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Nanocomposite membranes of silica and polysulfone for improved gas permeation

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Introduction

Polysulfone–Silica mixed matrix hybrid membranes have been prepared by incorporating silicon dioxide nanoparticles with average particle size of 136 nm. Two types of polysulfone-silica nanocomposite membranes were prepared by solution casting and solvent evaporation method to study the permeation of CO_2 and N_2 gases. Barrier properties were investigated as a function of nanoparticle composition for pure gases. SEM testing reveals that such composites have higher bounding with the polymeric matrix. Gas permeation measurements demonstrate that these materials show notable differences in gas separation efficiency, especially for the enrichment of nitrogen (N_2) from carbon dioxide (CO_2).

Methods:

Polysulfone (Mn ~ 22,000) and SiO_2 were purchased from Aldrich, USA. Chloroform was obtained from Fisher Scientific, UK.

All polysulfone (PSf) nanocoposite membranes were prepared by solution casting–solvent evaporation technique. Mixed matrix membranes were prepared by dispersing silicon dioxide (SiO_2) nanoparticles in concentrations of 0.5 and 1.0 wt. % in PSf (i.e., dispersing 100 and 200 mg, respectively, of nanoparticles with respect to 20 g weight of PSf) under high-speed ultrasonification at 50°C for about 30 min in 10 mL of chloroform, and then adding the sonicated solutions to homogenous PS solutions. The plain and mixed solutions of PS were cast as membranes in a dry atmosphere, resulting with an average dried membrane thickness of 100 μm. The prepared plain PSf, PSf-SiO_2 (0.5%) and PSf-SiO_2 (1%) are named as PSP, PS-0.5 and PS-1, respectively.

Results and Discussion

Pure gas permeability of the three PSf-based membranes as well as the corresponding CO_2/N_2 and N_2/CO_2 selectivities were measured at a feed pressure of 4 bar. Plain PS membrane (PSP) gave the lowest CO_2 permeability, with the highest selectivity CO_2/N_2. On the other hand, the PS-1 membrane exhibited the highest CO_2 permeability with the lowest CO_2/N_2 selectivity. The PS-0.5 membrane exhibited intermediate permeability and selectivity results between those of PSP and PS-1 membranes. Overall, it was found that the inclusion of SiO_2 enhances the permeability of both CO_2 and N_2. The selectivity of N_2/CO_2 was gradually increased when the SiO_2 content is increased in the membrane, and that of CO_2/N_2 was decreased when comparing PSP to PS-1. Therefore, it is found that the increase of SiO_2 content in the PS membrane increases the permeability of both CO_2 and N_2, but at the expense of the selectivity of CO_2/N_2.

Scanning Electron Microscopy (SEM) Analyses

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SEM images show that plain PSf membranes exhibited a uniform surface as shown in Fig. 1(A), and that Silica nanoparticles are uniformly distributed across the nanocomposite membrane matrix as shown in Fig. 1(B). These nanoparticles were spherical in shape with an average particle size of 136 nm (average of 16 nanoparticles). The shapes of these nanoparticles can be seen in Fig. 1 (C) and (D).

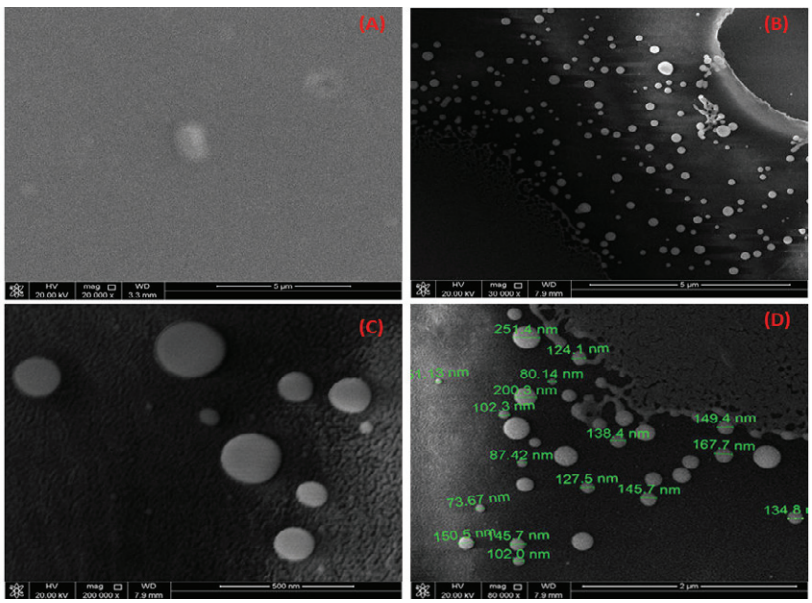

Figure 1. SEM images of (A) PSP (B) SiO_2 particles dispersed uniformly in the PS-1 (C) the spherical shape of the particles in PS-1 and (C) sample particle sizes of the SiO_2 nanoparticles in PS-1.

Conclusions

To improve PSf membrane performance, one can generally follow two distinct strategies: either to synthesize new polymers with specific chemical architectures or to modify the existing polymers by incorporating suitable fillers. The present work reports results obtained according to the latter route. It is realized from the literature that nanoparticle fillers can improve separation properties of membranes. The addition of even a small amount of SiO_2 particles into PSf membranes has improved the permeability of both N_2 and CO_2 over those of the plain PS membrane. Nonetheless, although the membranes remained more selective to CO_2 than N_2, their CO_2/N_2 selectivity has decreased.

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Keywords: Polysulfone, silica, nancomposite