Journal of Power Sources 245 (2014) 119-128

Contents lists available at SciVerse ScienceDirect

### Journal of Power Sources

journal homepage: www.elsevier.com/locate/jpowsour

# Effect and mechanism of Cr deposition in cathode current collecting layer on cell performance inside stack for planar solid oxide fuel cells



Wanbing Guan, Le Jin, Wei Wu, Yifeng Zheng, Guoliang Wang, Wei Guo Wang\*

Ningbo Institute of Material Technology & Engineering, Chinese Academy of Sciences, 519 Zhuangshi Road, Ningbo 315201, China

#### HIGHLIGHTS

- MOPD of the unit cell decreases or is independent of Cr in CCCL.
- Degradation of the unit cell increases or is independent of Cr in CCCL.
- Degradation of the repeating unit increases with increasing Cr content in CCCL.
- Cr affects the cell degradation, and has no influence on contact resistance.
- Cell degradation is mainly dependent on the ohmic resistance.

#### ARTICLE INFO

Article history: Received 11 April 2013 Received in revised form 1 June 2013 Accepted 18 June 2013 Available online 27 June 2013

Keywords: Chromium poisoning Power density Degradation rate Stack Solid oxide fuel cell

#### ABSTRACT

Quantitative effect and mechanism of Cr on cell performance inside stack are investigated by incorporating Cr in the cathode current-collecting layer (CCCL). The results show that the maximum output power density (MOPD) of the unit cell inside a stack decreases as the Cr content increases beyond 253.81  $\mu$ g cm<sup>-2</sup>. The MOPD is independent of Cr when its content is less than 253.81  $\mu$ g cm<sup>-2</sup> at the original operation stage. The degradation of the repeating unit inside the stack increases with increasing Cr content. When the Cr content is higher than 182.22  $\mu$ g cm<sup>-2</sup>, cell degradation increases. However, cell degradation is independent of Cr content is less than 182.22  $\mu$ g cm<sup>-2</sup>. The addition of Cr to the CCCL increases the ohmic resistance of the CCCL and the contact between the cathode and the electrode during the initial stage. The effect of Cr on cell degradation increases with time, but Cr content has no influence on the contact resistance, and is independent of polarization resistance.

© 2013 Elsevier B.V. All rights reserved.

#### 1. Introduction

Solid oxide fuel cells (SOFCs) have become a potential low-cost power generation technology due to their unique advantages, such as high-efficiency, having a non-noble metal catalyst in the electrode material, and being internal reforming fuel cells [1]. For commercialization of SOFC systems, they should reach 40,000 h operation time [2]. Ni–YSZ [3] and LSM–YSZ [4] are widely used as anode and cathode raw materials, respectively, for anode-supported SOFCs. For these traditional electrode materials, cathode poisoning by Cr, introduced during evaporation from metal alloys, is a main cause of cell performance [5]. Hence, the surface of Fe–Cr alloy as a metal interconnect, one of the most important

\* Corresponding author. Tel.: +86 574 8791 1363.

E-mail address: wgwang@nimte.ac.cn (W.G. Wang).

components in the SOFC stack, must be coated to prevent Cr evaporation leading to the poisoning of the cell cathode [6,7]. Applying a coating on the interconnect can protect the metal alloy from high-temperature oxidation and prevent Cr evaporation. Currently, a large number of high-temperature alloys containing Cr are used in the SOFC system hot box, including the heat exchanger, carburetor, burner, and gas tube [8]. At the high temperatures in the hot box, Cr in the SOFC system inevitably evaporates and is deposited on in the cathode as a result of high-speed gas flow, causing cell performance degradation.

To address this challenge, researchers have been diligently investigating the mechanism of Cr poisoning and how it affects cell performance, and have made significant progress [9–15]. The researchers realize the necessity for quantitative determination of the content and the distribution of Cr in the cathode, and develop methods for its measurement [16–18]. However, measuring the content and the distribution of Cr in the cathode side is difficult due



<sup>0378-7753/\$ -</sup> see front matter © 2013 Elsevier B.V. All rights reserved. http://dx.doi.org/10.1016/j.jpowsour.2013.06.112

to the complex operational environment of the SOFC, which is characterized by high temperature and high-speed flowing gas, among other factors. Some researchers have found that the evaporation rate of Cr is not equal to its deposition rate in the cell cathode and that the Cr distribution in the cathode is not uniform [19.20]. As a result, of these uncertainties regarding the presence and behavior of Cr in the cathode, it is difficult to verify the operating mechanism and the correlation between cell performance and the amount of Cr. Nevertheless, a few results have been obtained regarding the prediction of the influence of Cr on cell performance [6,19,21]. However, no clear relationship between Cr content and the cell performance inside an SOFC stack has been established, because many complex factors affect cell performance [20,22,23]. In 2012, Horita et al. [24] obtained the first correlation between cell performance and Cr content in the cathode by adding Cr into an LSM cathode. However, that research focused on the oxidized Cr/Pt-mesh/cathode/GDC/Pt-paste-Pt-mesh, which is considerably different from an actual SOFC stack and with the operating conditions.

The quantitative effect of Cr on cell performance during the actual stack operation is not found until now. However, the mechanism of Cr affects cell performance by poisoning the cathode has been widely reported [25-31]. The mechanism can be summarized as follows: Cr poisons the cell cathode in the triple-phase boundary, resulting in an increase in the polarization resistance of the cathode. An electrochemical reaction model, a chemical reaction model, and a physical model of Cr poisoning have each been established and demonstrated [32]. Recently, it was found that Cr deposition in a porous cathode causes serious deterioration in cell performance under open-circuit voltage (OCV) conditions for SOFCs, seemingly verifying the mechanisms of the chemical reaction model and the physical model of Cr poisoning of the cathode [33]. However, Cr poisoning mechanisms of the three models in the cathode side mentioned above may exist simultaneously, and affect cell performance during actual stack operation due to the complex operating environment. Therefore, the mechanism of Cr affecting cell performance by poisoning the cathode must be further studied and verified to reach a greater level of understanding.

Overall, the quantitative correlation between the amount of Cr and cell performance has not been determined for actual SOFC stack operation due to the difficulty in determining Cr content and its distribution in the cathode. The mechanism of Cr affects cell performance is yet to be verified and confirmed. In this study, the quantitative effect of Cr on cell performance is measured and the mechanism by which Cr affects cell performance is examined by investigating cell performance through incorporation of Cr into the cathode current-collecting layer (CCCL) during actual stack operation.

#### 2. Experimental

In this study, anode-supported Ni–YSZ/YSZ/LSM–YSZ and commercial ferritic stainless steel SUS 430 were used as the unit cell and metal interconnect, respectively. The size of a cell inside the stack is 10 cm  $\times$  10 cm with an active area of 63 cm<sup>2</sup>. Other parameters are indicated in our previously published report [34]. The structure of the gas channel on the anode side of the metal interconnect was formed along the regular line groove by the erosion etching method. A metal mesh was welded on the interconnect as the oxidized gas channel and cathode current collector. The Ni–Cr/LSM composite coating was applied using plasma spraying technology onto the cathode surface of the metal interconnect to protect it from deposition of vaporized Cr and to prevent the reduction in stack performance during operation under high temperature. The coating process and the microstructure of the Ni–

Cr/LSM composite coating are also described in our previous work [23]. A description of the performance of the Al<sub>2</sub>O<sub>3</sub>–SiO<sub>2</sub>–CaO-based glass sealing component can be found in our previous literature [35].

The anode current-collecting layer, a 130  $\mu$ m-150  $\mu$ m thick coating of NiO was applied to the cell anode by screen printing. A 100 um thick layer of porous nickel was pasted on the anode side of the metal interconnect during the assembly of the stack to enhance the anode current collection. An approximately 250 µm thick layer with the composition of (La<sub>0.75</sub>Sr<sub>0.25</sub>)<sub>0.95</sub>MnO<sub>3</sub> (LSM) was printed on the cell as the CCCL. In this study, in order to measure the quantitative effects of Cr on cell performance by poisoning the cathode, various amounts of Cr were introduced into the LSM current-collecting slurry. Specifically, the cathode currentcollecting slurry (CCCS) was mixed with Cr and LSM powders as raw materials. The nominal contents of Cr in the CCCS were 0, 0.1, 0.3, 0.5, 1.0, 1.5, and 3 wt. %. The actual content of Cr in the CCCS, determined by using an ICP-AES (Perkin-Elmer Optima 2100 model) apparatus, was 0, 0.13, 0.28, 0.41, 0.96, 1.21, and 2.61 wt. %. The overall quality of the CCCS for each cell was 3.9, 4.0, 4.1, 3.9, 4.1, 3.9, and 4.0 g, with a corresponding Cr quality of 0, 0.0052, 0.01148, 0.01599, 0.03936, 0.04719, and 0.1044 g. That is, the corresponding quality of Cr in the effective area was 0, 82.54, 182.22, 253.81, 629.05, 749.05, and 1657.14  $\mu$ g cm<sup>-2</sup>, respectively.

To investigate the quantitative effect of Cr on cell performance, a seven-cell stack (called stack 1) was assembled according to the structure shown in Fig. 1 [36]. The units cells were labeled with numbers 1–7 in increasing order of Cr content: Cell 1 had the lowest Cr content and Cell 7 the highest. A voltage lead was placed on the surface of the current-collecting layer on each of the two sides of the unit cells during the stack assembling process, as shown in Fig. 2. The cell voltage can be detected in real time to obtain the power density variation and degradation of the stack performance, as well as of each repeating unit and unit cell, through the voltage leads. In Fig. 2, the voltage between leads 1 and 2, 3 and 4, 5 and 6, 7 and 8, 9 and 10, 11 and 12, and 13 and 14 denotes the voltage of each of the unit cells, and the voltage between leads 1 and 3, 3 and 5, 5 and 7, 7 and 9, 9 and 11, 11 and 13, and 13 and 15 denotes the voltage of each of the repeating units (each repeating unit contains one interconnect and one unit cell).

After assembly, the stack was placed into a furnace, and heated at a rate of about 1  $^{\circ}$ C min<sup>-1</sup> to 850  $^{\circ}$ C. In order to ensure proper sealing effect, a pressure of approximately 10 N cm<sup>-2</sup> of the



Fig. 1. Schematic diagram of stack assembling structure.

Download English Version:

## https://daneshyari.com/en/article/7738605

Download Persian Version:

https://daneshyari.com/article/7738605

Daneshyari.com