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Characterization and Performance Evaluation of PDMS/PSF Membrane for CO_2/CH_4 Separation under the Effect of Swelling

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Abstract

In this work, Polydimethyl siloxane/polysulfone (PDMS/PSF) membrane was developed by dip coating of developed PSF membrane. Developed membranes were characterized in terms of thermal analysis, glass transition temperature, and membrane morphology. Performances of the developed membranes were tested using gas permeation equipment within the pressure range of 2-10 bar. To study the water swelling in membrane, developed membranes were soaked in distilled water for 5 minutes. Gas permeation in membrane was investigated before and after swelling. Based on the results, increase in CO_2 permeance was observed due to plasticization in membrane before swelling. However, CO_2 permeance decreased after swelling in membrane. Swelling affected the separation performance of membrane by decreasing its permeance. While, CO_2/CH_4 selectivity has increased after membrane swelled. Hence, swelling resulted in membrane contraction, which contributed to the increase of selectivity. Pure polysulfone membrane exhibited higher degree of swelling, whereas PDMS/PSF membranes demonstrated substantial high resistance toward swelling. Based on swelling degree of PDMS/PSF composite membrane, this membrane can be considered as a potential water (swelling) resistant polymeric membrane for CO_2/CH_4 separation.

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Keywords: CO_2/CH_4 separation; Swelling; Permeance; Selectivity

1. Introduction

Natural gas is one of the important and primary sources of energy. Natural gas reserves are contaminated with high percentages of CO_2. Purification of natural gas is necessary to meet pipeline specifications and to use it on

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domestic and commercial scale Major constituent of natural gas is methane with the composition range of 30-90 mol%[1]. Different technologies are used for natural gas processing and purification. Natural gas processing includes adsorption, absorption, cryogenic distillation and membrane process. All these processes face some limitations in terms of high cost and complexity in process[2].

Membrane technology is one of the most emerging techniques used for natural gas purification. The main advantage of membrane separation is a simple and economical process without any major limitations. Membrane process offers up to 90% separation efficiency in a very minimal cost. Different types of membranes are used in natural gas purification[3]. These types include inorganic membranes, mixed matrix membranes and polymeric membranes. Polymeric membranes are widely used in gas separation applications due to excellent separation performance. Moreover, variety of polymeric materials can be used as a membrane in gas separation applications. Polymeric membranes are best candidate to be used under aggressive feed conditions due to their modular nature[3, 4]. Performance of the polymeric membranes is affected by plasticization and swelling in membrane. Swelling is caused by the presence of humidity in feed gas. Membrane swelling results in the deformation of polymer structure and consequently it affects the separation performance of membrane by decreasing the separation factor [5, 6]. In this work, effect of swelling on separation performance of membrane was studied.

Composite membrane is one of the types of polymeric membrane. Composite membrane is a dual layer membrane with porous support and selective top layer. Composite membrane is a potential membrane to be used in harsh operating conditions due to its excellent mechanical strength [7]. Dip coating and manual film casting techniques are used to develop composite membrane. Natural gas separation through composite polymeric membrane has been reported in literature by many researchers. Shamsabadi et al. [8] investigated gas separation in polydimethyl siloxane/polyetherimide (PDMS/PEI) composite membrane developed by dip coating and solution casting. Membranes developed by dip coating showed better separation performance in case of H_2/CH_4 mixed gas. Mansoori et al.[9] prepared a polydimethyl siloxane/polysulfone (PDMS/PSF) membrane and reported the CO_2/CH_4 selectivity of 39.81 at the feed pressure of 10 bar. Sadrzadeh et al.[10] synthesized polydimethyl siloxane/polyether sulfone (PDMS/PES) composite membrane and investigated the gas permeation of CO_2, CH_4 and H_2 in developed composite membrane. Madaeni et al.[7] studied the effect of coating method on the separation performance of PDMS/PES composite membrane. Composite membrane was developed by dip coating and solution casting method.

In present work, polydimethyl siloxane/polysulfone (PDMS/PSF) membrane was developed by dip coating of PSF with PDMS. PDMS is a rubbery polymer having excellent permeability in gas separation with super hydrophobic characteristics. PDMS also exhibits excellent mechanical and chemical stability [7]. PSF is a glassy polymer with excellent separation performance in CO_2 separation [11]. The main purpose of this work was to investigate the gas separation performance of PDMS/PSF membrane under the effect of water swelling in membrane. Gas permeation properties of PDMS/PSF membrane were reported in literature by some researchers but the effect of membrane swelling on separation performance was not investigated.

Nomenclature

P/l	Permeance of any species in GPU
l	Membrane Thickness
j	Flux of the specific species
ΔP	Partial Pressure across the membrane
GPU	Gas Permeance Unit
PDMS	Polydimethyl Siloxane
PSF	Polysulfone
PDMS/PSF (60, 120 & 180)	PDMS/PSF membrane with coating time of 60, 120 & 180 minutes