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The performance of affordable and stable cellulose-based poly-ionic membranes in CO_2/N_2 and CO_2/CH_4 gas separation

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Abstract

The majority of commercial membrane units for large-scale natural gas sweetening are based on cellulose acetate (CA). However, the low selectivity and risk for and plasticisation affect adversely the performance of CA-based systems. Herein, we present a new class of CA-derived poly(ionic liquid) (PIL) as a thin film composite (TFC) membrane for CO_2 separations. CA is modified with pyrrolidinium cations through alkylation of butyl chloride, substituting the hydroxyl group in the polymer backbone, and further anion exchange to bis(trifluoromethylsulfonyl)imide, P[CA][Tf_2N]. The synthesised PIL material properties are extensively studied. The CO_2 separation performances of the newly synthesised materials is evaluated by gravimetric gas sorption experiments, single gas time-lag experiments on thick membranes, and mixed-gas separation experiments on TFC membranes. The results are compared to the parent material (CA) as well as a reference PIL (poly(diallyldimethyl ammonium) bis(trifluoromethylsulfonyl)imide (P[DADMA][Tf_2N])). The ideal CO_2/N_2 sorption selectivity of P[CA][Tf_2N] is constant up to 10 bar. The single gas transport measurements in P[CA][Tf_2N] reveal improved ideal CO_2 selectivity for the CO_2/N_2 gas pair and increased CO_2 permeability for the CO_2/CH_4 gas pair compared to the reference PIL. Mixed-gas permeation tests demonstrated that P[CA][Tf_2N]-based membranes with a 5 µm thick selective layer has a two-fold higher CO_2 flux compared to conventional CA. These results present CA modification into PILs as a successful approach promoting the higher permeate flows and improved process stability in a wide range of concentrations and pressures of CO_2/N_2 and CO_2/CH_4 gas mixtures.

Key words

Cellulose acetate, poly(ionic liquid), poly(diallyldimethyl ammonium) bis(trifluoromethylsulfonyl)imide (P[DADMA][Tf_2N]), thin-film composite membrane, time-lag, ideal sorption selectivity, gas separation, CO_2 capture, flue gas, biogas.