Optimisation of platinum-based catalysts for the dehydrogenation of perhydro benzyltoluene as LOHC

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Abstract

Hydrogen as an energy carrier offers many benefits for the environment, energy security, economy and end users [1]. Cost-effective, compact, safe and convenient storage of hydrogen are essential for large-scale implementation. However, the volumetric energy density of molecular hydrogen is low compared to other energy carriers [2]. One approach to address this challenge is the use of liquid organic hydrogen carriers (LOHCs) for chemical hydrogen storage. LOHCs are organic liquids that can chemically bind hydrogen in a reversible manner, which allows for long-term storage and safe transportation of hydrogen under ambient conditions [2]. Benzyltoluene/perhydro benzyltoluene (H0-BT/H12-BT) is a technical LOHC system that is thermally stable, has low toxicity, and has a wide liquid range. It has a hydrogen storage capacity of 6.2 wt.%, which is equivalent to 2.1 kWh kg^{-1} or 1.9 kWh L^{-1} [3]. However, to maximize the hydrogen storage capacity and the number of repeated loading and unloading cycles via catalytic hydrogenation and dehydrogenation, respectively, a superior catalyst selectivity and high conversions are of utmost importance.

In this study, the influence of promoters and the properties of the support material on the dehydrogenation activity of platinum-based catalyst systems are investigated. Therefore, bimetallic catalysts were prepared and a range of support materials was tested. The catalyst activity was mostly evaluated in semi-batch laboratory-scale dehydrogenation experiments to compare key performance indicators, such as the degree of dehydrogenation (DoDH) of perhydro benzyltoluene and the platinum-based productivity of the catalysts. Further, continuous testing in fixed-bed reactors and cyclic testing, that is consecutive hydrogenation and dehydrogenation of the LOHC, elucidated the commercial suitability of the developed catalysts.

Key results from the present study include the successful development of a bimetallic Pt-Re/Al_2O_3 catalyst and the identification of optimized support properties to prohibit pore diffusion limitation and strengthen interaction. The results indicate that the composition, structure, and morphology of the support may dictate the catalyst activity. Lastly, the new catalyst design was transferred to the preparation using shaped carrier pellets for bridging the gab between laboratory research and catalytic application in large-scale fixed-bed reactors for efficient H_2 release from perhydro benzyltoluene.

References

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