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STANFORD UNIVERSITY

GCEP Research Symposium 2009

New Research Directions in a Rapidly Evolving Global Energy Landscape



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Frances C. Arrillaga Alumni Center  
Stanford University

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# Advanced CO<sub>2</sub>/H<sub>2</sub> Separation Materials Incorporating Active Functional Agents

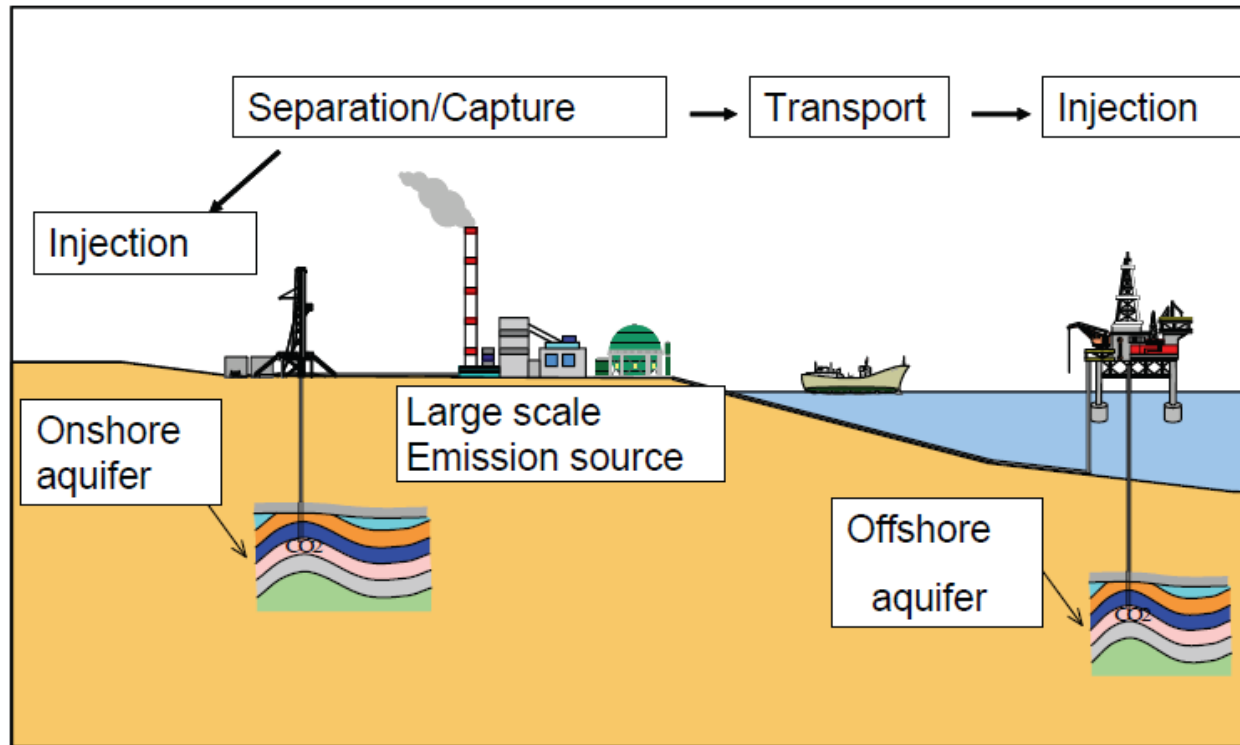
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Research Institute of Innovative Technology for the Earth (RITE)



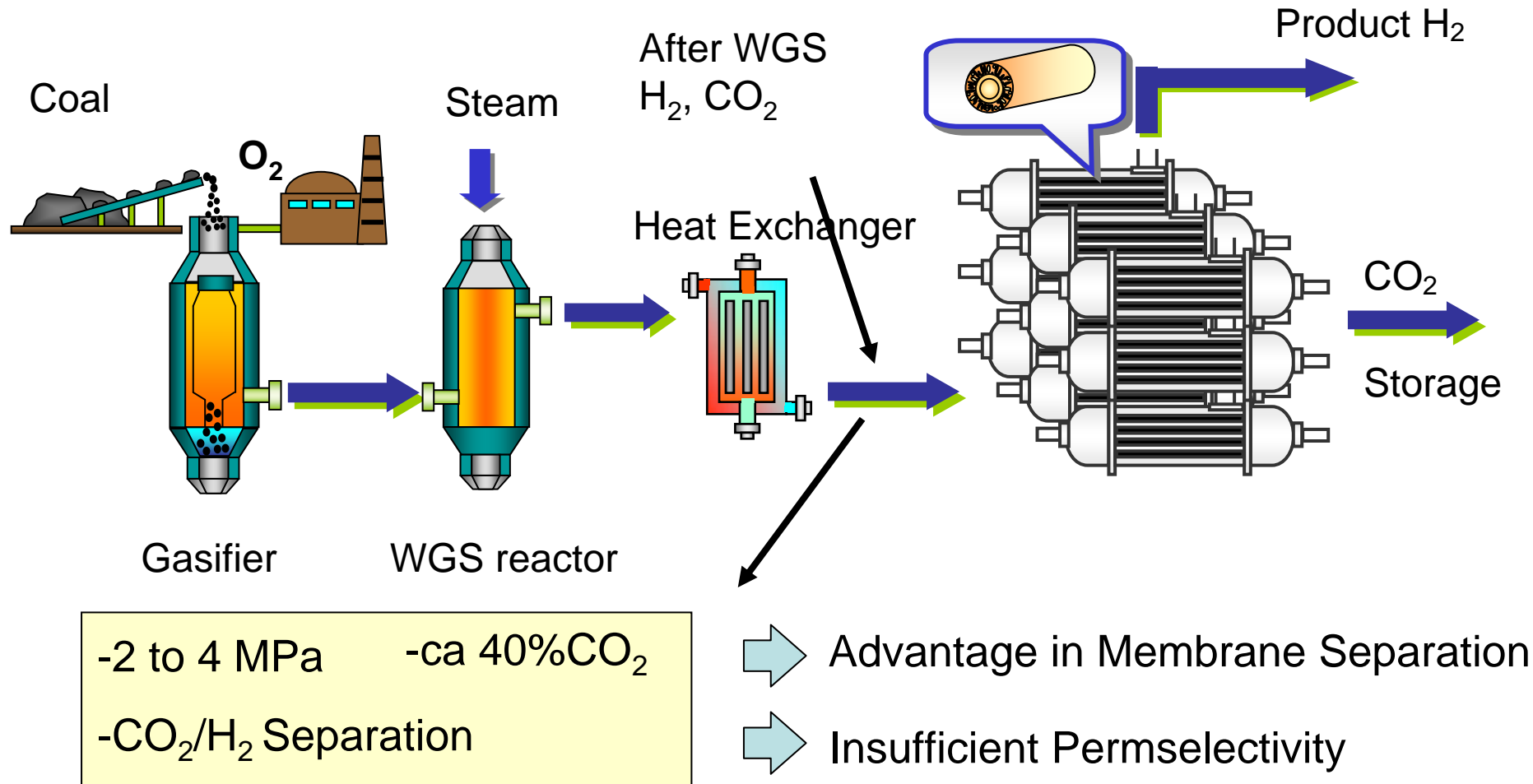
## Carbon dioxide Capture and Storage (CCS)



Cost of Separation/Capture : >70% of total cost of CCS

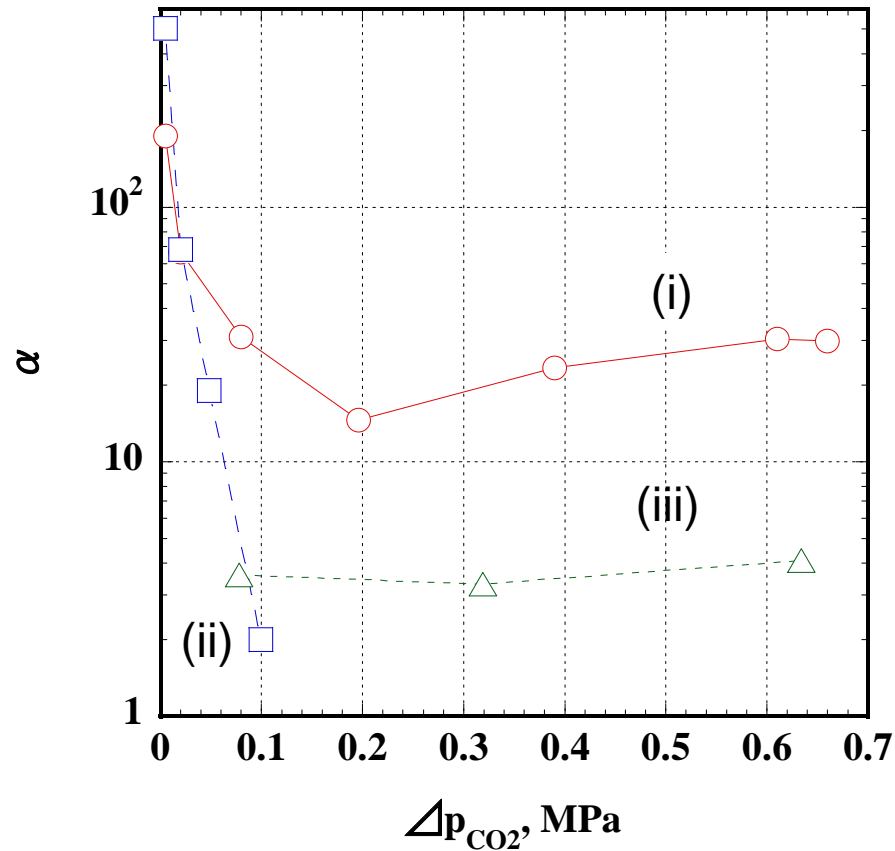
Development of novel high performance membrane will reduce the cost of CCS

# Schematic of IGCC with CCS

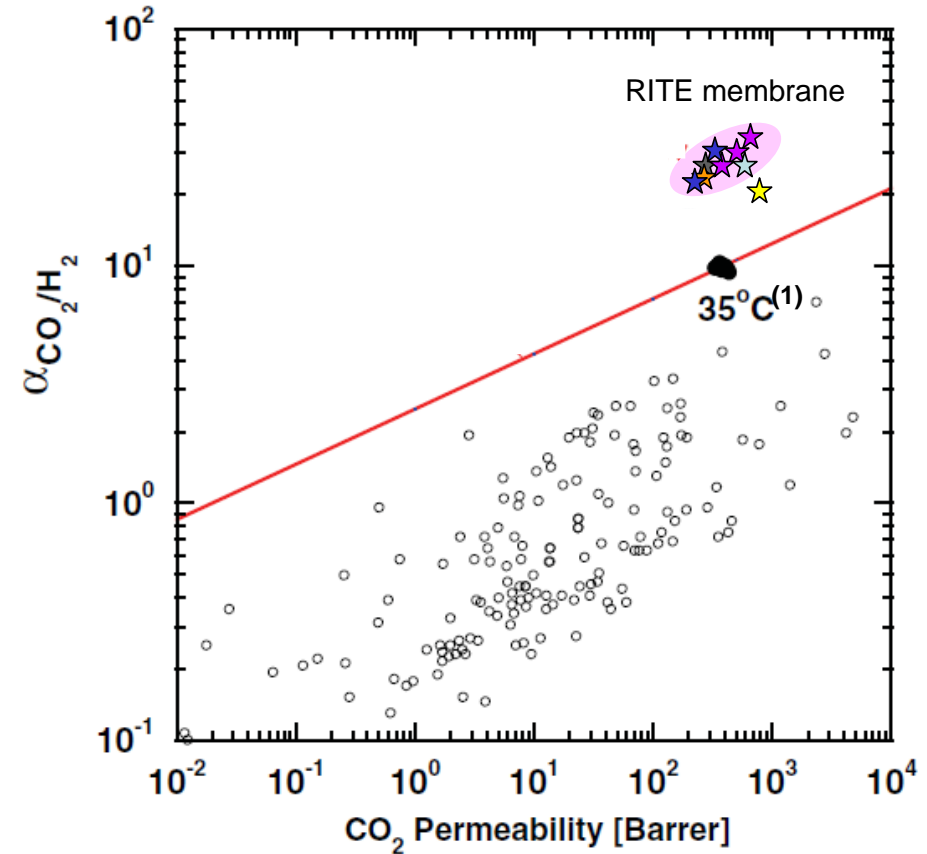


CO<sub>2</sub> separation system in Integrated Coal Gasification Combined Cycle (IGCC)





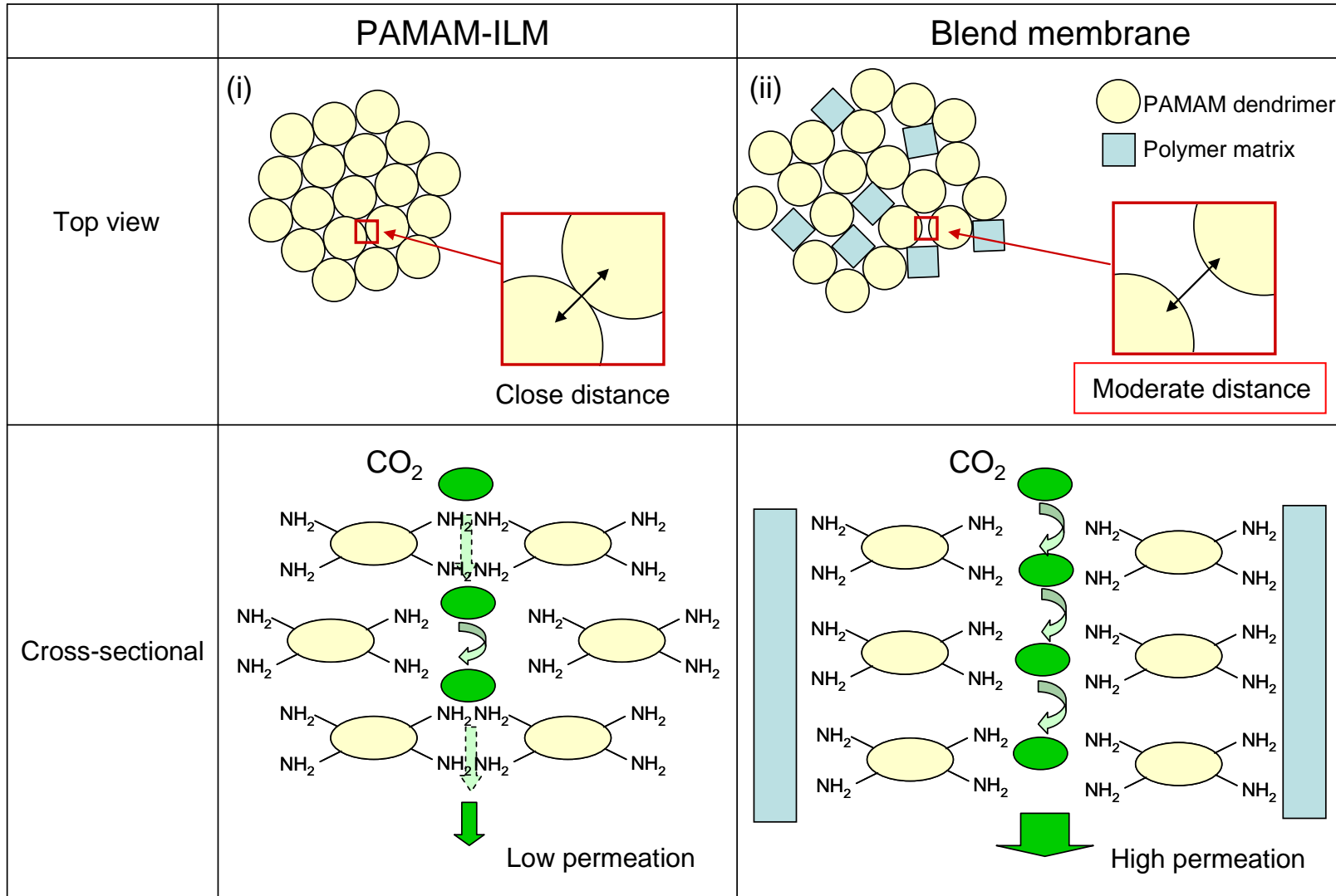
CO<sub>2</sub>/H<sub>2</sub> selectivity of  
 (i) Blend membrane of PAMAM/PEGDMA/TMPTMA  
 (ii) PAMAM ILM (immobilized liquid membrane)  
 (iii) PEGDMA/TMPTMA film (w/o PAMAM)



Selectivity/Permeability map  
 Experiment temp. : 25~55°C  
 CO<sub>2</sub> partial pressure : 0.6~0.7 MPa

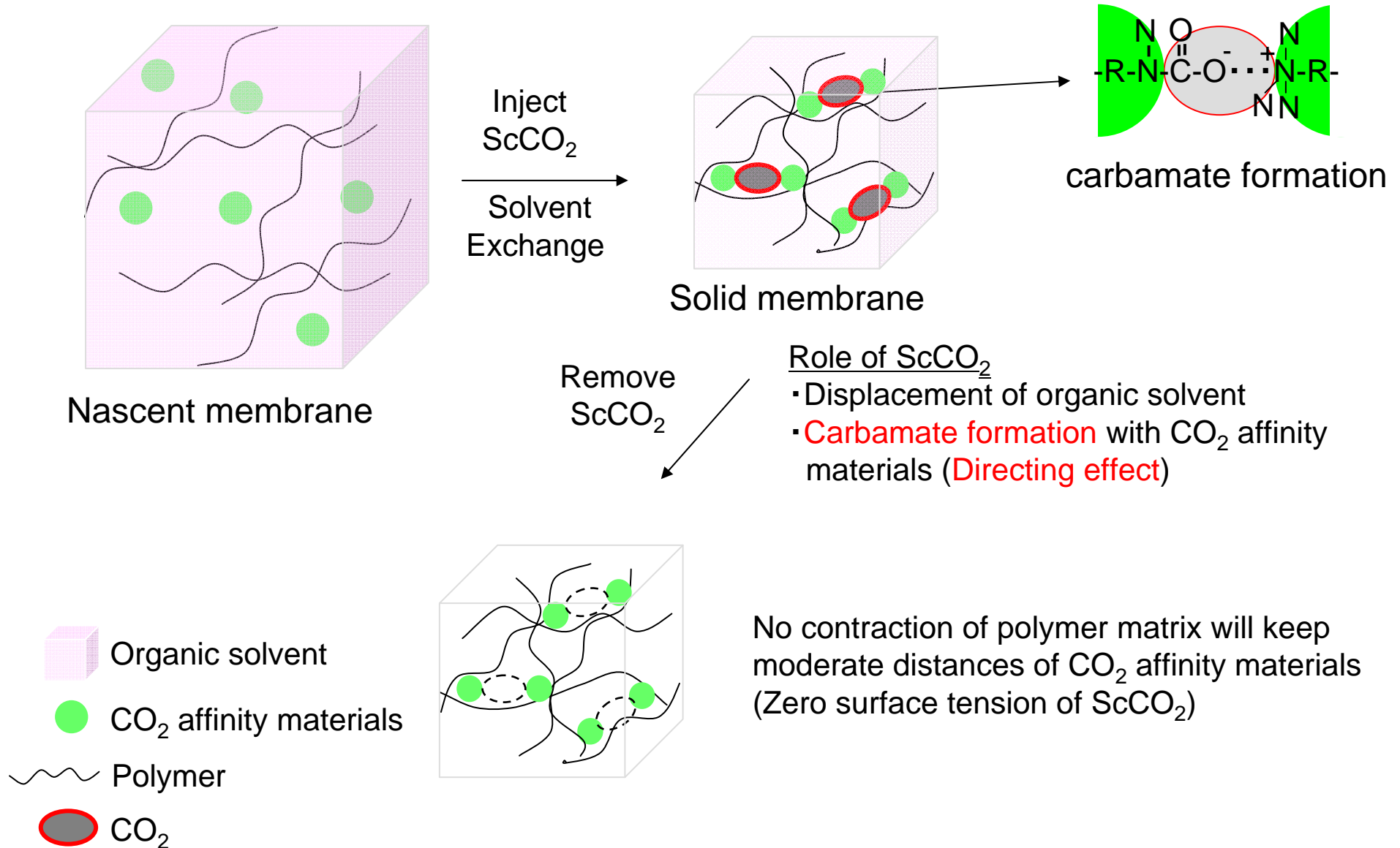
(1) H. Lin *et al.*, *Science*, **311**, 639-642 (2006).

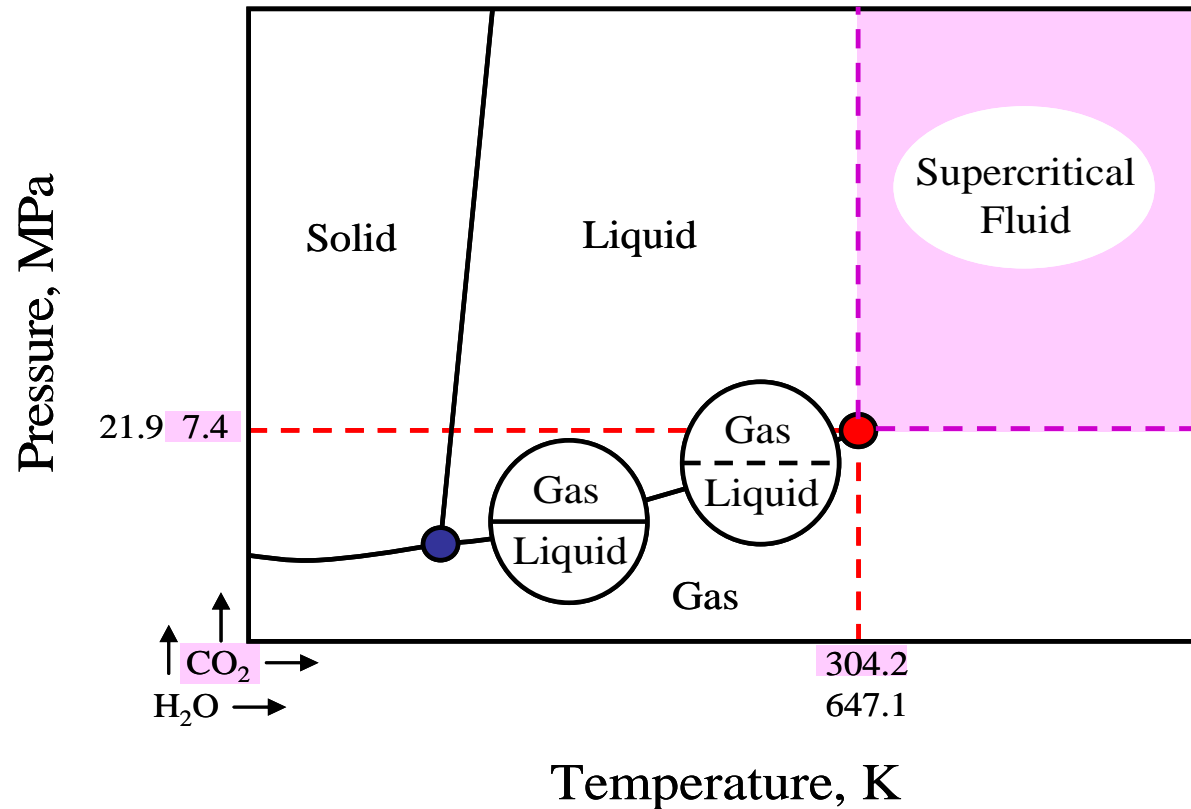
# Basic Concept for High Performance Membrane



Schematic representation of PAMAM dendrimer in ILM and blend membrane.  
(i), PAMAM-ILM; (ii), Blend membrane of PAMAM/PEGDMA/TMPTMA

# - Basic Concept of ScCO<sub>2</sub> Directing Method -

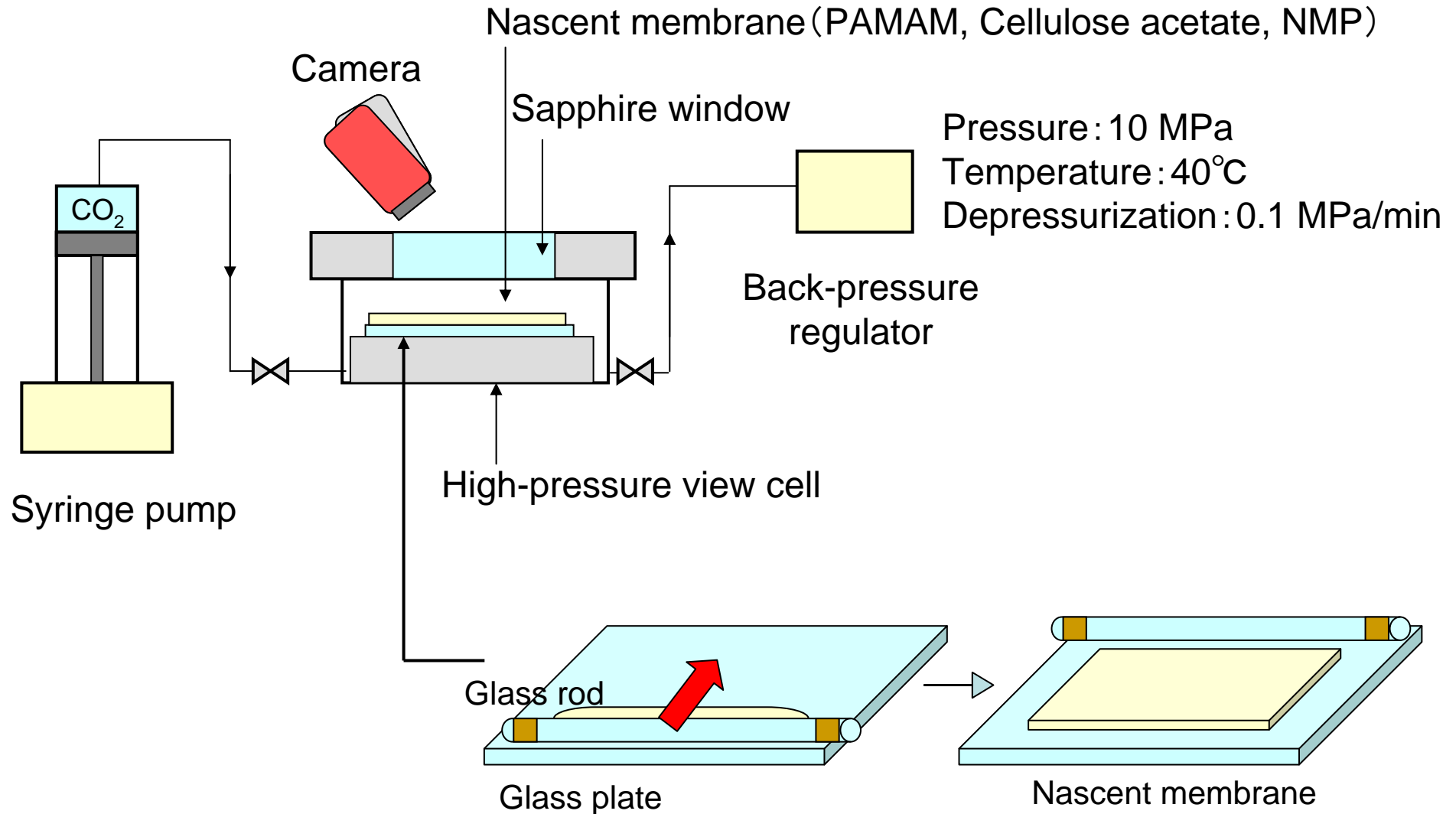


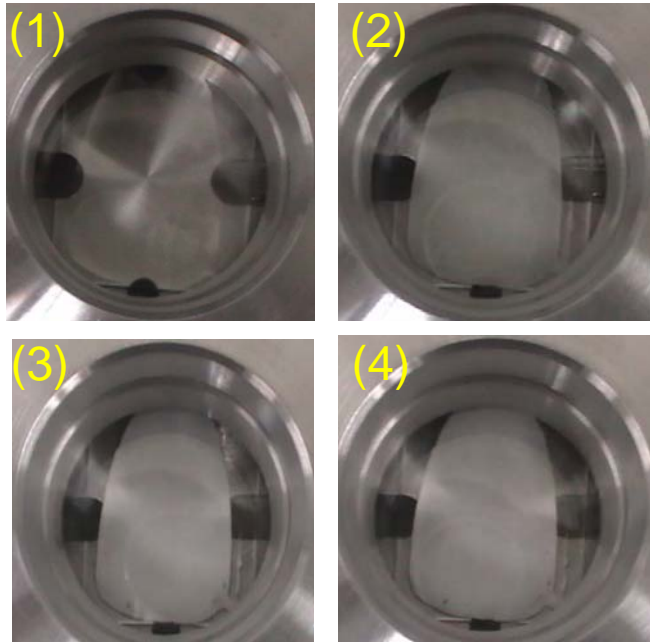


## Advantages of ScCO<sub>2</sub> usage for membrane creation

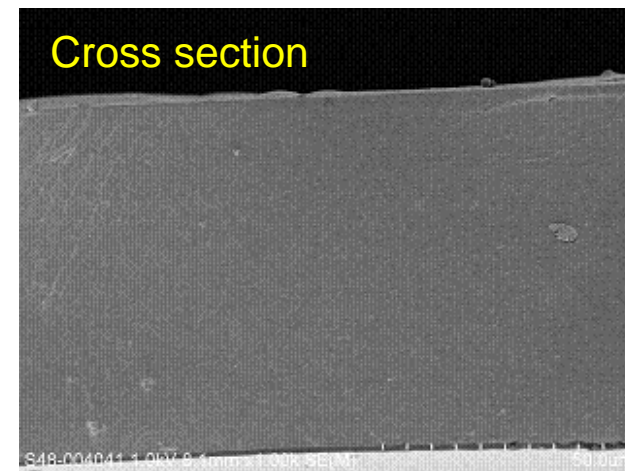
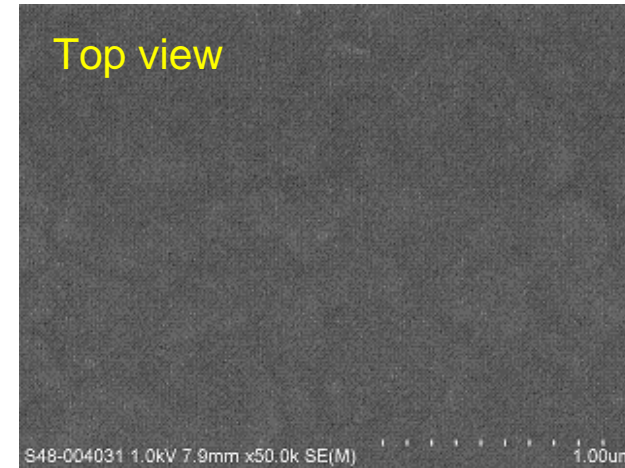
- Moderate critical constants (P<sub>c</sub> : 7.4 MPa, T<sub>c</sub> : 304.2 K)
- Zero surface tension
- Permits the extraction of non-polar to medium polarity solutes free from polar moieties

# Set Up of ScCO<sub>2</sub> Directing Method

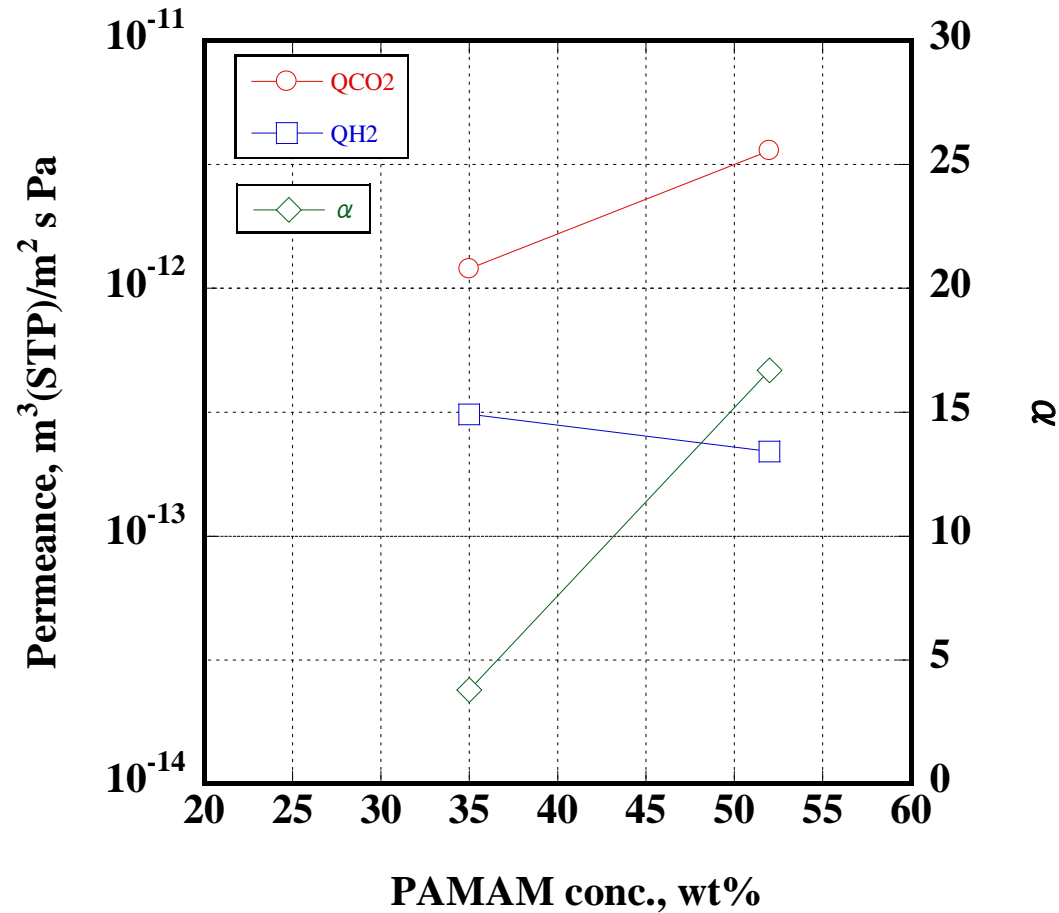




With increasing pressure (1→4), solvent was dissolved into  $\text{ScCO}_2$ . After that PAMAM/cellulose acetate blend membrane was obtained.



SEM images of obtained membrane



CO<sub>2</sub>/H<sub>2</sub> separation properties  
(Feed gas : T=313 K, 80%RH, p<sub>CO<sub>2</sub></sub>=0.08 MPa)

Basic concept of novel ScCO<sub>2</sub> directing method was invented for the preparation of Innovative CO<sub>2</sub>/H<sub>2</sub> separation membrane.

ScCO<sub>2</sub> acts as follows ;

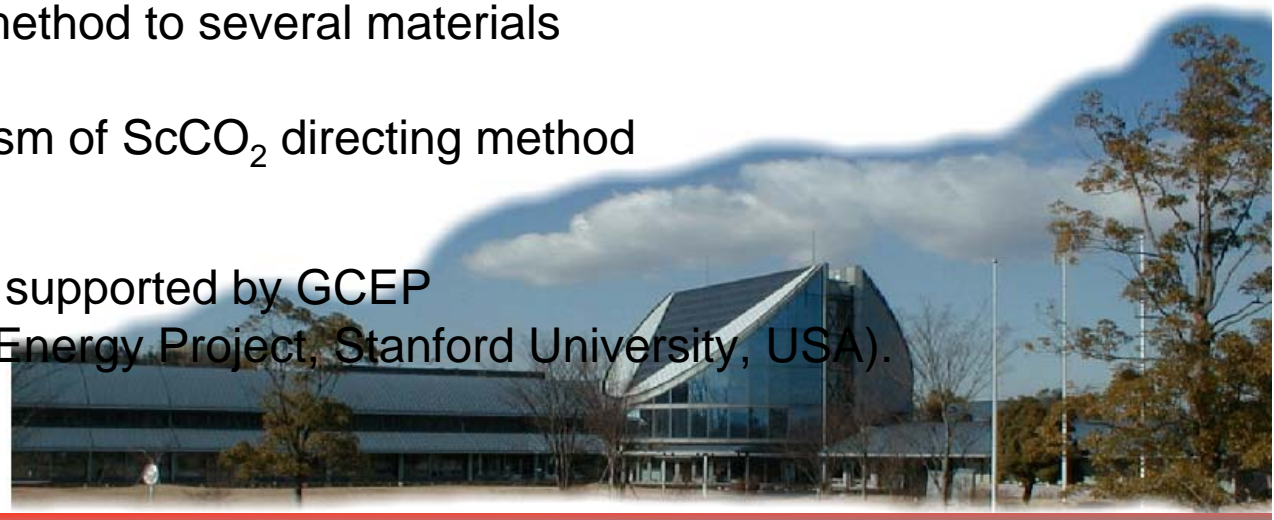
1. Structure directing agent to create and keep moderate distance between CO<sub>2</sub> affinity materials
  - Formation of carbamate with CO<sub>2</sub> affinity materials
  - Prevention of polymer matrix contraction because of its zero surface tension
2. Poor solvent for matrix polymer (high compatibility with organic solvent)

## Future Work

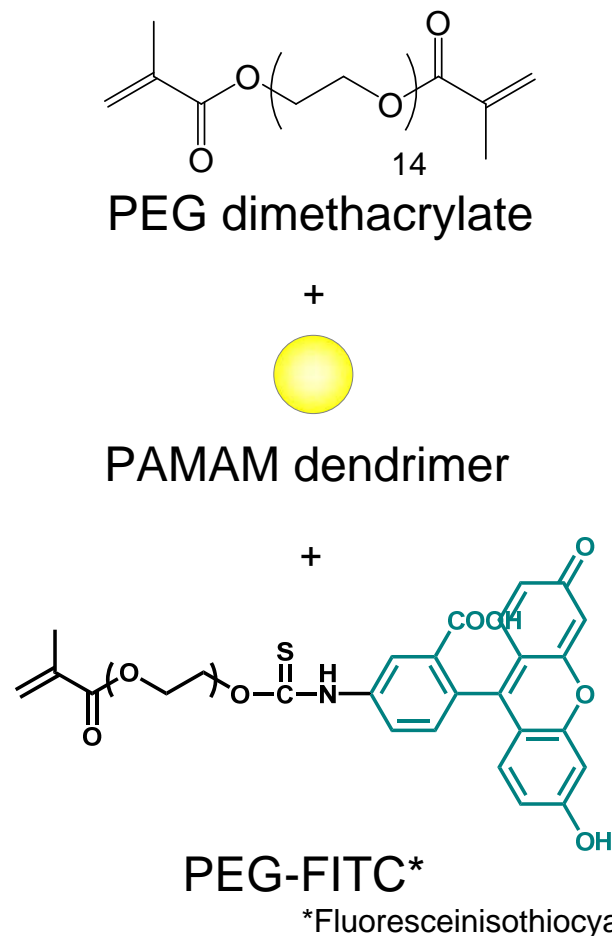
1. Apply ScCO<sub>2</sub> directing method to several materials
2. Investigate the mechanism of ScCO<sub>2</sub> directing method

## Acknowledgement

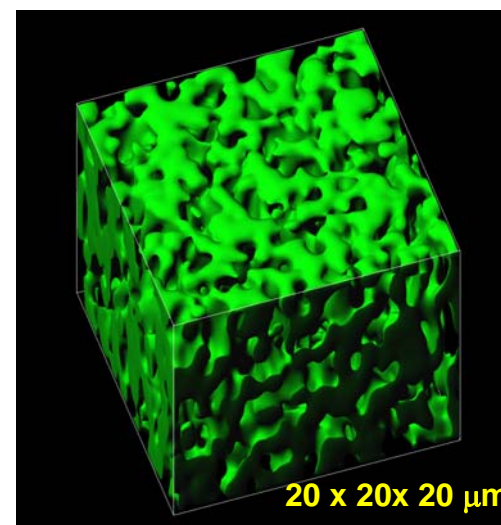
This research was supported by GCEP  
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### PAMAM dendrimer- in PEG network



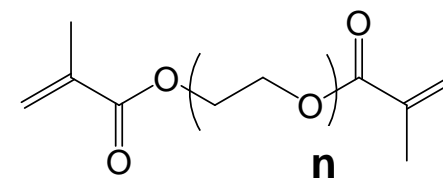
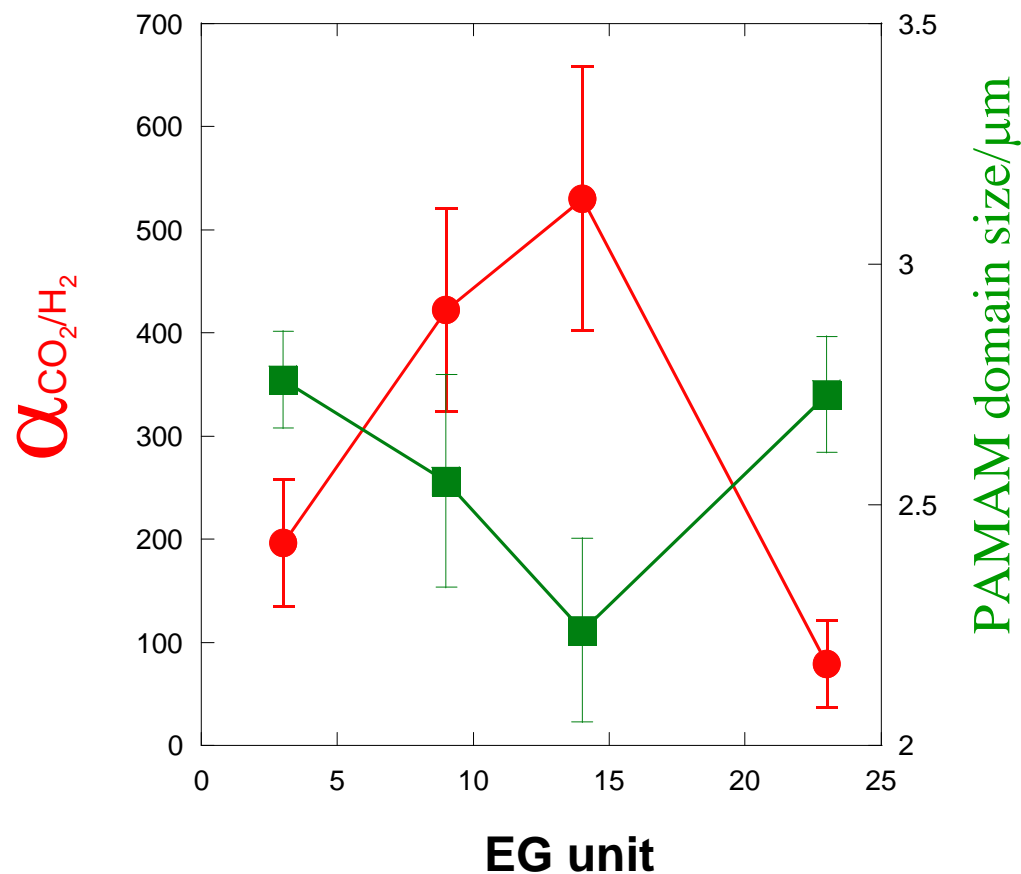
UV  
→



Bright section ··· PEG  
Dark section ··· PAMAM

Estimation of domain size

3D structure information (under CO<sub>2</sub> and H<sub>2</sub>O sorption)



PAMAM dendrimer: 0<sup>th</sup> generation, 50 wt%,  
 Feed gas: H<sub>2</sub>/CO<sub>2</sub> (95/5 by vol.) at 100 mL/min.  
 Sweep gas: He at 10 mL/min., Relative humidity: 80 % at 298 K  
 Error bars denote SD.