Gas permeation properties of amine loaded mesoporous silica membranes for CO₂ separation

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ABSTRACT

Gas permeation properties of amine loaded mesoporous silica membranes for CO₂ separation were evaluated using a mixture of CO₂/N₂ under dry and wet conditions. Although the 3-aminopropyl loaded mesoporous silica membrane was highly CO₂ selective under dry conditions, its selectivity declined in the presence of water. By contrast, 3-trimethoxysilylpropyldiethylenetriamine (TA) loaded mesoporous silica membranes showed high CO₂ selectivity even under wet conditions. Water condensed within the mesopores inhibited CO₂ permeation of the 3-aminopropyl loaded membrane. However, the subnanometer effective pore size of the TA loaded membrane (because of the long molecular length of TA), meant that CO₂ molecules still preferentially permeated in the presence of water. The size of mesopores and modifying reagents significantly influences CO₂ selectivity. In addition, the affinity between organoamines and polar molecules may also be exploited to increase selectivity.

Keywords: Mesoporous silica; Membrane; CO₂ separation; Amine; Wet condition; Gas adsorption

1. Introduction

Since the discovery of ordered mesoporous silicas such as M41S [1,2] and FSM-16 [3], various applications for these materials with uniform and large pore sizes, extremely high surface areas and large pore volumes have been investigated, e.g., catalyst supports [4,5], adsorbents [6–14], drug delivery systems [15] and electronic devices such as a low-k film [16]. In particular, their relatively large pore sizes compared to microporous materials such as zeolites mean that various large organic molecules can enter the pores, and these organic molecules can be immobilized on the pore surface through reaction with surface silanol groups. Amongst the considerable investigations into various modified mesoporous silicas [17–19], amine-modified mesoporous silicas with their surface basicity are of great interest for practical applications such as basic catalysts [5], removal of hazardous metals [6] and CO₂ separation [7–14]. In particular, amine modified mesoporous silicas as adsorbents for CO₂ separation have been extensively investigated for a decade. Various amines could be used as modification reagents to create materials for CO₂ separation, e.g., organosilanes including amines [7–10], ethylenediamine [11], polyethyleneimine [12] and polyamidoamine dendrimers [13]. A variety of mesoporous silicas have also been studied, including M41S [12,14], SBA-12 [10], SBA-15 [11,13], and MSU-H [9].

Membrane separation techniques are among the most promising alternatives for CO₂ recovery processes with lower energy consumption, and have also been investigated using these amine loaded mesoporous