

# Introducing Carbon Molecular Sieve Membranes Derived from Polymers of Intrinsic Microporosity for Efficient Gas Separation

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Current chemical separation procedures are highly energy-intensive. More specifically, the gas separation industry is facing challenges with extreme pressures and temperatures, from cryogenic distillation to amine absorption. In the quest to reduce massive energy consumption, membranes offer a promising alternative with a more sustainable, continuous, and diverse spectrum of applications. Herein, we report the optimization process of a novel carbon molecular sieve (CMS) membrane design, combining a polymer of intrinsic microporosity (PIM) precursor and a thin-film composite (TFC) morphology. While the naturally contorted structure of PIMs serves as an excellent precursor to durable CMSs, the TFC structure further enhances performance with a selective top layer and robust support. At first, PIM solutions were deposited on alumina porous supports. After molecular doping, the samples were pyrolyzed at 550-650 °C, and protective layers were added for defect control. Finally, performance was tested using H<sub>2</sub>, O<sub>2</sub>, N<sub>2</sub>, CH<sub>4</sub>, CO<sub>2</sub>, and He. This investigation explored the consequences of altering the following variables: top layer thickness, dopant material and quantity, physical aging duration, and pyrolysis parameters. The results revealed a significant effect of carbon chain collapse, making ~1800 nm-thick samples the most practical. Furthermore, both VPI and age enhanced selectivity, albeit with diminishing returns. Optimizing pyrolysis parameters facilitated translation from lab-scale disks to pilot-scale tubular membranes, increasing the active area from 0.55 cm<sup>2</sup> to 86 cm<sup>2</sup>. Whether used for natural gas sweetening, medical oxygen enrichment, carbon capture, or other purposes, these novel membranes promise to both minimize energy consumption and boost operational flexibility.