Investigation of the Influence of Si/Al Ratio on the Deactivation of ZSM-5 Zeolites in the Conversion of Ethanol to Hydrocarbons

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Abstract

In the modern chemical industry, interest in the resource-efficient production of fuels or basic chemicals is ever growing. Ethanol is an excellent starting material for conversion to hydrocarbons, which can be obtained biologically by fermentation. In petrochemistry, zeolites are the most promising materials for the conversion of alcohols to hydrocarbons. Especially zeolite ZSM-5 is perfectly suited for these reactions due to its three-dimensional pore system and its broad range of the Si/Al ratio available through synthesis. The deactivation is caused by the formation of coke in the pores of the zeolite. By reducing the coke formation, the lifetime of the catalysts can be significantly increased.

To study the influence of the Si/Al ratio on coking, various ZSM-5 samples were synthesized and characterized. Through the synthesis, the Si/Al ratio can be varied between 20 and 150. The samples were compared to a commercially available ZSM-5 by Clariant. The structure of the samples was examined by X-ray diffraction, the elemental composition by dissolution in hydrofluoric acid followed by ICP-OES measurement. The amount and strength of acid sites were determined by TPAD, and the surface areas were characterized by nitrogen adsorption experiments.

The catalytic tests reveal that there is a correlation between the deactivation tendency and the aluminum content of the catalyst sample. As the aluminum content is reduced, the tendency to deactivate as well as the initial activity decreases. The competition between these two effects create an optimum range for the Si/Al ratio which is between 40 and 60. In this range, the tendency to deactivate is low with simultaneously high initial activity. Among all the samples studied, the optimal Si/Al ratio provided efficient and best possible conversion of ethanol to hydrocarbons.