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CHARACTERIZATION OF MEMBRANES FOR ADVANCED DIRECT AIR CARBON CAPTURE

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ABSTRACT

Carbon capture is essential for lowering anthropogenic carbon emissions and, as a result, limiting global warming. Membrane technology has a lot of potential for extremely efficient carbon capture because of its energy-efficient and environmentally friendly properties. This research focuses on the development of a clean carbon dioxide (co_2) capture technique based on a ceramic membrane. DAC (direct air carbon capture) is a new method of extracting co_2 from the atmosphere with the potential to remove massive amounts of co_2. This study presents experimental results on the permeation of gases such as carbon dioxide and air through ceramic membranes with pore sizes of 200nm and 6000nm at temperatures of 20°C, 100°C, and 150°C. The behaviour of gases across the membrane was depicted in the experimental results, demonstrating that pressure is a major determining factor in determining the rate of flow for gases through the membrane, as the flow rate of both co_2 and air gases increased exponentially regardless of membrane geometry or operating conditions. Experimental results showed that the gas permeance for $C0_2$, Air, through a ceramic membrane with different pore sizes of 200nm, 6000nm, decreases with increasing pressure drop. It interested to note for ceramic membranes, with different pore sizes (200nm, 6000nm) the permeance of Air is larger than that of co_2. This indicated that co_2 can be adsorbed by ceramic membranes. The ceramic membrane's inner surface morphology was studied. The particles are equally scattered across the ceramic membrane's surface. The ceramic membrane's surface is crack-free and smooth. contact angle measurements were also used for ceramic membrane characterization. The ceramic membrane's water contact angle is 43.54 degrees, indicating that it has a hydrophilic surface. This is due to the presence of hydroxyl (OH–) groups having hydrophilic properties on their surface and pores.

KEYWORDS: Direct carbon capture, ceramic membrane, contact angle measurement, gas permeation. SEM analysis

1 INTRODUCTION

Global agreements on greenhouse gas reductions to attain peak emissions and carbon reduction have been proposed in this context, and efficient solutions to reduce carbon emissions are in high demand. Given that fossil fuels will continue to be the world's dominant energy source in the future decades, capture, utilisation, and storage (CCUS) has emerged as one of the most viable solutions to the pressing problem. dominant energy source in the future decades, carbon capture, has emerged as one of the most viable solutions to the pressing problem. (Mai bui et al. 2018, Gao et al. 2020. This has a huge impact on the earth's surface, causing temperature variations, drying/drought, and other ecosystem changes. Because evidence has demonstrated a direct link between global warming and climate change, the need to capture greenhouse gases has been a global priority in recent decades (Lashoff, and Ahuja, 1990) Ceramic membranes, on the other hand, are most typically formed of metal oxides such as silica, alumina, and zirconia. The presence of hydroxyl (OH–) groups on the surface of these materials makes them hydrophilic.) Membrane separation has various advantages over the traditional sorbent-based direct air carbon capture (DAC) technique in this context. Among the different separation processes, membrane separation is generally considered the most energy-efficient technology for CO_2 separation. Furthermore, this method of CO_2 capture does not necessitate the use of any special chemicals or sorbents. Membrane separation systems have the greatest benefit in that they are scalable and maybe put in several places. Because of these membrane separation features, membrane -DAC may be the best technology for ubiquitous and ambient DAC. Because of its distinctiveness, membrane -DAC can absorb CO_2 in ways that have never been explored before (Fujikawa et al. 2020).

2 METHODOLOGY.

The ceramic core technology used in this study can be utilised to replace traditional reservoir evaluation methodologies. The core materials used for this study were synthetic ceramic cores. They are suitable for this study because of their low cost, low energy consumption, durability, and high tensile strength, as well as their mechanical and thermal resilience, which allows them to be utilised in acidic, high-temperature settings like those found in the oil and gas industries. To prevent gas leakage, a porous ceramic core is put into the centre of an annulus of a shell and tube

mechanism, and both ends are sealed with graphite. Prior to each experiment, a leak test is performed by releasing the supply gas (natural gas) at twice the required pressure to detect any pressure drop along the lines, and a snoop solution is used to detect any leak. Before allowing the system to reach thermal equilibrium, it is preheated to the desired temperature. The natural gas (Co_2 and Air) from the gas cylinder is then released by the gas regulator and allowed to flow into the nano-core sample through the pressure valve, which is held in place by the core holder, which is coated with a heated jacket that functions as a heat absorber. The gas is permitted to pass through the ceramic membrane to an exit line that connects the core inlet to the flow metre output and then into a fume cupboard. The system is left to run for some time once the pressure gauge has been verified and set to the correct pressure and temperature Once this stability is attained, the data on the flow metre, pressure gauge, and thermocouple are recorded. This experiment was conducted on two different nano-core materials with pore sizes of 200nm and 6000nm at pressures of 0.2, 0.6, 1.0, 1.4, 1.8, 2.2, 2.6, and 3 bar. The experiment was carried out in a reservoir state of thermal stability of 20°C, 100°C, and 150°C for each of the two different pore size membranes

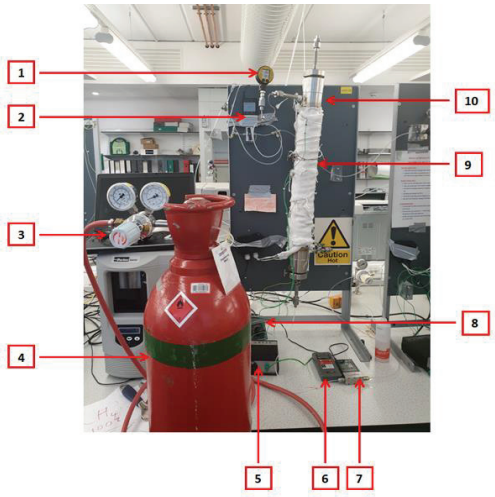

Figure 1 shows the experimental setup, which includes all the necessary equipment. As indicated in Figure 2, the following equipment is used to set up the experiment. (1) a pressure gauge (2) a pressure valve (3) a gas regulator (4) a gas cylinder (5) a thermometer (6) a thermocouple transducer (7) a flow metre (8) a heat regulator (5) a core holder

3. DISCUSSION AND RESULTS

3.1. EFFECT OF FLUX ON PRESSURE DROP

For three different membranes with pore sizes of 200nm and 6000nm, the experiment was carried out at two different temperatures with predefined pressures ranging from 0.2 to 3.0bar at 0.4bar increment intervals. To study the effect of pressure drop on flux, temperatures of 100°C, 150°C, and 200°C were chosen for all two membranes. The statistical plots in figures 2 and 3 show how natural gas reacts to pressure variations. Regardless of the temperature difference, the gas tends to travel quicker when the pressure rises from 0.2bar to 3bar, increasing the rate at which it flows per unit area in the system. The studies show that as reservoir pressure rises, permeability rises as well, implying that the direction and rate of gas flow in a reservoir are determined by the pressure gradient. The behaviour of gases across the ceramic membrane is depicted in Figures 3 and 4, demonstrating that pressure is a major determining factor in determining the rate of flow for gases through the ceramic membranes because the flow rate of both gases increased exponentially regardless of membrane geometry or operating conditions. Air, which has a lower molecular weight, flows through the membrane significantly faster than CO2 in each situation. Because of the Knudsen regime, where flow is inversely proportional to molecular mass squared, lighter gases permeate faster than heavier gases. The linear relationship between flux and pressure, on the other hand, implies that laminar flow is present. According to this series of studies, the molecular weight of the gases, which is 44 for carbon dioxide and 28 for air, influences the process of flow through the membrane.

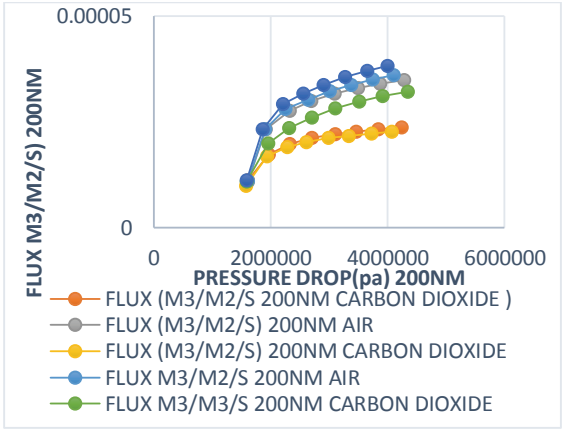

Fig 2 Effect of pressure drop on flux for 200nm membrane for co_2 and AIR at temperatures 20°c, 100°c, and 150°c,

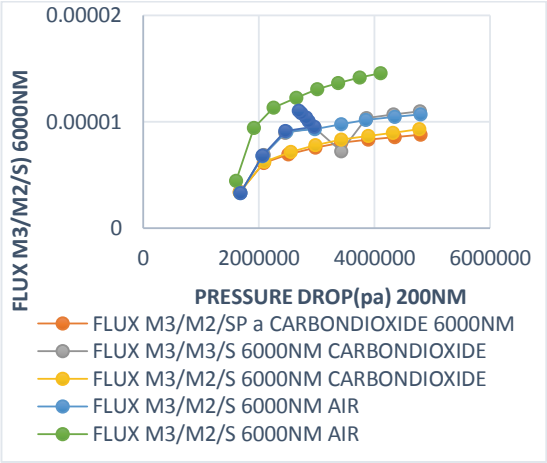

Fig 3 Effect of pressure drop on flux for 6000nm membrane for Co_2 and Air at temperatures 20°c, 100°c, and 150°c

3.2. EFFECT OF PERMEANCE

For two different membranes with pore sizes of 200nm and 6000nm, the experiment was carried out at three different temperatures with predefined pressures ranging from 0.2 to 3.0bar at 0.4bar increment intervals. To study the impact of pressure drop on permeance, temperatures of 100°C, 150°C, and 200°C were chosen for all two membranes based on the statistical plots in figures 2 and 3. The pressure drop was analysed and plotted against the permeance, which is a measure of how well the membrane allows gas to pass through it. The permeances of Co_2 and Air were temperature-activated, and the permeances decrease as the temperature increases, in figures 4, and 5. The permeance tends to decrease as the pressure drop rises, ending up having high permeance according to the charts. The needed membrane area is inversely related to the gas permeance property. As a result, only high permeance separation membranes with realistic size and pressure conditions can be considered a practicable choice for DAC (Fujikawa et al. 2020). Figure 4 and 5 shows that the gas permeance for $C0_2$, Air, through a ceramic membrane with different pore sizes of 200nm, and 6000nm, decreases with increasing pressure. It interested to note for ceramic membranes, with different pore sizes (200nm, 6000nm) the permeance of Air is larger than that of co_2. It illustrates that as pressure rises, the permeance of co_2 decreases significantly. This revealed that co_2 can be absorbed by ceramic membranes. The decrease in co_2 permeance with increasing pressure drop is primarily due to a decrease in the equilibrium sorption constant as temperature rises. (Lin and Kanezashi, 2017).

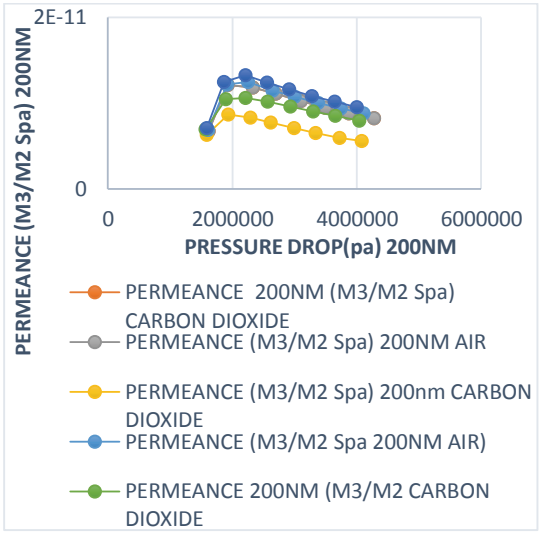

Fig 4 Effect of permeance on pressure drop for 200nm membrane FOR CO_2 and AIR at temperatures 20°c, 100°c, and 150°c,

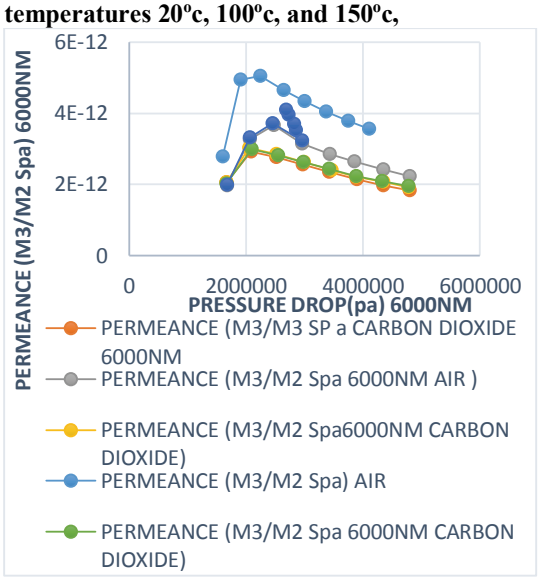

Fig 5 Effect of permeance on pressure drop for 6000nm membrane FOR CO_2 and AIR at temperatures 20°c, 100°c, and 150°c

3.3. CERAMIC MEMBRANE'S MORPHOLOGY RESULTS

SEM images of the ceramic membrane's inner surface morphology at different magnifications are displayed in figure 6. The particles are equally scattered across the ceramic membrane's surface. The ceramic membrane's surface is crack-free and smooth.

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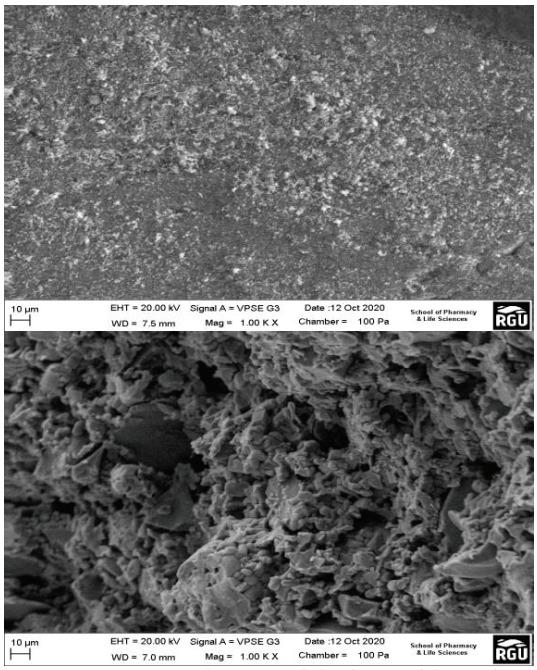

Fig. figure 6 SEM images of the inner side surface of the ceramic membrane.

3.4. CONTACT ANGLE MEASUREMENTS

The contact angle measurement is performed by the liquid in contact with the nano-porous core samples of a different form of nanocore samples. For this purpose, the sessile drop method is used in this study to measure contact angle. The ceramic membrane of 6000nm and 200nm was used for the contact measurement Contact angle measurements were carried out using the Attention theta tensiometer Biolin scientific. The size of the liquid droplet used was constant at 5.5µL. All measurements in these experiments were carried out at room temperature. the contact angle formed by a single drop of a very liquid was analysed and recorded by a software called "one Attention, on a system connected to the instrument. Image records were set to 90 seconds at %200FPS. The first contact of a water droplet with the ceramic membrane is seen in Figure 7. The ceramic membrane's water contact angle is 43.54 degrees, indicating that it has a hydrophilic surface. This is due to the presence of hydroxyl (OH–) groups having hydrophilic properties on their surface and pores.

Figure 7 water drop on the ceramic membrane surface

4 CONCLUSIONS

This research shows that membrane features and operating conditions are crucial in defining methane and carbon dioxide flow characteristics. It interested to note for ceramic membranes, with different pore sizes (200nm, 6000nm) the permeance of Air is larger than that of co_2. This indicated that co_2 can be adsorbed by ceramic membranes, in these conditions, the ceramic membrane can be considered a practicable choice for DAC. The permeance tends to decrease as the pressure drop rises, ending up having high permeance according to the charts The needed membrane area is inversely related to the gas permeance property. As a result, only high permeance separation membranes with realistic size and pressure conditions can be considered a practicable choice for DAC (Fujikawa et al. 2020). The ceramic membrane's inner surface morphology was studied. The particles are equally scattered across the ceramic membrane's surface. The ceramic membrane's surface is crack-free and smooth. contact angle measurements were also used for ceramic membrane characterization. The ceramic membrane's water contact angle is 43.54 degrees, indicating that it has a hydrophilic surface. This is due to the presence of hydroxyl (OH–) groups having hydrophilic properties on their surface and pores.

5. ACKNOWLEDGEMENTS

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