CARBON SEQUESTRATION LEADERSHIP FORUM
1st INTERNATIONAL WORKSHOP ON CSLF PROJECTS
29 September 2005 in Berlin, Germany

Research Institute of Innovative Technology for the Earth

Project Coordinator: JAPAN

CO_2 Separation from Pressurized Gas Stream

Development of Molecular Gate Membrane for CO_2 Capture

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CCS Cost Estimates：Geological CO_2 Sequestration

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NEDO Report (Example in Japan)

		Percentage
CO_2 Capture	45 \$/t-CO_2	70%
Total	62 - 67 \$/t-CO_2	

IEA Report (presented at 1st CSLF)

		Percentage
CO_2 Capture	15 – 40 \$/t-CO_2	90%
Total	17 – 45 \$/t-CO_2	

Cost reduction in CO_2 capture is a key issue of success in carbon sequestration !

Activities of CO_2 Separation in RITE:

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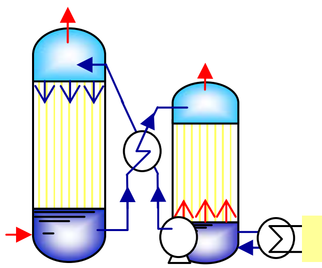
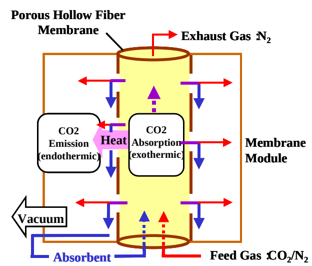
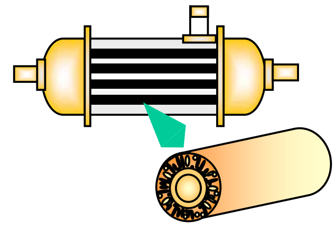
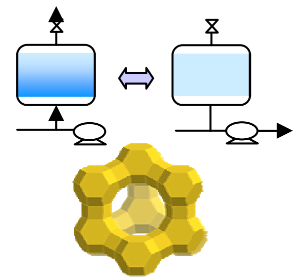
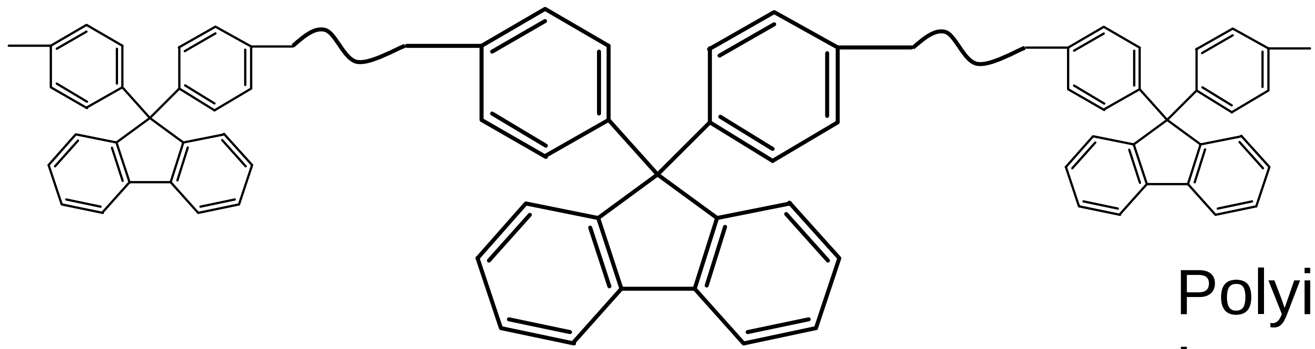
	Absorption	Membrane-Absorption Hybrid	Membrane	Adsorption
				
Material, Processing	Low Temperature Regeneration Absorbent	Hybrid Membrane Module	Cardo Polymer, Dendrimer, Zeolite Nano-structure Control, Fiber Fabrication	Zeolite, Mesoporous Silica Surface Modification
Separation Process	Waste Heat Utilization	Pressure Swing Control		
System	Design and Evaluation, Energy and Economy			

URL: http://www.rite.or.jp/

Cardo Polyimide (Membrane Activity):

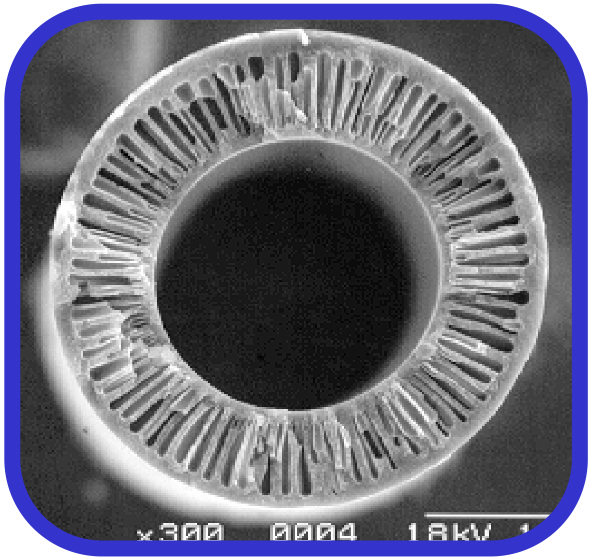


Polyimide Containing
Loop Shaped Moiety

Fluorene Moiety (RITE Cardo Polyimide)

1. Good Gas Permeability → Excellent CO_2/N_2 Separation Property
2. Good Solubility → Asymmetric Membrane Preparation
3. Good Thermal Stability → High Temperature Usage

Cardo Polyimide Asymmetric Hollow fiber:



SEM Image
Cross Section

100 micro meter

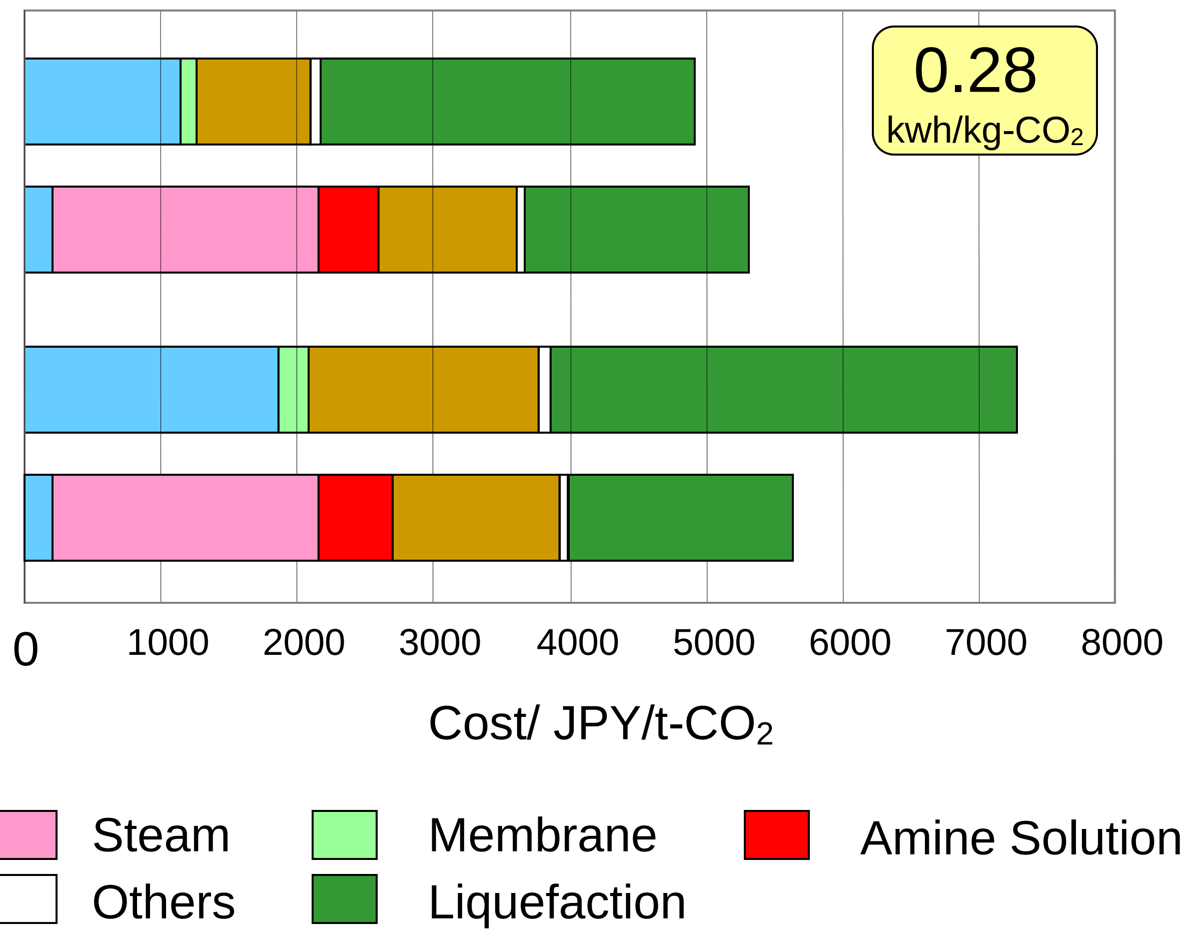
CO_2 Separation Property of Hollow Fiber Membrane
Made from Br-type Cardo Polyimide(PMBP64(4Me)-Br)

CO_2 Permeation Rate:	1×10^{-3} cm^3(STP) cm^{-2} s^{-1} $cmHg^{-1}$ ($=7.5 \times 10^{-9}$ m^3 m^{-2} s^{-1} Pa^{-1})
CO_2/N_2 Selectivity:	40

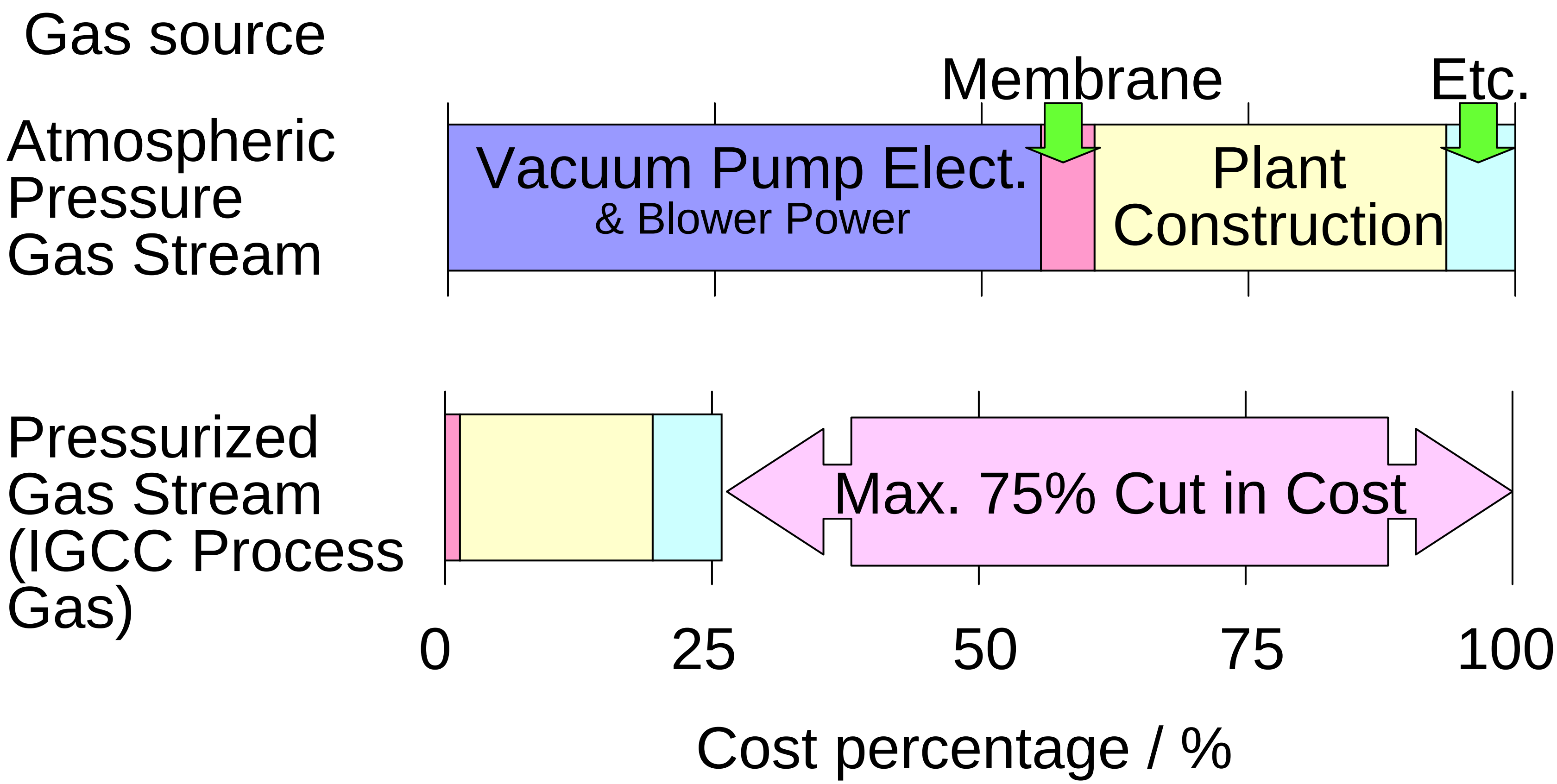
Measured at 25 ºC

Cost Estimates of CO_2 Separation & Liquefaction :

CO_2 Source	Separation Method
Steel Works CO_2 Conc. = 26.8%	Membrane (Cardo)
	Amine (KS Solution)
Coal Fired Power Station CO_2 Conc. = 13.2%	Membrane (Cardo)
	Amine (KS Solution)



Approaches to Cost Reduction:



- Cost breakdown of membrane CO2 separation

Selectivity Required for IGCC Gas:

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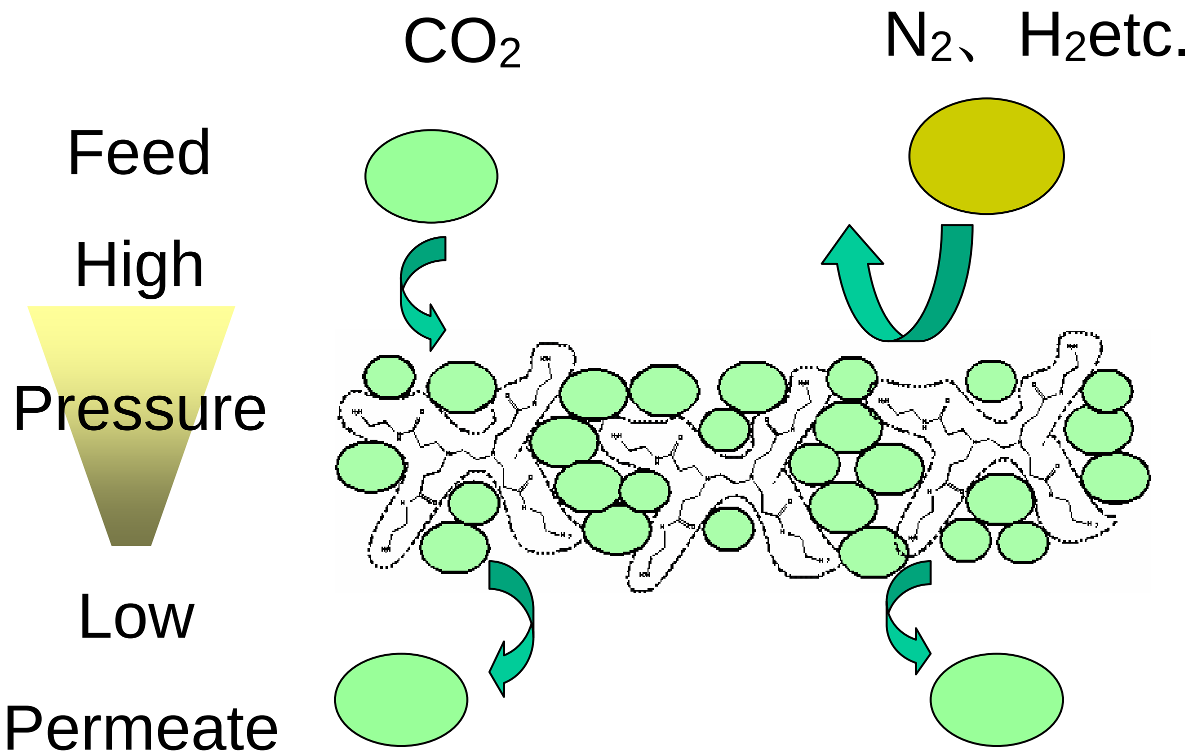
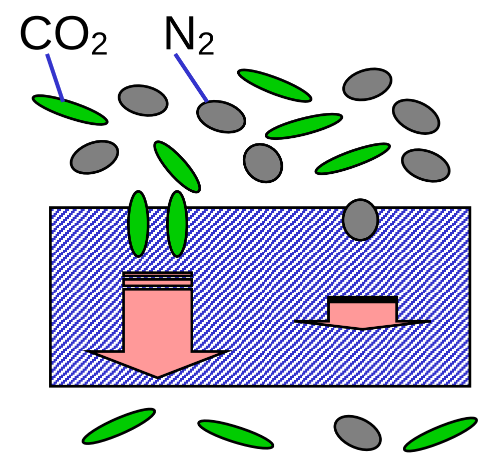
CO_2/H_2 Selectivity	After Membrane Separation: H_2 Rich Flow	After Membrane Separation: CO_2 Rich Flow
100 New Concept Membrane	H_2: 94% CO_2: 6%	H_2: 4% CO_2: 96%
0.3 Polymeric Membrane	H_2: 80% CO_2: 20%	H_2: 55% CO_2: 45%
0.1 Ceramic Membrane	H_2: 90% CO_2: 10%	H_2: 38% CO_2: 72%

Feed gas: composition: CO_2:40% and H_2:60%
pressure: 4 MPa

CO_2 Molecular Gate Membrane:



Conventional Polymeric Membrane：



CO_2/N_2 Selectivity: 35

Framework of this Project:

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Project Coordinator: Japan

RITE
-Molecular Gate Materials & Membranes
-Module Development -System Analysis

Cooperative Research

Meiji University
-Membrane Fabrication

Project Partner: USA

National Energy Technology Laboratory-DOE
-Module Testing (Modular CO_2 Capture Facility)

The University of Texas at Austin
-Membrane Testing, Information Exchange

Schedule, Budget & Objective:

	Duration/ Budget	Objectives
1st Stage	2003FY-2005FY 280 MJPY 2.5 M$	- CO_2 molecular gate to N_2 at ambient pressure -Test module preparation - Module testing
2nd Stage (Planned)	2006FY-2010FY 660 MJPY 6.0 M$	- CO_2 molecular gate to H_2 at high pressure - Commercial scale module - Bench testing

Synthesis and Chemical Structure of Hydroxyl PAMAM Dendrimer :

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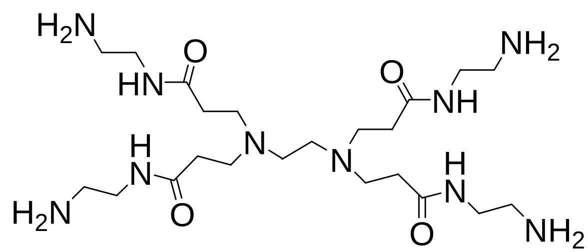
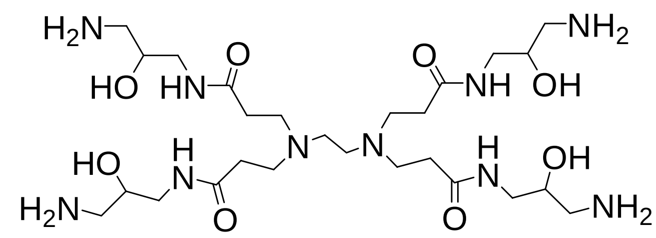
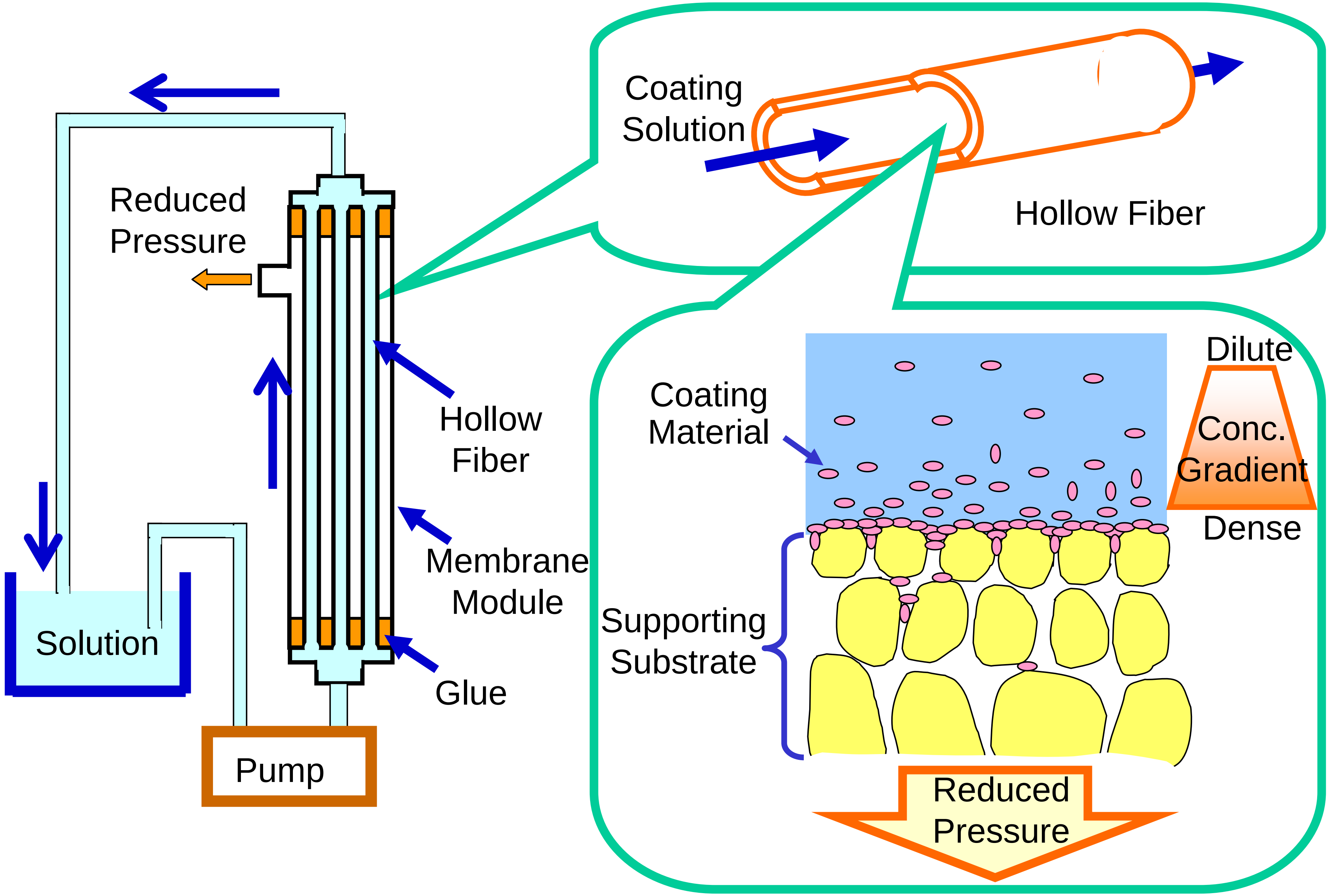




	Conventional Polyamidoamine(PAMAM) dendrimer	Novel hydroxyl modified Polyamidoamine(PAMAM) dendrimer
CO_2 Permeability [ml cm/cm^2 s cmHg]	3×10^{-9}	7×10^{-8}
CO_2/N_2 Selectivity	200	4000
CO_2/H_2 Selectivity		

In-situ Module Modification Method:



Dendrimer Composite Membrane Module:

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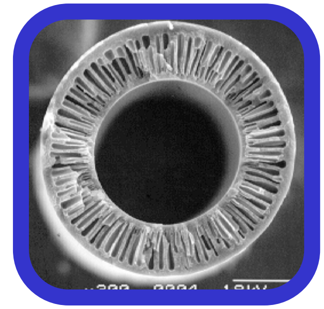
Pencil Module

800 mm, 3/8 inch

CO_2 Permeance
8×10^{-10} $m^3/(m^2\ s\ Pa)$

CO_2/N_2 Selectivity
400

Dendrimer: conventional PAMAM



Hollow fiber membrane

1 meter Module

1100 mm in length, 1 or 3 inch in diameter

CO_2 Permeance
2×10^{-10} $m^3/(m^2\ s\ Pa)$

CO_2/N_2 Selectivity
200

Dendrimer: conventional PAMAM

Concluding Remarks:

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- Membrane application for CO_2 capture from pressurized gas stream is promising way of reducing CO_2 capture cost and energy.
- Novel hydroxyl PAMAM dendrimer shows excellent CO_2 permeability and selectivity over N_2 and H_2.
- Dendrimer composite membrane has good CO_2 separation performance.
- Molecular gate membrane will contribute to great cost and energy reduction in CO_2 capture.


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