Influence of the temperature and surface charge on the performance of nanocellulose based facilitated transport membranes for carbon capture

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In recent years, significant efforts have been made to develop efficient and cost-effective methods for CO_2 separation from light gases with applications in the CCS value chain. Gas separation membranes have emerged as promising candidates, and ongoing research focuses on optimizing their performance. Previous studies demonstrated that nanocellulose-based facilitated transport membranes with L-arginine as a mobile carrier enable reliable CO_2/N_2 separation for post-combustion applications [1]. The present study investigates the combined effects of superficial charge density (SCD) and operating temperature under humid conditions (70–90% RH) on CO_2 permeability and CO_2/N_2 selectivity. Three nanocellulose matrices were evaluated: (i) softwood-derived nanocellulose, (ii) hardwood-derived nanocellulose, and (iii) carboxymethylated hardwood nanocellulose with SCD of 780 µequiv/g. Gas permeation tests were conducted using a custom-built apparatus under controlled humidity and temperature conditions (20–50°C). Permeability and selectivity were measured for both pristine membranes and membranes modified with L-arginine to assess the impact of facilitated transport. All pristine membranes exhibited increased CO_2 permeability with rising relative humidity(%RH), demonstrating the importance of water content in membrane transport mechanisms. Higher SCD correlated strongly with enhanced separation performance: at 95% RH and room temperature, pristine hardwood nanocellulose (SCD = 30 µequiv/g) showed a CO_2 permeability of 10 Barrer, while carboxymethylated nanocellulose (SCD = 780 µequiv/g) reached 38 Barrer. Corresponding selectivity values improved from 15 to 120.The addition of L-arginine significantly enhanced gas separation. CO_2 permeability doubled for softwood nanocellulose, tripled for hardwood nanocellulose, and increased by 50% for the high-SCD membrane at 90% RH and room temperature. Selectivity increased proportionally, confirming the effectiveness of facilitated transport. Temperature positively influenced membrane performance, as increased thermal energy enhanced carrier mobility and CO_2 transport. For some membranes, performance approached the 2019 Robeson upper bound. These findings demonstrate that optimizing SCD and incorporating amino acid-based carriers can substantially improve the CO_2/N_2 separation performance of nanocellulose membranes, reinforcing their potential in post-combustion CCS applications.

Keywords: nanocellulose, carbon capture, facilitated transport, surface charge density

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