# Transport Modeling in Fumasep FAA-3-50 Membrane for Optimizing Direct Air Capture Systems

This study optimizes Direct Air Capture systems using advanced membrane modeling. This improves efficiency in removing $CO_2$ from the atmosphere, making carbon capture more sustainable and cost-efficiently; essential for combating climate change.

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## Introduction & Goals

The engineering problem being addressed in this study is the time-dependent transport modeling in the Fumasep FAA-3-50 membrane used in moisture swing Direct Air Capture, a technology gaining attention as a potential solution for mitigating carbon dioxide emissions. Understanding the transport mechanisms in the membrane is crucial for optimizing the efficiency and performance of the membrane in DAC systems. Energy-efficient and continuous carbon dioxide membrane separation has recently gained attention with the advent of facilitated chemical transport and novel electrochemical methods. This study highlights the potential for continuously removing $CO_2$ from air using commercial anion exchange membranes driven exclusively by a water vapor gradient.

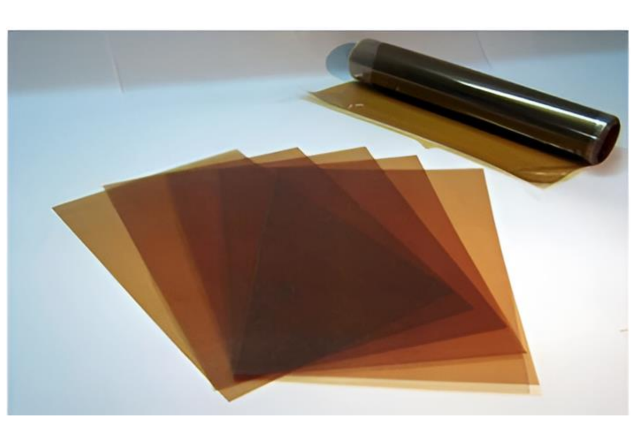

FIGURE 1. Fumasep FAA-3-50 membrane (Ref. 4)

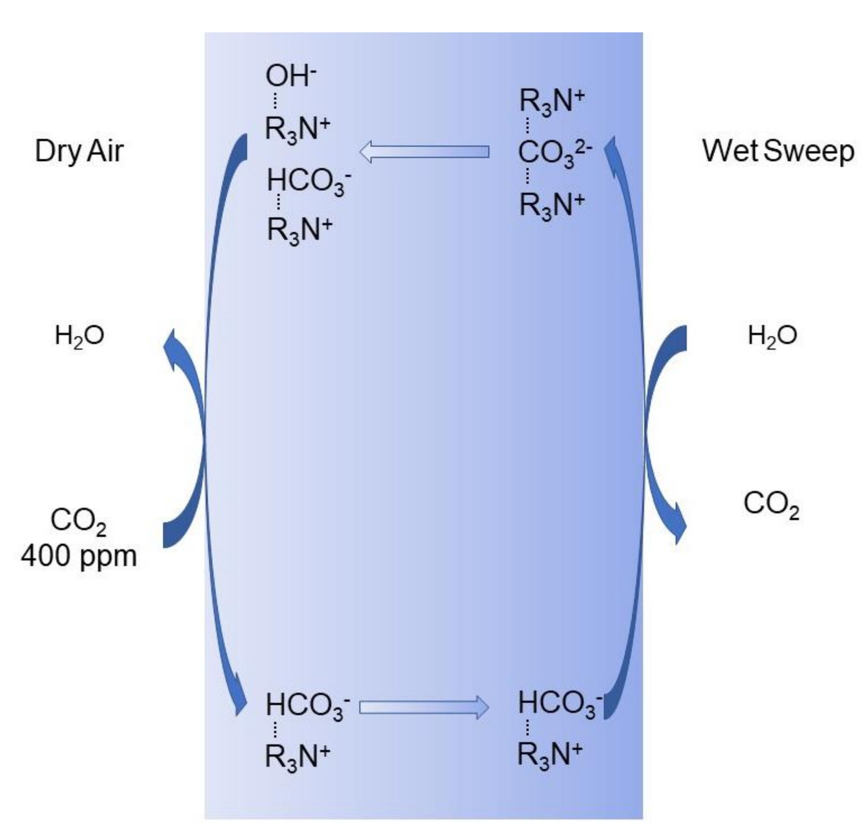


FIGURE 2. $CO_2$ Pumping in the presence of a water gradient in moisture-swing membranes (Ref. 1)

## Methodology

A 2D time-dependent simulation is conducted to study mass transport in a Fumasep FAA-3-50 anion exchange membrane. The simulation employs the Nernst–Planck Equations interface to model the diffusion and migration of dissolved ionic species. The flux of the ionic species i in the solution is given by the mass flux vector (SI unit: $mol/(m^2.s)$)

$$\mathbf{N}_i = -D_i \nabla c_i - z_i u_{m,i} F c_i \nabla V + c_i \mathbf{u}$$

The study considered two scenarios: one with $H_2O$ constant diffusivity and another with concentration-dependent diffusivity. This approach allows for a detailed analysis of how variations in diffusivity influence the overall transport behavior within the membrane.

## Results

The simulation results for steady-state carbon flux, including the flux of $HCO_3^-$, $CO_3^{2-}$, and $CO_2$, yielded 10.8 μmol/(m²·s), closely matching the published value of 11 μmol/(m²·s). For steady-state $H_2O$ flux, the values were 0.58 mmol/(m²·s) with a constant diffusion coefficient and 0.55 mmol/(m²·s) with concentration-dependent diffusivity, aligning well with the reported value of 0.58 mmol/(m²·s). Also, An ion concentration gradient generated an electric field of approximately 1.9 mV in the membrane. These results demonstrate the importance of maximizing carbon flux while minimizing water usage and energy costs effects to enhance DAC performance. Future work will extend these findings by incorporating electric field, making the system more efficient and sustainable for large-scale deployment.

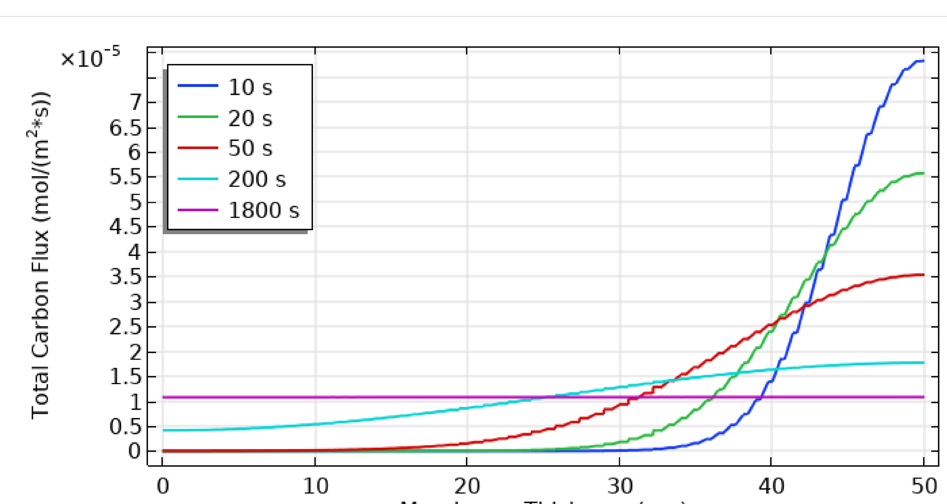


FIGURE 3. Total carbon flux distribution in the membrane over time

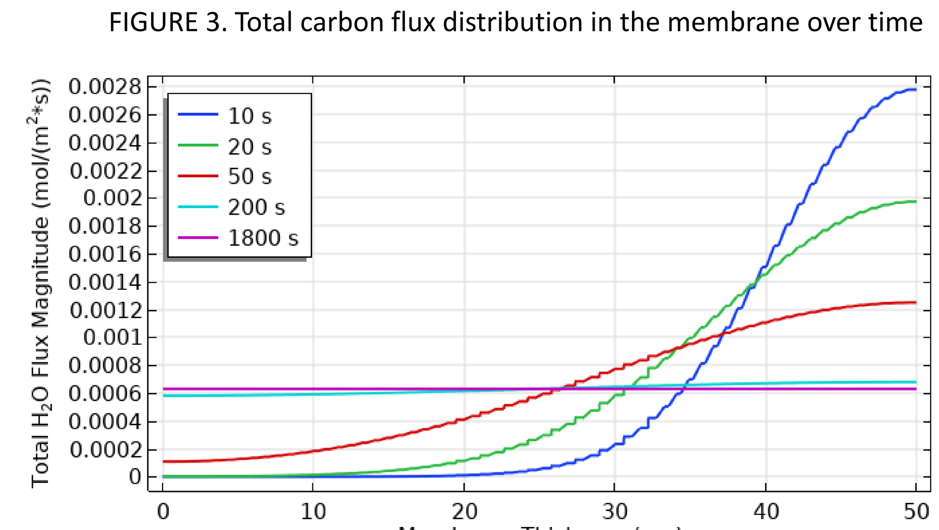


FIGURE 4. Total $H_2O$ flux distribution in the membrane over time

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Excerpt from the Proceedings of the COMSOL Conference 2024 Boston