Water transport in PEFC cold startup with temperature rise simulating adiabatic condition

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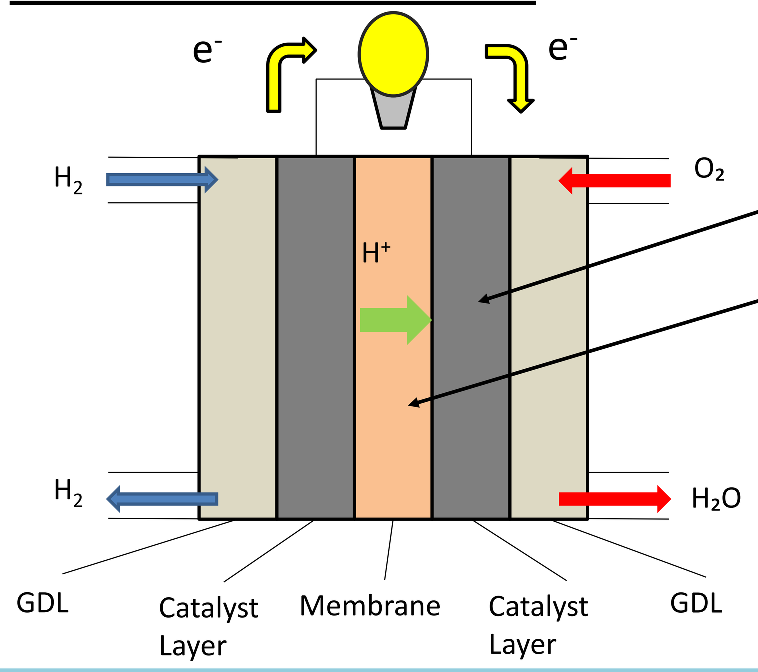
1. Introduction



Problems in the cold startup of PEFC

- Shutdown due to ice formation (CL, interface between CL and MPL)
- Dry-out at dry and very low temperature (membrane)

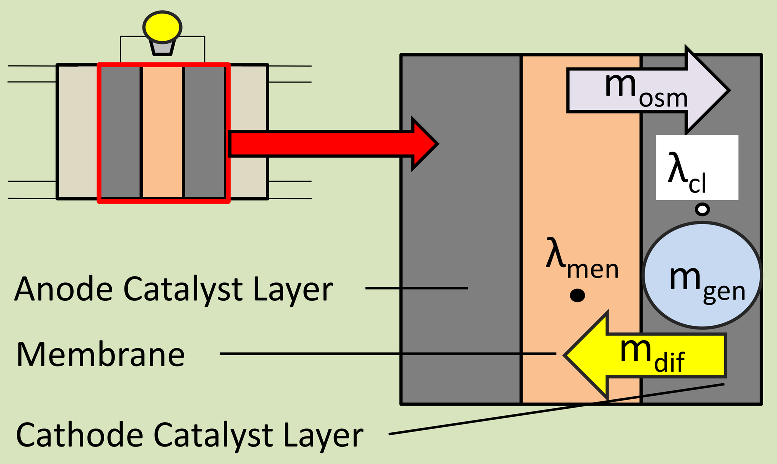
Objective
Improve cold start characteristics with temperature rise from -30˚C

Approach

Model analysis
- Estimate water content in membrane
- Determine dry-out condition at -30˚C

Experiment
- Determine dry-out condition at -30˚C
- Cold startup simulating adiabatic condition by heater

2. Model analysis procedure



Simple assumption
- One-dimensional model
- Considering water transport in membrane and cathode catalyst layer

Water generation	$m_{gen}=\frac{I_{ORR}}{2F}M_{water}$
Electro-osmosis	$m_{osm}=\beta_\lambda \frac{I_{H^+}}{F}M_{water}$
Back diffusion	$m_{dif}=\rho_{mem}\varepsilon^{1.5}D_\lambda \frac{\partial \lambda}{\partial y}M_{water}$

$$\frac{\partial \lambda_{mem}}{\partial t}=\frac{(m_{dif}-m_{osm})A}{M_{water}\,s_{mem}}$$

$$\frac{\partial \lambda_{cl}}{\partial t}=\frac{(-m_{dif}+m_{osm}+m_{gen})A}{M_{water}s_{cl}}$$

Proton conductivity of membrane[1]

$$\kappa=(-4.2263\times10^{-5}\lambda^2+1.2631\times10^{-3}\lambda-0.0023)\exp\left[\frac{E}{R}\left(\frac{1}{243}-\frac{1}{T}\right)\right]$$

$$\frac{E}{R}=-32.025\lambda^3+619.76\lambda^2-3770.2\lambda+10722$$

[1] X. Wang et al., *J. Power Sources* 195 (2010) 6680-6687.

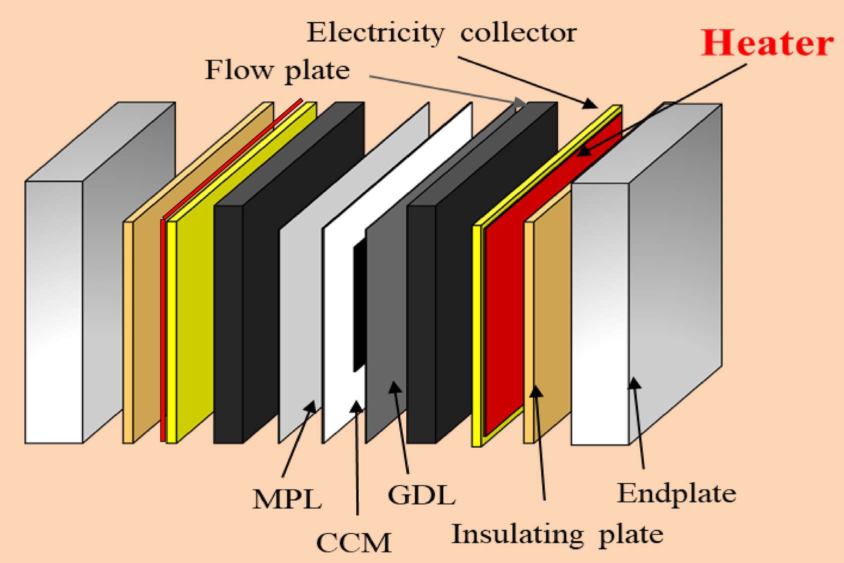
3. Experimental procedure

Aging → Wet purge → Cooling → Cold startup

5hours, 3hours, 1~2hours

- Constant current density
- Initial temperature : -30˚C

Apparatus of simulating adiabatic condition

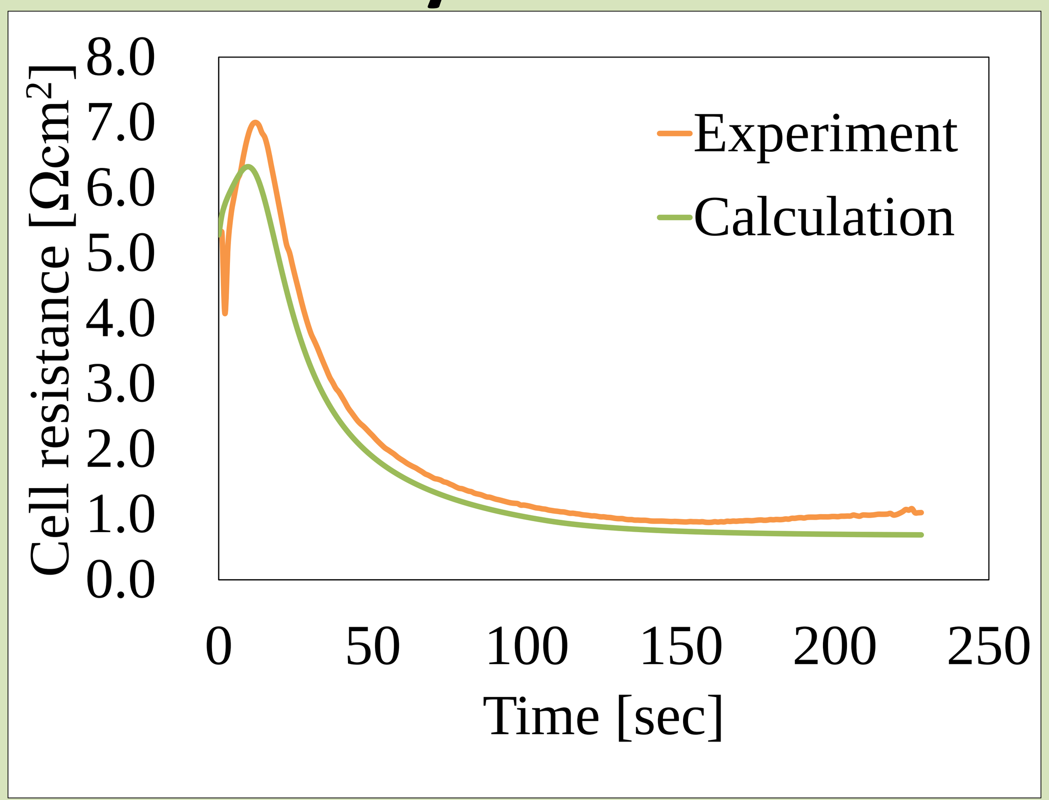


Assumption
In adiabatic condition, cell temperature rises with reaction heat.

Simulate adiabatic condition of single cell with heaters

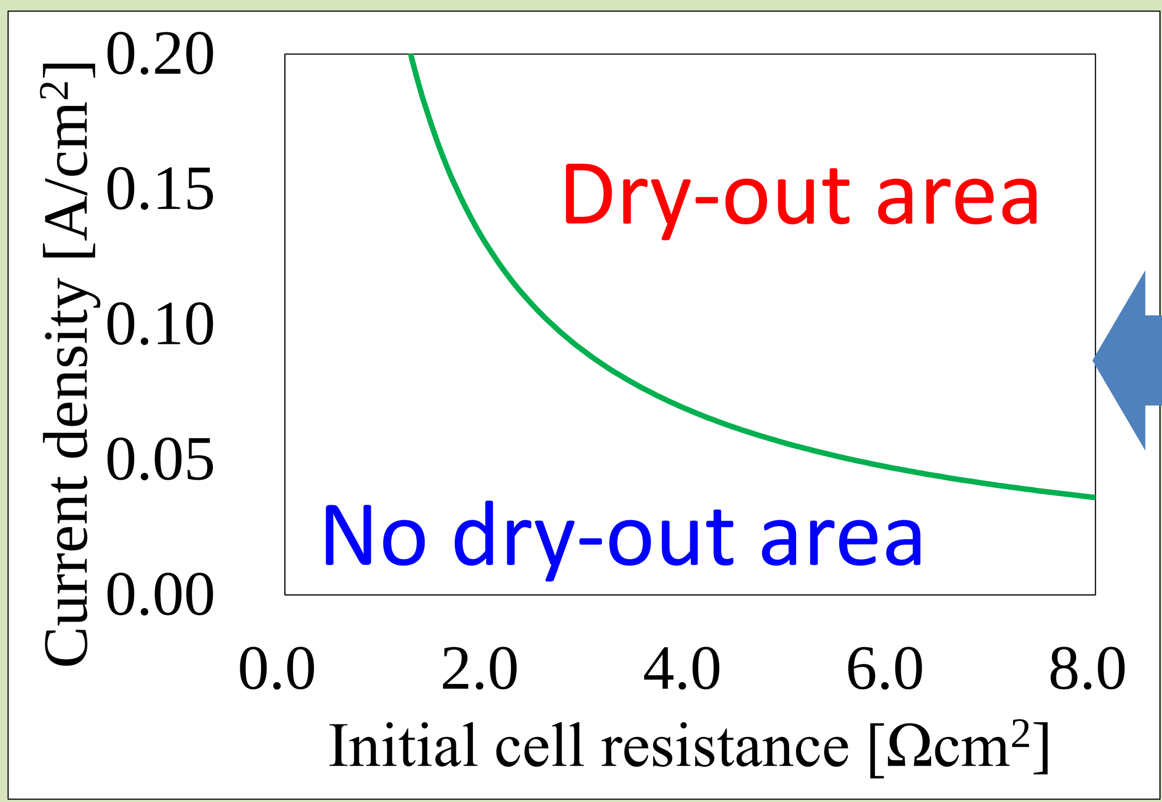
4. Results and discussion (dry-out)

Model analysis



Cell resistance transition

Parameter fitting corresponding to experimental results of cell resistance

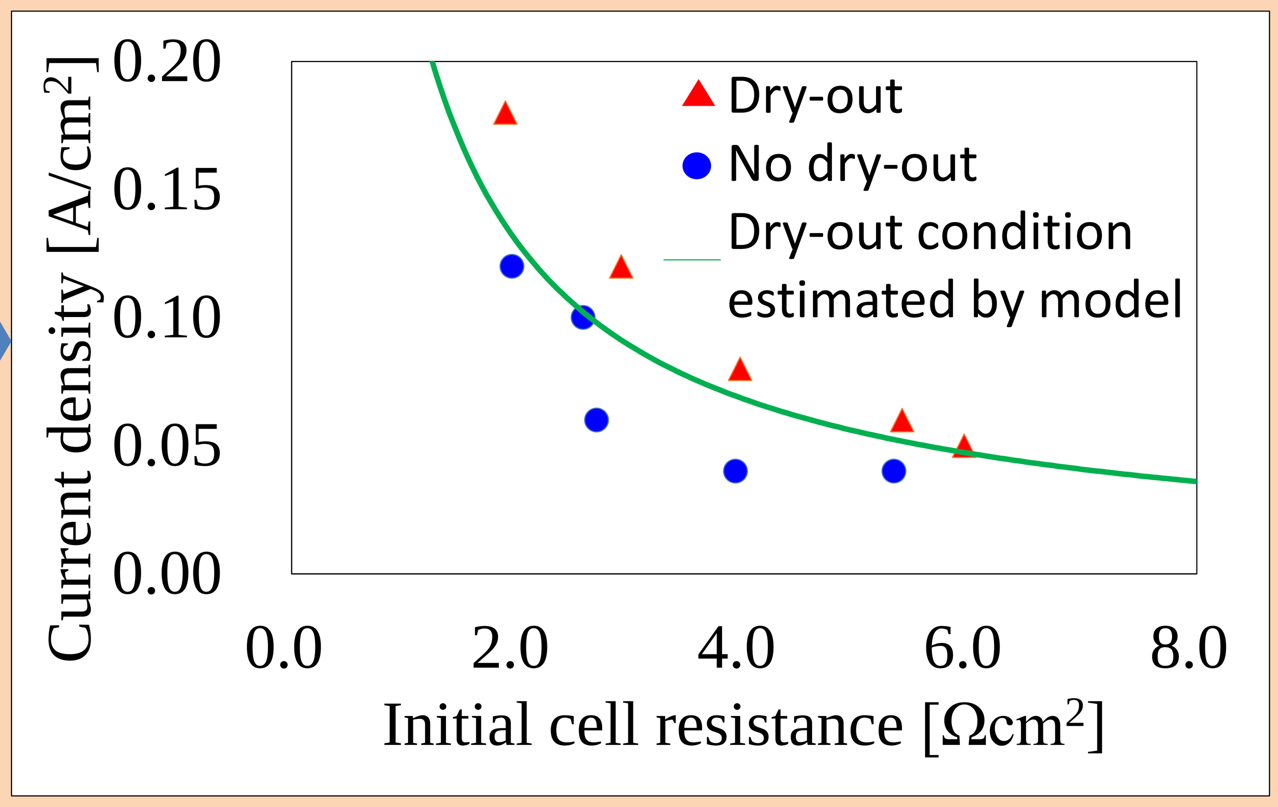


Dry-out condition

Threshold of dry-out
Resistance overvoltage 0.35V or above

Experiment

Dry-out condition fits experimental results

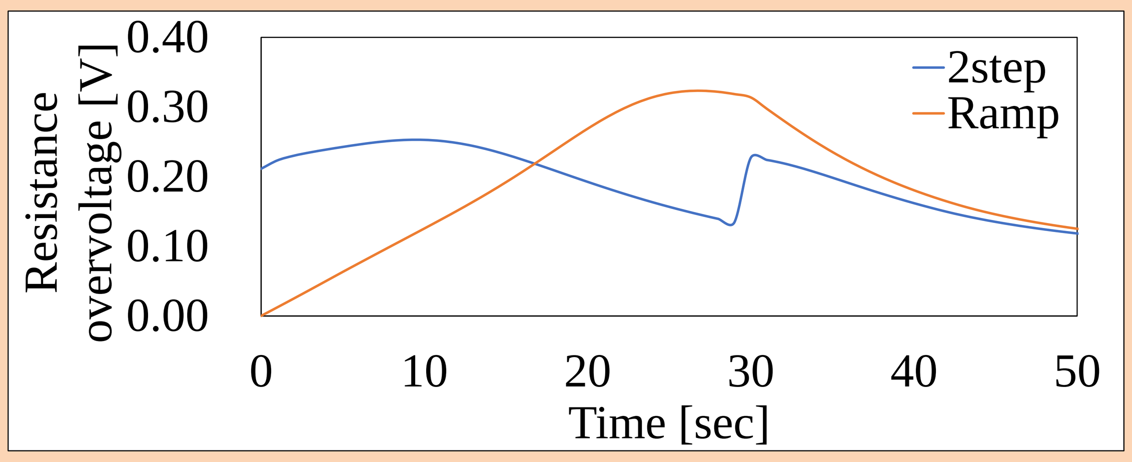


Limitation of loading current density corresponds to initial cell resistance.

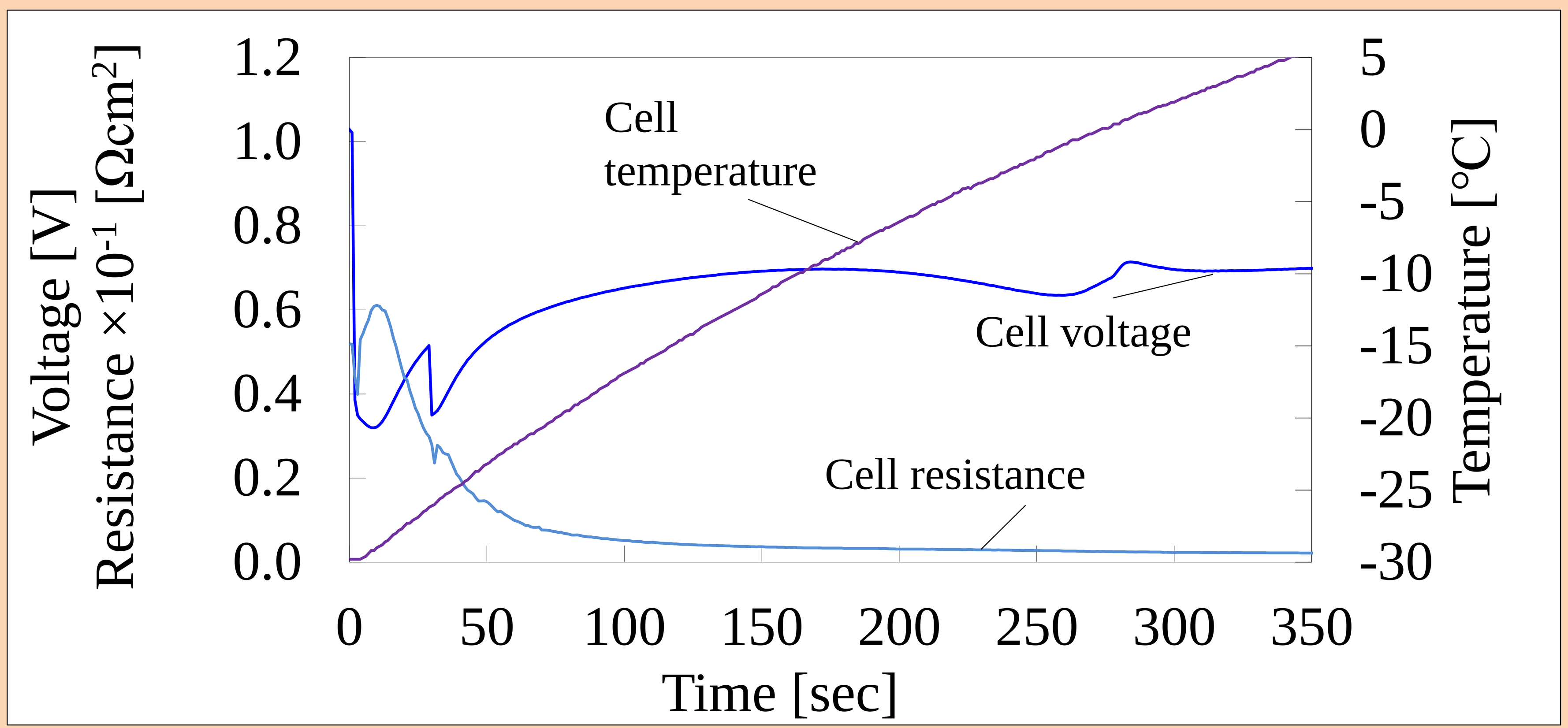
5. Experimental results and discussion (with temperature rise)

Target current density
0.07A/cm² after 30sec

2 step loading : lower resistance overvoltage



Condition	
Current density(A/cm²)	0.04→0.07 (after 30 sec)
Flow rate (sccm)	H2 : 348 Air : 829



Cold startup from -30°C without dry-out and ice formation

Conclusions
- Estimate dry-out condition at -30˚C with experiment and model analysis
- Improve cold start characteristics from -30˚C with temperature rise simulating adiabatic condition

Future work
- Effect of MPL wettability and initial temperature on dry-out condition
- Method of simulating adiabatic condition