Chapter 9
Carbon Capture From Natural Gas via Polymeric Membranes

Nayef Mohamed Ghasem
UAE University, UAE

Nihmiya Abdul Rahim
UAE University, UAE

Mohamed Al-Marzouqi
UAE University, UAE

ABSTRACT

Polymeric membrane is a promising energy and an active alternative for conventional CO2 absorption column. The type of absorption liquid and operating parameters plays an efficient role in the ultimate absorption/stripping performance using gas-liquid membrane contactor. The gas flow rate has a significant effect on CO2 absorption performance; by contrast, it has no effect on stripping performance. Further, the CO2 absorption performance in membrane contactor could be enhanced by high liquid flow rates. The gas-liquid contact time was a key factor in enhancing the stripping flux at low temperature while liquid phase boundary layer thickness and associated mass transfer resistance is important at elevated temperature. By controlling the liquid phase velocity and the length of module at low temperature, better stripping performance can be achieved. The effect of liquid temperature on absorption performance in gas-liquid is not straightforward, since the liquid temperature cooperatively influences several factors.

INTRODUCTION

With the rapid development of technology, there is an increasing demand for fuels. Natural gas is an environmentally friendly, renewable, and clean energy source. It is also the third largest proportion in energy structure throughout the world after coal and oil. The composition of the raw natural gas extracted from producing wells depends on the type, depth, and location of the underground deposit and the geology of the area. Natural gas consists primarily of methane as the prevailing element but it also contains considerable amounts of light and heavier hydrocarbons as well as contaminating compounds

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of CO_2, N_2, Hg, He, H_2S and etc. The presence of acid gases such as CO_2 and H_2S can cause corrosion of pipeline and equipment and they present a major safety risk. Also they reduce the energy content of the gas and affect the selling price of the natural gas. Further in Liquefied Natural Gas (LNG) processing plant, while cooling the natural gas to a very low temperature, the CO_2 can be frozen and block pipeline systems and cause transportation drawback. Consequently, natural gas produced at the wellhead must be processed, i.e., cleaned, before it can be safely delivered to the high-pressure, long-distance pipelines that transport the product to the consuming public.

The traditional method for CO_2 separation is amine scrubbing. Although high product yields and purities can be obtained, the disadvantage of this method is its high energy consumption, especially during stripper, in combination with high liquid losses due to evaporation of the solvent in the stripper (Naim et al., 2012). In addition, as liquid and gas streams cannot be controlled independently the occurrence of flooding, foaming, channeling and entrainment of the absorption liquid also limits the process. Membrane technology is a promising method to replace the conventional absorption technology. It has a high energy efficiency, is easy to scale-up because of its modular design and it has a high area-to-volume ratio. A limitation can be found in the permeability-selectivity tradeoff relation. Gas–liquid membrane contactor (GLMC) combines the advantages of membrane technology with those of absorption liquid (Ze et al., 2014). In a GLMC the microporous membrane acts as a fixed interface between the feed gas and the absorption liquid without dispersing one phase into another and this decoupling of the gas and liquid phase prevents any momentum transfer occurring across the phase boundary. As a consequence, the operation problems and constraints take place in conventional absorption technology can be resolved. Further the employment of microporous membrane elucidates the permeability-selectivity tradeoff relation drawback challenged in membrane technology. The performance of GLMC as CO_2 absorber and stripper depend upon several factors such as type of membrane, type of absorption liquid, module configurations and process parameters. Understanding the optimistic attributes of these factors on CO_2 separation performance of GLMC is vital important to develop the GLMC that gives the outstanding CO_2 absorption/stripping performance. The focus of this work is to illustrate the potential for the energy efficient and effective separation of CO_2/CH_4 gas mixture via lean solvent and regenerating of the rich solvent through absorption/stripping mechanism taking place in a hollow fiber GLMC process.

BACKGROUND

GLMCs have attracted great interest over the past decade as CO_2 absorber and stripper. In the absorber, CO_2 diffuses from the feed gas through the porous membrane and is then absorbed in the flowing liquid. Then this CO_2 rich liquid circulated form the absorber to the stripper membrane contactor module in which stripped CO_2 will be carried by sweep gas (Figure 1).

In the GLMC, gas and liquid flow on the different side of the microporous membrane and membrane acts only as a barrier between two phases without dispersing one phase to another. In general, when hydrophobic microporous membranes are used in membrane contactors, the gas-liquid interface is immobilized at the opening of the pores of microporous membrane by careful control of the pressure difference between the two phases. For applications in gas–liquid absorption/desorption, the driving force is based on the concentration gradient. The gas molecules to be separated diffuse from the concentrated phase to the gas liquid interface via the membranes pores the then contacts the diluted phase on the other

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