstock, its fraction in the applied syngas has to be increased and new catalyst systems have to be developed. One promising alternative are indium oxide catalysts as they have a higher long-term stability and methanol selectivity under CO<sub>2</sub>-rich conditions.<sup>[3]</sup>

In this study, we enhanced the CO<sub>2</sub>-hydrogenation activity of supported indium oxide catalysts by the promotion with different metals. The most potent promotor was identified while the yield of methanol could be increased by over 60% compared to the un-promoted catalyst. Additionally, the loss of hydrogenation activity was decreased by over 50% under CO<sub>2</sub>-rich conditions. Furthermore, a recently developed method for the atomic layer deposition on particles was utilized to increase the dispersion and utilization of In<sub>2</sub>O<sub>3</sub>.<sup>[4]</sup> Consequently, the yield of methanol per mass of indium was improved compared to samples prepared by impregnation. Moreover, an experimental fingerprint method was developed to quantify active sites on the indium oxide surface. The resulting trend could be correlated with the hydrogenation performance of the indium-based samples.

### References

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**Preference:** Oral presentation  Poster