Chemical Engineering Doctoral Defense

Synthesis and Xylene Separation Performance of Polycrystalline MFI Zeolite Membranes with Different Microstructure

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Abstract

Separation of xylene isomers is one of the most energy-intensive processes in the petrochemical industry. MFI-type zeolite membranes offer an attractive alternative to the traditional energy-intensive xylene separation processes. However, current MFI-type zeolite membranes, including b-oriented ones, are prepared on non-scalable supports and only offer good xylene separation characteristics at low xylene vapor pressures (low activity). It is not clear how the microstructure of MFI zeolite membranes affects the xylene isomer separation characteristics, especially at high xylene activities. These unresolved matters hinder their potential industrial separation applications.

The objectives of this dissertation are to understand the effects of MFI zeolite membrane microstructure on xylene isomer separation performance of these membranes and explore the synthesis of high-performance b-oriented MFI zeolite membranes on scalable stainless-steel supports. The work includes exploring the relationship between the synthesis, orientation, microstructure, quality, and separation efficiency of xylene isomers, investigating the dependence of xylene activity with distinct microstructures and orientations of zeolite membranes, developing high-quality b-oriented membranes with an uncomplicated synthesis method fabricated on expandable macroporous supports, which can be manufactured at a reduced cost, and investigating the effect of operating conditions such as temperature and xylene vapor pressure on the separation performance of random and b-oriented membranes synthesized with and without a template.

The research shows that the intercrystalline defects concentration and framework stability in randomly oriented MFI zeolite membranes at high p-xylene loading play a key role in separating xylene isomers via vapor permeation mode. The impact of structural distortion is particularly prominent in pervaporation separation under conditions corresponding to the highest loading of xylene in the zeolite framework. Randomly or b-oriented MFI membranes synthesized without a template offer a significant enhancement in xylene separation performance. Stainless-steel supports can be modified for use as supports for growing MFI zeolite membranes. High-performance b-oriented MFI zeolite membranes can be synthesized on such modified stainless-steel supports by scalable filtration seeding of MFI zeolite nanosheets followed by secondary growth. An improved understanding of the effects of membrane microstructure and synthesis of b-oriented MFI zeolite on stainless steel supports has further advanced zeolite membrane.

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