Separation and Purification Technology 307 (2023) 122752

Contents lists available at ScienceDirect

Separation and Purification Technology

journal homepage: www.elsevier.com/locate/seppur

Review

A review on the recent advances in composite membranes for CO_2 capture processes

Yangyang Dai, Zhenhua Niu, Wenjia Luo, Yuanyuan Wang, Peng Mu [*], Jian Li [*]

Key Laboratory of Eco-functional Polymer Materials of the Ministry of Education, College of Chemistry and Chemical Engineering, Northwest Normal University, Lanzhou 730070, PR China

ARTICLE INFO

Keywords:
2D nanomaterials
Composite membranes
CO_2 capture
Gas separation

ABSTRACT

In order to achieve the goal of “double carbon”, CO_2 capture should be carried out in a reasonable and efficient manner. As one of the common gas separation technologies, membrane separation technology has the advantages of low consumption, small footprint and environmental friendliness. However, the high preparation cost of inorganic membranes and the trade-off effect limiting the separation performance of polymer membranes have hindered the development of inorganic and polymer membranes. Therefore, the urgent need to prepare a high-performance composite membrane has become a current research hotspot. In recent years, 2D nanomaterials have become popular in the field of membrane separation due to their ultra-thin thickness and high specific surface area. This review focuses on membrane materials, starting from the membrane separation mechanism, and mainly introduces the breakthrough research progress of composite membranes with 2D nanomaterials as fillers in the field of gas separation. Finally, the challenges and future development directions of composite membranes in this field are analyzed.

1. Introduction

With the development of modern industry, global energy consumption is increasing, especially the burning of fossil fuels has caused a sharp increase in the concentration of CO_2 in the air. This leads to a series of serious phenomena such as the greenhouse effect [1,2] and water pollution [3]. Therefore, the efficient capture and separation of CO_2 are of great importance for improving the environment [4]. Common CO_2 capture technologies include absorption, adsorption, low-temperature distillation and membrane separation, etc [5].

The membrane separation method is based on the difference in the permeation rate of each gas component through the membrane for selective separation [6,7]. Compared with the traditional low-temperature distillation, adsorption and absorption methods, membrane separation is a novel separation technology. Owing to its many advantages such as low cost, low pollution, low energy consumption and small footprint, it is widely used in the field of gas separation [8,9]. Up to now, among a variety of CO_2 separation membranes, they can be mainly classified into inorganic membranes [10], polymer membranes [11] and composite membranes [12–14] according to membrane materials. Inorganic membranes possess high gas permeability and strong stability, but their large-scale development is limited by factors such as high fabrication costs and poor membrane-forming properties. Polymer membrane is a dense membrane formed by polymerizing polymer materials. Although its preparation cost is low, its permeability and selectivity are limited by the trade-off effect. However, composite membranes can simultaneously combine the advantages of inorganic membranes and polymer membranes, making them a current research hotspot [15]. The composite membranes usually used for CO_2 separation are mainly mixed matrix membranes (MMMs). For single inorganic or polymeric membranes, the development is limited by their respective limitations. The MMMs combine the compactness of polymer membranes with the high permeability of inorganic membranes and are expected to break the trade-off effect.

Nevertheless, the structure of the filler is considered one of the critical factors in the diffusion rate of gas molecules in the MMMs. Meanwhile, thickness of filler, composition of the filler and distribution of filler in the substrate are crucial [16]. Ultra-thin nanofiller can significantly reduce the mass transfer resistance of gas molecules in the membrane and provide faster molecular transport channels to enhance gas permeability. According to their size and shape, filler materials can be simply divided into zero-dimensional (0D), one-dimensional (1D),

* Corresponding authors.
E-mail addresses: pengmu2019@nwnu.edu.cn (P. Mu), jianli83@126.com (J. Li).

https://doi.org/10.1016/j.seppur.2022.122752
Received 17 September 2022; Received in revised form 19 November 2022; Accepted 21 November 2022
Available online 26 November 2022