CCS WORKSHOP
Jakarta, 22 February 2011
16:00 – 16:25

7. CO_2 Membrane Separation

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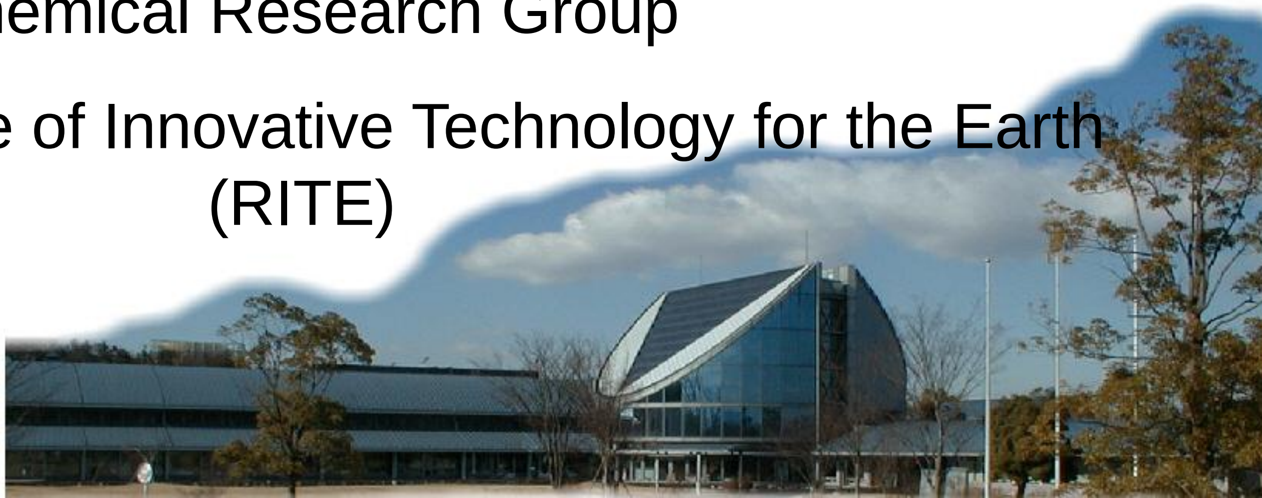
Chemical Research Group

Research Institute of Innovative Technology for the Earth (RITE)



Present Cost of CCS（coal fired power plant）

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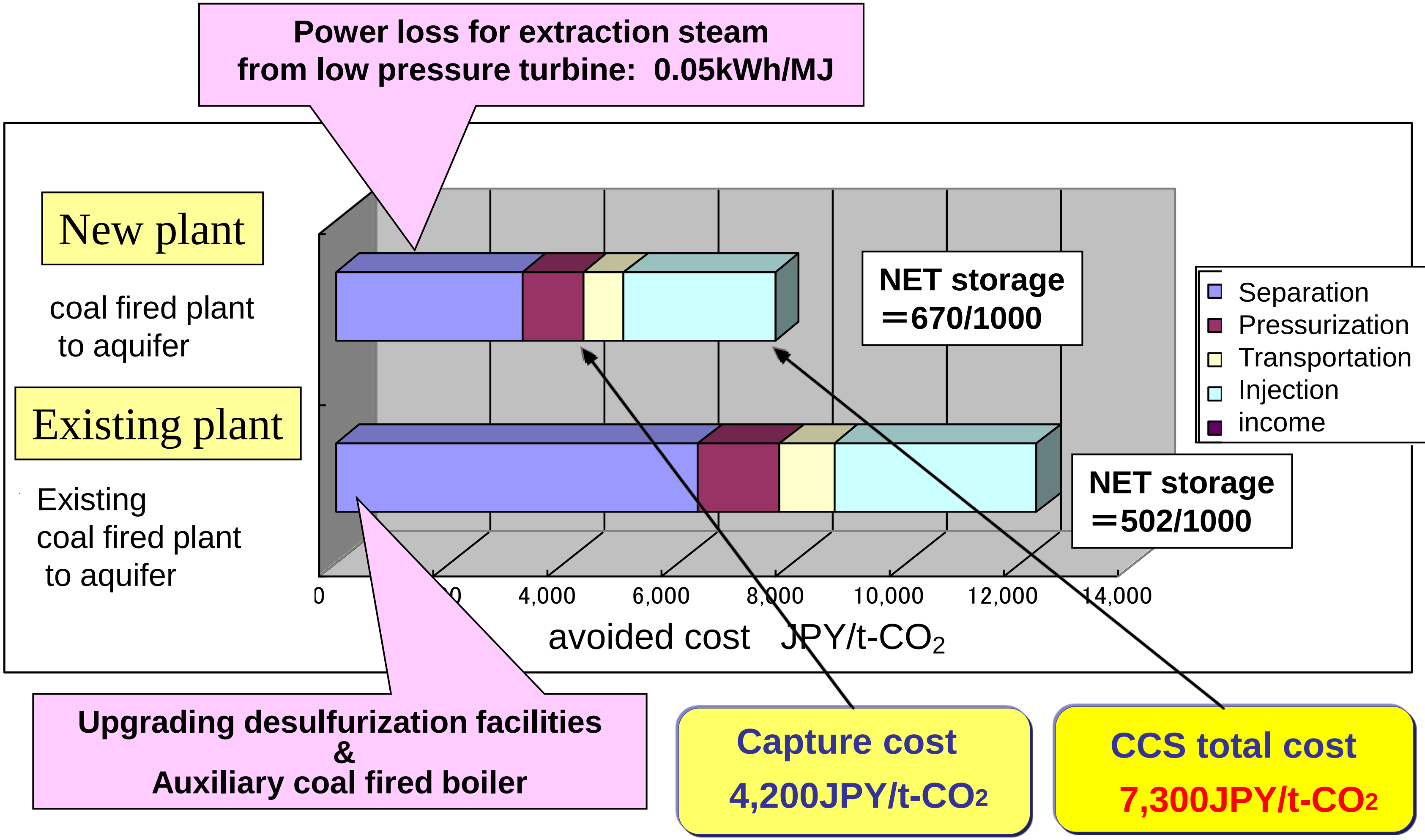
recovery amount:1Mt-CO_2/yr、 distance:20km、pressure:7MPa
injection method：ERD、 injection amount ：0.1Mt-CO_2/yr/well



CO_2 capture methods for various Sources

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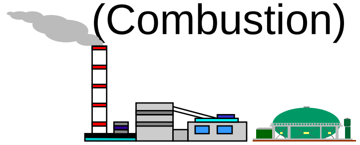
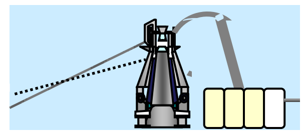
1. CO_2 Sources

Fossil Fuel
Bio-Mass

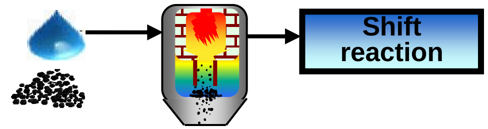
Power plant (Combustion)



Blast-furnace



Gasification



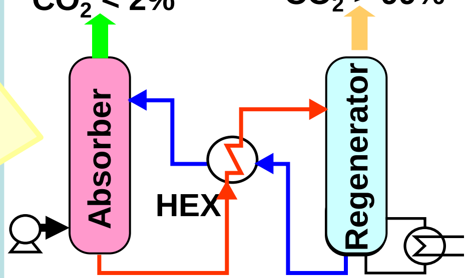
Natural Gas
EOR

2. CO_2 Capture (Chemical Research Group)

R. & D.

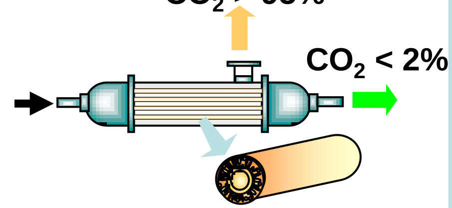
Chemical absorption pilot Plant (COURSE50: NEDO Project)
Source: Nippon Steel Eng. HP.

Absorption



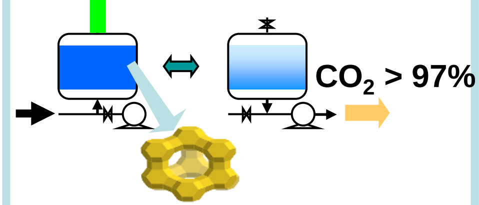
Absorbent
Novel process
Waste heat utilization

Membrane



Polymer
Zeolite
Carbon
Nano composite material

Adsorption



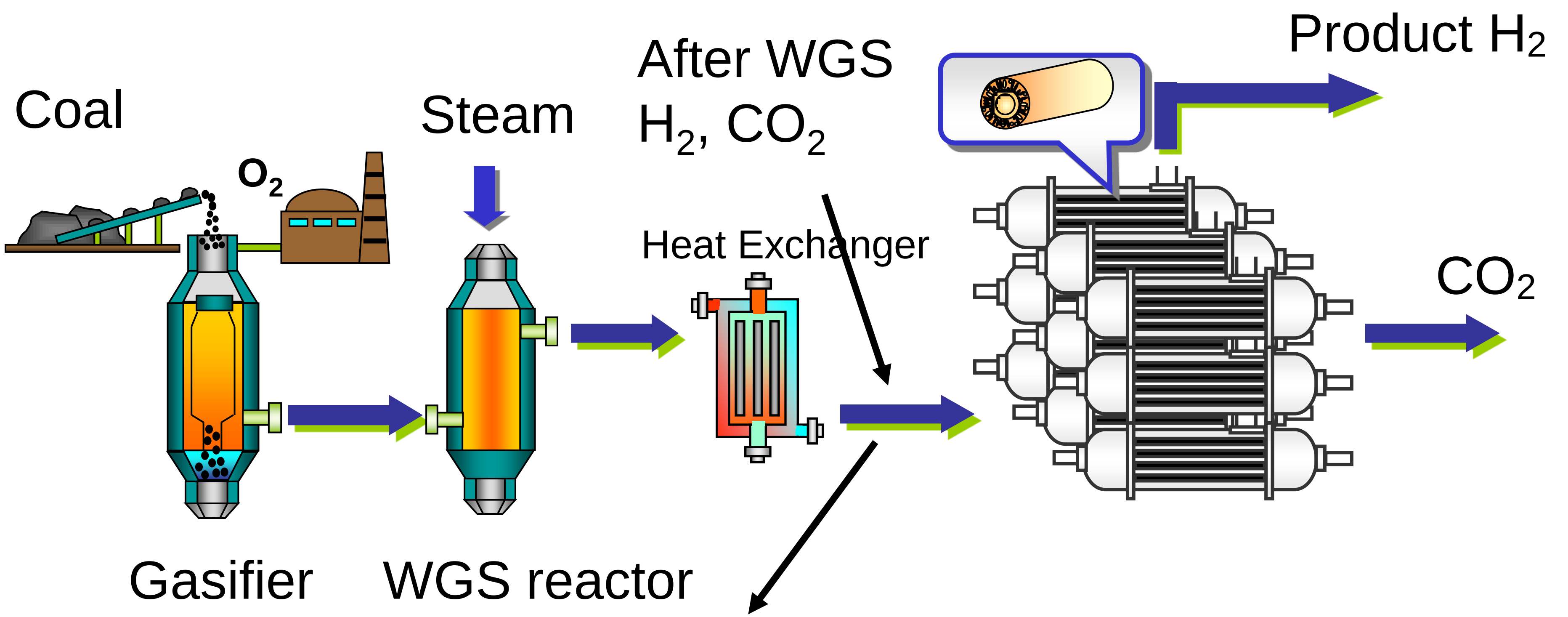
Zeolite,
Mesoporous silica

Plant analysis for the decreasing energy and cost

3. Storage (CO_2 Storage Group)

Geological   Utilization   Ocean

Schematic of IGCC with CO_2 Capture



- 2 to 4 MPa
- ca 40% CO_2

- CO_2/H_2 Separation

→ Advantage in Membrane Separation

→ Insufficient Selectivity

Prospect for CO_2 Separation Cost of Membrane Separation

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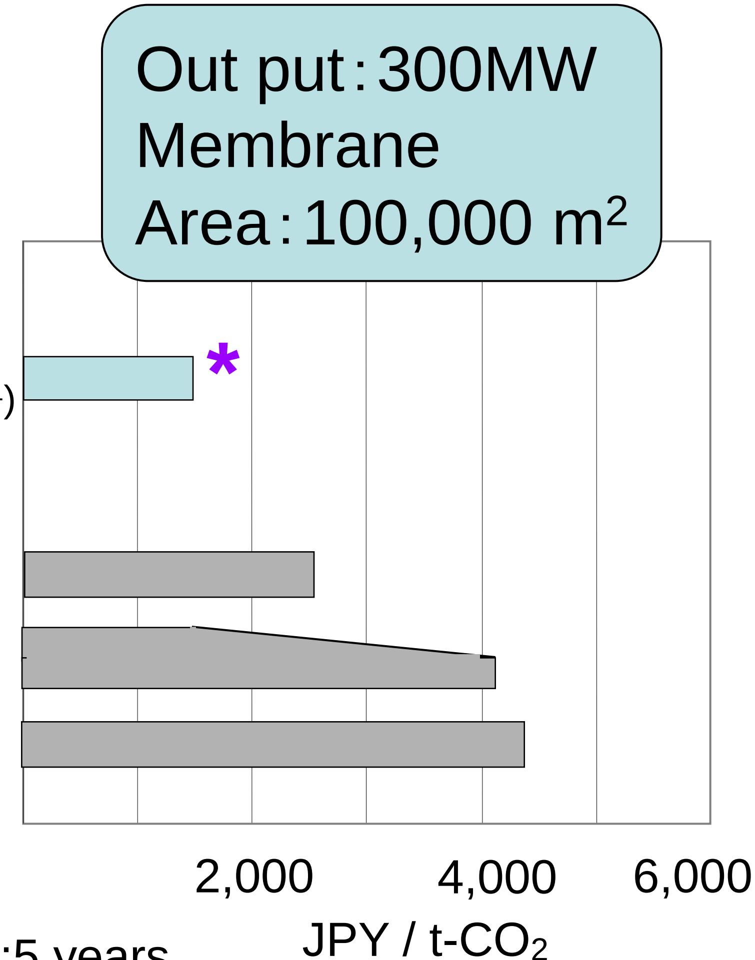
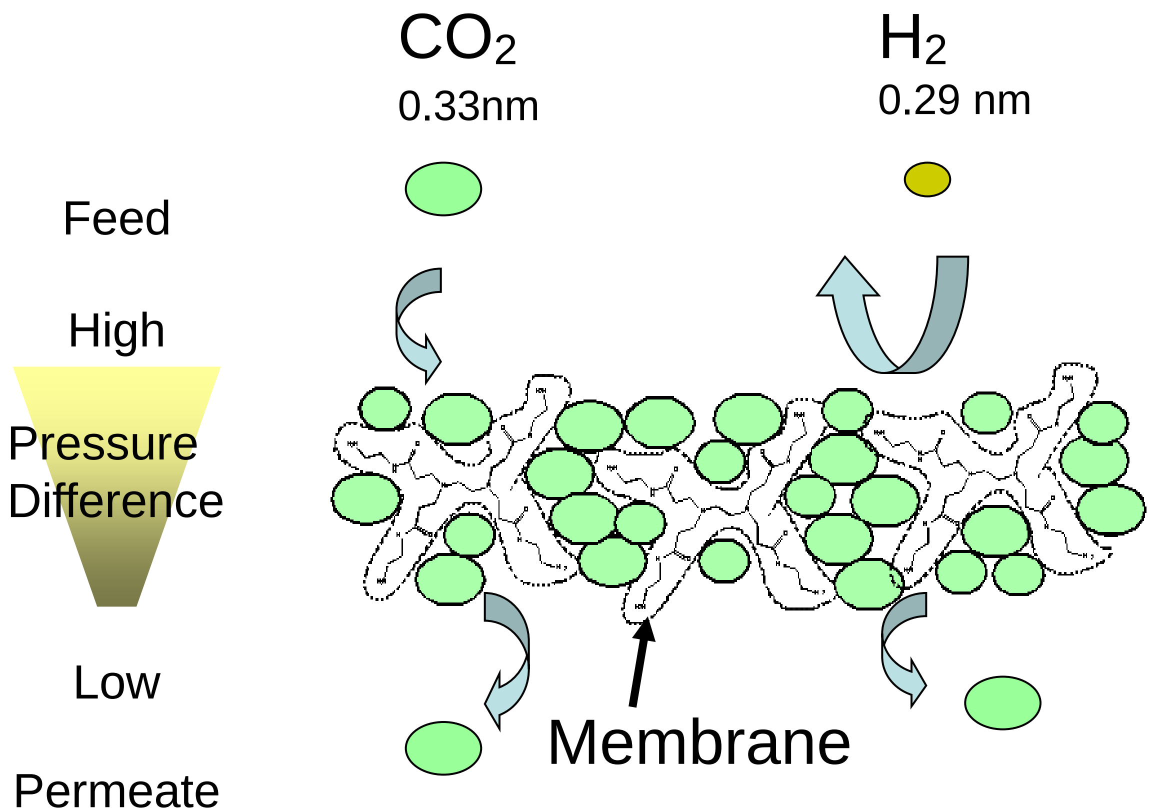
CO_2 Source	Gas Pres.	Gas Comp.	Membrane Performance (Target)
H_2 Prod. Plant	4MPa	CO_2:40% H_2, H_2O	$\alpha CO_2/H_2$: 30 CO_2 Permeance :1×10^{-9}($m^3\ m^{-2}\ s^{-1}\ Pa^{-1}$)
Ref. Absorption	4MPa	Amine solution (MDEA-Flash)	
	4MPa	Phys Absorption	
	0.1MPa	Amine solution (KS solution)	



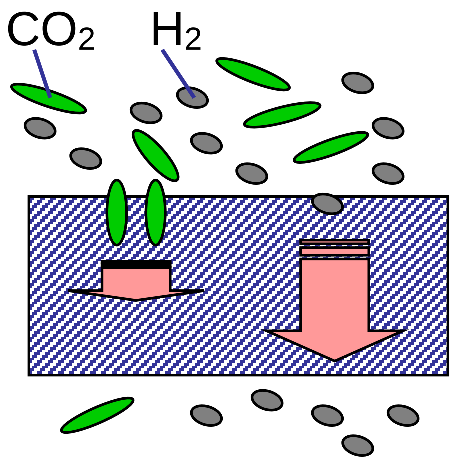
* Duration period　Facility:15 years　Membrane:5 years

Membrane Skid Cost: 50,000JPY/m^2

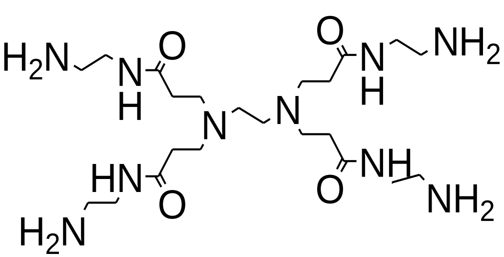
CO_2 Molecular Gate for CO_2/H_2 Separation



Conventional Polymeric Membrane:

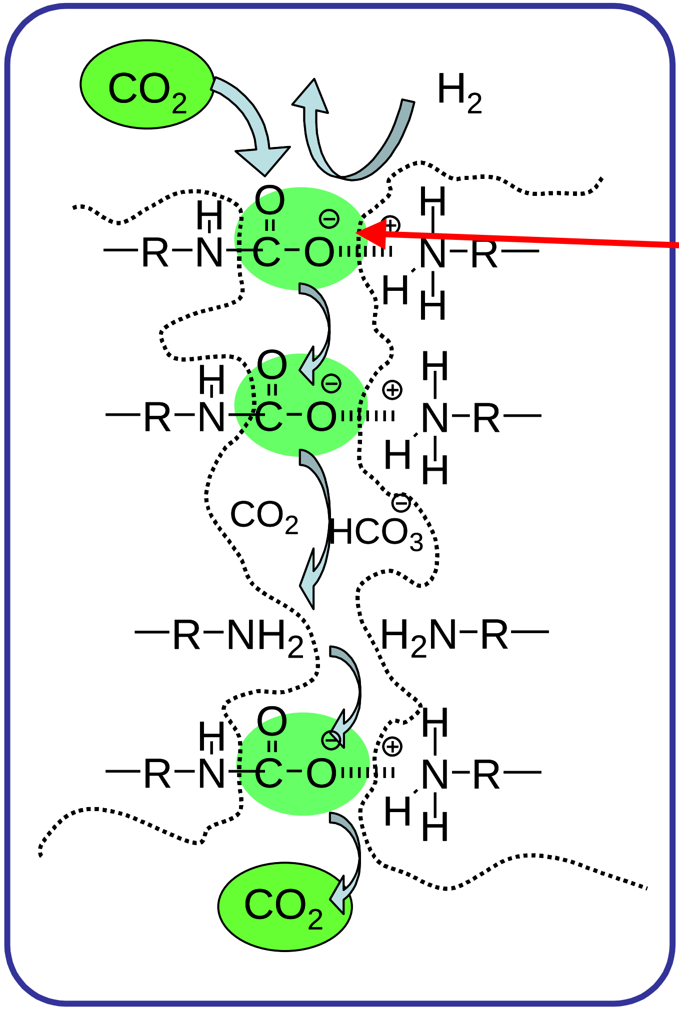


CO_2/H_2 Selectivity: <1



Excellent CO_2 selectivity

Possible Model of H_2 Perm. Blockage

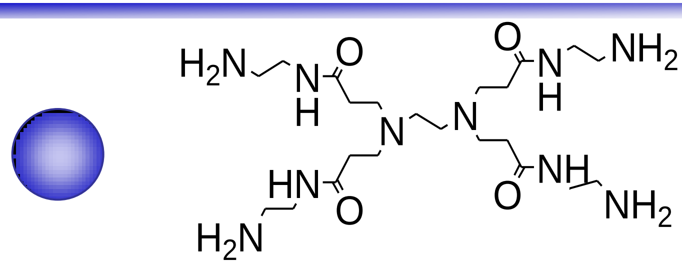


Carbamate Formation

Pseudo-cross-linkage

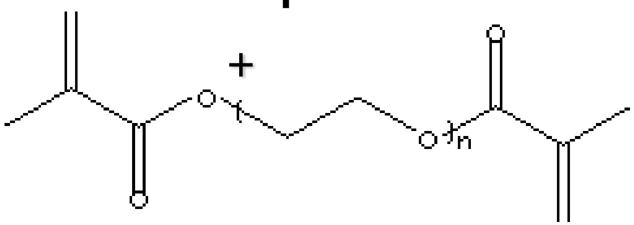
H_2 permeation blockage

Dendrimer Membrane for CO_2 Capture from Pressurized Gas Stream



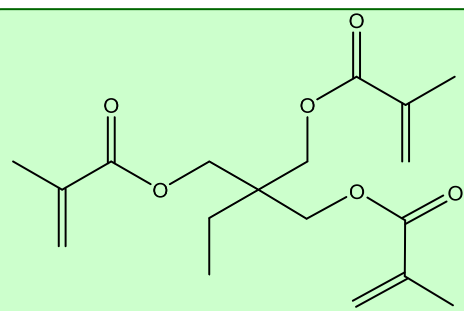
O-OH-PAMAM dendrimer

+



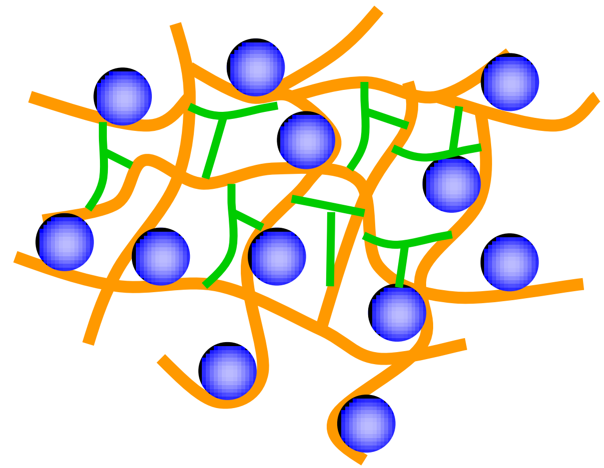
PEGDMA

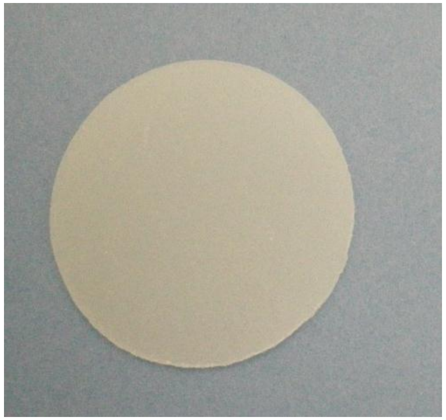
+



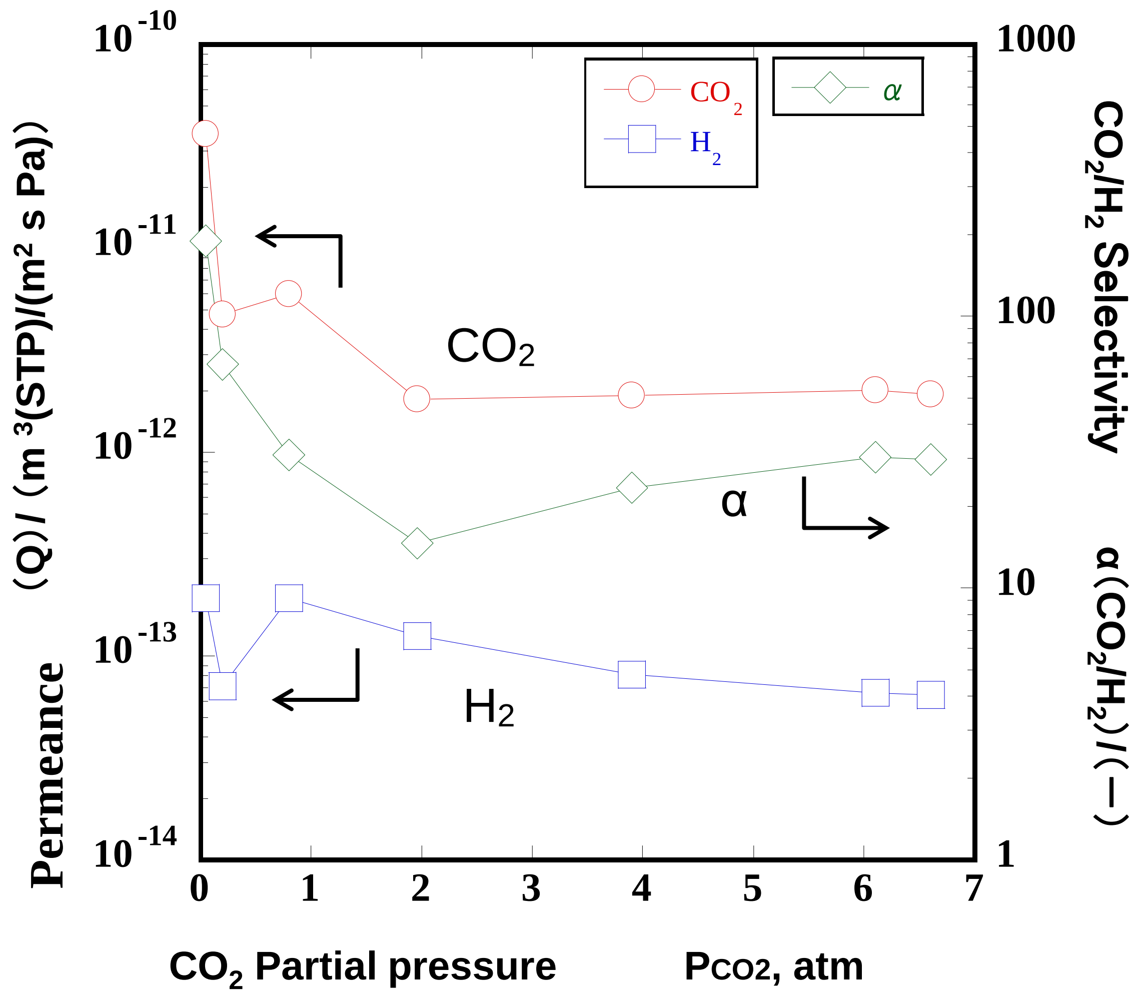
TMPTMA

UV Curing



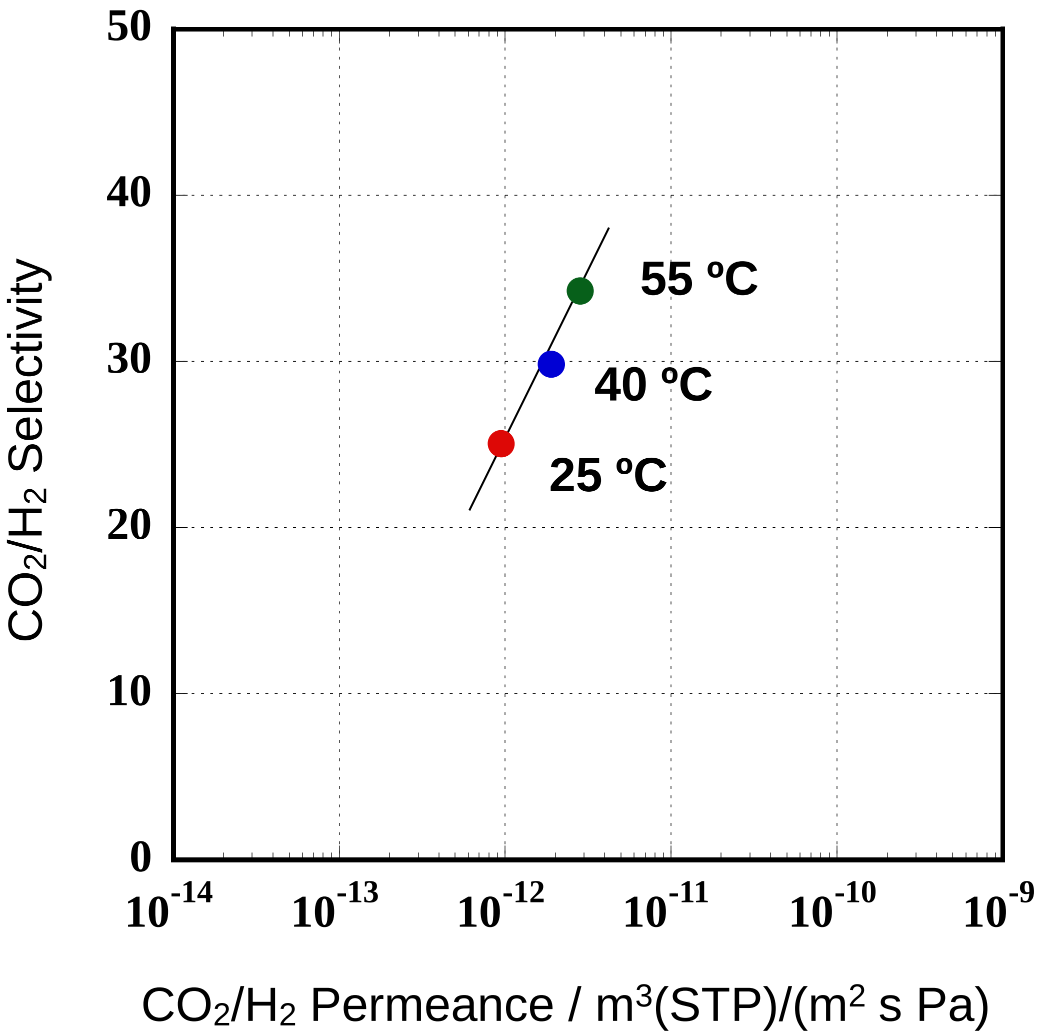


Dendrimer membrane for CO_2 capture from a pressurized gas stream



PAMAM/PEGDMA/TMPTMA = 50/37.5/12.5, Feed : 100 mL/min,Sweep : 20 ml/min, T = 313 K, R.H. = 80%

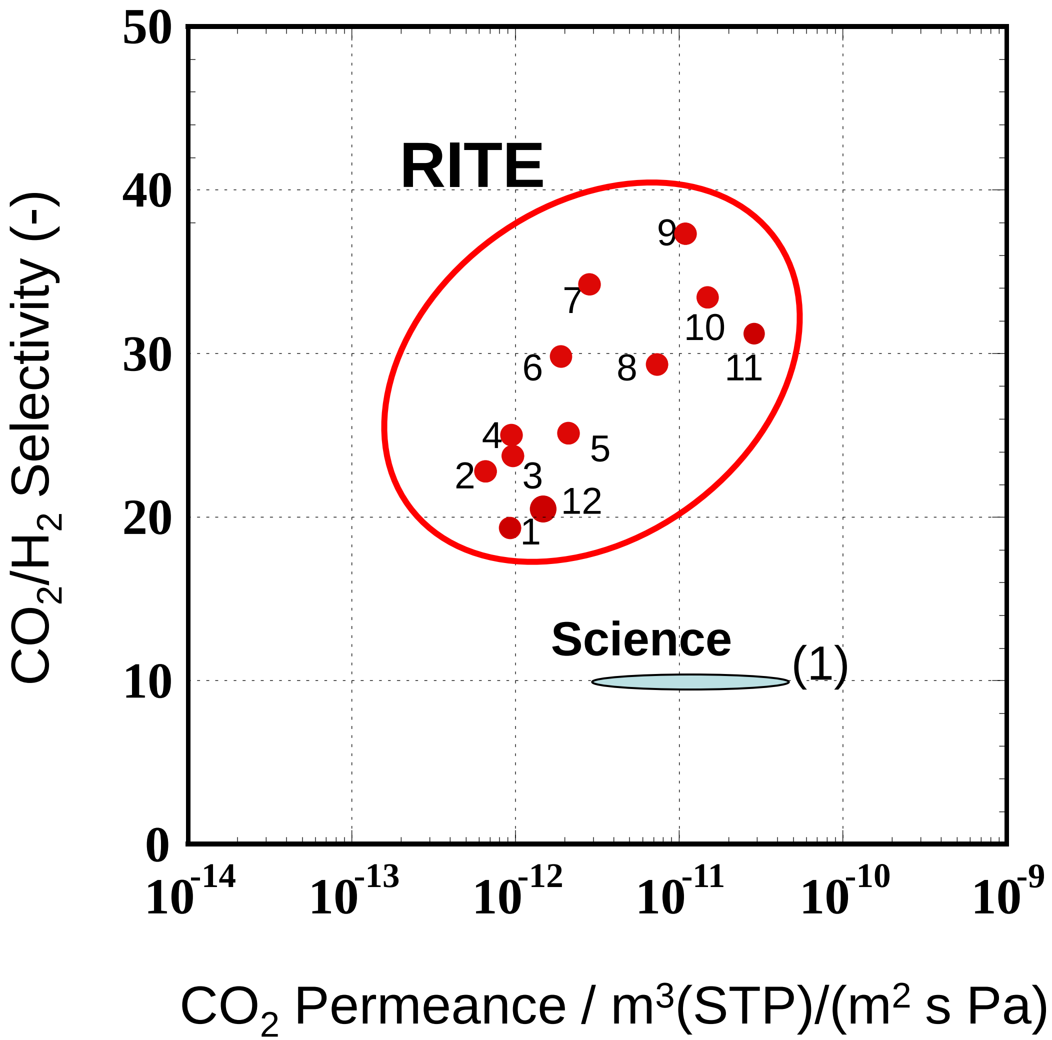
Temperature and Performance



PAMAM/
PEGDMA/
TMPTMA =
50/37.5/12.5

Thickness: 500μm

CO_2/H_2 Separation Properties of Dendrimer Membranes at High Pressure



(1) H. Lin, B.Freeman *et al., Science*, **311**, 639-642 (2006)

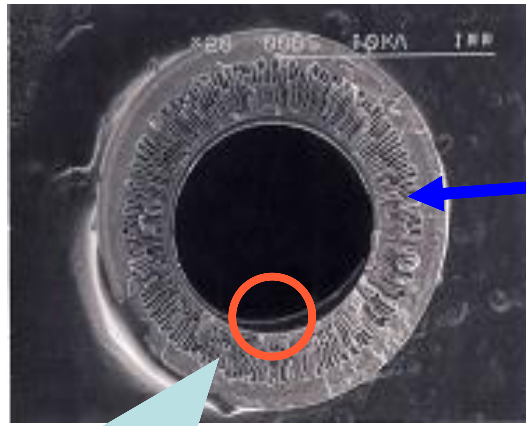
Separation of CO_2/CH_4 using molecular gate membranes

	CO_2 conc. in Feed	CO_2 conc. in Permeate	Permeance, Q_{CO2}	Separation factor, $\alpha_{CO2/CH4}$
Membrane A	79.6	99.2	7.6×10^{-12}	30
Membrane B	74.5	99.9	1.2×10^{-11}	260

Temperature: 40 °C, Total pressure in feed gas: 0.1 MPa,
Relative humidity in Feed gas: 80%, He sweep gas at permeate side.

Molecular gate membranes possess high potential for separation of CO_2/CH_4 mixed gas

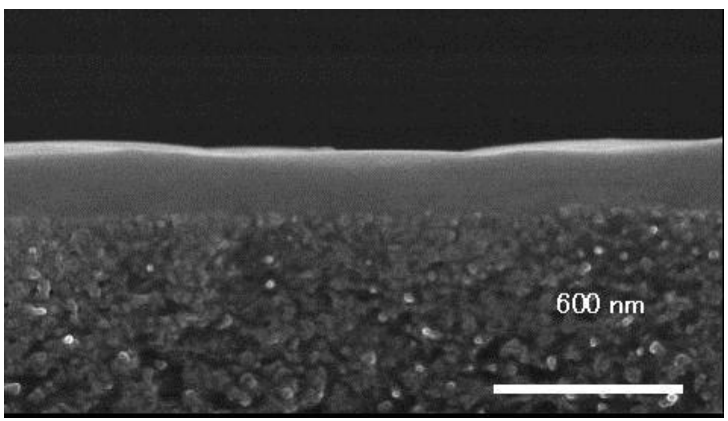
Dendrimer Composite Membrane



1 mm

Substrate of UF Membrane (commercial)

300 nm



Selective Layer 0OH Dendrimer/ Polymeric Matrix

Porous Substrate

For CO_2 separation from ambient pressure gas stream (1st Term)

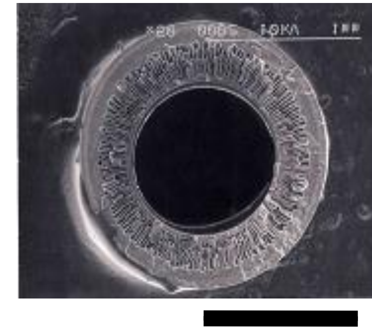
Dendrimer Composite Membrane Module

#1, 2

200, 800 mm, 3/8 inch

#3

1100 mm in length, 1 inch in diameter



1 mm

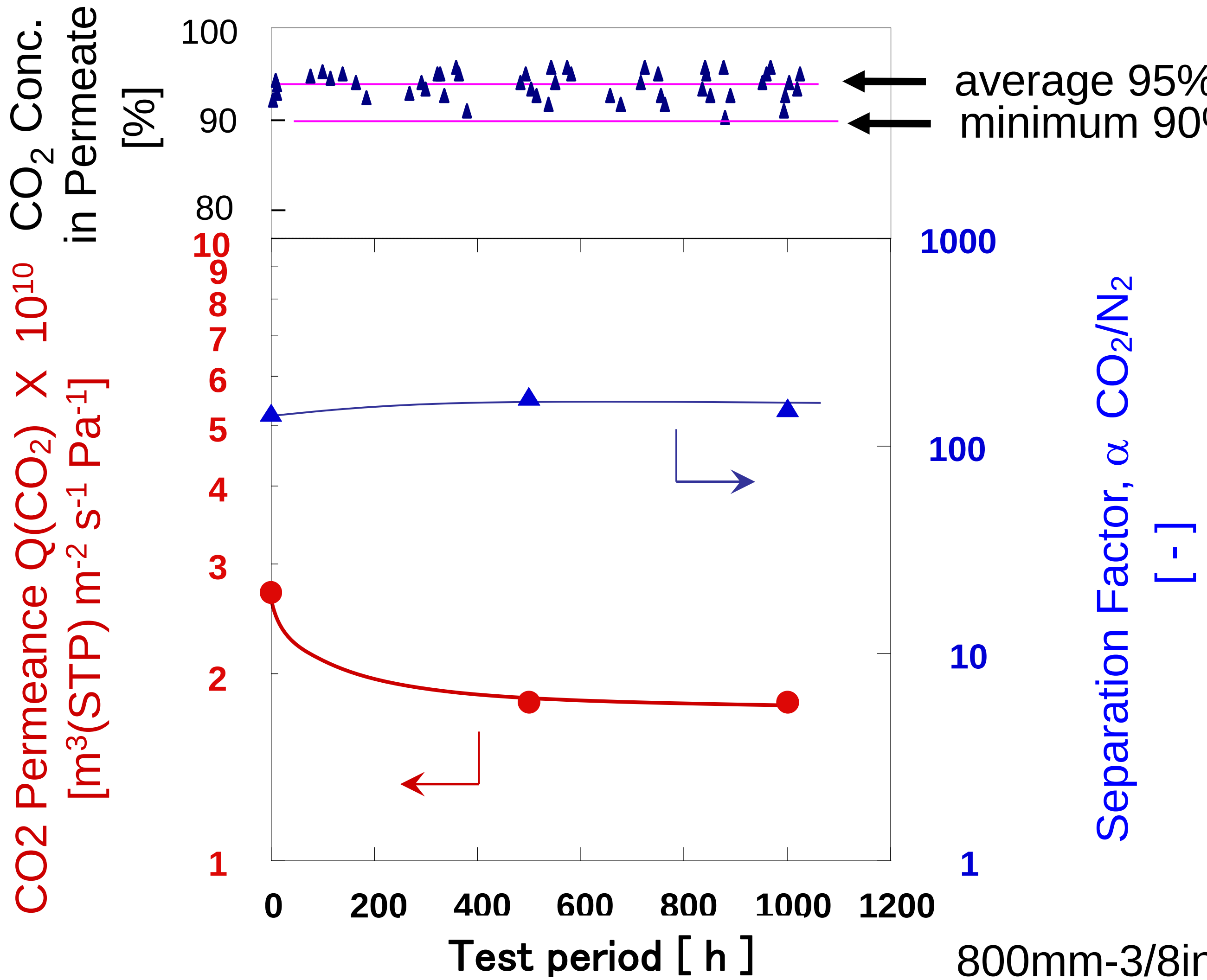
Cross section of membrane

Module #	Membrane Area cm^2	CO_2/N_2 Selectivity $\alpha_{CO2/N2}$
1	17	290
2	180	150
3	4000	150

Dendrimer: conventional PAMAM dendrimer (0OH), Temperature: 25 °C

For CO_2 separation from ambient pressure gas stream (1st Term)

Long-term Stability



800mm-3/8inch module

Feed gas mixture: CO_2/N_2 (32/68 v/v%) containing unknown amount of water vapor
Measured temperature: 14-25^{o}C, Pressure difference between feed and permeate: 0.1MPa

Membrane modules

Hollow-fiber module:

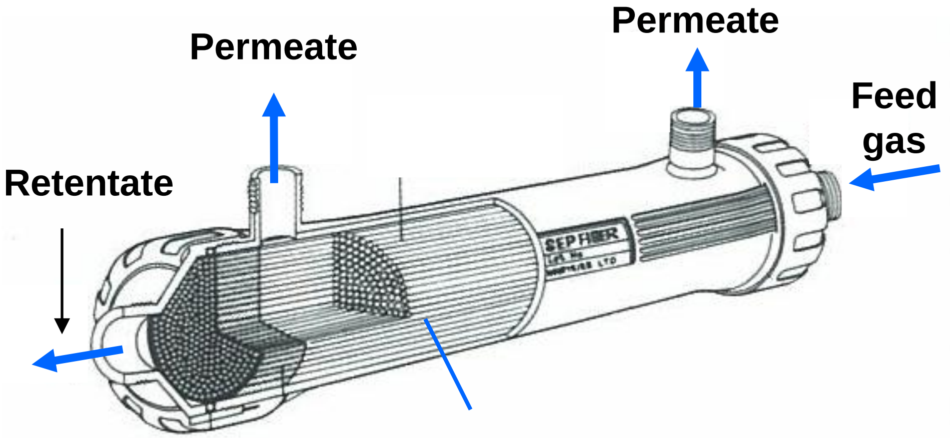
Merits:
- Well-studied structure for gas separation
- Large membrane area per unit volume

Issues:
- Pressure durability up to 4MPa
- Coating method for hollow-fibers

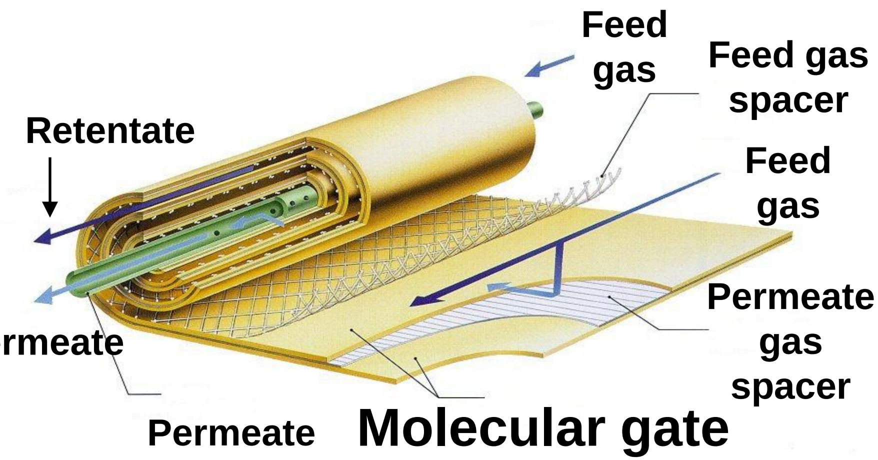
Spiral-wound Module (flat-sheet membranes):

Merits:
- Pressure durability up to 10MPa (water)
- Easy to coat flat-sheet membranes

Issue:
- Membrane area per unit volume



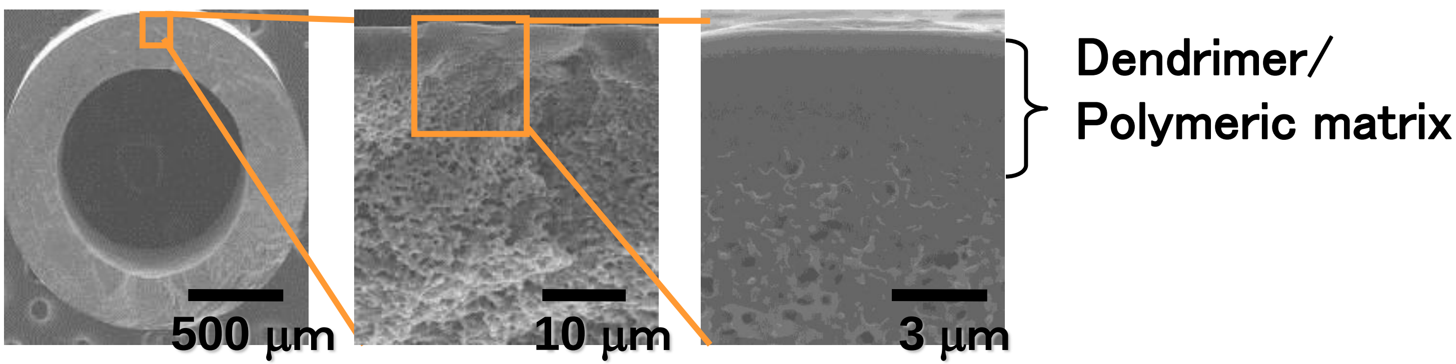
Molecular gate
Hollow-fiber membranes

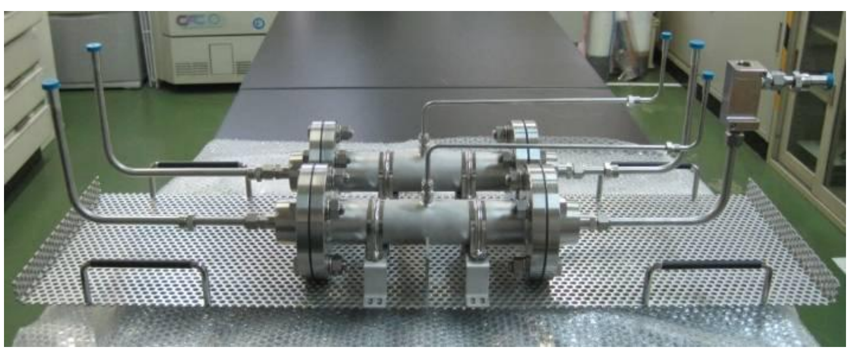


Molecular gate
flat-sheet membranes

Cooperation with private companies (Development of Membrane module)

Cooperation with
Four membrane companies (Kuraray, Daicel, Toray, Nitto-Denko)
Engineering company (Nippon Steel Engineering)





Membrane module test using syngas

Testing apparatus at ECOPRO Gasifier, Nippon Steel Corporation (Yawata plant), Nippon Steel Engineering Co., Ltd.

ECOPRO： JCOAL project supported by METI

Acknowledgements

This study is supported by:

- Ministry of Economy, Trade and Industry (METI), Japan.

- Nippon Steel Engineering Co., Ltd.

Thank you for your attention!

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