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Polymers of Intrinsic Microporosity-Based Membrane for CO_2 Capture: A Review on Performance Under Realistic Conditions

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ABSTRACT

Polymers of Intrinsic Microporosity (PIMs) have gained significant attention as advanced membrane materials for CO_2 capture due to their exceptionally high gas permeability that often reaching the order of 10^3 to 10^4 Barrer and their tunable selectivity for CO_2 over other gases. While numerous studies have demonstrated their promising separation performance under ideal laboratory conditions, the transition of PIM-based membranes to industrial-scale application remains challenging. Understanding PIMs-based membranes' performance under challenging operating conditions such as high pressure, temperature, the presence of humidity and impurities in feed gas is essential to developing the membrane for commercial applications. Most of the previous reviews on PIMs or PIM-based membranes have been reported focusing on materials synthesis, gas transport properties and modification strategies. Despite these excellent reviews, work focusing on analyzing the performance of PIM-based membranes under challenging operating conditions is limited. Thus, this review aims to critically evaluate the performance of PIM-based membranes under realistic operating environments that better reflect practical CO_2 separation scenarios. Specifically, this review starts with a discussion of the fundamentals of membrane separation and an overview of PIM as a promising polymer in membrane gas separation. Then, the effects of operational parameters, such as pressure, temperature, gas impurities, mixed gas, and long-term operation, on the gas transport behavior in PIM membranes are explored. The analysis from this review demonstrated that although PIM-based membranes have remarkably high

CO_2 permeability and promising selectivity, their separation efficiency is highly dependent on practical operating conditions rather than optimal laboratory data. This review provides comprehensive insights into the realistic performance limitations of PIMs and guiding future development and potential industrial deployment of membrane-based CO_2 capture technologies.