Empowering catalyst supports
– A new concept for catalyst design

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While most of the processes within the Power-to-X envelope are industrially established, the new boundary conditions of small-scale renewable energy-based plants can require a significant redesign of the catalytic materials to withstand the expected harsher reaction conditions. We have been focusing especially on the stability of promoters under reaction conditions and have developed a new design concept combining the physical structure of an oxidic support material with the provision of promotional functionality – empowered supports (Fig. 1) – and demonstrated this concept in the iron-based Fischer-Tropsch synthesis (FTS).

The exact speciation of promoter elements in classic catalysts under reaction conditions is still not fully resolved. Low concentrations and promoter mobility [1] present the most significant challenges in this regard. Without a clear understanding of the interaction between the promoter and the active phase, catalyst optimization through design is not possible. Innovative preparation techniques have shown that when an intimate contact between the active phase and the promoter is achieved, the promoting effects observed surpass effects reported for catalysts prepared with conventional impregnation approaches [2].

Based on a rhombohedral $LaAlO_3$ perovskite, a series of supports was synthesized, partially replacing La with K and Al with Mn. Iron oxide nanoparticles were deposited on these materials and the resulting catalysts tested under FTS reaction conditions.

Extensive material characterisation supports the success of the catalyst synthesis. While iron supported on $LaAlO_3$ showed no enhanced activity or selectivity compared to conventional supports, the presence of K in the perovskite structure enhances conversion. To compare selectivity, the space velocity had to be increased by a factor of 3.75. Under these conditions, the promoted catalyst displays a lower methane selectivity and enhanced chain growth as well as a much higher olefin to paraffin ratio in the hydrocarbon product. The CO_2 selectivity, the product of the water-gas shift reaction (WGS), is only slightly increased. The addition of small amounts of Mn further reduces methane and CO_2 selectivity while maintaining the high olefin to paraffin ratio. Compared to iron supported on $LaAlO_3$ promoted conventionally via impregnation, the here developed materials have a much lower C1 product fraction, predominantly due to the decoupled enhancement of the FTS and the WGS reaction.

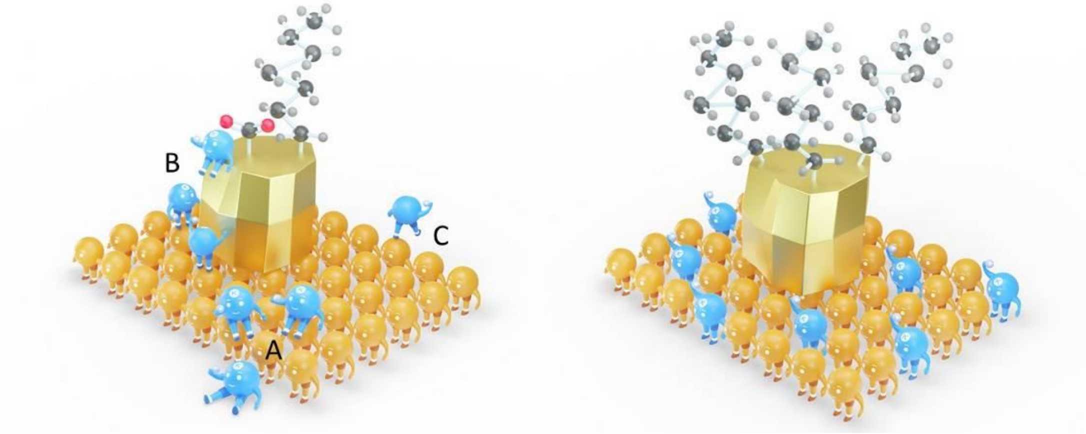

Figure 1. Left, Schematic representation of classic impregnation approach with (A) promoter present on the support structure adjacent to the active phase, (B) in direct contact with the active phase and partially covering active sites, and (C) mobile under reaction conditions. **Right,** Schematic representation of empowered catalyst support design concept with promoter elements locked and dispersed in the support structure.

We have no reason to believe that the here described effects represent a singularity for the chosen promoters and the FTS but expect that this new catalyst design concept can also be applied to and improve various industrially relevant promoter dependent catalytic processes such as the Haber-Bosch synthesis.

References

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