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Atomic Layer Deposited Thin Film for Low-Temperature Solid Oxide Fuel Cell Electrolyte

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Abstract

Solid oxide fuel cells (SOFCs) are promising candidates for next-generation energy conversion devices. Recently, the use of atomic layer deposition (ALD), which can deposit thin films or nanostructures with precise thickness control, has been explored as engineering tools to tune or improve the interfaces of SOFCs. In this talk, the input of ALD to engineer SOFC electrolytes will be discussed.

1. Introduction

Solid oxide fuel cells (SOFCs) are promising candidates for the next-generation energy conversion devices. While conventional SOFCs are operated at high temperature usually above 800°C, low temperature SOFCs (LT-SOFCs) that operate at even lower temperature range (<500°C) may solve the practical issued of the high temperature counterparts, e.g., thermal degradation, materials selection, etc. The use of thin film electrolytes in LT-SOFCs is essential because the ohmic loss associated with the electrolyte hugely increases at low temperature. Nevertheless, the mechanical and chemical stability of thin film electrolytes are generally inferior to the thicker ones, resulting in lower performance represented by low open circuit voltage or fast thermal degradation.

In this talk, we will report the design and fabrication of thin film composite electrolytes with high mechanical/chemical stability as well as superior ionic conductivity/surface exchange. The input of atomic layer deposited yttria-stabilized zirconia (YSZ) thin film in the highly ionically conductive doped ceria electrolyte is shown to be effective in fabricating the high performance and stable thin film electrolyte.

2. Experimental

The thin film SOFCs were fabricated on top of nanoporous anodized aluminum oxide (AAO) substrate. Sputtered Pt anode, thin film electrolyte composed of samaria-doped ceria (SDC)/YSZ/SDC, and sputtered Pt cathode were sequentially deposited on top of AAO substrates.

Especially, YSZ was deposited using atomic layer deposition (ALD). Customized thermal ALD system was used for the ALD process. Tris(methylcyclopentadienyl)yttrium ($(CpCH_3)_3Y$) and tetrakismethylethylamino zirconium (TEMA Zr) were used as precursors for Y_2O_3 and ZrO_2, respectively. The Zr and Y precursors were maintained at 190 °C and 75 °C, respectively, and the deposition temperature was maintained at 225 °C. H_2O and N_2 gases were used as the oxygen source and the carrier gas, respectively.

Electrochemical performances of the SOFC samples were analyzed in a customized test station built on a temperature-controllable heater. Dry hydrogen gas (20 sccm) was supplied to the anode through the pore of the AAO template, and the cathode was exposed to the ambient air. Electrochemical analysis such as OCV characterization, linear sweep voltammetry (LSV) (for current–voltage measurement), and electrochemical impedance spectroscopy (EIS) were performed at 450 °C using a potentiostat. [1]

3. Results and Discussion

The thin film composite electrolyte fabricated by the combination of RF sputtered SDC and ALD YSZ is shown in the TEM image in Fig. 1. Relatively bright part in the middle of the electrolyte represent the ALD YSZ layer of ~ 20 nm in thickness while the other parts of the electrolyte are sputtered SDC layers. Total thickness of the electrolyte was ~ 400 nm in thickness. The thin film electrolyte shows grain-boundaries, which can induce the electrical or chemical shorting in operation at elevated temperature. Nevertheless, the ultra-thin ALD YSZ layer is shown to perfectly block the propagation of through-grain-boundaries between electrodes.

The OCV of the thin film SOFC with the composite electrolyte show the high value of 1.04-1.05 V. This value is much higher than the OCV of the identical cell without ALD YSZ layer (~0.3 V). Furthermore, the OCV keeps the high value and does not degrade at all even at prolonged operation for 10 hours at 450 °C, which means that the electrolyte is mechanically and chemically stable. SEM and TEM images of the composite electrolyte confirm that the improved stability of the thin film electrolyte is due to the conformal and dense coating of the ALD YSZ.

In the polarization test, the thin film LT-SOFC employing the composite electrolyte showed the high performance of ~500 mW/cm^2 at 450 °C, which is among the highest for LT-SOFCs. In the electrochemical impedance spectroscopy, the composite electrolyte shows low activation and ohmic resistances, and the combined effect contributes to the high power density of the cell at relatively low temperature.

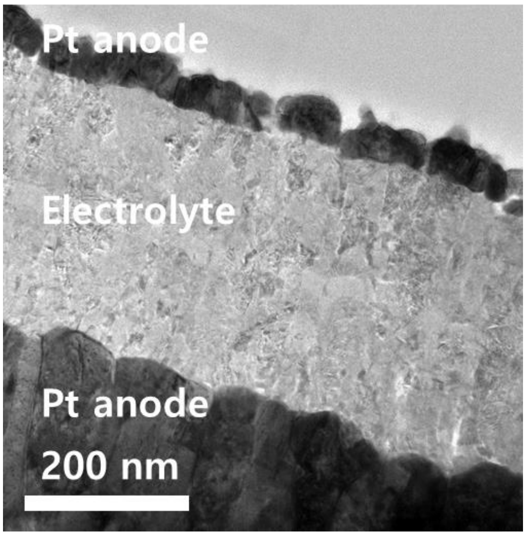

Fig. 1 Cross-sectional TEM image of the thin film SOFC with the composite electrolyte used in this study

4. Conclusions

We have fabricated and tested the thin film composite electrolyte for LT-SOFC. The mechanical and chemical stabilities of the thin film electrolyte have greatly been enhanced by employing the ALD YSZ layer in the middle of the electrolyte. Eventually, the high and stable OCV as well as high power density of 500 mW/cm^2 at 450 °C was achieved. The design and fabrication of high performance and stable thin film electrolyte may greatly contribute the development of LT-SOFC based power sources, which eventually can be used as portable power sources.

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References

[1] S. Oh, et al, J. Mater. Chem. A. **6** (2018) 7401.