ELSEVIER
CrossMark
Available online at www.sciencedirect.com
ScienceDirect
Energy Procedia 61 (2014) 2347 – 2350
Energy Procedia

The 6th International Conference on Applied Energy – ICAE2014

Numerical study on mass transfer performance of a spiral-like interconnector for planner Solid Oxide Fuel Cells

Min Yan[1], Min Zeng[1], Ting Ma[1], Pei Fu[1], Qiuwang Wang[1]*

[1]Key Laboratory of Thermo-Fluid Science and Engineering, MOE, Xi'an Jiaotong University, Xi'an 710049, Shaanxi, PR China

Abstract

In order to transfer more fuel of a planner SOFC (Solid Oxide Fuel Cell) from gas channel into porous anode, this paper has designed a novel spiral-like SOFC interconnector, a 3-D model is made by COMSOL 3.5a and the cell was operated with the mixture of H_2 and H_2O as fuel at 1023K. The result shows that, compared with conventional direct channel interconnectors, the new interconnector in this paper could not only improve the gas velocity parallel to the TPB(Triple Phase Boundary), but also with much higher gas velocity perpendicular to it, which has led to the H_2 molar fraction close to the TPB in anode is almost two orders of magnitude higher than that of director channel interconnector SOFC, which would be helpful to improve the electrical performance of SOFCs.

Peer-review under responsibility of the Organizing Committee of ICAE2014

Keywords: Solid Oxide Fuel Cell; Spiral-like interconnector; Mass transfer performance; Half-cell; 3-D model

1. Introduction

As a high efficiency and clean secondary resource system, SOFCs (Solid Oxide Fuel Cells) are attracting the world's attention. For the sake of obtaining higher electrical performance, many researchers have focused on the material, structures, manufacture and operation of SOFCs. Precious metal, metal matrix ceramic and perovskite structure are widely used in porous anode [1]. An envelope-type solid oxide fuel cell stacks was studied by H. Yoshida et al. [2] An external manifold for planner SOFCs stack was also invented by D Yan et al.[3].

* Corresponding author. Tel.: +86-029-82665539; fax: +86-029-82665539.
E-mail address: wangqw@mail.xjtu.edu.cn.

Peer-review under responsibility of the Organizing Committee of ICAE2014
doi:10.1016/j.egypro.2014.12.001

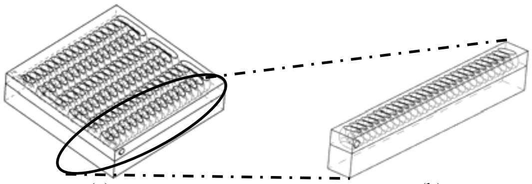


Fig. 1. (a) The illustration of the spiral-like interconnector; (b) The single-unit model used for the simulation

Although all these studies are helpful to make more fuel spreading into the porous anode, they could only disturb the fuel along the channel. QY Chen et al. have invented a bi-layer interconnector planner SOFC which could bring a slight perturbation perpendicular to anode [4], but H_2 molar concentration in gas channel is still one order of magnitude more than that in anode. How to make more fuel permeating into the porous anode is still a serious problem. This paper has developed a novel spiral-like interconnector for planner SOFCs, which could not only increase the inlet gas velocity with the same mass flux compared to conditional channel, but could also make more gas spreading perpendicular to the TPB (Triple Phase Boundary), thus provide abundant fuel for the reactions happened in anode and decrease the concentration difference.

2. Physic model of spiral-like interconnector

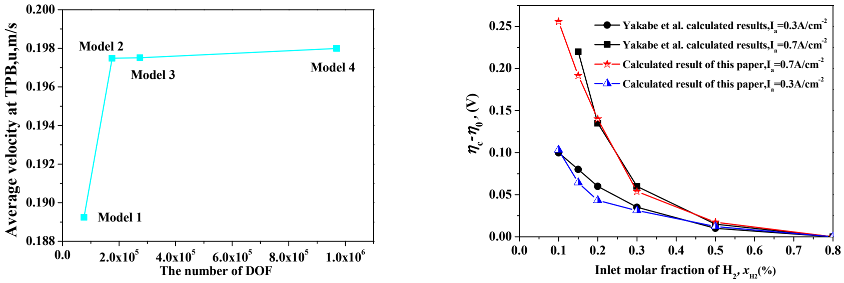
In this study, an spiral-like interconnector for planner anode-supported SOFC is developed. The structure of this novel interconnector is shown in Fig.1. (a). For mass transfer in cathode of normal anode-supported SOFCs is abundant, This paper has simplified the model followed literature [5] etc. Only fuel channel and porous anode are included in this 3-D model. Fig.1. (b) has shown the single-unit model used for the simulation. The pitch of the single-unit model is 0.65mm, the distance between the center circle and axis is 0.68mm, the radius of cross section is 0.6mm. The other size of the single-unit model is the same with literature [4].To simplify the 3-D model, this paper has made the following assumptions to study the mass transfer performance of the new structure: the inlet fuel(idea gas) velocity is 8.4m/s(the same inlet mass flux in literature [4]) and the whole system working steadily at the constant temperature of 1023K(1atm), the electrochemical reaction are happened at the interface of anode and electrolyte, there is no consideration of the influence of radiation, the working voltage of the cell is steadily and the current is distributing uniformly, the material of the cell is isotropy.

3. Mathematic model of the cell

This paper uses Dusty-Gas model to study the gas transfer performance in gas channel and porous anode. The fuel includes H_2, H_2O and Ar. There isn't has any electrochemical reactions in gas channel, so the source term of which is zero, while at the interface of porous anode and electrolyte, the source term are defined as (I_a is the given current density/$A\cdot m^{-2}$, F is the Farady constant /$C\cdot mol^{-1}$):

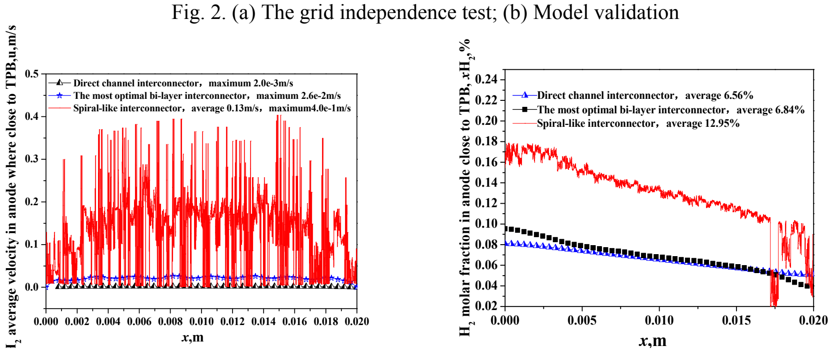
$$S_{H_2} = -I_a/(2F), \qquad S_{H_2O} = I_a/(2F) \tag{1}$$

At the inlet of the gas channel, the inlet molar fraction of H_2 is 20% and H_2O is four times of that. The mass transfer rate cause by diffusion at the outlet is zero, the other boundaries are set as symmetry. In gas channel, the steady state N-S equations are used and Brinkman equations are used in porous anode [4]. Velocity (8.4m/s) is defined as the boundary condition of the gas inlet and the outlet is set as pressure, the interface of gas channel and porous anode is continuous and the other boundaries are set as slip wall.



(a) (b)

Fig. 2. (a) The grid independence test; (b) Model validation



(a) (b)

Fig. 3. (a) H_2 average velocity in anode close to TPB; (b) H_2 molar fraction in anode close to TPB

4. The grid independence test and model validation

There are four groups of different numbers of grids are considered in Fig.2. (a). The DOF for these models are 0.76e5, 1.76e5, 2.74e5, 9.69e5, respectively. The gas velocity curve is becoming smoothly with the increase of grid. The velocity deviation among Model 2, Model 3 and Model 4 is less than 0.3%. So, this paper has chosen the grids similar to Model 2.

The calculated parameters of SOFCs with direct gas channels by Yakabe et al. [5] are used for model validation of this paper. This paper has defined that when x_{H2}=,80% and x_{H2O}=20%, the concentration overpotential is η_0, Ar here is used for adjusting the fraction of H_2. The concentration overpotential $\eta_{conc,an}$-η_0 is shown in Fig.2. (b). The maximum deviation is 12.9%, thus the model of this paper could have a better presentation for the mass transfer performance of SOFC.

5. Results and discussion

Fig.3. (a) illustrates the H2 average velocity of an inner face in porous anode along the channel where close to TPB. Compared with the direct channel interconnector (DCI) and bi-layer interconnector (BLI), the average velocity of spiral-like interconnector in the same location is one order of magnitude higher than BLI and even two orders of magnitude higher than DCI. That not only because the inlet velocity of H2 is increased (with the same mass flux in DCI and BLI), but also because of that most of the fuel is washing vertically towards the TPB, many vortexes are forming in porous anode because of high velocity, which have changed the flow state in porous anode. Fig.3. (b) shows the H2 average velocity and H2 molar fraction along the channel. For the velocity has increased in porous anode, the average H2 molar fraction of spiral-like interconnector is 12.95%, which is almost twice as much as that of DCI and BLI.

6. Conclusions

This paper has studied the mass transfer performance of a novel spiral-like interconnector for planner SOFCs, the velocity field and concentration field are calculated. The results show that for the model of this paper, the concentration overpotential is in good agreement with the previous works. The spiral-like structure could increase the velocity and concentration of gas in porous anode significantly, although the maximum pressure differential has increased almost to 1800Pa, compared that with some SOFC-DT systems, the pressure drop is acceptable. Thus this novel structure of interconnector could have a great help to increase the electrical performance of SOFCs.

Acknowledgements

This work is supported by the National Science Foundation for Distinguished Young Scholars of China (Grant No. 51025623) and the Funds for International Cooperation and Exchange of the National Natural Science Foundation of China (Grant No. 51120165002).

References

[1] Lin TN, Lee MC, Yang RJ, et al. Chemical state identification of Ce3+/Ce4+ in the $Sm_{0.2}Ce_{0.8}O_{2-\delta}$ electrolyte for an anode-supported solid oxide fuel cell after long-term operation. *Materials Letters*, 2012;**81**:185-188.

[2] H. Yoshida, H. Yakabe, K. Ogasawara, T. Sakurai. Development of envelope-type solid oxide fuel cell stacks.*J Power Sourc*, 2006;**157**(2):775-781.

[3] D Yan, Z Bin,DW Fang, J Luo, XP Wang, J Pu, et al. Feasibility study of an external manifold for planar intermediate-temperature solid oxide fuel cells stack. *International Journal of Hydrogen Energy*, 2013;**38**(1):660-666.

[4] QY Chen, M Zeng, J Zhang.Optimal design of bi-layer interconnector for SOFC based on CFD-Taguchi method. *International Journal of Hydrogen Energy*, 2010;**35**:4292-300.

[5] Yakabe H, Hishinuma M, Uratani M, et al. Evaluation and modeling of performance of anode-supported solid oxide fuel cell. *Journal of Power Sources*, 2000;**86**(1-2): 423-431.

Min Yan is a PHD student in School of Energy and Power Engineering, Xi'an Jiaotong University. She received her master's degree in safety engineering from Xi'an University of Science and Technology, P.R. China, in 2009. She main research interests are numerical and experimental study on Solid Oxide Fuel Cells (SOFC).

Qiu-Wang Wang is a professor in School of Energy and Power Engineering, Xi'an Jiaotong University. He received his Ph.D. in engineering thermophysics from Xi'an Jiaotong University in 1996. He then joined the faculty of the university and took the professor post in 2001. His main research interests include Computational Fluid Dynamics and Numerical Heat Transfer, heat transfer enhancement, transport phenomena in porous media, compact heat exchangers, building energy savings, indoor air quality, etc. He has also been authors or co-authors of 4 books and more than 100 journal papers. He has obtained 16 China Invent Patents and 2 US Patents.