

Engineering of Highly Active Indium-based Catalysts for the Hydrogenation of CO₂ to Methanol

Robert Baumgarten¹, Hamideh Ahi², Elias Frei², Edvin Fako², Sandip De², Raoul Naumann d'Alnoncourt¹, Chiara Boscagli³, Stephan Schunk³ and Frank Rosowski^{1,2}

¹ BasCat – UniCat BASF JointLab, Technische Universität Berlin, 10623 Berlin, Germany

² BASF SE, Carl-Bosch Strasse 38, 67056 Ludwigshafen, Germany

³ hte GmbH, Kurpfalzring 104, 69123 Heidelberg, Germany

Abstract

The utilization of CO₂ as feedstock for the chemical industry is a highly appreciated measure to control inevitable emissions. CO₂ 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 CO₂ 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 acetic 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, CO₂, H₂) over a copper-zinc catalyst at 50-100 bars and 200-300°C. Typically, the CO₂ content is minimized as the selectivity for the reversed water gas shift reaction (RWGS) intensifies with a rising partial pressure of CO₂. The resulting water leads to hydrothermal conditions causing severe changes of the copper-zinc interface and reduction of the hydrogenation activity.^[1,2] Yet, in order to utilize CO₂ 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 CO₂-rich conditions.^[3]

In this study, we enhanced the CO₂-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 CO₂-rich conditions. Furthermore, a recently developed method for the atomic layer deposition on particles was utilized to increase the dispersion and utilization of In₂O₃.^[4] 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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Corresponding author:

Academic degree: Dr.
First name: Raoul
Name: Naumann d'Alnoncourt
Company: BasCat – UniCat BASF JointLab, Technische Universität Berlin
Street: Hardenbergstraße 36
ZIP code, City: 10623 Berlin
Email: r.naumann@bascat.tu-berlin.de
Phone: +49 -(0)30-314-736 83

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