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PE13) Evaluation of the Performance of Gas Separation Membranes in CO_2/CH_4 Mixtures

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1. INTRODUCTION

Membrane technology as a tool for separating gas mixtures has been existent even before the 1980s [1]. One renowned application of the membrane technology is the separation of the carbon dioxide and methane gas, among which is the biogas processing [2]. Biogas is a product of landfill treatment or anaerobic digestion and is composed mainly of carbon dioxide and methane. The anaerobic digestion is the breakdown and assimilation of food by microorganisms in the absence of oxygen. It is usually regarded as the most appropriate method for converting wet material such as animal wastes to a useful fuel. [3] In order to utilize the optimum energy that can be provided by this fuel, the methane gas must be separated from the carbon dioxide gas.

Good permselectivity is one of the important factors in assessing the success of a separation. In the case of gas separations, the use of glassy polymers is usually preferred over the use of rubbery polymers due to its good permselectivity [4]. One of the glassy polymers that has a high permselectivity is polysulfone which was the membrane used in the first commercial gas membrane process. Such a membrane was selected due to its relatively good gas pair selectivities, and superior thermal, chemical and mechanical properties. [5]On the other hand, cellulose acetate was chosen due to its low cost [6] and widespread use as a gas separation membrane [7].

In this study, the feasibility of a commercial hollow fiber and cast flat sheet membrane to separate CO_2 from CH_4 in an anaerobic digestion biogas effluent was evaluated. A polysulfone Hisep® hollow fiber membrane module and a cellulose acetate (CA) solution cast on polyester (PE) flat sheet membrane support was used for the hollow fiber and flat sheet membrane experiments, respectively.

2. MATERIALS AND METHODS

The polysulfone gas separation hollow fiber membrane module, Grade PFCD-117 was purchased from Chemicore, Inc., Korea. The selectivity and gas permeances were determined for both pure and mixed gas experiments at 40°C. Gas permeances in single gas experiments were determined at different pressures from 1 to 5 bars whereas in mixed gas, permeances were obtained at varying feed flow rates aside from varying pressures. As the feed flow rate was varied, the operating pressure was maintained at 1 bar. Likewise, operating pressure was controlled at constant feed flow rate that yielded 18% CO_2/82% CH_4 composition.

Cellulose acetate (CA) was used as received from Aldrich. The 10 wt % CA solution was prepared by dissolving CA in tetrahydrofuran. The resulting solution was then cast on a PE support of 0.1 μm thickness. Solvent was evaporated after which for 3-4 hours in a vacuum oven yielding a final membrane of thickness 100 μm. Similar operating conditions with the hollow fiber system, a temperature of $40^{\circ}C$ and pressure variations from 1 to 4 bars, were adapted in the flat sheet experiments.

3. RESULTS AND DISCUSSION

Mixed gas experiments yielded lower selectivity values of 2-3 than that from pure gas 13-15 due to the competition effect of the gases for the hollow fiber membrane experiments. Carbon dioxide and methane recoveries at the permeate and retentate, respectively, were acquired in order to identify the set of operating conditions that yields superior CH_4 and acceptable CO_2recovery values. Results revealed that increasing the feed flow rates and pressures slightly enhanced the membrane selectivity and CO_2 recovery while no significant effect was observed on CH_4recovery. Based on the data obtained from the flat sheet experiments, membrane selectivity and CO_2 permeability decreased nonetheless CH_4 permeability was affected otherwise as the pressure was increased. Pure gas data can for both membranes can be seen in Figure 1 while mixed gas data for the hollow fiber membrane can be seen in Figure 2.

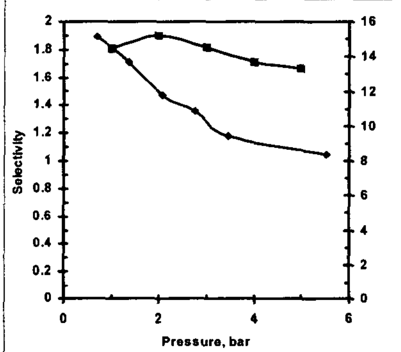

Figure 1. Membrane selectivity for single gas feed.

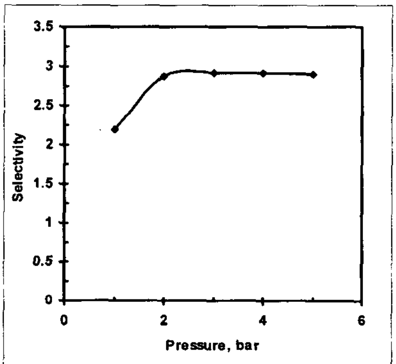

Figure 2. Membrane selectivity for mixed gas feed.

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