OPEN ACCESS Freely available online

ISSN: 2155-9589
Journal of Membrane Science & Technology

Short Communication

CO_2 Selective Membranes: Innovative Separation Platforms for Carbon Management Applications

Lucas Ferreira*

Department of Chemical and Environmental Engineering, Atlantic Nova University, Lisbon, Portugal

DESCRIPTION

CO_2 selective membranes are advanced separation materials designed to preferentially allow carbon dioxide molecules to pass through while limiting the movement of other gases. These membrane systems have gained importance in environmental and industrial applications because carbon dioxide separation is required in processes such as natural gas purification, hydrogen production, biogas upgrading and carbon management systems. Their ability to provide selective gas transport offers an efficient approach for reducing carbon dioxide emissions from different sources. Carbon dioxide is a major component of industrial gas streams produced by activities such as power generation, chemical manufacturing, cement production and fuel processing. Removing carbon dioxide from mixed gas streams requires separation technologies that can achieve high efficiency with reduced energy consumption. Membrane-based separation systems provide an alternative approach by using selective transport properties rather than relying on energy-intensive phase changes [1-3].

The performance of CO_2 selective membranes depends on several factors, including membrane structure, material composition, gas permeability and molecular interactions. An effective membrane must allow rapid carbon dioxide movement while maintaining separation from gases such as nitrogen, methane and hydrogen. The balance between permeability and selectivity is an important consideration in membrane development. Polymer membranes are among the most commonly used materials for carbon dioxide separation. These membranes are valued because of their flexibility, processability and ability to form thin selective layers. Different polymer structures provide different interactions with carbon dioxide molecules. Functional groups within polymers can influence gas solubility and transport behavior, allowing researchers to improve separation performance [4,5].

Mixed matrix membranes represent another important category of CO_2 selective materials. These membranes combine polymer materials with inorganic or organic fillers to create improved transport properties. Nanomaterials, porous structures and specialized particles can modify membrane characteristics and enhance interactions with carbon dioxide. The combination of different materials provides opportunities for developing membranes with improved separation abilities. Inorganic membranes, including ceramic and molecular sieve membranes, are also used for carbon dioxide separation. These materials often provide high thermal stability and chemical resistance. Their well-defined pore structures allow selective movement of gas molecules based on differences in molecular size and interaction properties. Inorganic membranes are useful for applications involving demanding operating conditions [6,7].

Metal organic frameworks and other porous materials have received attention for CO_2 selective membrane applications. These materials contain organized structures with adjustable pore environments. Their unique characteristics allow selective interaction with carbon dioxide molecules. When incorporated into membrane systems, they can influence gas transport pathways and improve separation performance. Carbon capture applications represent a major area for CO_2 selective membrane technology. Industrial facilities release large quantities of carbon dioxide through combustion and chemical processes. Membrane systems can be integrated into these facilities to separate carbon dioxide from exhaust gases before release into the atmosphere. Their compact design and continuous operation make them suitable for large-scale applications. Natural gas purification is another important application of CO_2 selective membranes. Natural gas often contains carbon dioxide that must be removed to improve fuel quality and meet pipeline requirements. Membrane separation systems can selectively remove carbon dioxide while retaining valuable methane. This process supports efficient gas processing and resource utilization [8,9].

Hydrogen production also benefits from carbon dioxide separation membranes. During hydrogen generation from hydrocarbon-based processes, carbon dioxide is produced as a by-product. Selective membranes can separate carbon dioxide from

Correspondence to: Lucas Ferreira, Department of Chemical and Environmental Engineering, Atlantic Nova University, Lisbon, Portugal, E-mail: lucas.ferreira@shortmail.com

Received: 29-May-2026, Manuscript No. JMST-26-32124; **Editor assigned:** 01-Jun-2026, Pre QC No. JMST-26-32124 (PQ); **Reviewed:** 15-Jun-2026, QC No. JMST-26-32124; **Revised:** 23-Jun-2026, Manuscript No. JMST-26-32124 (R); **Published:** 29-Jun-2026, DOI: 10.35248/2155-9589.26.16.450

Citation: Ferreira L (2026). CO_2 Selective Membranes: Innovative Separation Platforms for Carbon Management Applications. J Membr Sci Technol. 16:450.

hydrogen streams, improving hydrogen purity and supporting cleaner energy production. Biogas upgrading is another area where CO_2 selective membranes are applied. Biogas contains methane and carbon dioxide along with smaller quantities of other gases. Removing carbon dioxide increases methane concentration and improves the quality of the final gas product. Membrane systems provide a continuous method for separating these gas components [10].

Despite their advantages, CO_2 selective membranes face several challenges. Membrane materials must maintain performance under different temperatures, pressures and gas compositions. Long-term stability, resistance to contaminants and consistent separation efficiency are important factors for practical applications. Material improvements and process optimization are required to address these challenges. Surface modification is an approach used to improve membrane performance. By changing surface characteristics or adding functional groups, scientists can influence interactions between carbon dioxide and membrane materials. These modifications may improve selectivity and control gas transport behavior.

CONCLUSION

Computational modeling has become an important tool in membrane development. Simulation methods help analyze molecular interactions, transport pathways and material behavior. These approaches assist scientists in understanding membrane performance and identifying suitable material combinations. Sustainable membrane manufacturing is also receiving increasing attention. Developing membranes from environmentally friendly materials and reducing energy requirements during production can support greener separation processes. Renewable polymers and recyclable materials are being explored for future membrane systems.

REFERENCES

1. Ling K, Men F, Wang WC, Zhou YQ, Zhang HW, Ye DW, et al. Carbon monoxide and its controlled release: Therapeutic application, detection and development of Carbon Monoxide Releasing Molecules (CORMs). J Med Chem. 2018;61:2611–2635.
2. Pickles CA, Elliott R. Thermodynamic analysis of selective reduction of nickeliferous limonitic laterite ore by carbon monoxide. Miner Process Extr Metall. 2015;124:208–216.
3. Ashford B, Tu X. Non-thermal plasma technology for the conversion of CO_2 . Curr Opin Green Sustain. Chem. 2017;3:45–49.
4. Checchetto R, De Angelis MG, Minelli M. Exploring the membrane-based separation of CO_2 /CO mixtures for CO_2 capture and utilisation processes: Challenges and opportunities. Sep Purif Technol. 2024;346:127401.
5. Sidhikku Kandath Valappil R, Ghasem N, Al Marzouqi M. Current and future trends in polymer membrane-based gas separation technology: A comprehensive review. J Ind Eng. Chem. 2021;98:103–129.
6. Bakhtin DS, Sokolov SE, Borisov IL, Volkov VV, Volkov AV, Samoilov VO ,et al. Mitigation of physical aging of polymeric membrane materials for gas separation: A review. Membranes. 2023;13:519.
7. Han Y, Salim W, Chen KK, Wu D, Ho WSW. Field trial of spiral-wound facilitated transport membrane module for CO2 capture from flue gas. J Membr Sci. 2019;575:242–251.
8. Mokarizadeh H, Moayedfard S, Maleh MS, Mohamed SIGP, Nejati S, Esfahani MR, et al. The role of support layer properties on the fabrication and performance of thin-film composite membranes: The significance of selective layer-support layer connectivity. Sep Purif Technol. 2021;278:119451.
9. Liang CZ, Chung TS, Lai JY. A review of polymeric composite membranes for gas separation and energy production. Progress Polym Sci. 2019;97:101141.
10. Abdellah L, Boutevin B, Guida-Pietrasanta F, Smaihi M. Evaluation of photocrosslinkable fluorinated polydimethylsiloxanes as gas permeation membranes. J Membr Sci. 2003;217:295–298.