

# Three-Dimensional Thermal Distribution Research in Internal Reforming SOFC Fueled by Biogas

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## 1. Introduction

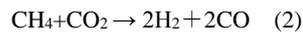
Currently, due to a problem such as global warming, exhaustion of fossil fuels and more, the efficiency of how to use energy and the expansion of renewable energy use are demanded internationally. Utilization of solid oxide fuel cell (SOFC) at high temperature is efficiency and it has attracted attention that SOFC is power generation method which can operate direct internal reforming of the various fuel species, including biomass. However, when you directly supply biogas in SOFC fuel electrode, strong endothermic reforming reaction leads to distribution of temperature gradient and carbon formation in the cell configuration as in the past. Therefore, there is a problem which causes thermal stress deterioration and decrease in the performance and durability of the catalyst. So, in terms of cooperation of experiment and theory, we have been working to solve the problem with paper-structured catalyst (PSC) technology which is easy to control functional gradient of the catalyst [1-3]. In this study, our goals are to conduct three dimensional analysis of thermal distribution in fuel electrode of a near practical SOFC with Three-Layered Stack Model and to theoretically design a catalytic arrangement equalizing the thermal distribution. To be concrete, we use Three-Layered Stack Model with hydrodynamics and chemical reaction, calculating how thermal distribution is varied for the catalytic arrangement when we introduce a methane / carbon dioxide mixture gas.

## 2. Numerical Details

In this study, we performed numerical computational fluid dynamics (CFD) using the Ansys Fluent 13.0. It was determined the gas composition changes and thermal distribution by solving the following convection diffusion equation.

$$\frac{\partial}{\partial t}(\rho Y_i) + \nabla(\rho \bar{v} Y_i) = -\nabla \bar{J}_i + R_i \quad (1)$$

where  $t$  is time,  $\rho$  is density,  $Y_i$  is mass fraction of species  $i$ ,  $\bar{v}$  is averaged velocity,  $\bar{J}_i$  is the diffusion term for  $i$  obtained by Fick's laws,  $R_{i,r}$  is the source term for species  $i$  in  $r$ th reaction. Analysis conditions were the following situations. Temperature was 1073 K, pressure was 1atm, the supply gas was  $CH_4:CO_2:N_2 = 1:1:1$  mixed gas, total inflow were 270cc/min and inflow line speed was 0.0705m/s. Reaction in the catalyst layer was consider the following two gas-phase overall reaction.



By comparison with the temperature profile and the experimental measurements in single cell model, Order and back reaction rate constant are  $k_{f,2} = 1.1 \times 10^5 \exp(231266/RT)$ 、 $k_{b,3} = 1.71 \times 10^{-2} \exp(103191/RT) \text{ m}^3/\text{kmol}^1\text{s}^1$  respectively, and heat conductivity was 2.25 W / m · K. The calculation model used is shown in Figure 1. We placed three sheets of paper catalyst shaped square 5 cm on a side and supported with Ni having a thickness of 0.15 cm in alumina jig. Between the catalyst layers, we provided a virtual gas channel layer and a space of the electrode and electrolyte respectively thickness of 0.3, 0.22 cm [3]. The catalyst layer is porous body of porosity 0.9. We considered a homogeneous catalyst model having all homogeneous catalytic function and functionally-graded catalyst model with variation of four divided catalytic function.

We simulated the function by varying the frequency factor of the methane dry reforming reaction (2).

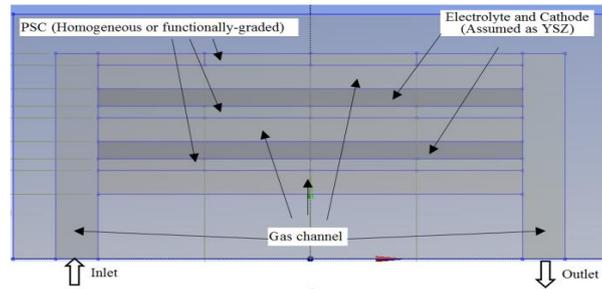


Figure 1. Schematics of Three-Layered Stack Model in this research

### 3. Results and Discussion

Temperature distribution in the homogeneous catalyst model (excluded gas channel layer) shown in Figure 2. We supplied fuel gas which is constant at 1073K in inlet gas channel. We saw that each catalyst layers were rapidly decreased temperature at near the entrance, and then were slowly increased temperature. The temperature drop was the largest in the lower catalyst layer, and it became smaller as the catalyst layer became the top of the catalyst layer. The maximum temperature drop was about 75K at the bottom layer and about 40K at the top layer in the homogeneous catalyst model, but we could suppress the maximum temperature drop to approximately 25K. But, in functionally-graded catalyst model, the maximum temperature drop was about 25K at the bottom layer and about 10K at the top layer. So maximum temperature drop amount in functionally-graded catalyst model was smaller than the maximum temperature drop amount in the homogeneous catalyst model and we suppressed the local temperature drop at near the inlet of catalyst. we considered that this reason was that the reaction at near the inlet was suppressed and was able to occur in behind flow direction, for we selected functionally-graded catalyst model in each of the catalyst. Other more numerical details will be reported in the day of the poster presentation.

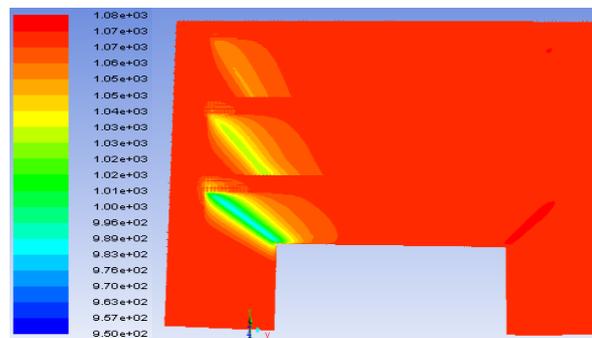


Figure 2. Temperature distribution in functionally-graded three-layered stack catalyst model

### Acknowledgements

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### References

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