Catalyst development for Methanol-to-Synfuels

Graduate

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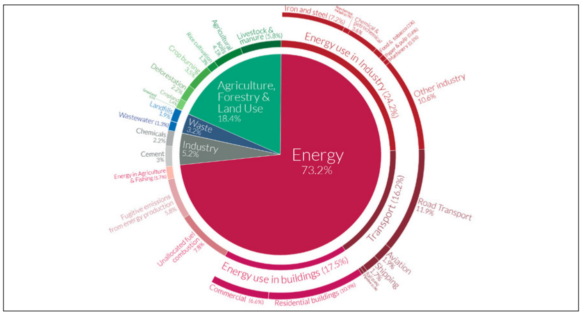
Initial Situation: The global challenge of reducing CO2 emissions is crucial achieving the climate goals of the Paris Agreement. The transportation sector significantly contributes to greenhouse gas emissions, particularly with heavy-duty vehicles and aviation, where electrification is not a practical solution. In this context, synthetic fuels made from renewable methanol are gaining importance. Synthetic fuels offer a promising alternative as they can be used in existing combustion engines, thus utilizing the infrastructure for fossil fuels.
The Fischer-Tropsch process is the industrial method currently employed to produce synthetic hydrocarbons. This well-established technology converts syngas into a range of hydrocarbons, including fuels and chemicals. In contrast, the methanol pathway, which converts methanol into hydrocarbons, usually utilizes zeolites. The main application today is a zeolite with medium pore size (Zeolite ZSM-5) for the production of synthetic gasoline (C5-C10).
The Methanol pathway offers numerous advantages over Fischer-Tropsch synthesis: superior selectivity, direct CO2 conversion, simpler process conditions, reduced cost, and lower energy demand.

Objective: The main objective of this work was to investigate the development of catalysts for the production of synfuels from methanol. Specifically, the aim was to improve the selectivity of the catalysts towards longer hydrocarbon chains, in the Kerosene range (C10-C16) by using zeolites with larger pores (Zeolite-Y). Additionally, the use of elements such as zinc and magnesium to enhance catalyst stability, as well as the role of copper in hydrocarbon formation and the potential direct conversion of syngas to hydrocarbons, were examined.

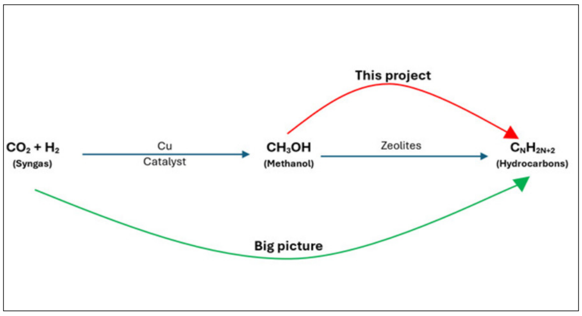
Result: The use of zeolites with larger pores (Zeolite-Y) led to increased formation of longer hydrocarbon chains. However, increased coke formation was also observed, which negatively impacts the lifespan and efficiency of the catalysts.
Addition of magnesium showed positive effects in terms of reducing catalyst deactivation. Magnesium stabilized the active sites and prevented their deterioration during reactions.
Copper improved the performance of the ZSM-5 catalyst, while it caused a slight impairment in Zeolite-Y. These results require further investigation for a direct conversion of syngas into hydrocarbons.

The results show that zeolites with larger pores are promising for the production of longer hydrocarbon chains, but optimizations regarding coke formation are necessary. Magnesium and copper proved to be important elements for improving catalyst performance and stability. The unclear role of zinc requires further research to fully understand its potential.
This study provides valuable insights into the development of catalysts for the production of synthetic fuels from methanol. The results offer a solid foundation for future research and technological applications that can contribute to the reduction of CO2 emissions in the transportation sector.

Global CO2 emissions by sector (2016).
https://ourworldindata.org/ghg-emissions-by-sector



Representation of the indirect (blue) and the direct (green) route as well as the focus of the project (red).
Own presentment



Overview of the main results regarding catalytic performance and carbon deposition.
Own presentment

Sample	Test procedure	Max. MeOH conversion [%]	Max DME concentration	Temperature of the Max DME c. [°C]	Max C4+ concentration	Temperature highest C4+ increase [°C]	Carbon deposition [%]
Pure Z-Y 15	Long	82.0	0.03845	400	7.65524E-4	200 - 250	9.4
Pure ZSM5 15	Long	84.3	0.05799	300	0.00125	300 - 400	4.6
ZSM5 15 1.3 wt% Cu	Short	95.9	0.05106	300	0.00104	300 - 400	2.5
Z-Y 15 5%Cu	Short	77.1	0.04153	400	1.23959E-4	200 - 300	10.0
Z-Y 15 1.3 wt% Cu	Short	75.4	0.03189	300	0.00101	200 - 300	6.2
Z-Y 15 1.3 wt% Zn	Short	65.7	0.03236	400	2.06014E-4	200 - 300	7.0
Z-Y 15 0.5 wt% Mg	Short	80.1	0.03347	400	0.00104	200 - 300	5.0

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Subject Area
General environmental technology, General energy technology