Nanocellulose based nanocomposite hollow fiber membranes for CO_2 capture

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Abstract:

In order to boost the depletion of CO_2, industry is craving for more efficient and reliable CCS solutions. Membrane technology has the potential to offer several advantages compared to traditional technology (amine absorption or solid adsorbents), but the development of ultra-thin selective layers is crucial to make membrane separation process economically feasible for post-combustion applications [1]. Among the possible configurations, hollow fiber membranes feature the highest packing density, allowing the achievement of significant reduction in terms of size of the separation unit and, thus, resulting extremely attractive for large-scale applications. Nanocellulose is a bio-based sustainable nanomaterial, which has been widely investigated as reinforcing nanofiller for sustainable packaging materials. The nano-dimensions of the structural elements result in a high surface area and hence the powerful interaction of the nanocellulose with surrounding species, such as water, organic and polymeric compounds [2].

In the present work, nanocellulose crystals (CNC) and nanocellulose fibers (CNF) were incorporated into polyvinyl alcohol (PVA) matrix and the nanocomposite materials were fabricated as the selective layer of the thin-film-composite hollow fiber membranes via dip-coating technique. Poly(*p*-phenylene oxide) (PPO) hollow fiber was selected as the support substrate. The resulted membranes were characterized using different technics including SEM, FTIR, TGA and mixed gas permeation test. From the SEM results, it is found that the selective layer has a thickness in the range of 300~700 nm. In addition, even though the viscosity of the PVA/CNC does not change significantly, the selective layer thickness slightly increases with the increasing CNC or CNF content.

The effects of the fabrication parameters and operating conditions on CO_2 separation performances of the hollow fiber membranes were investigated using CO_2/N_2 mixed feed gas at 100% relative humidity (RH) and room temperature. The presence of CNC and CNF significantly improves both CO_2 permeance and CO_2/N_2 selectivity, as shown in **Figure 1**. In the case of PVA/CNC membranes, membrane with 80 wt.% CNC exhibits a CO_2 permeance of 672 GPU with a CO_2/N_2 selectivity of 43.6, which is higher than that of the neat PVA membrane (CO_2 permeance of 407 GPU and CO_2/N_2 selectivity of 33.7). However, the addition of CNF only slightly increases the CO_2 permeance from 408 to 470 GPU with negligible improvement on CO_2/N_2 selectivity.

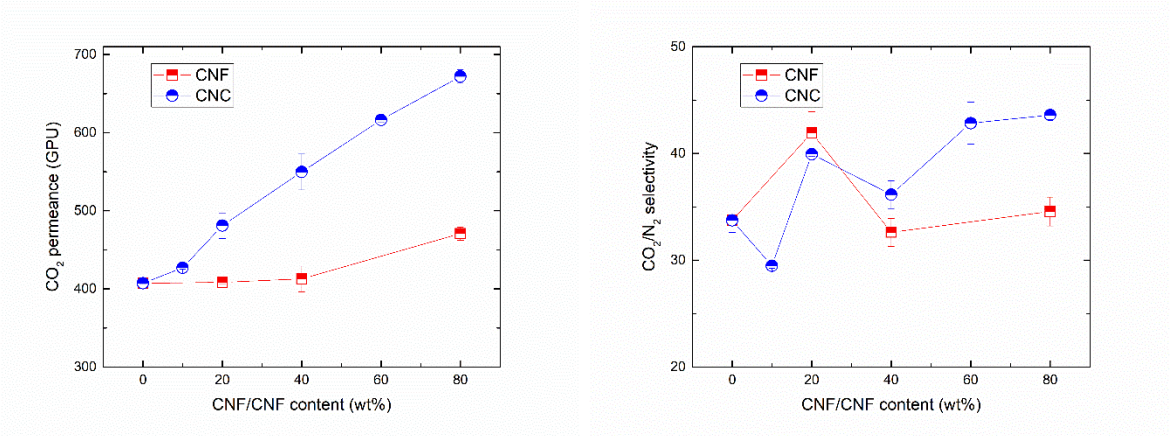

Figure 1. CO_2 permeance (left) and CO_2/N_2 selectivity (right) of PVA/CNC and PVA/CNF with different additive content at 100%RH.

The coating of the nanocomposite layer also significantly improves the membrane long-term stability compared to the neat PPO hollow fiber membranes. As shown in **Figure 2**, the CO_2 permeance of the PPO membrane reduced from 848 GPU to 433 GPU within 40 hours, while the 80 wt.% PVA/CNC nanocomposite hollow fiber membrane exhibited stable performances.

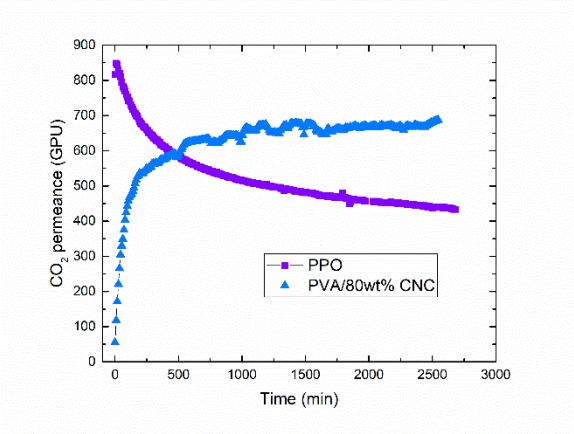

Figure 2. Comparison of long-term separation performances of PPO support and PVA/CNC composite membrane

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