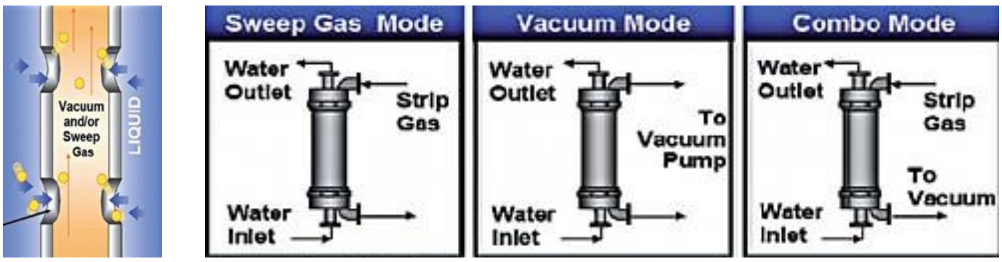
Investigation of liquid-infused membranes as gas-liquid membrane contactors for CO_2 stripping from water

1- Overview

In this project a novel type of polymeric membrane known as slippery liquid-infused membrane (SLIM) [1, 2] will be investigated as the hydrophobic membrane in a gas-liquid membrane contactor (MC) module. In MCs, gas and liquid come into direct contact with each other, for the purpose of mass transfer between phases, without dispersing one phase into the other (see **Figure 1(a)**).[3] MCs are hydrophobic which do not allow liquid phase to pass through the pores into the gas side. The required pressure to force water into the pores is calculated from Young-Laplace equation ($\Delta P = \frac{2\gamma Cos\theta}{r}$). According to Henry's law ($p = Hx$), if the gas partial pressure (p) is reduced, the amount of dissolved gas in water (x) will be reduced correspondingly. Partial pressure of gas can be lowered by either lowering the total pressure of gas (applying vacuum) or altering the concentration of gases (a strip gas that contains little or none of the gas being removed from water can be introduced into the gas side (see **Figure 1(b)**)).

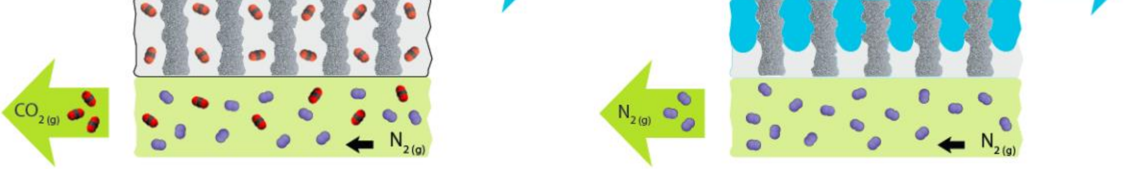


(a) **(b)**

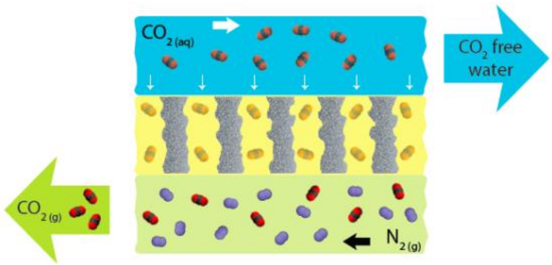
Figure 1. (a) gas transfer mechanism in a hollow fiber membrane contactor. (b) Different gas stripping techniques used in membrane contactor modules.[3]

2- Problem statement

The main issue with the conventional dry hydrophobic membranes in MC applications is the failure of the membranes due to partial wetting of the membrane pores (see **Figure 2(b)**). This can subsequently lead to the total pore wetting of the pores by the liquid phase. Once the pores get filled by the liquid phase, gas and liquid will mix and no mass transfer of the desired species would occur. The unwanted pore wetting can happen slowly or quickly in the course of the MC process depending on the applied pressure. This pressure should be lower than the breakthrough pressure (Young-Laplace pressure) which depends on the interfacial tension between the liquid phase and the fluid phase presents in the pore (γ), pore radius (r) and the contact angle between the liquid phase and the polymer material of the membrane pore (θ). Considering a fixed pore radius, the lower the interfacial tension, the lower the breakthrough pressure leading to the unwanted water permeation through the pores. This phenomenon is significant specially when surfactants present in the liquid phase.



(a) **(b)**



(c)

Figure 2. Schematic drawing of a membrane contactor (MC) process between the carrier gas (N_2) and the liquid phase (water with dissolved CO_2) for stripping CO_2 gas using **(a)** conventional dry hydrophobic membrane in which the pores are filled with air. **(b)** Failure of the conventional hydrophobic membrane in MC application due to partial pore wetting by water. **(c)** Application of liquid-infused membrane in which the pores are filled with the infusion liquid (yellow) as the hydrophobic membrane in the MC process.

3- Possible solution

Hydrophobic liquid-infused membranes (LIMs) in which the pores are pre-filled with a low surface tension, fluorinated oil can be a potential alternative to address the pore wetting issue of the normal hydrophobic membranes. It has been already shown that the required breakthrough pressure of water in LIM is lower than that in normal dry membrane.[2] Additionally, it is being demonstrated that the CO_2 solubility in the infusion liquid (Krytox 101) is higher than that of ionic liquids with highest CO_2 solubilities.[4-6] Although, the overall diffusivity of the gas species through the air-filled pore in dry membrane might be higher than that through the liquid-infused pore in LIM, the long-term applicability of later without failure can be higher.

4- Objectives

In this assignment the applicability of LIM as gas-liquid membrane contactor is investigated in both small scale microfluidic experiments as well as larger scale experiments using commercial MC modules. The mass transfer modeling/analysis should be also performed to better compare the performance of dry and liquid-infused membranes.

References

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