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Post-Combustion CO_2 Capture: From Membrane Synthesis to Module Intensification

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Abstract : This work aims to explore the potential applications of polymeric hydrophobic membranes and green ionic liquids (ILs). Protic and aprotic ILs were synthesized in the lab., characterized, and tested for CO_2/N_2 and CO_2/CH_4 separation using hydrophobic polymeric membranes via supported ionic liquid membrane (SILM). ILs were verified by FTIR spectroscopy. The SILMs were stable at room temperature up to 0.5 MPa. For CO_2, [BSmim][tos] had the greatest coefficient of solubility and permeability, along with all ILs. At 0.5 MPa, IL [BSmim][tos] was found with a selectivity of 56.2 and 47.5 for pure CO_2/N_2 and CO_2/CH_4, respectively. The ILs synthesized for this study are rated as [BSmim][tos]>[BSmpy][tos]>[Bmim][Cl]>[Bpy][Cl] based on their SILM separation performance. Furthermore, high values of selectivity of [BSmim][tos] and [BSmpy][tos] support the use of ILs for CO_2 separation using SILMs. The study was extended to synthesize and test the ammonium-based ILs, [2-HEA][f] and [2-HEA][Hs]. These ILs achieved 50 % less selectivity for CO_2/N_2 as compared to [BSmim][tos] and [BSmpy][tos]. Nevertheless, the permeability of CO_2 achieved with [2-HEA][f] and [2-HEA][Hs] is more than 20 times higher than the [BSmim][tos] and [BSmpy][tos]. Later, the CO_2/N_2 permeability and selectivity study was extended using a flat sheet membrane contactor with recirculated IL. The contact angle effects, liquid entry pressure (LEP), initial CO_2 concentration, and type of solvents and membrane material on the CO_2 capture efficiency and membrane wetting in the post-combustion capture (PCC) process have been experimentally investigated and evaluated. Polytetrafluoroethylene (PTFE) has shown the most hydrophobic property with 6-170 loss in the contact angle. Furthermore, [Omim][BF4] and [Bmim][BF6] have exhibited only 5-8 % loss in LEP using PTFE membrane support. The CO_2 capture efficiency has been achieved as 80.8-99.8 % in different combinations of ILs and membrane support, keeping all other variables constant. While increasing CO_2 concentration from 15 to 45 % vol., an increase of nearly three folds in the CO_2 mass transfer flux was observed. The combination of [Omim][BF4] and PTFE membrane witnessed good long-term stability with only a 20 % loss in CO_2 capture efficiency in 480 min of continuous operation. A 3- D simulation model for non-dispersive solvent absorption in membrane contactors provides insight into the optimum design of a separation system for a specific application minimizing the overall cost and making the process environment-friendly.

Keywords : Post-combustion CO2 capture, membrane synthesis, process development, permeability and selectivity, ionic liquids
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