Thin film catalysts for Fischer Tropsch Synthesis of C5+ products

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Introduction

The Helmholtz Zentrum Berlin hereby presents the concept of using thin film catalysts for the Fischer Tropsch synthesis (FTS) of C_{5+} hydrocarbons, suitable for up-conversion to aviation fuel, to be tackled within the CARE-O-SENE project. Our goal is to develop an FTS process based on thin film catalysts that achieves comparable or even better product yields, service lifetimes, product selectivity all at a low economic and environmental cost. We hereby describe our approach to maximise the benefits of thin film heterocatalysts while overcoming their limitations compared to powder/particulate materials.

Opportunities and challenges related to thin film catalysts

Thin films may reduce the costs, the environmental footprint and the energy demand of FTS using CO_2 from the atmosphere or point sources and hydrogen from electrolysis powered by renewable energies. The reproducibility and scalability of thin film deposition techniques is proven on a commercial scale for applications ranging from tribology, corrosion protection, photovoltaics, coatings for fenestration, and various opto-electronic devices. Well-ordered directionally oriented thin films, with strong adhesion to the support, uniform thickness, and composition, can be synthesised using a lower energy input than nano particles. Thin films also provide a 2D model system suitable for studying effects of metal-support interactions on catalyst properties and surface reactions for thermochemical processes. Thus, their use in an industrially relevant process, eases transfer of learnings from fundamental studies to application.

The extant literature provides insights of how to overcome likely challenges of using thin film materials as heterocatalysts. Firstly, the number of active surface sites on thin films is expected to be lower than that of particulate catalysts which have a 3D geometry. The type of support material may compensate for the low surface area of thin films, for example, catalysts with surface areas as low as 50 m^2/g on supports with a high alpha-alumina content have shown a higher C_{5+} selectivity than high surface area catalysts on alumina with a high gamma- content [1]. Moreover, the surface area of thin films can be increased by coating substrates with rough surfaces or high porosity. Also, the high density of grain boundaries in poly crystalline materials (including thin films) can enhance the chain-growth probability of Co catalysts consisting mainly of otherwise, less active crystal phases [2,3]. Secondly, thin film catalysts may degrade under industrially relevant operating conditions, for example, via oxidation, carbon deposits and/or heat induced structural transformation. Past studies suggest that capping cobalt polycrystals with non-reducible oxides delays degradation and promote selectivity, activity, and Anderson–Schultz–Flory distribution comparable to industrial grade particle catalysts [3].

Micro-channel reactors (MCRs) are likely the most suitable reactors for thin film hetero catalysts. Their design facilitates fast removal of heat from the catalyst to the reactor walls allowing operation at isothermal conditions required for the exothermic FTS process [4]. Besides, MCRs can enable high C_{5+} selectivity with high conversion rates [5], and their scalability has been demonstrated [6].

Activities in CARE-O-SENE

The effort planned within the CARE-O-SENE project towards this goal includes:

1. Optimising thin film Co catalysts and oxide interlayers grown using atomic layer deposition which enables control of the film structure during growth with almost atomic precision, for full coverage of rough substrates [4].
2. Combining the knowledge identified from literature on catalyst structure relations as well as *in operando* x-ray spectroscopy and diffraction studies to understand the mechanisms of activity, selectivity, and stability of thin film catalysts.
3. Development of micro-channel reactors (MCRs) specifically tailored for thin film catalysts.

Conclusion

We anticipate that MCRs using thin film catalysts, will initially find application in distributed plants for small to medium scale FTS of fuels.

References

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