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Coking analysis for catalytic pyrolysis of polyolefins to produce light olefins – from microscale to macroscale

Aim

The primary objective of this research proposal is to investigate the coking behaviour of polyolefins during catalytic pyrolysis at multiscale and to develop effective modification strategies on catalysts for mitigating coking to improve the yield of light olefins. The results of this study are expected to provide fundamental insights into the mechanisms of coking and to guide the development of efficient and sustainable catalytic pyrolysis processes for the industrial conversion of polyolefins into light olefins.

Justification

Polyolefins as the most widely used plastics globally have caused severe environmental impacts due to their robust nature and low degradation rate. Two-staged catalytic pyrolysis of polyolefins to produce light olefins over modified zeolites is one of the most promising alternative sustainable technologies. However, the formation of carbonaceous deposits (coking) during pyrolysis severely limits the catalytic activity and catalyst lifetime. Understanding the mechanism of coking and developing strategies to mitigate coking while maintaining the light olefin yield is essential for scale-up polyolefin catalysis.

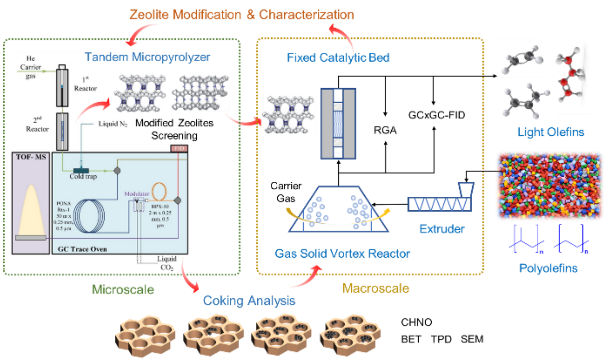

Figure 1: Overview of the multiscale coking analysis

In this work, various analytical techniques, including GCxGC, RGA, TPD, BET, and CHNO analysis will be applied to product and catalyst characterization. Since the development of effective strategies for catalytic coking resistance is contingent upon the design of suitable catalysts, a number of techniques, such as surface functionalization and framework substitution, will be employed to fine-tune the structure and surface acidity of the parent zeolites, with the aim of prohibiting the accumulation of carbonaceous species on the catalyst surface and meanwhile enhancing the catalytic activity. Specifically, this work will focus on the mesoporous introduction strategies via base/acid hydrothermal treatment for typical zeolite (HZSM-5) modification. Then, the modified zeolites will be tested by a tandem micropyrolyzer for rapid screening, and the most promising catalysts identified in microscale experiments will be further applied in a macroscale reactor. A novel gas-solid vortex reactor coupled with the catalytic fixed bed will be used for the pyrolysis-catalysis of polyolefins. The effects of operational conditions, such as pyrolysis temperature, space velocity, and zeolite-to-feed ratio on the coking behaviour will be systematically investigated.

Program

- Literature survey on the zeolites modification procedure and how to ensure catalytic activity and stability on a larger scale.
- Micropyrolyzer catalytic experiments: Rapid screening of mesoporous introduced zeolites with base/acid treatment.
- Macroscale experiments: Validate in a bench-scale reactor with the optimized catalyst.
- Coke characterization and mechanisms analysis on each scale.