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Fine-tuning zeolite pore structures with carbon coating for enhanced gas separation in polyimide-based mixed matrix membrane

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ABSTRACT

Impregnated zeolite-carbon (IZC), also known as pore-modified zeolite, was used as a potential filler in a P84 co-polyimide-based hollow fiber mixed matrix membrane (HF MMM) to enhance gas separation. The presence of carbon structure on the zeolite framework pore was to avoid the trapped moisture that could lead to permeability reduction. This work seeks to investigate the impact of IZC addition (0.5, 1.0, and 1.5 wt%) to the P84 membrane and examine its permeability and separation performance. Adding IZC filler to the P84 membrane generates the enhancement of gas selectivity and permeability. The optimal enhancement was observed at 1 wt% of IZC loading, in which selectivity of CO_2/CH_4, CO_2/N_2, O_2/N_2, H_2/N_2, and H_2/CH_4 was enhanced by 50.506, 51.042, 5.693, 16.712, and 16.338%, respectively. On the other hand, H_2, CO_2, and O_2 permeability at the loading were improved from 11.182 to 26.761, from 4.683 to 14.501, and from 1.637 to 3.546 Barrer, respectively. The improvement of gas selectivity was contributed by the presence of carbon in the zeolite framework, providing a molecular sieving effect while tuning carbon properties with pore regularity by templating in the zeolite framework enhances the gas permeability.

1. Introduction

The development of membrane technology for gas separation has accelerated over the past two decades. The technique is user-friendly, energy-efficient, and cost-effective on a small scale (Caralin et al., 2021; Widyanto et al., 2022a, 2021; Wijiyanti et al., 2020). Polymeric membranes are the most common membrane type for gas separation membranes. However, it has a number of disadvantages, including low heat and chemical resistance (Caralin et al., 2022; Gunawan et al., 2019; Ismail et al., 2018; Sari et al., 2019). To avoid these drawbacks, a suitable polymer precursor must be chosen. Polyimide is one of the most commonly utilized polymers in the membrane industry (Favvas et al., 2014; Guo et al., 2018; Salleh et al., 2011). Polyimides are thermoplastic polymers with a glass transition temperature of 300 °C. In addition, polyimides are relatively affordable, possess high mechanical stabilities, and are adaptable to a variety of membrane module modifications (hollow fiber, flat, and supported). This polymer is one of the most efficient precursors for producing carbon molecular sieve membranes. The C-N was associated with at 1350 cm^{-1} band, while the symmetric and asymmetric C═O were associated with the bands in 1715 and 1780 cm^{-1}, respectively (Choi et al., 2010a; Gunawan et al., 2021; Sazali et al., 2019; Widyanto et al., 2022b).

Advanced membrane materials, such as developing mixed matrix membrane, is a feasible approach that increasing thermal, mechanical, and separation properties of the membranes. Introducing inorganic filler into polymer matrix membrane is the most efficient method for improving the overall performance of membranes (Wijiyanti et al., 2023; Zhang et al., 2014). This sector has recently attracted much

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