Development of Highly Efficient Direct Air Capture (DAC) and Carbon Recycling Technologies

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Final goal

Research Institute of Innovative Technology for the Earth

R & D items 1. "Development of high-efficiency CO_2 capture technology from the atmosphere"

・Several tons/d-scale of DAC will be demonstrated and establishing practical DAC technology enough for FT synthesis.
・Low energy/cost DAC system for countermeasure against global warming will be revealed.
（**Target: Achieving high performance DAC system exceeding overseas**）

R & D items 2. "Development of CO_2 conversion technology for carbon recycling into valuable resources"

・Develop a high-efficient FT synthesis converting the recovered CO_2 to a liquid hydrocarbon fuel.
・Control FT synthesis reaction by Extractor-Distributor all-in-one membrane reactor.
・Investigate a suitable process using the membrane reactor with pilot-scale tests.
（**Target: Achieving 80% or more of conversion efficiency**）

R & D items 3. "Practicality assessment as a liquid hydrocarbon fuel using LCA method"

・Final confirmation of the net CO_2 reduction amount produced by the whole of the DAC ＆ FT synthesis system by applying the Life Cycle Assessment.
・Evaluate the performance of synthesized liquid hydrocarbon fuel by user companies.
（**Target: Identifying issues for practical use**）

➡ **Realize carbon recycling society**

R & D items

RITE
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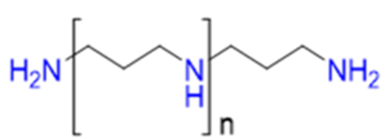
Item / Fiscal year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
DAC										
Development of new solid sorbent materials for DAC (RITE)	Development of new materials			Optimization of synthetic process		Improving materials and synthetic process				
Development of effective systems for DAC (KU, RITE, Engineering company)	Development of DAC process (Indirect heating, rotary TSA)					Improving DAC system				
	Simulation for DAC			Simulation for pilot scale equipment		Optimization of DAC process by simulation				
		Development of DAC system		Development of DAC system with small bench test		Improving DAC system				
Scale up DAC equipment（Engineering company）						Design of pilot-scale equipment	Fabrication of pilot-scale equipment		Pilot test	
CO_2 conversion										
Development of a high-efficient FT synthesis process (RITE)	Development of the water separation and hydrogen separation membranes			Durability test		Development of a high-efficient FT synthesis converting the recovered CO_2 to a liquid hydrocarbon fuel				
Design and fabrication of scale up equipment (Engineering company)						Design and Fabrication of bench/small pilot equipment		Demonstration		
Evaluation of e-fuel and LCA for whole system (Automobile company)				Economically analysis of e-fuel		Evaluation of e-fuel with car engine			Life cycle assessment	

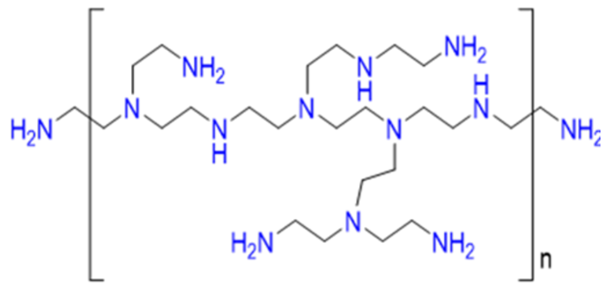
Development of amine for DAC

Screening of amines for DAC

- Previous amines for DAC



polyamine

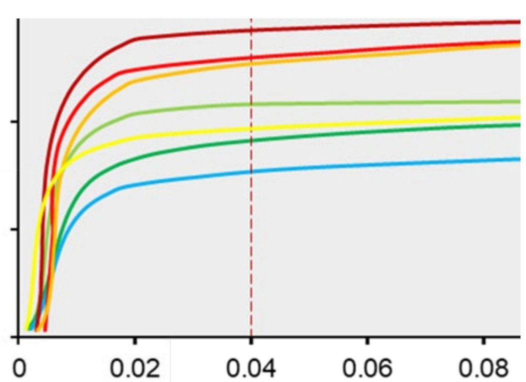


PEI

Screening of amines structure

$H_2N-(CH_2)_{n_1}-NH-(CH_2)_{n_2}-NH_2$

Various amines



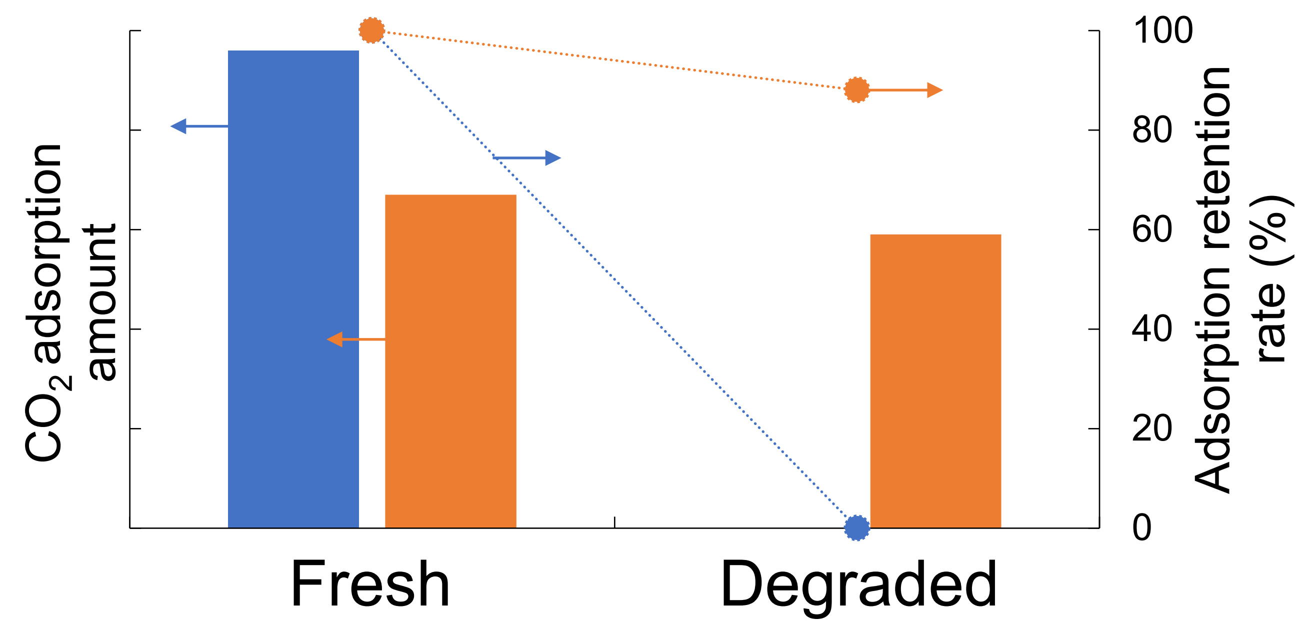
- Screening of amine species for DAC

Key point: Adsorption capacity, Thermal stability, Oxidative degradation resistance

Synthesis of New amine

Evaluation of New amine

Oxidative degradation resistance

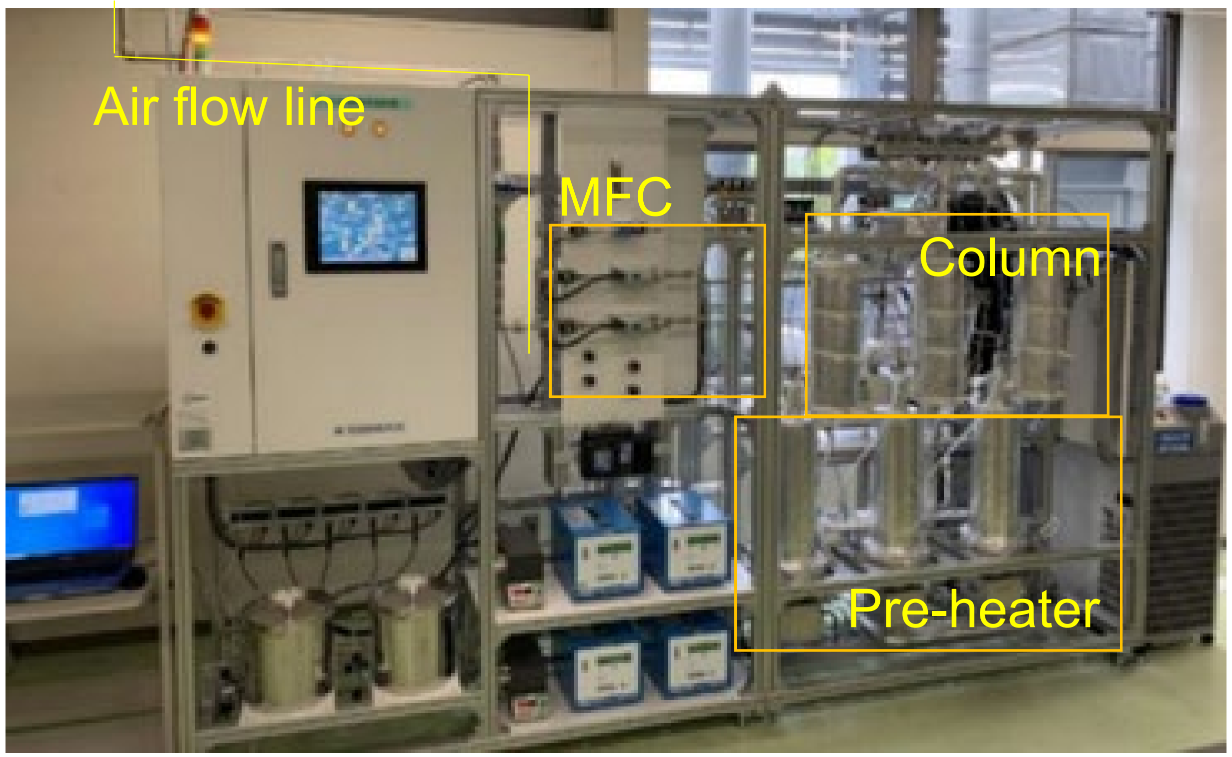


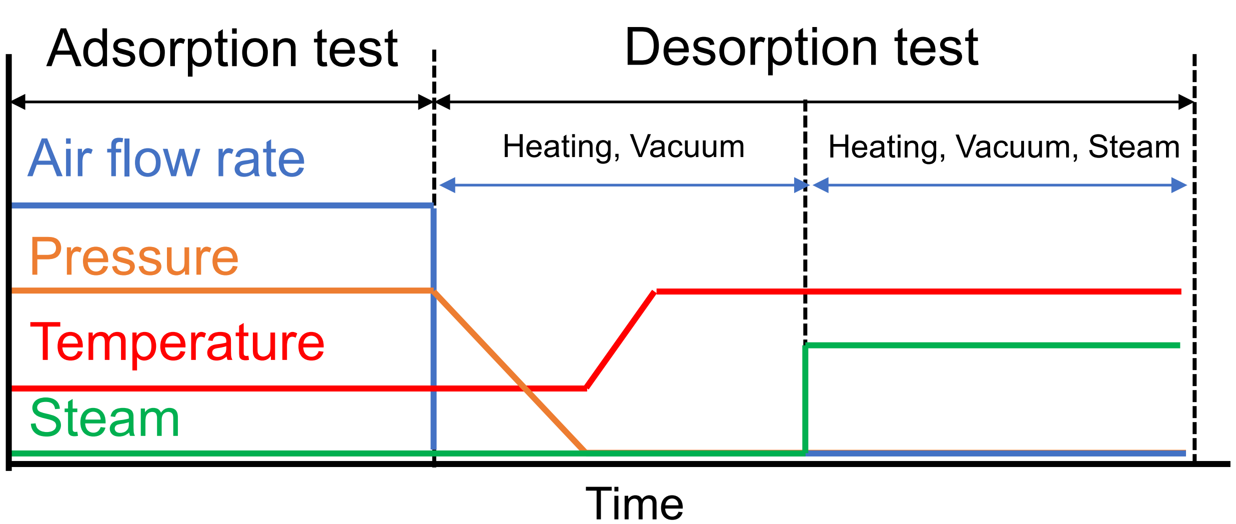
- Oxidative degradation resistance : New amine>>Commercial amine

Steam regeneration system

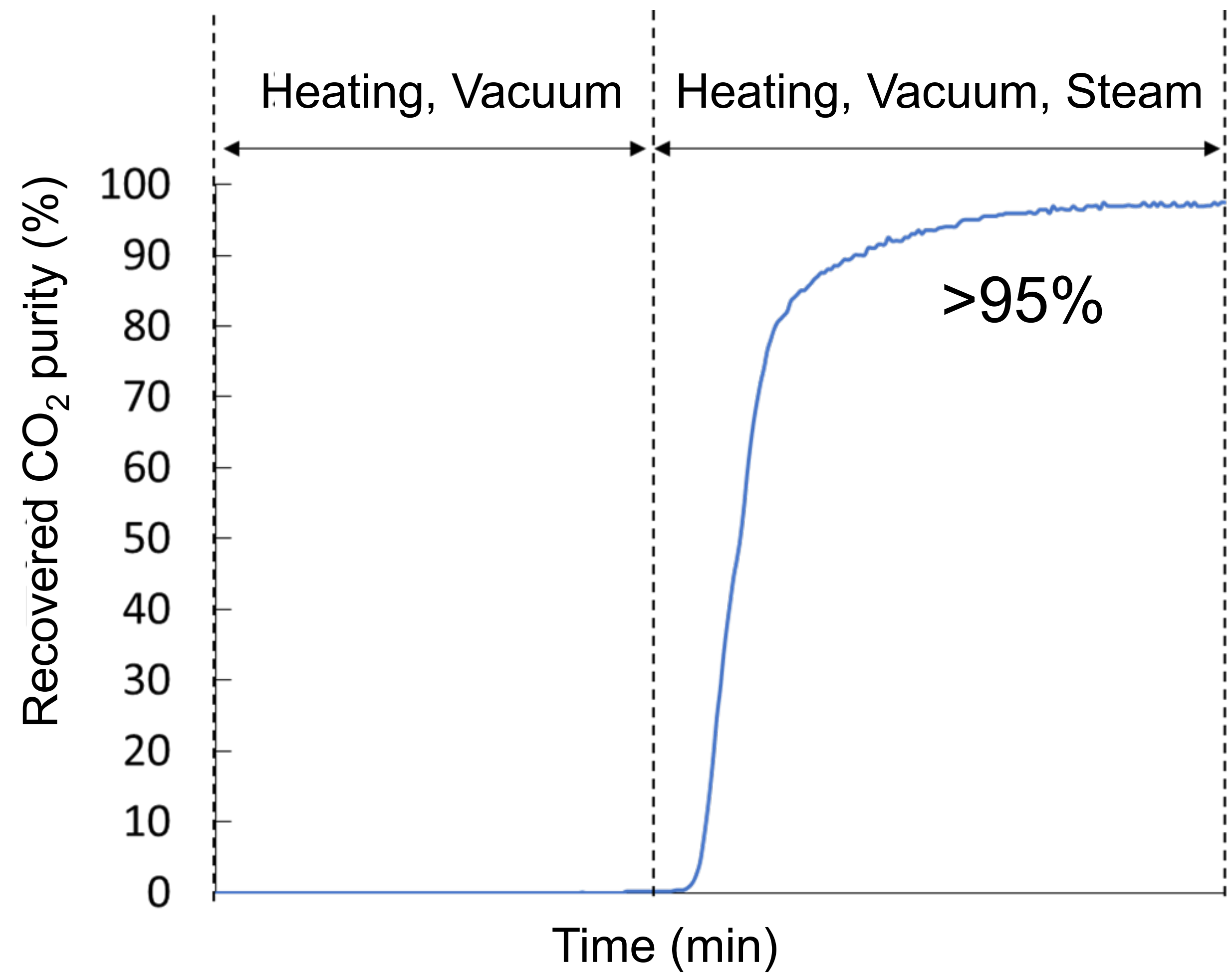
Steam regeneration

Lab-scale equipment





CO_2 desorption test using Lab-scale equipment



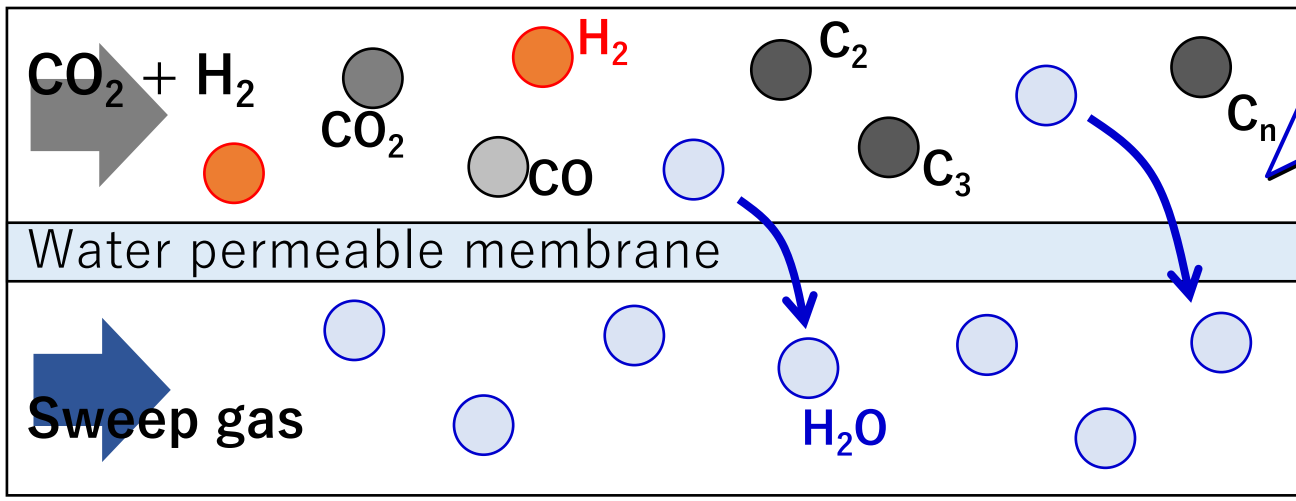
- CO_2 can be recovered with high purity.
- We also plan to build a small bench-scale equipment to a scale-up study.

Highly efficient CO_2 conversion using membrane reactor

Development of CO_2 conversion technology for carbon recycling into valuable resources

＜Extractor-type＞

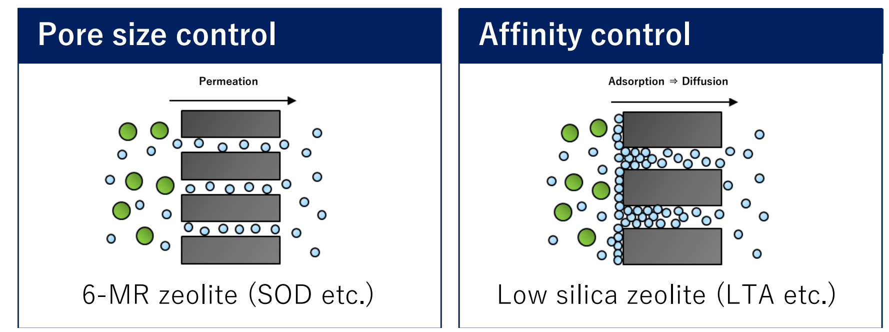
Water permeable membrane＋Cat.



＜Zeolite membrane＞

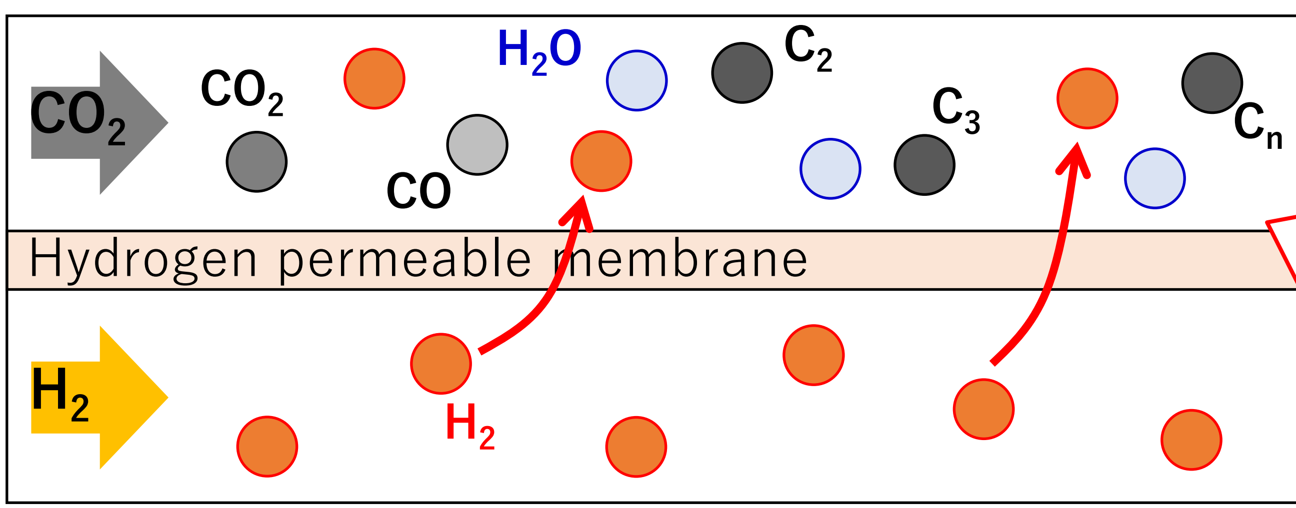
Controlling the Si/Al ratio

⇒ high water permeance & hydrothermal stability



＜Distributor-type＞

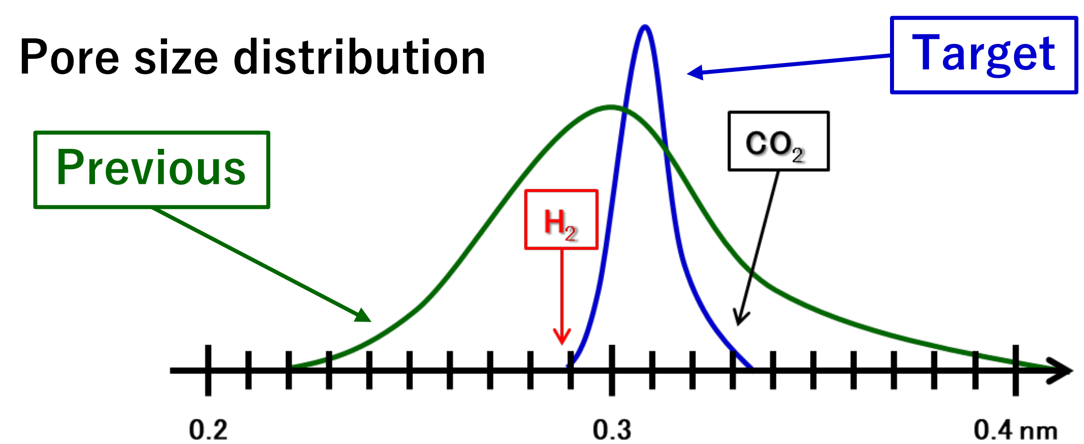
Hydrogen permeable membrane＋Cat.



＜Silica membrane＞

Controlling the pore size distribution

⇒ high H_2 permeance & H_2/CO_2 selectivity

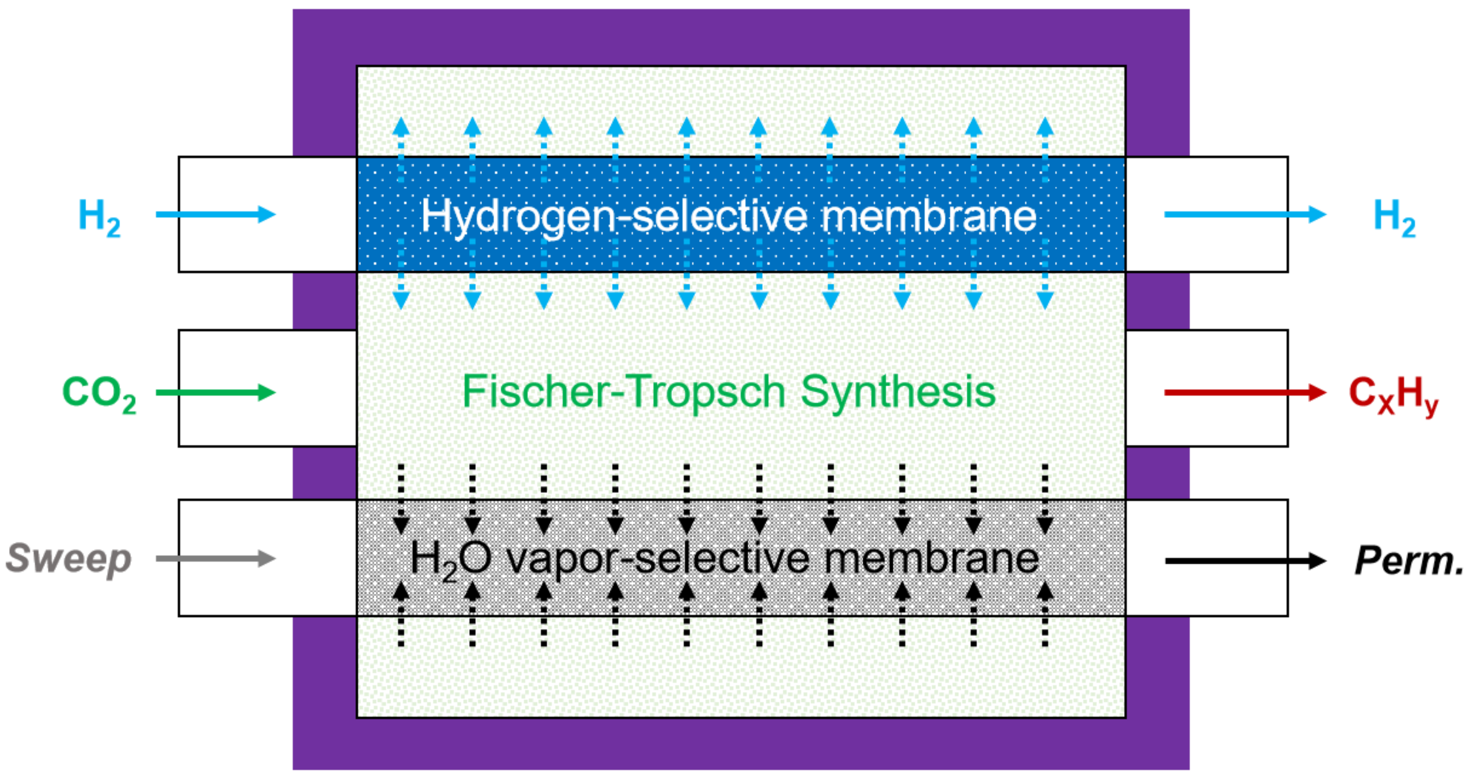


Highly efficient CO_2 conversion using membrane reactor

Research Institute of Innovative Technology for the Earth

Development of CO_2 conversion technology for carbon recycling into valuable resources

＜Simulation model (membrane reactor for FT synthesis)＞



$$CO + 3H_2 \xrightarrow{R_1} CH_4 + H_2O \quad (1)$$

$$2CO + 4H_2 \xrightarrow{R_2} C_2H_4 + 2H_2O \quad (2)$$

$$2CO + 5H_2 \xrightarrow{R_3} C_2H_6 + 2H_2O \quad (3)$$

$$3CO + 7H_2 \xrightarrow{R_4} C_3H_8 + 3H_2O \quad (4)$$

$$4CO + 9H_2 \xrightarrow{R_5} \text{n-}C_4H_{10} + 4H_2O \quad (5)$$

$$4CO + 9H_2 \xrightarrow{R_6} \text{i-}C_4H_{10} + 4H_2O \quad (6)$$

$$6.05\,CO + 12.23\,H_2 \xrightarrow{R_7} C_{6.05}H_{12.36}\,(C_5^+) + 6.05\,H_2O \quad (7)$$

$$CO + H_2O \overset{R_8}{\Leftrightarrow} CO_2 + H_2 \quad (8)$$

＜Simulation results＞

x 1.5

- Membrane reactor：CO_2 conv.＝**94%**
- Packed bed reactor：CO_2 conv.＝65%

Pressure: 1.7 MPa, Temperature: 250℃

Reaction rate equation（Fe-HZSM-5）*

$$R_i = k_i \exp\left(\frac{-E_i}{RT}\right) P_{CO}^m P_{H_2}^n$$

*Marvast et al., Chem. Eng. Technol., 2005, 28, 1, 78-86.

Membrane reactor for FT synthesis showed higher CO_2 conversion.

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