Efficient membrane-based Direct Air Capture (m-DAC) technology using Graphene Oxide/Pebax based Mixed Matrix Membranes

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The increasing concentration of carbon dioxide (CO_2) in the atmosphere is a significant driver of global warming and climate change, necessitating effective strategies to capture and reduce CO_2 emissions, even from dilute sources. This paper investigates advanced membrane-based technologies for capturing CO_2 from air. Traditional carbon capture methods, such as amine-based absorption, are effective but come with significant drawbacks, including high energy consumption, increased costs, and substantial water usage. Membrane gas separation offers a promising alternative due to its process simplicity, and lower energy demands [1]. Hence, this research explores the development of highly selective and permeable polymeric asymmetric membranes for capturing CO_2 from low concentration sources. The membranes were synthesized by forming Pebax -MH1657 films, which were incorporated with Graphene Oxide (GO) to improve permeability and selectivity, on a macroporous support made of poly(sulfone) (PSF) to provide the mechanical support necessary for the active layer to stand. Further amine functionalization to the GO was also investigated to study the impact of amine group attachment to the matrix in the performance, and two types of amines were used, Primary amine (NH_3) and Polyethylenimine (PEI). Chemical, physical, and morphological analysis to investigate the nature and compatibility of produced membranes to the desired application were done. As well as Pure gas and mixed gas (10% v/v CO_2 and 0.04% v/v CO_2 content in N_2) permeance tests were performed to study the performance of the membranes by obtaining the permeance and selectivity of the membranes at different loadings of GO in the matrix. The MMMs prepared in this research were able to achieve, under DAC condition, selectivity and permeability of 68 and 21.27 GPU with the A-GO MMM (0.3 wt.% loading), and 56and 16.9GPU with the PEI-GO MMM for the same loading. The findings demonstrate the potential of membrane technology in efficiently capturing CO_2 from dilute sources, paving the way for more sustainable and cost-effective solutions to mitigate climate change.

References

[1] Omnya Al Yafiee, Fatima Mumtaz, Priyanka Kumari, Georgios N. Karanikolos, Alessandro Decarlis, Ludovic F. Dumée, Direct air capture (DAC) vs. Direct ocean capture (DOC)–A perspective on scale-up demonstrations and environmental relevance to sustain decarbonization, Chemical Engineering Journal, Volume 497, 2024,
[2] [dataset] B.D.F.a.L.M.R. A. W. Thornton, Polymer Gas Separation Membrane Database, CSIRO, 2012. https://research.csiro.au/virtualscreening/membrane-database-polymer-gas-separation-membranes/.

Figures

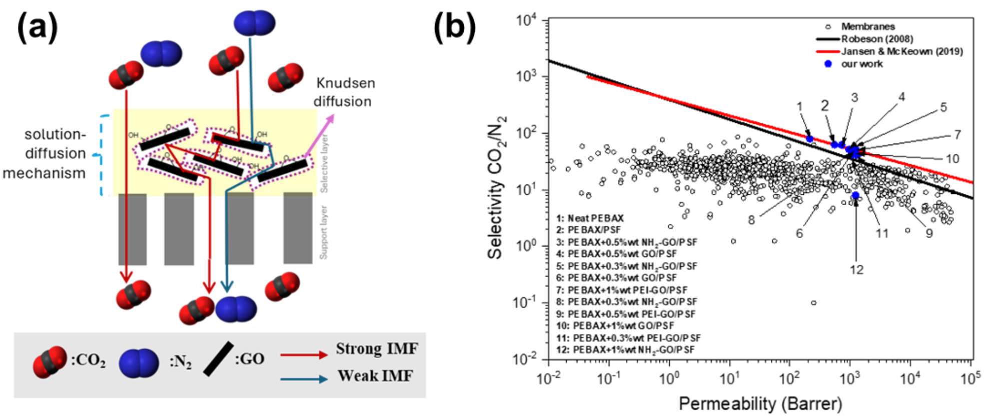

Figure 1: (a) The GO-based Mixed matrix membrane MMMs structure and diffusion mechanisms expected to occur, (b) Pure Gas permeation results :The ideal selectivity plotted against Permeability in Barrer; the white dots represent data from literature [2].