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Zeolite-templated carbon catalysts for electrified methane pyrolysis – an experimental study

Aim

Improved carbon catalyst stability for methane pyrolysis to produce H_2 in an electrified fluidized-bed reactor.

Justification

Transforming to a climate-neutral community will heavily rely on the production of low-emission hydrogen (H_2) given its potential as sustainable energy carrier and feedstock. The International Energy Agency (IEA) projects the annual H_2 production to increase from 97 million metric tons (2023) to 150 million metric tons by 2030. Moreover, 45% of this production must originate from low-emission technologies to meet the Net Zero Emissions by 2050 scenario. Therefore, alternative H_2 production technologies with little to no greenhouse gas emissions (GHG) need to be explored while remaining economically competitive with the conventional steam methane reforming (SMR) or autothermal reforming process (ATR). Methane pyrolysis is emerging as a promising sustainable technology for producing "turquoise" H_2 by directly splitting methane or natural gas into hydrogen and solid carbon, which can be valorized in polymer/rubber applications and in electronics.

To improve the cost-effectiveness of methane pyrolysis, it is crucial to develop a catalyst with high activity per unit volume, high yield of H_2, high mechanical and thermal stability, and extended on-stream lifetime. However, the deactivation of catalysts, particularly prevalent for metal-based catalysts, remains a significant challenge due to the accumulation of carbon deposits on the catalyst surface. Carbon catalysts helps alleviate deactivation concerns, as the deposited carbon exhibits an autocatalytic effect. However, the loss of surface are due to pore blockage reduces the overall catalyst activity. Ordered mesoporous carbons (OMC's), characterized by their well-defined pore structures within the mesopores range (2-50 nm), combine a high specific surface area and pore volume, enabling them to accumulate large quantities of carbon deposition over time.

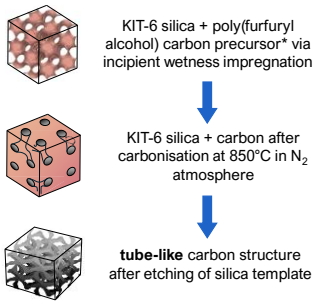

Fig. 1. Hard-templating synthesis of carbon CMK8 based on KIT-6 template.

In this study, a hierarchical OMC catalyst will be synthesized through a hard-templating technique, as exemplified in Fig. 1. The pores of a zeolite template will be impregnated with a carbon precursor. Subsequently, the carbon precursor is converted to carbon through a heat treatment, after which the zeolite template is dissolved to obtain an OMC with a structure, negative to the original zeolite structure. The catalyst will then be characterized through N_2-physisorption, X-Ray diffraction, scanning electron microscopy, and Raman spectroscopy prior to assessing the catalyst performance in an electrothermal fluidized-bed reactor (Fig. 2).

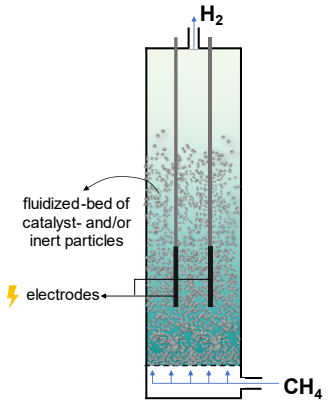

Fig. 2. Electrothermal fluidized-bed reactor. A voltage difference over the electrodes induce a current through the bed particles, where heat is dissipated.

Program

- Literature study: 1) carbon catalysts performances for the methane pyrolysis, and 2) electrical properties of carbons and its governing parameters.
- Synthesis of zeolite-templated carbon catalyst.
- Characterization of the synthesized material (N_2-physisorption, XRD, SEM, Raman).
- Methane pyrolysis in an electrothermal fluidized-bed reactor.

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