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Interphase-engineered Pebax®1657/Fe3O4@ZIF-8 membranes for CO2/N2 separation: role of magnetic alignment and humidity

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This study reports the effects of magnetic alignment of the hybrid Fe3O4@ZIF-8 filler and operating parameters (humidity, membrane swelling, feed pressure, and long-term stability) on CO2/N2 separation in Pebax® 1657 thin-film nanocomposite membranes. The combined effects of filler loading, magnetic alignment, and humidity were systematically analysed to elucidate their influence on the structure and gas transport behaviour of Pebax® 1657. Structural characterization using scanning electron microscopy, differential scanning calorimetry, Fourier-transform infrared spectroscopy, and positron annihilation lifetime spectroscopy revealed that magnetic alignment modifies the microstructure of the Pebax® 1657 matrix, improving the selectivity. Compared with the pristine Pebax® 1657 membrane (CO2 permeance 7.3 GPU, CO2/N2 selectivity 56.9), the incorporation of Fe3O4@ZIF-8 and magnetic alignment improves the separation performance under both dry and humid conditions, however with significantly reduced permeance. The optimized membrane containing 4 wt% Fe3O4@ZIF-8, fabricated under an external magnetic field, exhibited a CO2/N2 selectivity of 117.9 with a CO2 permeance of 5.7 GPU under humid conditions. The enhanced separation performance is attributed to the reduced aggregation (effect of magnetic orientation) and rigidified polymer regions that preferentially suppress N2 transport while maintaining CO2 sorption affinity (effect of filler). Additionally, humidity-assisted transport further enhances CO2 permeance through plasticization and increased CO2 solubility in rigidified Pebax® 1657/Fe3O4@ZIF-8 matrix.

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