Unexpected H_2 solubility of polyimide/polyphthalonitrile H_2-selective membranes with tailorable microstructure and performance

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Membrane separation technologies are emerging as energy-efficient alternatives to traditional distillation processes. The growing demand for clean energy on “hydrogen economy” has highlighted the need for high-performance H_2-selective gas separation membranes. Polyimides (PIs) show promise in these applications due to their excellent thermal stability, good hydrogen permeability, and processability. However, PIs often have insufficient selectivity, mainly because they have a poor affinity H_2 over other gases. Despite the rigid molecular structure of polyimides provides excellent size-sieving property for hydrogen, the low H_2 solubility of PIs limits the H_2 selectivity, which is crucial for hydrogen purification. To address this issue, this study demonstrated a simple blending method to fabricate polyimide/polyphthalonitrile blend membranes with adjustable microstructure.

The study found that the blend membranes exhibited remarkable H_2 separation performance that the H_2/CO_2 and H_2/N_2 selectivity over 60 and 1600, respectively, exceeding the Roberson's upper bound (2008). The improved gas separation performance was attributed to enhanced H_2 solubility, resulting in superior H_2 solubility selectivity. The addition of polyphthalonitrile benefits the blend membranes toward a more narrowed distribution of fractional free volume, promoting the sorption of H_2 over 8 times higher than both polyimide or polyphthalonitirle. Additionally, gas separation performance of the blend membranes can be further adjust through thermal crosslinking of the blend membranes into a semi-interpenetrating network (semi-IPN). Overall, this study presents a novel approach to tailoring the polymer matrix of polyimide-based membranes, opening up possibilities for the development of advanced gas separation membranes.

Keywords: polyimides, polyphthalonitrile, polymer blend, hydrogen purification, gas separation membranes