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Hierarchical MFI Zeolite Membranes for Superior Xylene Separation

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Abstract

The xylene isomers p-xylene (PX), o-xylene (OX) and m-xylene (MX) are important chemical feedstocks used to produce polymers in the petrochemical industry. As the most valuable xylene, PX has to be separated from xylene isomers individually. However, such process is challenging and energy intensive in industry because the three xylene components have similar molecular weights and boiling points. Membrane separation has been recognized as a promising alternative to traditional separation techniques such as distillation and adsorption because of its low energy consumption and cost-effectiveness. MFI zeolite membrane, owning three-dimensional pore structure comprising sinusoidal channel (0.51 nm × 0.55 nm) and straight channel (0.53 nm × 0.56 nm), has been recommended as an ideal candidate for xylene isomers separation. However, current MFI membranes are still expensive, which hinders their widespread application. Reducing the thickness of MFI membrane can improve its flux and therefore to lower the membrane cost. Synthesizing ultrathin (< 1 μm) MFI membrane is highly desired but remains challenging.
MFI zeolite is well known as various crystal morphologies (like 0D nanobeads, 2D nanosheets and 3D bulk crystals and so on, which present distinct growth habits when used as seeds. Inspired by this, we demonstrate a novel and facile strategy for synthesizing hierarchical MFI zeolite membrane from multidimensionally assembled (2D@0D) seed layer (representing a 2D MFI nanosheet seed layer wrapped with a 0D MFI nanobead seed layer, analogous to the core@shell structure). Owing to the rapid growth of 0D MFI seeds and the voids-preserved growth of stacked 2D MFI seeds, the hierarchical MFI membrane synthesized for 2 h yielded an ultrathin skin layer (~255 nm thick) and a sublayer embedded with many macro-voids (void fraction: 14.86%), which facilitated molecular permeation and simultaneously maintained high separation selectivity of zeolitic pores (Fig. 1a). The membrane exhibited over 7-fold higher p-xylene permeance (2.81×10^{-7} mol m^{-2} s^{-1} Pa^{-1}) and over 3-fold improved p-/o-xylene separation factor (1228) than the conventional MFI membrane (Fig. 1b).

Figure and Tables

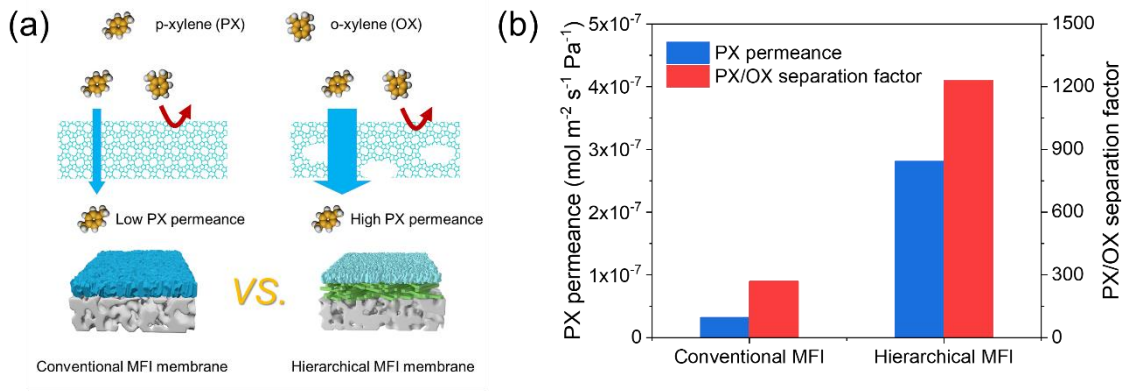

Fig. 1 Comparison in xylene separation between conventional and hierarchical MFI membranes: (a) schematic illustration; (b) separation performance.