Scandia Stabilized Zirconia (ScSZ) SOFCs for The Direct Oxidation of Hydrocarbon Fuels

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Introduction

The development of solid oxide fuel cells (SOFCs) operating at intermediate temperatures (< 700°C) can reduce stack cost and improve cell stability [1, 2]. Most of state-of-art SOFCs use yttria-stabilized zirconia (YSZ) as the electrolyte, but its resistance at temperatures below 700°C can limit cell performance. Therefore, alternative electrolytes are receiving increased attention. [1, 3-7]. One promising candidate is scandia-stabilized zirconia (ScSZ) that has higher ionic conductivity [5-10]. ScSZ electrolyte cells have been used with hydrogen fuel at 700°C – 1000°C [8]. In this study, Cu-CeO_2-ScSZ anode-supported cells with a thin-film ScSZ electrolyte (~ 60 microns) have been fabricated. The cell performance of these cells with hydrogen and hydrocarbon fuels such as butane and methane are reported.

Experimental

The scandia-stabilized zirconia (9mol%Sc_2O_3; 9ScSZ) powder is prepared using a co-precipitation technique. The phase structure of the 9ScSZ powder is examined using X-ray diffractrometer (Rigaku). The electrical conductivity of a dense 9ScSZ pellet in air has been determined in the 300°C to 900°C temperature range using a HP 4192 Impedance Analyzer with a 2-probe configuration.

A tape-casting technique is used to fabricate a 9ScSZ layer onto which another layer of 9ScSZ mixed with pore formers is cast. After heating at 1500°C for 4 hrs, the 9ScSZ layer becomes a dense electrolyte that is supported by a porous-9ScSZ structure. The LSM ($La_{0.8}Sr_{0.2}MnO_3$)-YSZ (50:50 wt%) composite cathode is then attached to the dense 9ScSZ layer. Copper and cerium oxide are then impregnated into the porous 9ScSZ layer to form a $Cu_{20\%}$-$CeO_{2(10\%)}$-9ScSZ anode.

Dry hydrogen (H_2), butane (C_4H_{10}) and methane (CH_4) are introduced into the porous anode layer. The cell performances at 650°C to 750°C are characterized using a Solartron 1287 electrochemical interface with a Solartron 1250 frequency response analyzer. These are controlled using a Dell computer equipped with Corrware and Zplot softwares. After the electrochemical cell measurements, the cell microstructures are observed using a JEOL6300 scanning electron microscopy (SEM).

Results

The XRD pattern of the prepared 9ScSZ powder shown in Fig. 1 confirms the formation of single-phase cubic 9ScSZ powder. The calculated average crystalline size of the particles is ~7.1 nm.

Fig. 2 shows the I-V, power-density and current density curves of a Cu-CeO_2-ScSZ/ScSZ/YSZ-LSM single cell in H_2, C_4H_{10} and CH_4 at 700°C. The cell is able to operate using dry H_2, C_4H_{10} and CH_4 fuels. The open circuit voltages are 1.2 V, 1.1 V and 0.9 V, and the maximum power densities are 289mW/cm^2, 148mW/cm^2 and 115mW/cm^2 for H_2, C_4H_{10} and CH_4 fuel, respectively.

Conclusions

Single-phase cubic 9ScSZ powder has been synthesized using a co-precipitation technique. The electrical conductivity of 9ScSZ is consistent with the value in literatures. The powder has been used to prepare anode-supported cells with a ~ 60 micron thick 9ScSZ electrolyte using a tape casting method. The fabricated single cells with a Cu-CeO_2-9ScSZ anode and a YSZ-LSM cathode demonstrate the ability to operate with dry hydrogen, butane and methane fuels in the 650°C to 750°C temperature range.

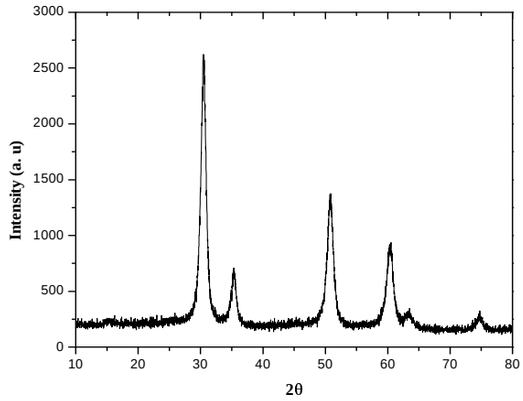

Fig.1 XRD pattern of the 9ScSZ powder

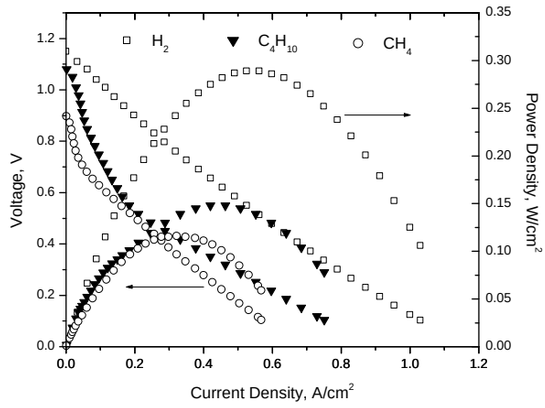

Fig.2 I-V and IP curves of a Cu-CeO_2-ScSZ/ScSZ/YSZ-LSM single cell with H_2, C_4H_{10} and CH_4 fuels at 700°C

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References

1. C. Lu, W.L. Worrell, J. M. Vohs and R. J. Gorte, Proceedings of a Symposium in Honor of the 65th Birthday of Professor Wayne L. Worrell, High Temperature Materials, edited by S.C.Singhal. 72 (2002)
2. S.P.S. Badwal, F.T. Ciachi, S. Rajendran, J. Drenna, *Solid State Ionics*, **109**167(1998)
3. K. Huang, M. Feng and J.B. Goodenough, *J. Am. Ceramic. Soc.*, **81**(2) 357(1998)
4. C. Xiao, F. Chen and M. Liu, *Electrochemical and Solid-State Letters*, **4**(5) A52 (2001)
5. S.P.S. Badwal, F.T. Ciacchi and D. Milosevic, *Solid State Ionics*, **136-137** 91 (2000)
6. K. Nomura, Y. Mizutani, M. Kawai, Y. Nakamura and O. Yamamoto, *Solid State Ionics*, **132** 235(2000)
7. S.P.S. Badwal, Solid Sate Ionics **143** 39(2001)
8. Y. Mizutani, M. Kawai, K. Nomura, Y. Nakamura and O. Yamamoto, Proceedings of the fifth International Symposium. Solid Oxide Fuel Cells V, eds.U. Stimming, S.C. Singhal, H. Tagawa and W. Lehnert. 165(1997)
9. Conghua Wang and Wayne L. Worrell Proceedings of a Symposium in Honor of the 65th Birthday of Professor Wayne L. Worrell, High Temperature Materials, edited by S.C.Singhal. 9(2002)
10. Anri Nakajima, Mareo Ishigame, *Solid State Ionics*, **146** 133(2002).