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

Al Karam, Merza (School: Rowad Alkhaleej International School)

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 H2, O2, N2, CH4, CO2, 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 cm2 to 86 cm2. 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.

Awards Won: