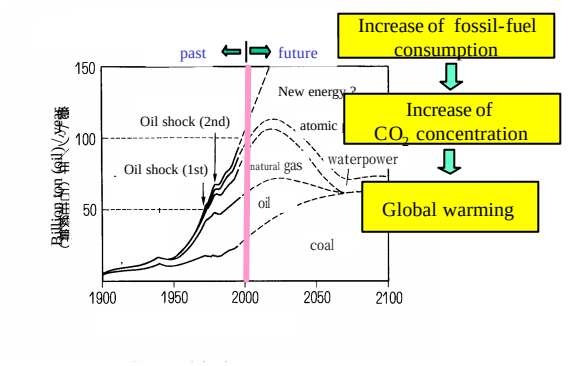
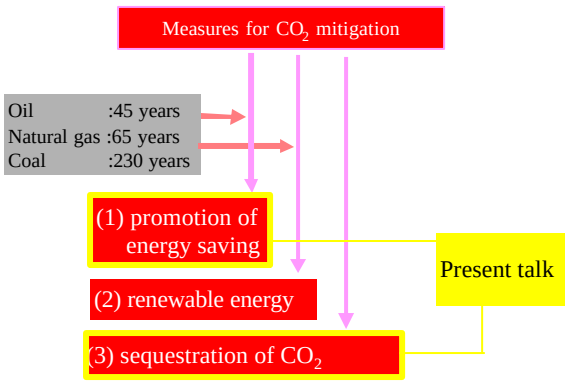
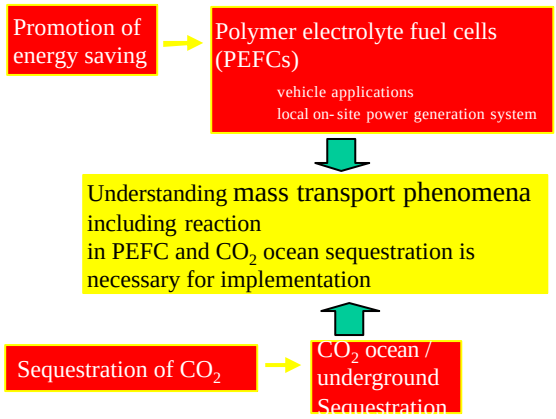
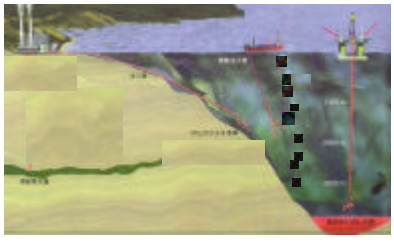
化学反応、燃焼とCO2隔離

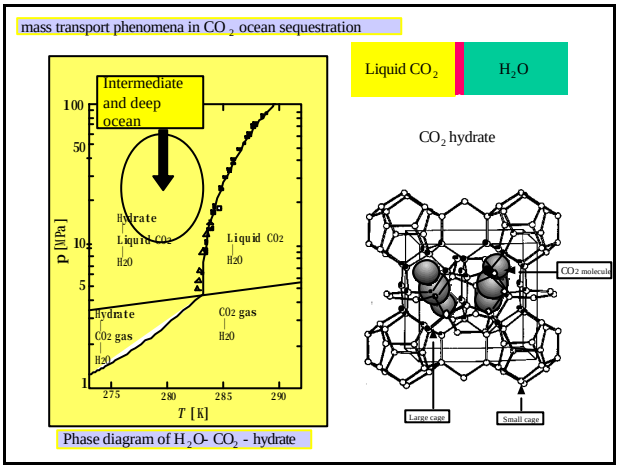
Chemical Reaction ,Combustion and CO2 sequestration

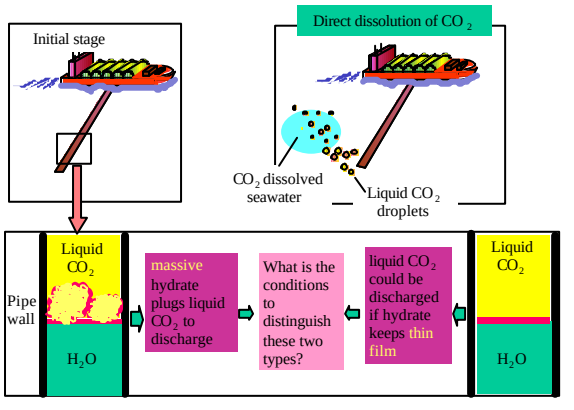


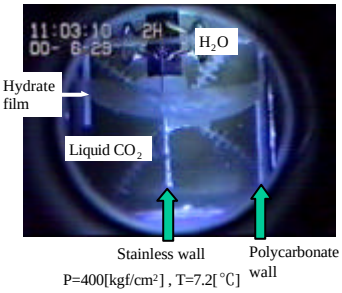








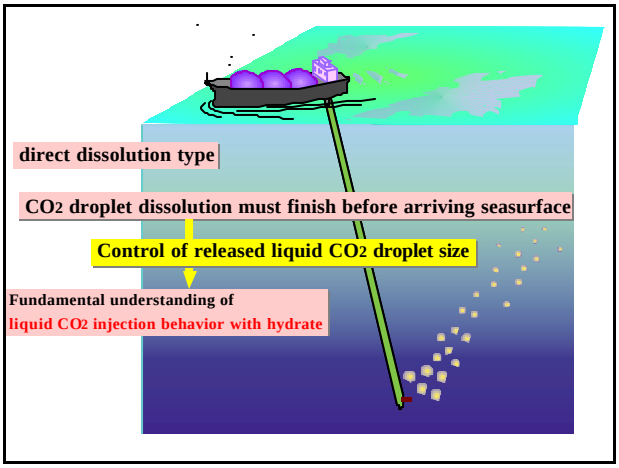




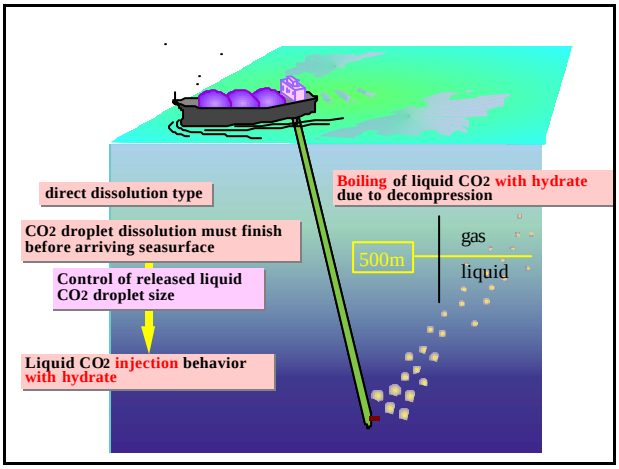
massive hydrate formation → Stainless wall → low-polar-surface free energy

No massive hydrate formation → Polycarbonate wall → high-polar-surface free energy

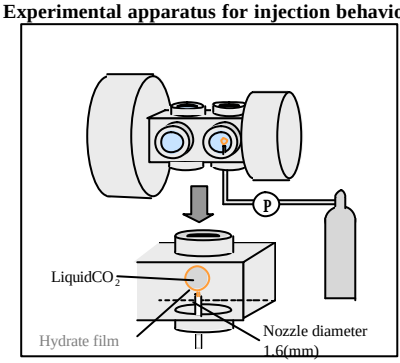
use of low-polar surface free energy material for pipe wall would prevent massive hydrate growth to plug liquid CO_2 discharge

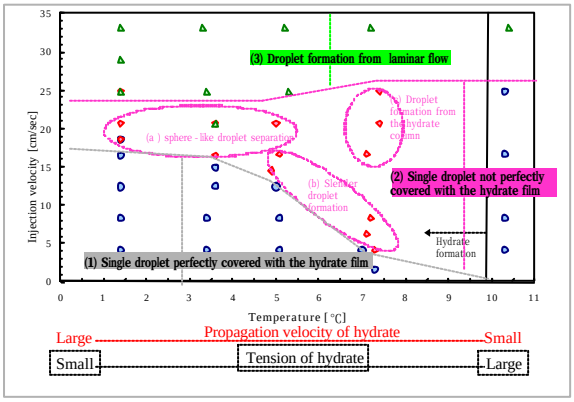


Injection and Boiling of Liquid CO_2 with Hydrate

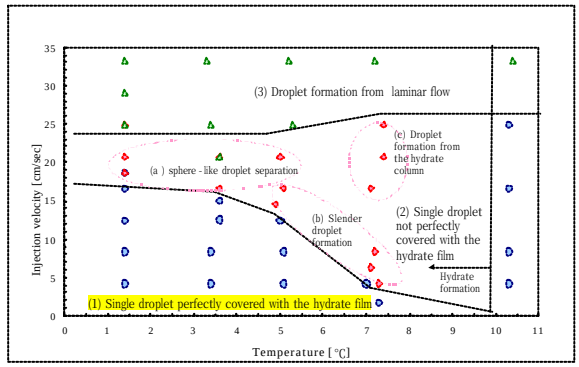


Experimental apparatus for injection behavior





Map of injection behavior of liquid CO2 with hydrate varying injection velocity and temperature



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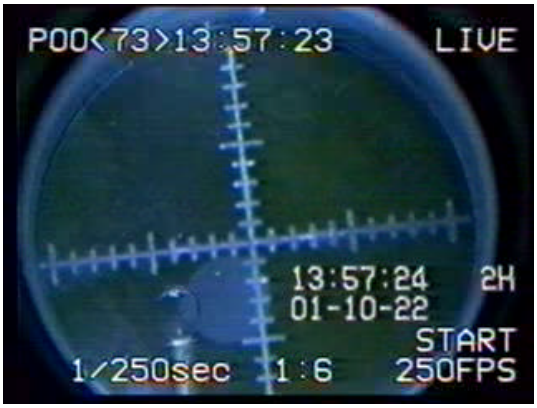
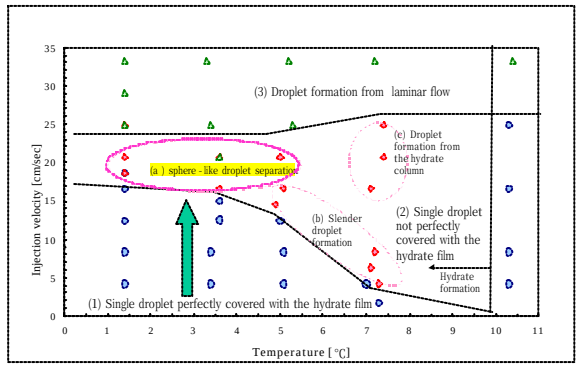
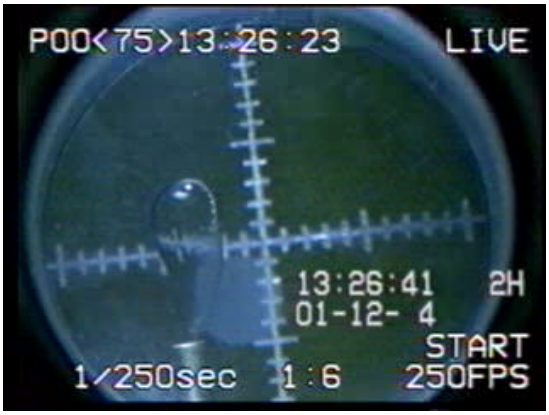
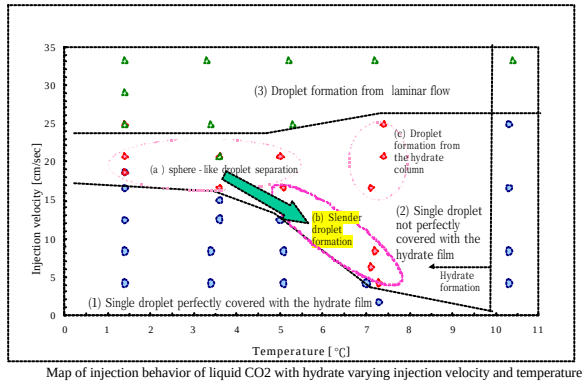


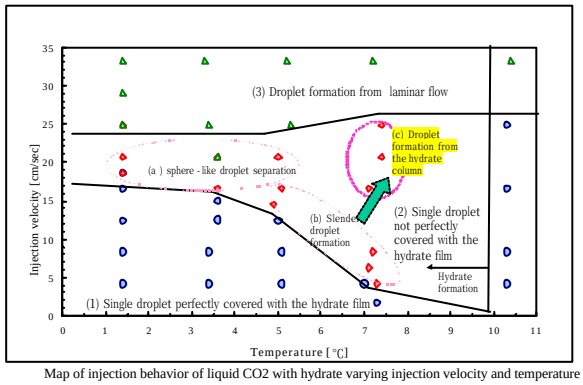


Map of injection behavior of liquid CO2 with hydrate varying injection velocity and temperature

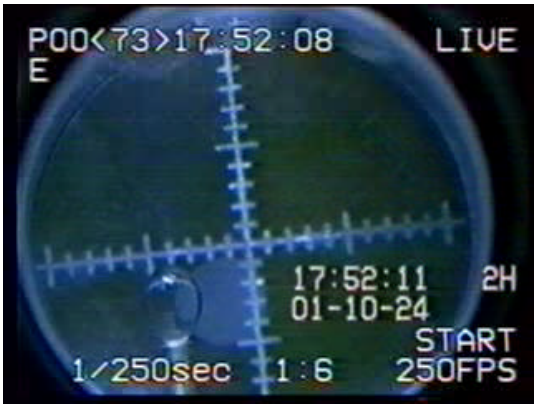


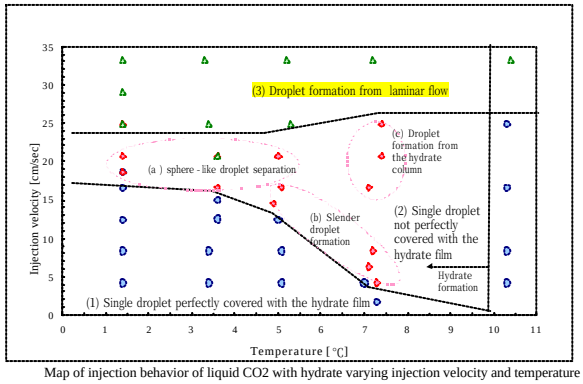


Map of injection behavior of liquid CO2 with hydrate varying injection velocity and temperature

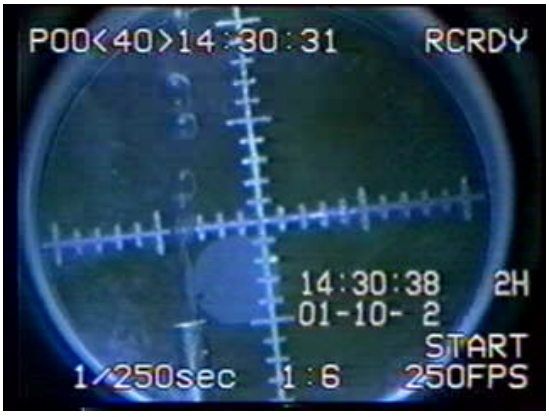


Map of injection behavior of liquid CO2 with hydrate varying injection velocity and temperature

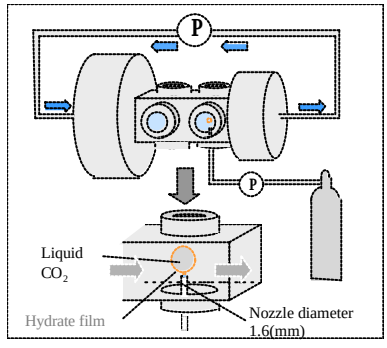


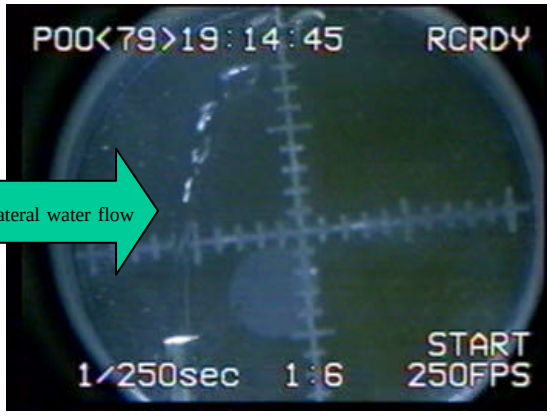


Map of injection behavior of liquid CO2 with hydrate varying injection velocity and temperature

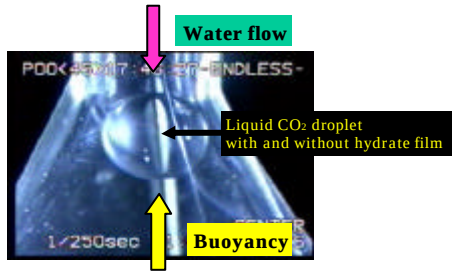


Injection Behavior with Lateral Flow
(Typical case)

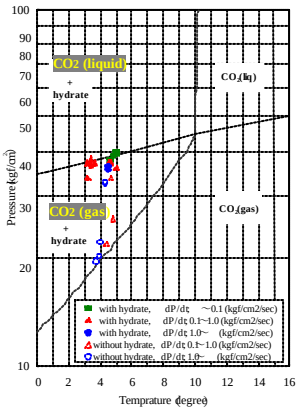




Boiling of Liquid CO_2 by Decompression with Hydrate Film



Decrease of pressure → Boiling

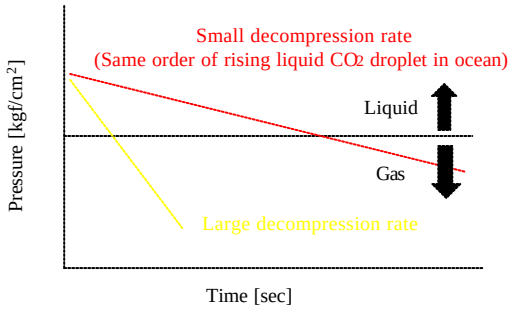


Effect of hydrate film on boiling

Boiling starts as soon as pressure is lowered beyond the liquid-gas boundary in the case with hydrate.

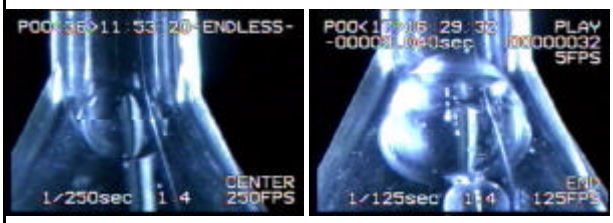
Effect of decompression rate on boiling

Decompression rate



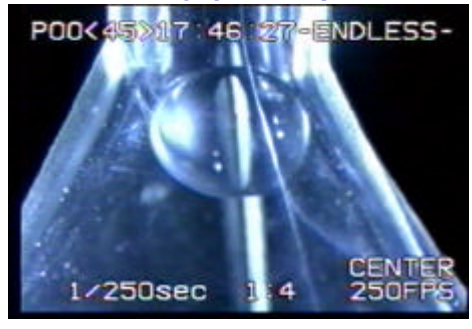
Video

Video (High speed camera)



Large decompression rate

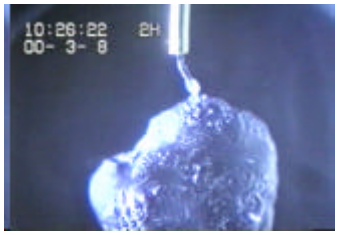
Decompression rate (Small)
Same order of rising liquid CO2 droplet in ocean



Liquid CO_2 injection in CO_2 saturated water

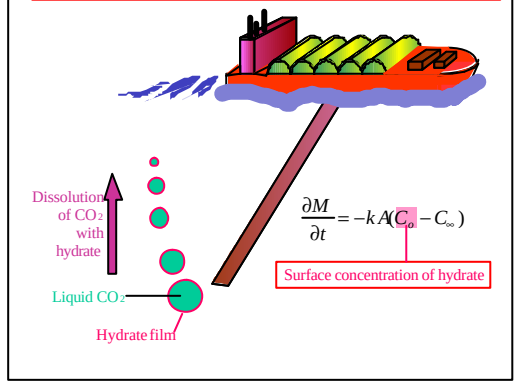
Temperature 281K

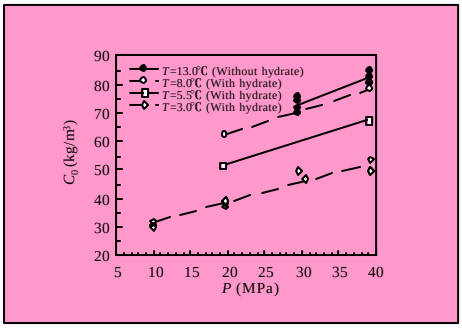
Pressure 39.2MPa (4000m depth)

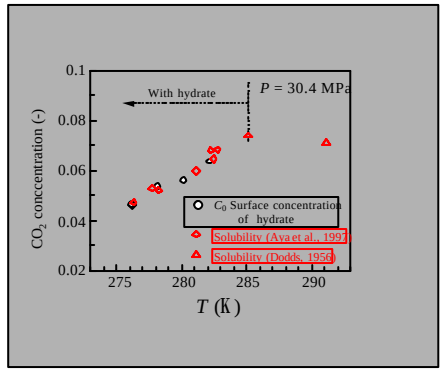


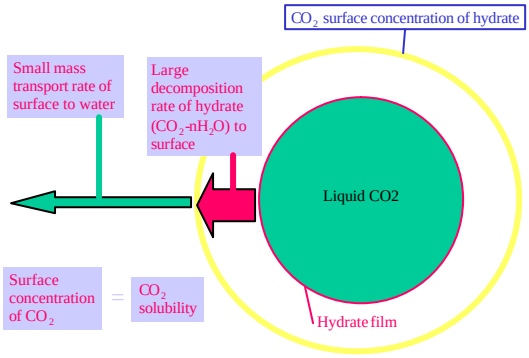
- Remarkable ruggedness was formed on the hydrate film

Simulation of dissolution of liquid CO_2 droplet with hydrate film

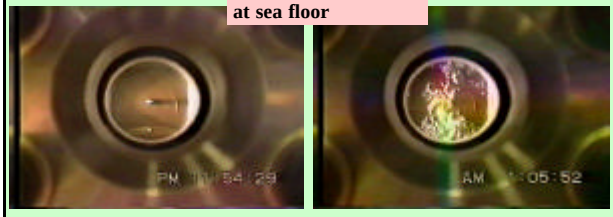


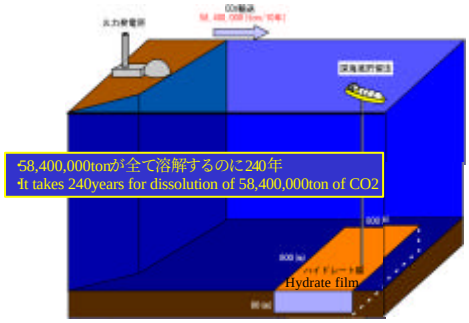


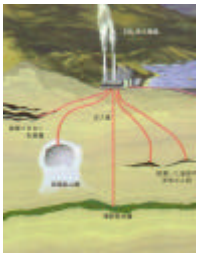




深海底貯留
Sequestration of CO2 at sea floor

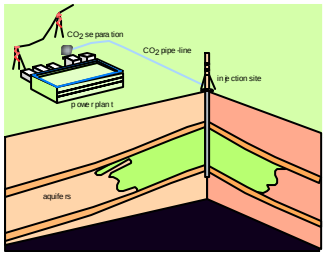


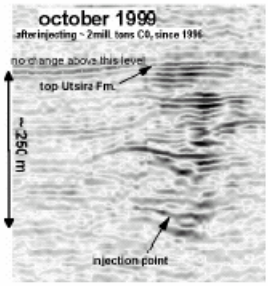


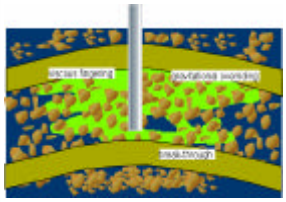


地下帯水層へのCO$_2$ 隔離
Underground disposal of CO2

- 帯水層への圧入
- Injection of CO2 into aquifer

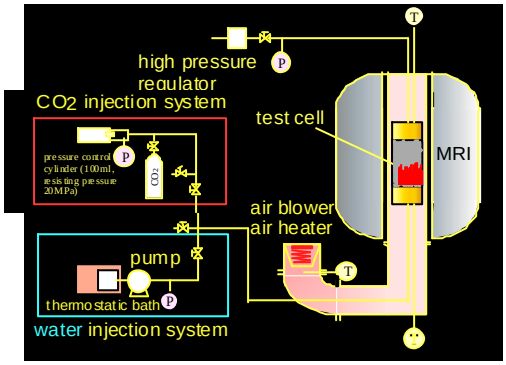




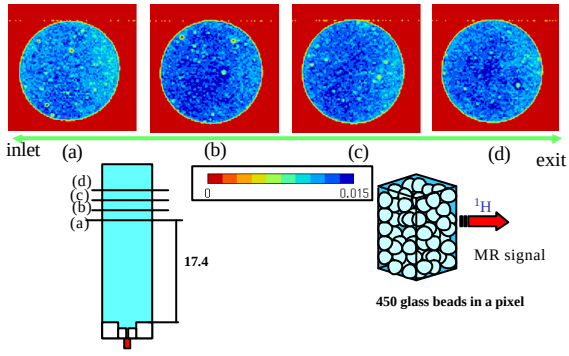


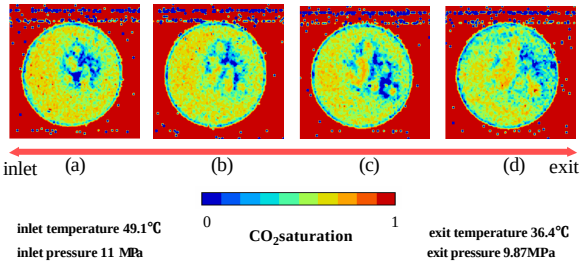
van der Meer et al., GHGT6

帯水層に圧入された超臨界CO$_2$ の可視化
Visualization of super-critical CO2 in aquifer

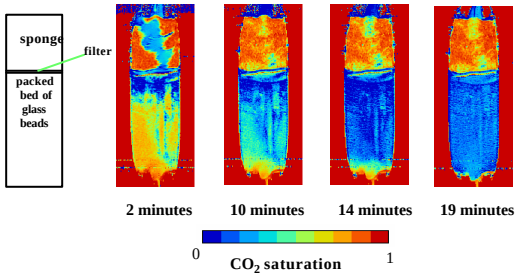


CO$_2$圧入前
Before CO2 injection

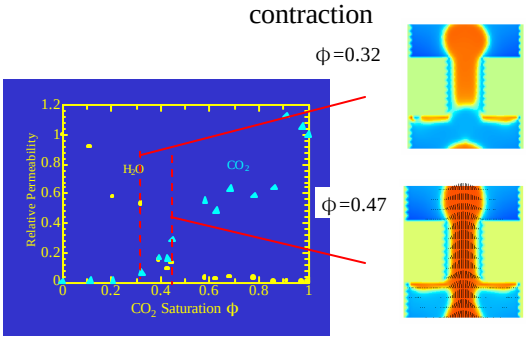




超臨界CO_2の浮力による移動
Super-critical CO2 behavior due to buoyancy



縮流部をすぎるCO_2と水
Numerical simulation of CO2 - water through contraction



Promotion of energy saving → Polymer electrolyte fuel cells (PEFCs)
vehicle applications
local on-site power generation system

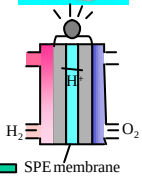
Understanding mass transport phenomena including reaction in PEFC and CO_2 ocean sequestration is necessary for implementation

Sequestration of CO_2 → CO_2 ocean / underground Sequestration

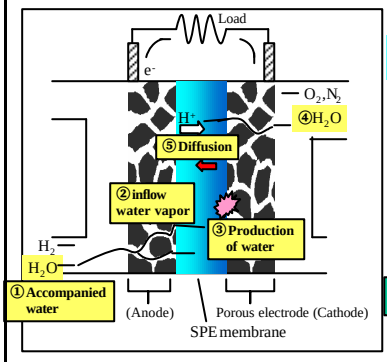
Polymer Electrolyte Fuel Cell (PEFC)
High efficiency & high power density
Vehicles and local on-site power generation system

Water management is very important because...

-. Solid Polymer Electrolyte (SPE) membrane shows high proton conductivity only in the wet (hydrated) state.



Water transport in PEFC



To control hydration of the SPE membrane properly...

We need to know water behaviors inside PEFC. Especially,
-. Water diffusion
-. Water distribution under PEFC operation.

But not easy to measure by conventional method.

How about NMR/MRI?

Magnetic Resonance Imaging (MRI) technique

Advantages and potential

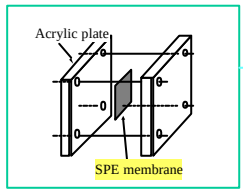
In-vivo and *in-situ* measurement

- Visualization of molecules that include ^{1}H inside the medium non-optically accessible
  e.g. porous media, polymer, complex flow system, etc...
- 3D Flow and temperature measurements
- Chemical spices can be identified.
- Self-diffusion coefficient can be measured.

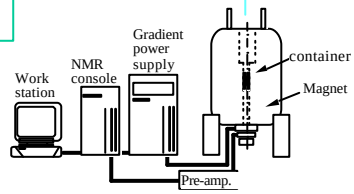
Disadvantages

- nuclei limited (normally ^{1}H, ^{13}C, ^{19}F...)
- difficulties on gas phase
- materials used in experimental apparatus
- temporal resolution

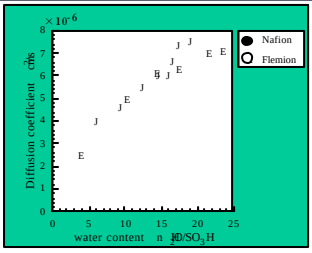
Exp. apps. (Diffusion measurement)



SPE membrane
-. Nafion117
-. Flemion

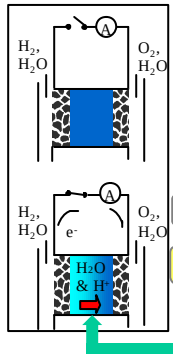


Self-diffusion coefficient of water in the SPE membrane



-. Self-diffusion coefficient decreases with decrease of water content in the membrane.
-. In the most hydrated condition, self-diffusion coefficient is as 1/3 as that of pure water.
-. Similar behaviors in both Nafion117(1100EW) and Flemion(1000EW)

Experimental condition for measurement of H_2O



Circuit: Open

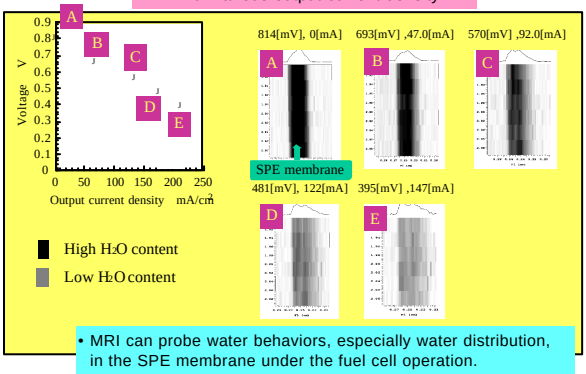
Suddenly closed

H_2O & H^+ & e^- starts to move

How does the H_2O in SPE membrane changes?

SPE membrane:	Aciplex 340 μm
Spatial resolution:	25 μm × 780 μm
Slice thickness:	10 mm
Averaged image:	128
Acquisition time:	40 min/image

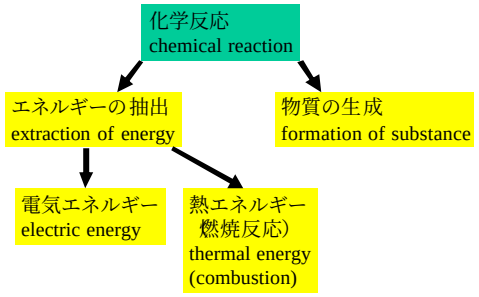
Water distribution in the SPE membrane with various output current density

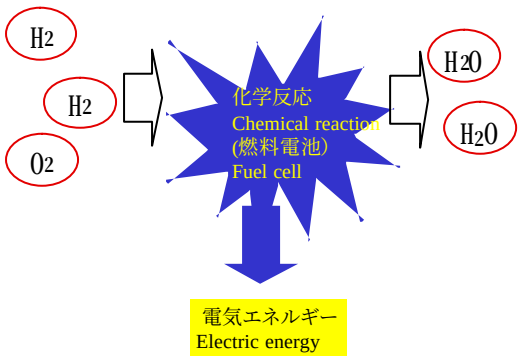


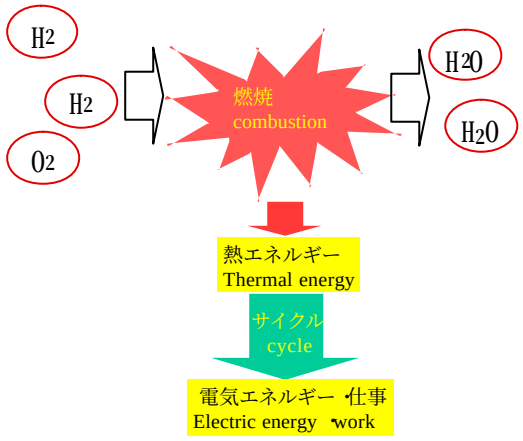
- MRI can probe water behaviors, especially water distribution, in the SPE membrane under the fuel cell operation.
- The SPE membrane gradually gets dried after the cell starts.

化学反応・燃焼と環境問題

(chemical reaction, combustion and environmental problems)







$$H_2 + \frac{1}{2}O_2 \rightarrow H_2O$$

熱エネルギー Thermal energy $D_rH = 241.8\text{kJ/mol}H_2$

反応熱(heat of reaction)

電気エネルギー Electric energy $DG = 228.6\text{kJ/mol}H_2$

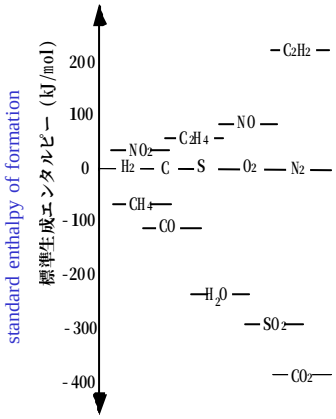
25℃, 0.1013MPa（1気圧）で安定な物質
Substance stable at 25℃, 1 atm

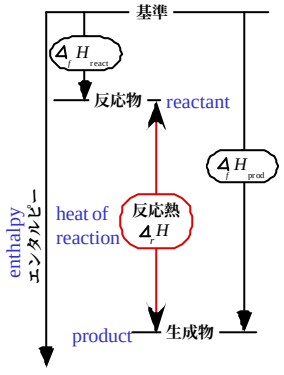
標準物質(reference substance)

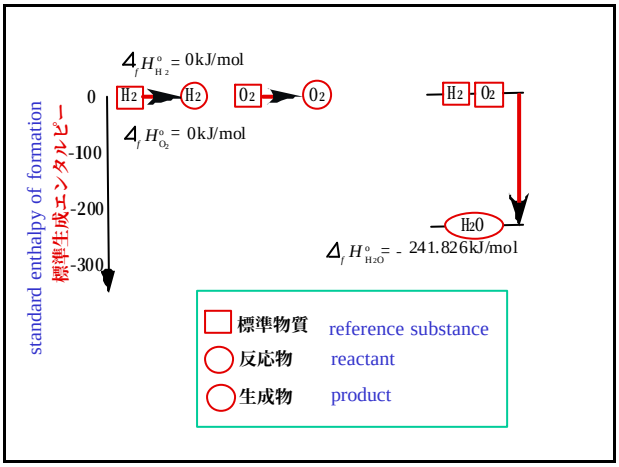
H2, O2, N2, C, S

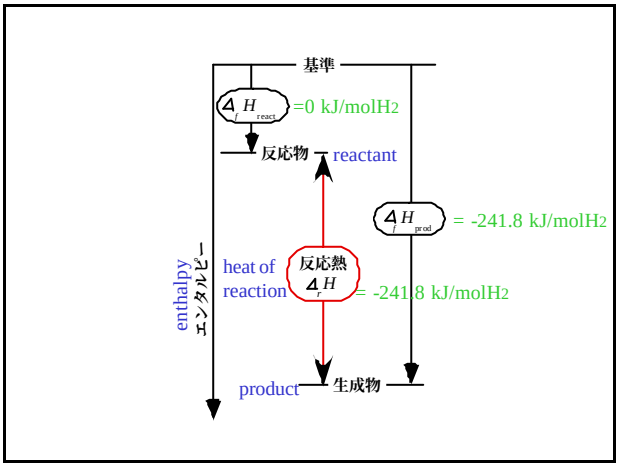
D_fH° 標準生成エンタルピー
(standard enthalpy of formation)

標準物質からある物質を生成するときのエンタルピー
Enthalpy to form a substance from reference substance









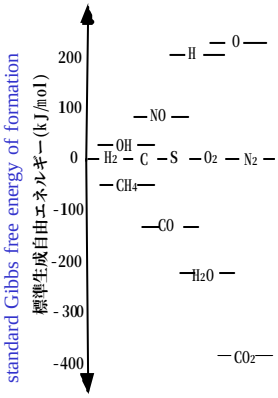
25℃, 0.1013MPa（１気圧）で安定な物質
Substance stable at 25℃, 1 atm

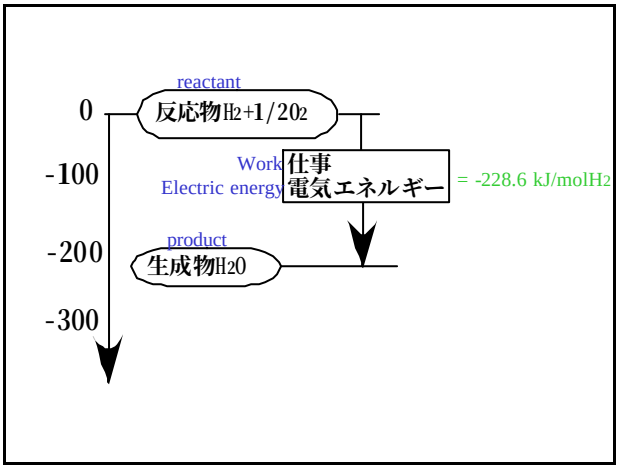
標準物質 (reference substance)

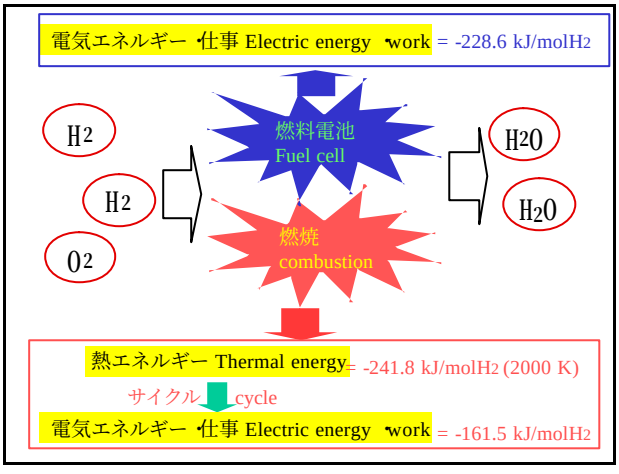
H2, O2, N2, C, S

$D_f G^\circ$ 標準生成ギブス自由エネルギー
(standard Gibbs free energy of formation)

標準物質からある物質を生成するときのギブス自由エネルギー
Gibbs free energy to form a substance from reference substance







水素からエネルギーを抽出する場合について，燃焼させるよりも燃料電池を用いる方が効率がいいことを示しているが，これは理論値を示しているだけで，実際のエネルギーの有効利用を考えるには，各種損失やエネルギーの輸送まで含めた全体のシステムとして評価することが重要となる．

Energy extraction from H_2 shows that efficiency using fuel cell is higher than combustion. It is noted that it just demonstrates a theoretical value. Efficient utilization of energy must evaluate whole system including loss, energy transportation.

Compare two CO_2 mitigation strategies; CO_2 sequestration and application of fuel cell to automobiles. How much would be the CO_2 mitigation for these two in case of Japan. Consider the case for various parameters, for example, how many automobiles are changed from internal combustion engines to fuel cell.