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NUMERICAL ANALYSIS OF MATERIAL TRANSPORTATION PROBLEMS IN FUEL CELL WITH MICRO POROUS LAYERS

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ABSTRACT

Many experiments prove the desired effects of covering Micro Porous layer (MPL) in the Polymer Electrolyte Fuel Cell (PEFC). Using the MPL, water control performance inside the cell is improved. We make this phenomenon clear by numerical analysis.

The analysis model is shown in Fig. 1. There are six main layers in the modeled domain; cathode gas diffusion layer (cGDL), cathode micro porous layer (cMPL), cathode catalyst layer (cCL), polymer electrolyte membrane (MEM), anode catalyst layer (aCL), and anode gas diffusion layer (aGDL). In this analysis, anode and cathode gas channels (aGC and cGC) are not included in the domain. Essential boundary conditions are between GC and GDL. The boundary conditions are related to temperature, humidity, and gas pressure.

This paper describes the following unknown behaviors; p_i or p_{Liq} the partial gas or liquid pressure, T_g the gas temperature, Φ_{ion} or Φ_{elec} the electrical potential of the ionically conducting phase or the electronically conducting phase. Each of them influences other behaviors. The governing equations for these unknown functions are represented in Table. 1.

Results: Fig. 2 shows numerical analysis results of the liquid water partial pressure. Essential boundary conditions of this analysis are assumed between GC and GDL by using complete dry air and hydrogen and making water by chemical reaction. Results of analsis indicate that by changing the MPL permeability not only amount of distribution but also distribution character is modified.

Table. 1 Important governing equations.

$$\nabla\cdot(\nabla p_i) = -\frac{RT_g}{D^{eff}_{k_i}}\nabla\cdot N_i + \sum_{j\neq i}\frac{RT_g}{p_G D^{eff}_{i,j}}(\nabla\cdot(p_i N_j) - \nabla\cdot(p_j N_i)),$$

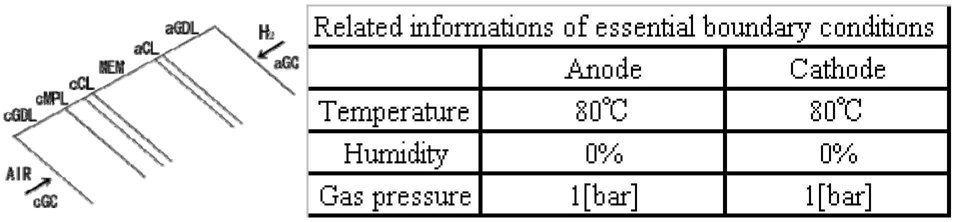
$$-\frac{k}{V_i\mu}\nabla\cdot\nabla p_{Liq} = A_k, \qquad \sigma\nabla\cdot\nabla\Phi_{elec} = B_k,$$

$$\kappa\nabla\cdot(\nabla\Phi_{ion}) + \frac{\kappa\xi}{F}V_i\nabla\cdot(\nabla p_{Liq}) = C_k,$$

$$\frac{\kappa\xi}{F}\nabla\cdot(\nabla\Phi_{ion}) + (\alpha + \frac{\kappa\xi^2}{F^2})V_i\nabla\cdot(\nabla p_{Liq}) = D_k,$$

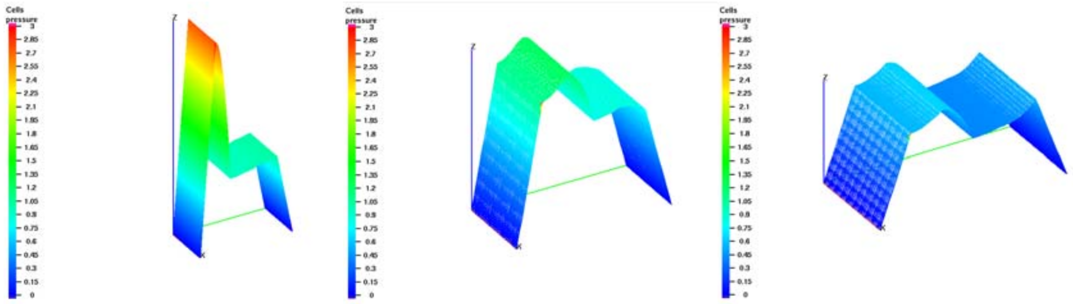
$$\nabla\cdot(\rho_g c_p\nabla p_g T_g - \lambda_g\nabla T_g) = E_k,$$

where N_i : superficial flux density of species i [mol/(cm^2・s)], R : Universal gas constant [J/(K・mol)], D^{eff}_k : Effective Knudsen diffusion coefficient of species i [cm^2/s], $D^{eff}_{i,j}$: Effective diffusion coefficient of i in j [cm^2/s], p_G : Total gas phase pressure[bar], k : Saturated permeability [cm^2], V_i : Molar volume of species i [cm^3/mol], μ : Viscosity [bar・s], σ : Conductivity of the electronically conducting domain [S/cm], κ : Conductivity of the ionically conducting domain [S/cm], ξ : Electro-osmotic coefficient [S/cm], F : Faraday's constant [C/equiv], ρ_g : Gas density [g/cm^3], c_p : specific heat at constant pressure [J/(g・K)], λ_g : thermal conductivity[W/(cm・K)], $A_k \sim E_k$: Source term including unknown functions.



Related informations of essential boundary conditions		
	Anode	Cathode
Temperature	80℃	80℃
Humidity	0%	0%
Gas pressure	1[bar]	1[bar]

Fig. 1 The 2D domain and boundary conditions between GC and GDL.



(a) (b) (c)

Fig. 2 Results of liquid water partial pressure distribution in changing MPL permeability to (a) $1.6\times10^{16}[cm^2]$, (b) $1.6\times10^{15}[cm^2]$ and (c) $1.6\times10^{14}[cm^2]$.

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