A New Air Pollution Filter for Effective Gas Separation and Purification: High-Performance Polymer-Blended Mixed-Matrix Membranes with Triad Compatibilizers - Small Organic Molecules, Metal Organic Frameworks, and Carbon Nanotubes

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This research has created an innovative gas-separation membrane by combining inorganic membranes with polymeric membranes. A highly selective polymer (polybenzimidazole) and a highly permeable polymer (6FDA-Durene-DABA) were blended for matrices of the membrane to create a novel polymer-blended mixed-matrix membrane (PB-MMM) with significantly improved gas-separation properties. Moreover, this research pioneered the usage of triad-compatibilizers—the small organic molecule 2-methylimidazole, the metal-organic framework zeolitic-imidazolate framework-7 (ZIF-7), and functionalized carbon nanotubes—to improve the mechanical strength as well as the gas permeability and selectivity of the membrane. Characterization and testing showed that, compared to non-compatibilized membranes, the triad compatibilized membrane (6FDA-Durene-DABA:PBI+10%2MI+10%ZIF7+10%CNT) had double the Young's Modulus, triple the tensile strength, and an extrapolated onset decomposition temperature 184.89°C higher. Even more remarkably, the high-performance membranes achieved an H2 permeability and an H2/CO2 selectivity 30.87 and 4.02, respectively, times greater than that of non-compatibilized membranes. The unprecedented approach successfully created gas-separation membranes with robust mechanical stability, and superior permeability and selectivity: the membranes surpassed the Robeson upper bound and reached the commercially attractive region, an achievement never consistently attained in all previous works. The membrane's success demonstrates high viability for implementation to reduce harmful emissions of carbon dioxide and other polluting gases before they are even released into the atmosphere.

Awards Won:

Second Award of $2,000

China Association for Science and Technology (CAST): Award of $1,200