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Gas permeation properties of commercial polyphenylene oxide and Cardo-type polyimide hollow fiber membranes

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Abstract

Gas separation properties of commercially available polyphenylene oxide (PPO) and Cardo-type polyimide (PI) hollow fiber membranes were investigated by CO_2/CH_4 and O_2/N_2 separation experiments. The pure gas permeation and the mixed gas separation experiments indicated that the two hollow fiber membranes were suitable candidates for O_2/N_2 and CO_2/CH_4 separations. Average O_2/N_2 permselectivities of 3.9 and 5.7 for PPO and PI hollow fibers, respectively, average CO_2/CH_4 permselectivities of 16.4 and 36.0 for PPO and PI hollow fibers, respectively, CO_2 permeances of 210 and 110 GPU at 100 psig for PPO and PI hollow fibers, and O_2 permeances of 40 GPU and 15 GPU for PPO and PI hollow fibers were achieved. The CO_2/CH_4 mixture separation was carried out at three different CO_2 concentrations and three stage-cuts at 100 psig pressure. Separation factors of up to 21.1 and 7.5 for PI and PPO membranes, respectively, and permeances of up to 83 GPU and 140 GPU for PI and PPO, respectively were obtained.

Furthermore, it was found that CO_2 permeance varied proportional to the ratio of stage-cut to feed concentration and it was observed that when the stage cuts were set equal to the concentrations of CO_2 in the feed (vol.%), the obtained separation factors were approximately equal.

Keywords: Commercial membranes; Gas separation; Stage-cut effects; Hollow fiber

1. Introduction

Although the concept of gas separation by membranes is more than 150 years old, the industrial applications of this process remained limited for many decades. While the knowledge of such membrane properties roots back in the investigations by Mitchell and Graham [1,2], the major breakthrough came with the development of high flux asymmetric cellulose acetate (CA) membranes by Loeb and Sourirajan [3]. Although the early applications of CA membranes were in water desalination, they exhibited high permeation rates and permselectivities to gases if properly dried [4,5].

In comparison with traditional gas separation technologies, membranes offer a number of advantages including: operational simplicity, weight and space efficiency, and operation flexibility. On the other hand, membranes cannot compete with some of the traditional technologies on the basis of product purity. In many applications a hybrid system consisting of membranes for bulk separation and a secondary process for final purification proves to be the most efficient and economical alternative. For example, in the case of natural gas sweetening, the bulk of CO_2 can be removed by membranes while the final purification to pipeline quality can be achieved by an amine absorption process. On the other hand, a capacity increase may result from integration of membrane units to an existing amine plant.

Selection of a membrane for gas separation applications is essentially based on its gas permeation properties such as permselectivity, mechanical strength and long-term durability. However, most membranes that show high permeability for gases usually exhibit low to moderate permselectivity. This trade-off was demonstrated by Robeson's upper bound lines [6,7].

Among glassy polymers, polyimides and polyphenylene oxide (also mentioned in the literatures as polyphenylene ether

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