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

Ken Hirai and Yutaka Tabe
Division of Energy and Environmental Systems, Hokkaido University, Japan

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

2. Model analysis procedure
- Simple assumption
  - One-dimensional model
  - Considering water transport in membrane and cathode catalyst layer
- Water generation
  \[ m_{\text{gen}} = \frac{1}{2} \frac{V_{\text{cell}}}{F} \]
- Electro-osmosis
  \[ m_{\text{osm}} = \frac{1}{2} \frac{V_{\text{cell}}}{F} \]
- Back diffusion
  \[ m_{\text{dif}} = \rho \frac{\lambda_{\text{me}}}{\lambda_{\text{w}}} \frac{\partial \lambda_{\text{me}}}{\partial y} \]
- Proton conductivity of membrane
  \[ \kappa = \frac{3.8263 \times 10^{-5} \lambda + 1.3631 \times 10^{-4} \lambda - 0.0023}{3.8263 - 0.7} \]
  \[ E = -32.025 \lambda + 619.76 \lambda^2 - 3770.2 \lambda + 10722 \]

3. Experimental procedure
- Aging
  - 5 hours
- Wet purge
  - 3 hours
- Cooling
  - 1~2 hours
- Cold startup
  - Constant current density
  - Initial temperature: -30°C
- Apparatus of simulating adiabatic condition
  - 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
  - Dry-out area
  - No dry-out area
  - Threshold of dry-out: Resistance overvoltage 0.35V or above

5. Experimental results and discussion (with temperature rise)
- Target current density: 0.07A/cm² after 30sec
- 2 step loading: lower resistance overvoltage

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