Passive CO_2 Separation Membranes for Hot Flue Gases

LUNA
DEFYING IMPOSSIBLE.

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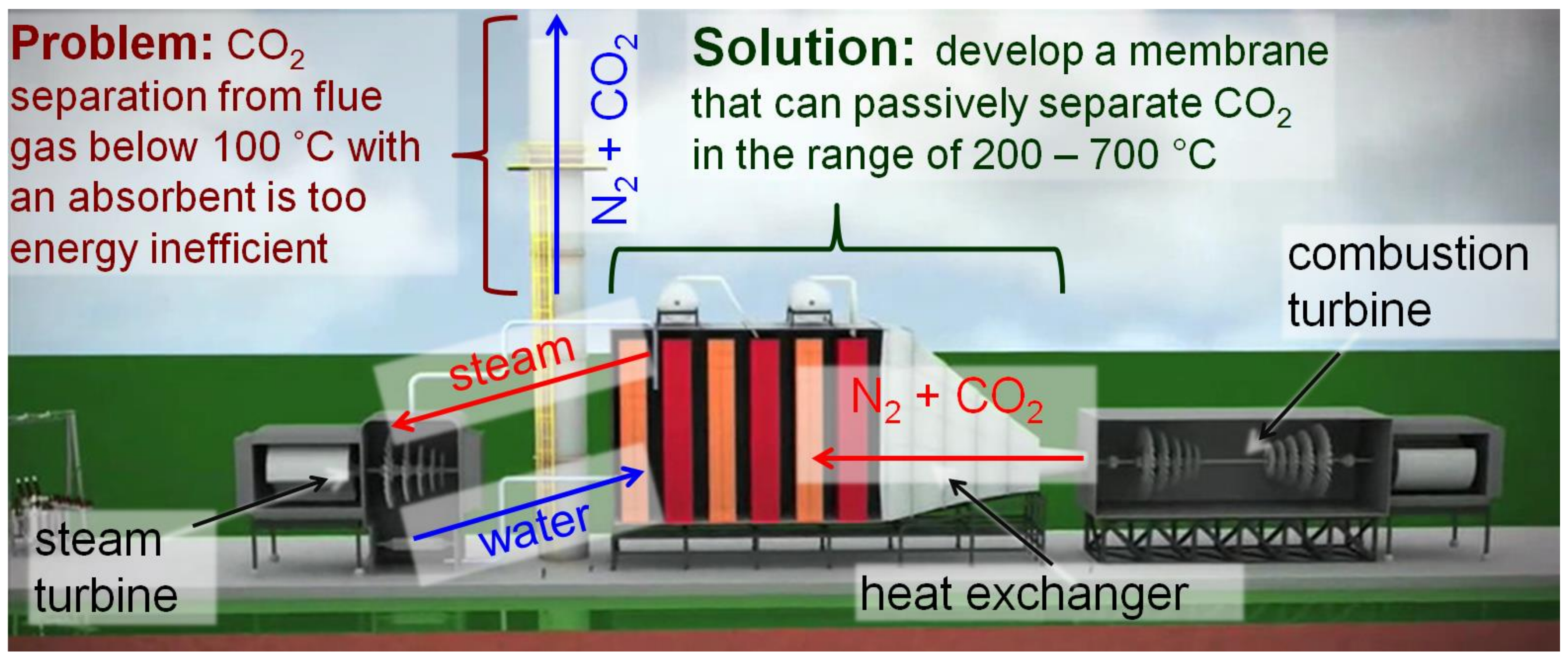
Improving CO_2 capture energy efficiency by integrating passive separation membranes into heat recovery steam generators (HRSG) and boilers

Overcoming the Conventional Energy Efficiency Limitations of CO_2 Capture



The dual phase membrane enables passive CO_2 separation from incipient flue gas in the temperature range of 200 – 700 °C and 1 – 20 ATM.

The Need: An economically practical technology is needed to retrofit existing infrastructure for capturing CO_2 from fossil fuel power plants and other, large scale sources of flue gas.

The Problem: Conventional CO_2 technologies capture cold (< 150 °C) CO_2 and divert power from electricity generation to thermally regenerate the CO_2 sorbent. Further development of CO_2 sorbents can only offer incremental improvements to the severe energy costs of the additional heat cycle required for thermally regenerating CO_2 sorbents.

The Solution: ***To achieve substantial improvements in overall energy efficiency, this new technology must avoid the Carnot energy inefficiency caused by the additional heat cycles. The solution is to apply passively separation membrane to the flue gas while the CO_2 is still hot and at high pressure.*** A process that can passively separate CO_2 from the flue gas while it is still hot is more energy efficient with a theoretical minimum separation energy 10-15 times smaller (0.2 GJ/ton CO_2 at 300 °C) than the conventional amine solvents.

The Technology: Luna is developing a robust, inorganic membrane capable of separating CO_2 and other acid gases from flue gases in the operational conditions of 200 – 700 °C and 0.1 – 20 ATM. Luna is partnering with Nooter/Eriksen to integrate the modular membrane technology into heat recovery steam generation systems (HRSG).

Application Highlights

- Both low (200 – 500 °C) and high temperature (500 – 700 °C) membranes under development for modular insertion into HRSG temperature zones.
- Separation of acid gases (CO_2, NO_2, SO_X) from non-acid gases (N_2, O_2) may eliminate need for selective catalytic reduction (SCR) systems.
- Adaptation of separation chemistry to efficiently separate O_2 from air at 200 – 300 °C for oxy-fuel combustion and gasification.

Separation Membranes and Features

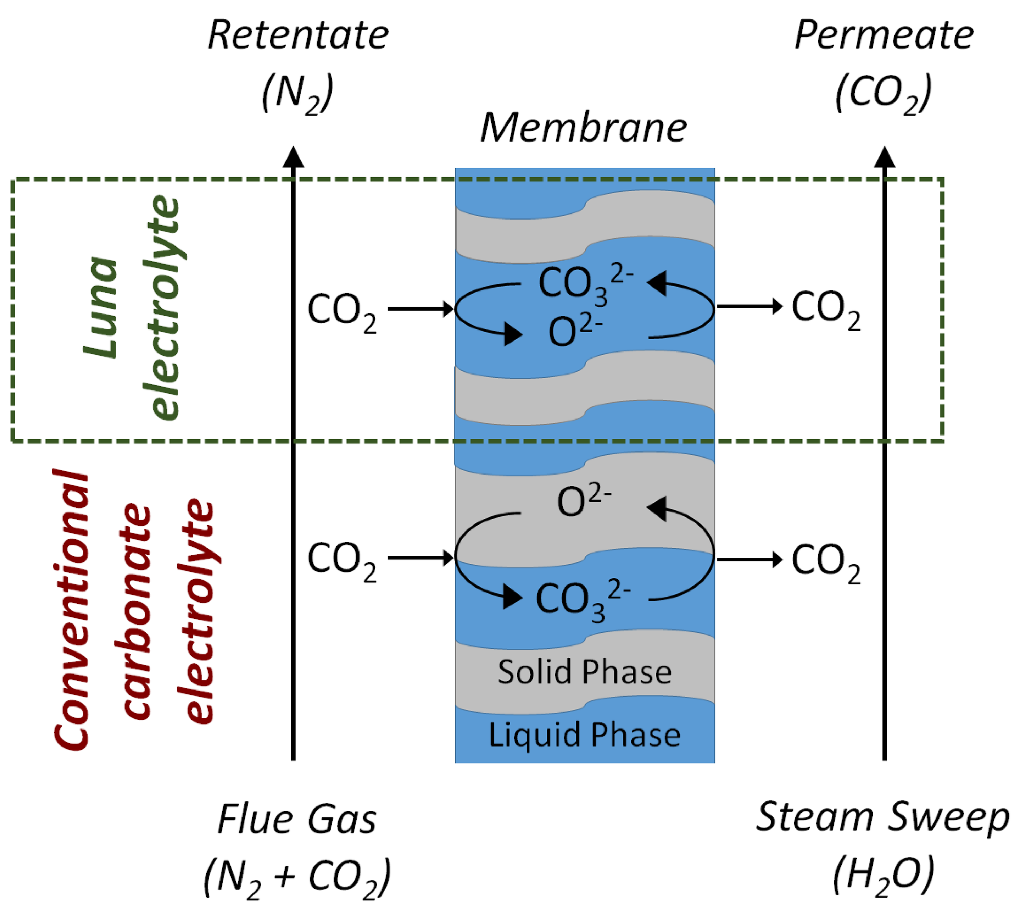
Dual Phase Membrane: The non-volatile liquid phase is retained in the nanoporous solid phase with capillary pressures up to 100 ATM.

The Liquid Phase: The liquid phase is a molten electrolyte that selectively and reversibly sorbs gases as ions. All mass transport is conducted within the liquid phase for rapid permeation through the fastest ion conductors in the temperature range.

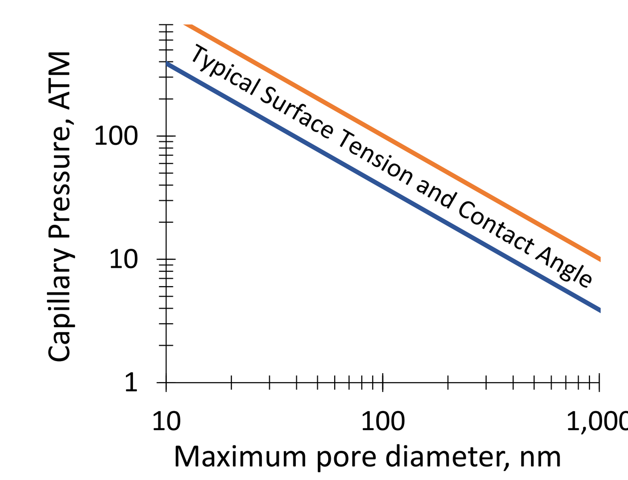
The Solid Phase: The solid phase is an inert, high strength ceramic forming thin membranes capable of withstanding high pressures.

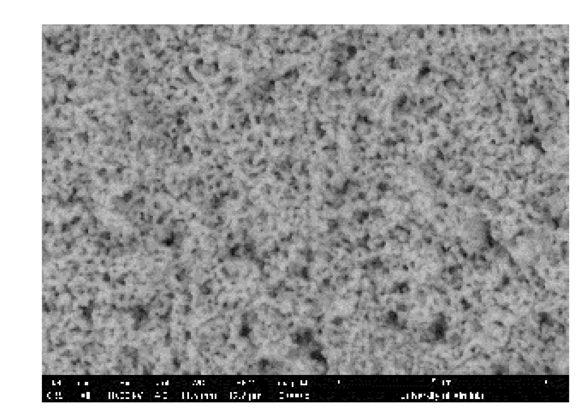
The Performance: ***The combination of selectivity and permeability exceed those of competitive technologies and meet performance requirements expected for post-combustion capture of CO_2 with membranes (Ramasubramanian, J. Membrane Science 2012).***

Operational Conditions: The inorganic, oxidation resistant membranes enable separation in previously unattainable conditions that include 200 – 700 C and 0.1 – 20 ATM.

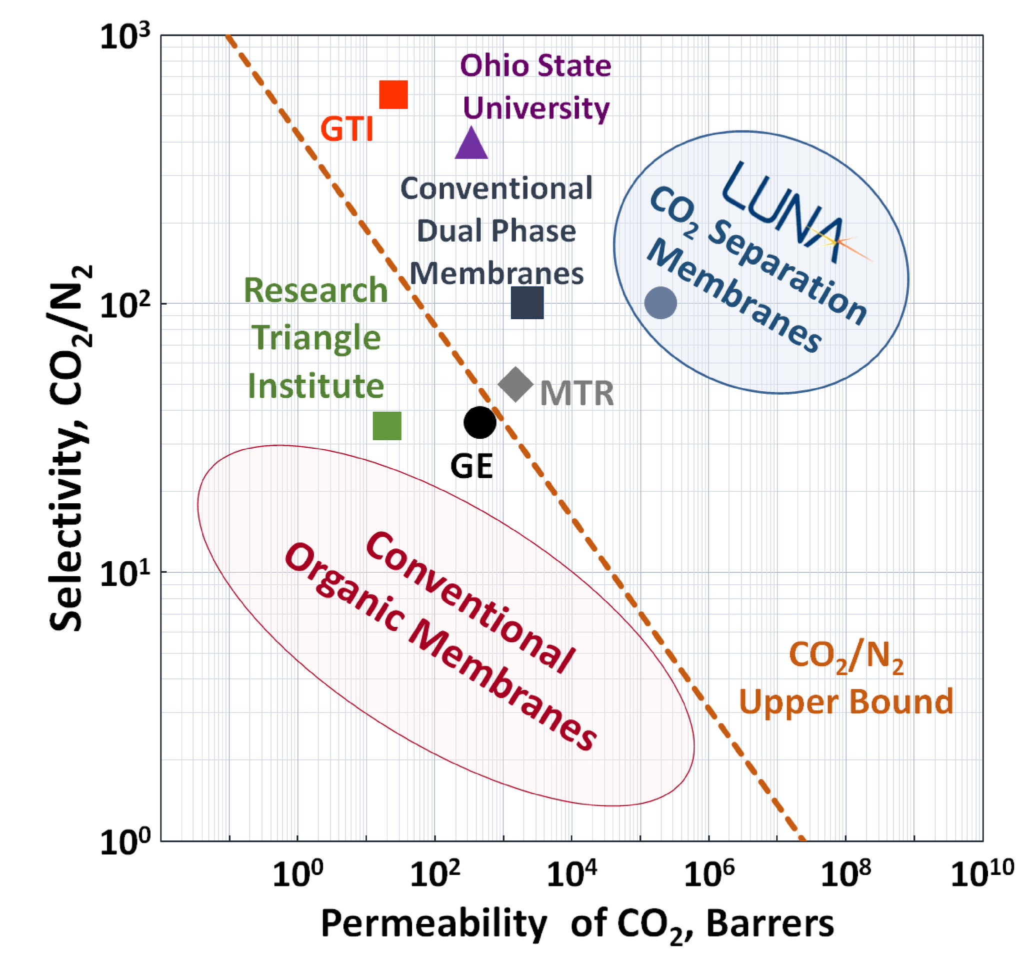


Luna's membrane is distinct from conventional dual phase membranes in that all mass transport is conducted through the liquid phase. In contrast, conventional ceramic-carbonate dual phase membranes are slow and require >700 °C because of dependence on solid oxide ion conduction.



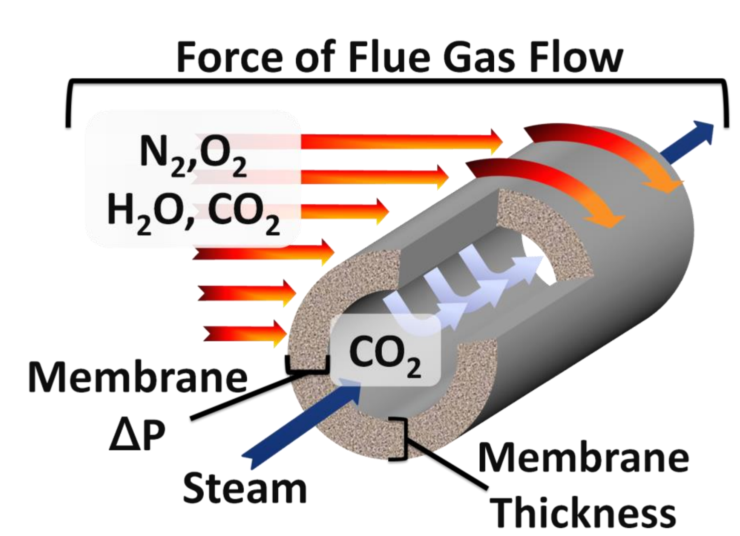


The nanoporous, ceramic solid phase retains the liquid separation phase with capillary action capable of withstanding 10's of ATM pressure gradients.

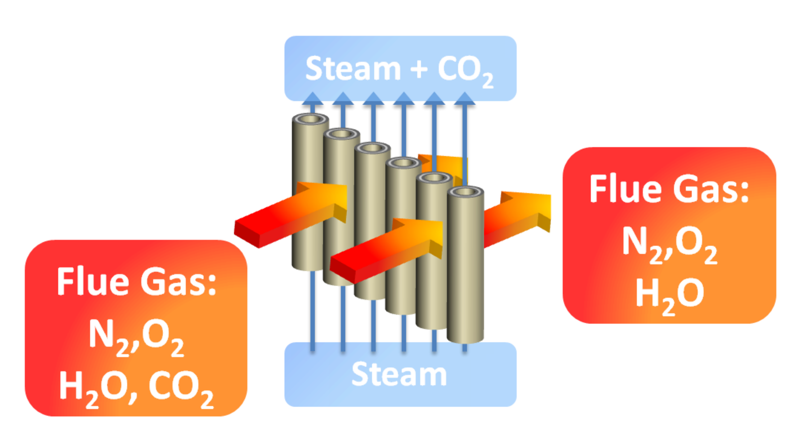


The dual phase membrane is similar to membranes used in molten fuel cells and is not limited by the physics governing Robeson's Upper Bound.

- Ohio State University, 2017 NETL Continuation Application Status Meeting
- Membrane Technology and Research (MTR), NETL Advanced CO_2 Capture R&D Program Technology Update May 2013
- Research Triangle Institute, 2013 NETL Advanced CO_2 Capture R&D Program Technology Update
- General Electric (GE), 2013 NETL Advanced CO_2 Capture R&D Program Technology Update
- Gas Technology Institute (GTI), 2017 NETL BP1 Review Meeting
- Lu, B. and Lin, Y.S., Journal of Membrane Science 444 (2013) 402–411



The post-combustion CO_2 capture membranes are being developed with computer assisted design (CAD) and finite element modeling (FEM). The determination of membrane dimensions are based upon factors including safety, separation performance, material properties, and operational stresses.



In partnership with Nooter/Eriksen, the next steps include designing modular units with computational fluid dynamics (CFD) and system level analysis modeling for integration into N/E HRSG systems.

Performance Highlights

- Molten phase sorption reactions and mass transport produce unrivaled combination of selectivity and permeability.
- Stable inorganic materials enable operation in previously unattainable temperatures, pressures, and environments.
- The separation chemistry is being adapted to O_2, NH_3, HCl, Cl_2, and NO_2 for widespread industrial applications.

Acknowledgments

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