Advancing Direct CO2-to-Methanol Conversion Through Novel Macroporous Cobalt-Indium Catalyst Design

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Conventional methanol production relies on a two-step process, where carbon dioxide is first converted into synthesis gas (syngas) and then methanol. This syngas step requires increased energy input, contributing to higher operational costs. As a result, direct carbon dioxide hydrogenation to methanol has emerged as a promising alternative. However, it is difficult to achieve high methanol selectivity and CO2 conversion rates under direct CO2 hydrogenation. Cobalt oxide-supported indium oxide (Co@In) catalysts have shown strong potential for CO2 hydrogenation. The purpose of this project is to develop Co@In catalysts with macroporous structures as a one-step CO2 hydrogenation system, testing them for structural stability, crystalline phase accuracy, and catalytic performance. To enhance performance and increase surface area, macropores were incorporated into the structure using a template-assisted approach, in which precursors were synthesized on polystyrene spheres. Three catalysts were synthesized: one without macropores, one with minimally defined macropores, and one with partially defined macropores. Under CO2 hydrogenation conditions at 50 bar and 300 ? with a gas hourly space velocity of 15,000 h?¹, all three catalysts exhibited moderate CO2 conversion rates of 11-13%. Selectivity varied, with minimally defined macropores favoring the reverse water-gas shift reaction, whereas partially defined and non-macroporous catalysts successfully produced methanol at 50-60% selectivity. Overall, the novel template-assisted approach used in this study could contribute to advancing current industrial processes for methanol production and CO2 hydrogenation.

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