International Journal of Engineering & Technology, 7 (4.35) (2018) 513-515

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

A Short Review of Material Combination in Bilayer Electrolyte of IT-SOFC.

Zuraida Awang Mat[1]*, Yap Boon Kar[2], Tan Chou Yong[3], Saiful Hasmady Abu Hassan[4]

[1,4]*Department of Mechanical Engineering, College of Engineering, Universiti Tenaga Nasional, KM 7, Jalan Uniten-Ikram, 43000 Kajang, Selangor, Malaysia*
[2]*Department of Electronic & Communication, College of Engineering, Universiti Tenaga Nasional, KM 7, Jalan Uniten-Ikram, 43000 Kajang, Selangor, Malaysia*
[3]*Department of Mechanical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur,Malaysia*
**Corresponding author E-mail: zuraida.awangmat@gmail.com*

Abstract

The technology of solid oxide fuel cell (SOFC) is attractive as it is considered as one of promising clean energy due to its efficiency and clean production of electricity. However, high operating temperature of SOFC are main issue in range of applications such as in transportation and portable equipment. One of many goals of SOFC is to lower the operating temperature. Bi-layer electrolyte has become one of the solution in order to reduce the high operating temperature. This review article provides the preliminary information of bi-layer electrolyte in order to achieve high performance at intermediate temperature.

Keywords: *SOFC, Electrolyte, Bi-layer*

1. Introduction

Fuel cells is a device that can convert chemical energy into electricity [1]. Hydrogen is used as the fuel, thus it exhaust only pure water Fuel cell, as per depicted in Fig. 1, manifest high energy conversion efficiencies and consequently is seen as one of future green energy sources. This technologies of fuel cell can be applied in almost every application such as transportation, portable power sources, and also in power plant [2].

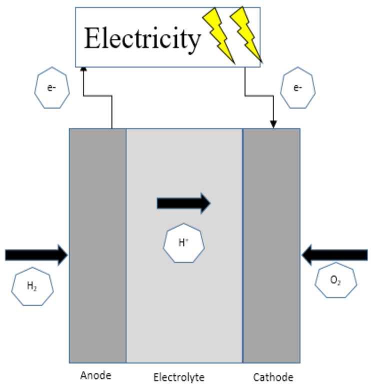

Fig. 1: Basic Operation Scheme of a fuel cell [3].

There are few types of fuel cells: Solid oxide fuel cell (SOFC), alkaline fuel cells (AFC), proton exchange membrane fuel cells (PEMFC), and molten carbonate fuel cells (MCFC). These types of fuel cell are determined by its electrolyte materials, its operating temperature and the type of fuel desired [3].

2. Operating Temperature of SOFC

Recently, the type of fuel cell that received tremendous research interests is SOFCs. SOFC have an upgrade fuel flexibility which is their high operating temperature which is at 1000 ^{o}C. The high operating temperature will accelerates the electrode reaction rates. However, such high operating temperature also inflict a large number of challenges, such as material thermal stress, mechanical stress and slow start-up time [4].
Lowering the operating temperature of SOFC potentially can reduce the SOFC operating and fabrication cost. This is because it will allow the manufacturer to use in-expensive materials for SOFC component. Besides, it would as well resulting in improved and enhanced mechanical and chemical stability. Consequently, the study of the high performance IT-SOFC is significant in order to increase their marketability.
Research studies shows that, there are several ways to lower the operating temperature of SOFC. One of the suggested strategy is involved and focused on electrolyte as the electrolyte is the main contributor of resistance [5]. These include by using high conductivity of electrolyte materials and also, reducing the thickness of electrolyte used [4 - 5].

2.1. High Conductivity Electrolyte Materials

In SOFC, the common electrolyte materials used are Yttria-Stabilized Zirconia (YSZ), Scandia-Stabilized Zirconia (ScSZ), Samarium-Doped Ceria (SDC) and Gadolinium-Doped Ceria (GDC).
Fig. 2 shows the comparison of conductivity of various electrolyte materials. The common electrolyte material used is YSZ due to its availability and cheaper price in market. However, YSZ has good

ionic conductivity only at high temperature. The ionic conductivity will decreased once the operating temperature dropped to 800 °C, hence it is not a good choice to use at IT-SOFC [6 - 7].

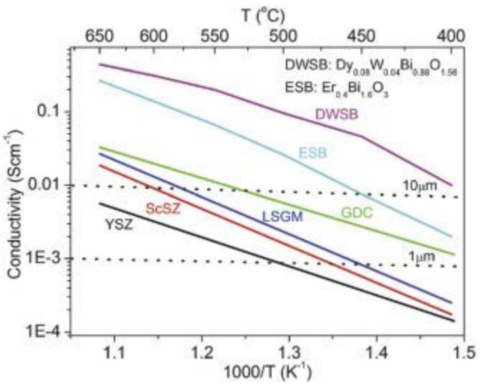

Fig. 2: Comparison of electrolyte materials conductivity [6]

ScSZ, SDC and GDC have higher ionic conductivity than YSZ. These materials also can operate at lower operating temperature and have good mechanical performance. However, for ScSZ especially, this material does not exhibit good phase and chemical stability compare to YSZ [8].

2.2. Reducing Thickness of Electrolyte

Reducing the thickness of electrolyte can lower the operating temperature. This is due to the fact that, the resistance value is minimized when the electrolyte to become thin [8].
However, it is crucial to make sure that the thin electrolyte produced is dense, crack free and in uniform layer in order to prevent any gas permeability. One of the latest technology that can be used to produce thin electrolyte is thin film deposition technique [4 - 5].

3. The Effect of Bilayer Electrolyte in SOFC

Since the electrolyte determine the operating temperature of SOFC, the efforts to develop electrolyte that can be used in IT-SOFC have intensified. There is a potential for using a bi-layer electrolyte to provide high ionic conductivity without sacrifice of its performance.
The electrolyte is supposedly to drive the oxide-ions from the cathode to the anode during operating. The materials used as electrolyte must exhibits high oxide ion/ proton conductivity, which implies low ohmic loss [9].
In contrary, electrolyte material also have to exhibits low electronic conductivity which causes low voltage loss. The electrolyte should show chemical stability in terms of air thermal and fuel stability. It is also need to be stable under the oxygen potential gradient. It should also display good mechanical strength, cost of raw and processing [10].
To decrease the ohmic resistance and to improve performance of the electrolyte, the researcher have developed the thin electrolyte, bi-layer or tri-layer electrolyte with various process method based on anode-supported cell platform. With such tackle, SOFC based on Yttria-Stabilised Zirconia (YSZ), can perform a reasonably high performance (>1 W cm-2) at 650 °C [11].
Many researchers are decided to fabricate bi-layered electrolyte SOFC for intermediate temperature operation. Base electrolyte material should be high ionic conductive and occupies most electrolyte thickness. Also, functional electrolyte material should supplement the demerits of main material and be thin.
The high conductive electrolyte material and functional layer structure has been selected for lowering operating temperature and preventing chemical stability[12].

3.1. YSZ Combine with ScSZ

Zirconia-based electrolyte are commonly choose as electrolyte as it has good chemical and mechanical stability. YSZ especially preferred as the natural choice for HT-SOFC and ScSZ is preferred candidate for IT-SOFC due to its superior ionic conductivity. However, ScSZ [13] exhibit poor cubic phase stability, grain boundary resistance, poor electrical properties and a bit expensive compare to YSZ.
In this case, ScSZ is considered as an alternative to YSZ ceramics. Hence, the combination of YSZ and ScSZ bilayer as an electrolyte material can maintain high ionic conductivity and improve stability.
This combination of both zirconia-based material might be a promising approach to the strength and fracture toughness of layered electrolyte. It was reported that, thermal residual stresses and tensile stress has been studied in approaching the bi-layered design and structure [14].
On the other hand, the bi-layered of YSZ/ ScSZ electrolyte can be manufactured via tape-casting, Atomic Layer Deposition (ALD) and cold-pressed method then need to sinter at a certain temperature for a certain duration [13– 15].

3.2. YSZ Combine with SDC and GDC

Doped-ceria [16] is a promising choice for an electrolyte material in order to improve cell performance at low temperature. Doped-ceria electrolyte such as SDC and GDC has high ionic conductivity twice compared to YSZ. However, doped-ceria material have disadvantages of poor chemical and mechanical stability, and in anodic conditions, it becomes mixes conductor. This condition can cause cell voltages loses and effect fuel efficiency.
Hence, SDC and GDC has been studied to be combined together with zirconia-based electrolyte material in bilayer electrolyte. This YSZ/SDC and YSZ/GDC bi-layered electrolyte show a very high performance at IT-SOFC. The outcome of this zirconia-based material and doped-ceria bi-layering is the better performance and also, the current leakage through cerium oxide based electrolyte layer can be minimized [17].

3.3. Fabrication Method

Fabrication method for producing bilayer electrolyte are shown is Table 1.

Table 1: Summary of the fabrication of the bilayer electrolyte [18 - 19]

Bi-layer combination	Fabrication Method	Comments
YSZ/ScSZ	Cold-Pressed Method and Tape Casting	Further study on the correct sintering temperature to avoid interfusion between YSZ/ScSZ
YSZ/SDC	Pulsed-Laser Deposition , Spray Depostion and Dip-Coating	Porosity of interlayer reduces thereby reduce ohmic resistance, hence better ionic conductivity.
YSZ/GDC	Screen Printing and Physical Vapor Deposition (PVD)	PVD techniques is better than screen printing.

4. Conclusion

The aim of this review paper is to review IT-SOFC development by focusing on the bi-layered electrolyte materials. The present review is limited to conventional HT-SOFC with structural and cost. Hence, in this case, the newly developed with high conductivity bi-layered electrolyte design will provide a path for further performance improvement at IT-SOFC. However, the research carried out so far already proves that the concept of bi-layered electrolyte is realizable and can be operate at Intermediate Temperature. More work will be carried out on bi-layered electrolyte in IT-SOFC to analyse the complex mechanical and electrochemical behaviour of the bi-layer electrolyte combination.

Acknowledgement

This work is fully funded by research grant no. U-TV-RD-18-21.

References

[1] A. S. Mehranjani, D. J. Cumming, D. C. Sinclair, and R. H. Rothman, "Effect of the Deposition Time on LSCF – SDC Carbonate Thin Film Formation by the Electrophoretic Deposition Method," *J. Eur. Ceram. Soc.*, vol. 37, no. 13, pp. 3981–3993, 2017.
[2] N. E. L. Och, *Technology review – solid oxide fuel cell*. 2015.
[3] I. Yahyaoui, J. F. Fardin, and F. Tadeo, "technologies," no. Irec, 2018.
[4] L. Code, "Study of Anode Supported GDC / YSZ Bi-layered Electrolyte Solid Oxide Fuel Cell via Cold Press Process."
[5] L. Code, "Fabrication and Characterization Yttria Stabilized Zirconia on Ceria Electrolytes."
[6] B. Singh, S. Ghosh, S. Aich, and B. Roy, "Low temperature solid oxide electrolytes (LT-SOE): A review," *J. Power Sources*, vol. 339, pp. 103–135, 2017.
[7] N. Laosiripojana, W. Wiyaratn, W. Kiatkittipong, A. Arpornwichanop, A. Soottitantawat, and S. Assabumrungrat, "Reviews on solid oxide fuel cell technology," *Eng. J.*, vol. 13, no. 1, pp. 65–83, 2009.
[8] B. Shri Prakash, R. Pavitra, S. Senthil Kumar, and S. T. Aruna, "Electrolyte bi-layering strategy to improve the performance of an intermediate temperature solid oxide fuel cell: A review," *J. Power Sources*, vol. 381, no. February, pp. 136–155, 2018.
[9] Y. Jee, G. Cho, J. An, H. Kim, J. Son, and J. Lee, "High performance Bi-layered electrolytes via atomic layer deposition for solid oxide fuel cells," *J. Power*, 2014.
[10] S. G. Kim, S. P. Yoon, S. W. Nam, S. H. Hyun, and S. A. Hong, "Fabrication and characterization of a YSZ/YDC composite electrolyte by a sol-gel coating method," *J. Power Sources*, vol. 110, no. 1, pp. 222–228, 2002.
[11] B. Shri Prakash, S. Senthil Kumar, and S. T. Aruna, "Properties and development of Ni/YSZ as an anode material in solid oxide fuel cell: A review," *Renew. Sustain. Energy Rev.*, vol. 36, pp. 149–179, Aug. 2014.
[12] J. Patakangas, Y. Ma, Y. Jing, and P. Lund, "Review and analysis of characterization methods and ionic conductivities for low-temperature solid oxide fuel cells (LT-SOFC)," *J. Power Sources*, vol. 263, pp. 315–331, Oct. 2014.
[13] Q. XUE, X. HUANG, H. ZHANG, H. XU, J. ZHANG, and L. WANG, "Synthesis and characterization of high ionic conductivity ScSZ core/shell nanocomposites," *J. Rare Earths*, vol. 35, no. 6, pp. 567–573, 2017.
[14] V. V. Lakshmi, R. Bauri, A. S. Gandhi, and S. Paul, "Synthesis and characterization of nanocrystalline ScSZ electrolyte for SOFCs," *Int. J. Hydrogen Energy*, vol. 36, no. 22, pp. 14936–14942, 2011.
[15] Y. Chen *et al.*, "Layered YSZ/SCSZ/YSZ electrolytes for intermediate temperature SOFC Part I: Design and manufacturing," *Fuel Cells*, vol. 12, no. 5, pp. 722–731, 2012.
[16] Y. Cui, C. Jigui, H. Haigen, and G. Jianfeng, "Ni / SDC Materials for Solid Oxide Fuel Cell Anode Applications by the Glycine-Nitrate Method," vol. 435, no. 3, pp. 731–734, 2010.
[17] X. Zhang, M. Robertson, and C. Decès-petit, ") and bi-layered electrolyte of the SDC layer with proton conducting ceramic material BCY (BaCe 0.9 Y 0.1 O," vol. 78, no. 1, pp. 429–439, 2017.
[18] R. J. Yang *et al.*, "Fabrication and characterization of a Sm 0.2Ce 0.8O 1.9 electrolyte film by the spin-coating method for a low-temperature anode-supported solid oxide fuel cells," *J. Power Sources*, vol. 206, pp. 111–118, May 2012.
[19] N. A. Baharuddin, A. Muchtar, A. B. Sulong, and H. Abdullah, "Effect of the Deposition Time on LSCF – SDC Carbonate Thin Film Formation by the Electrophoretic Deposition Method," vol. 618, no. June 2012, pp. 1813–1818, 2013.