저온 작동을 위한 연료극 지지형 박막 고체산화물 연료전지 공정에 관한 연구

Development of anode-supported thin-film solid oxide fuel cell for low-temperature operation

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Abstract

Lowering the operating temperature of solid oxide fuel cell (SOFC) has been one of the most challenging issues of researchers for past 10-15 years, because high operating temperature above 800 °C causes severe performance degradation of cells, crack formation by thermal expansion, limitation of materials for interconnectors, sealing problems and so on. There are two ways to operate SOFC at low temperature. One is to find new materials having very **high ionic conductivity at low temperature** regime for SOFC, and another is to make extremely **thin film electrolyte which has very short ionic conduction path**. This study covers thin-film SOFC, which is a state-of-art technology utilizing physical vapor deposition method to fabricate thin and uniform layer of ceramic electrolyte. Scalable and comparably low-cost fabrication process was developed and electrochemical performance of the single cell was also measured and analyzed.

Introduction

▪ Solid Oxide Fuel Cell (SOFC)

- High energy conversion efficiency ➔ Best alternative future energy
- Uses ceramic membrane as an electrolyte
- Generally operates at very high temperature above 800 °C
- Issues for commercialization

➔ Systemization problem: Limited Interconnector, Sealant materials

→ Lowering the operating temperature is necessary

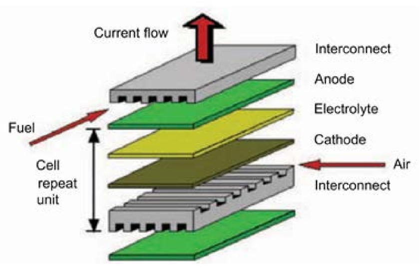
▪ Previous researches about Low-T SOFC

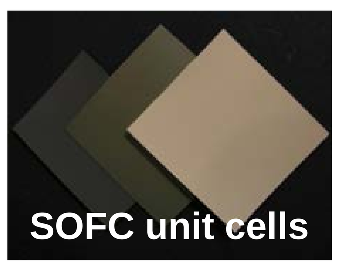
- Limitation: High cost, small active area, poor durability
- Thin film technologies are generally high-cost, non-scalable and time consuming processes

→ Process development for thin-film SOFC is necessary

▪ Thin-film SOFC fabrication

- This study introduces comparably low-cost, scalable fabrication process
- Morphology and electrochemical performance were also measured





Experimental

▪ NiO-YSZ substrates for mechanical supports

− Tape casting process: Low cost, commercially available

▪ Anode functional layer (AFL) for thin-film deposition

− Dense and smooth surface is needed for thin-film electrolyte deposition

▪ Thin film electrolyte deposited by reactive sputtering

− YSZ-GDC thin films deposited by sputtering technique

▪ LSCF-GDC cathode

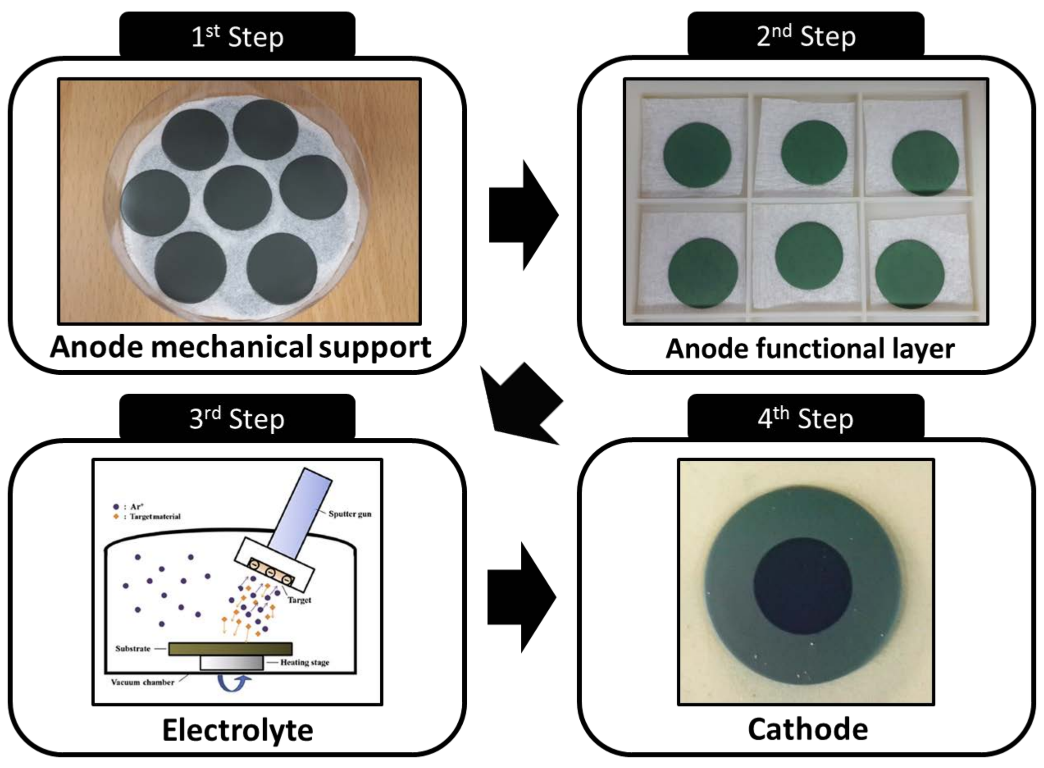
− Screen printing method

▪ I-V & EIS measure

− Open circuit voltage
− Maximum power density
− Ohmic impedance
− Faradaic impedance

▪ Micromorphology

− Cell cross-section
− AFL, electrolyte surfaces



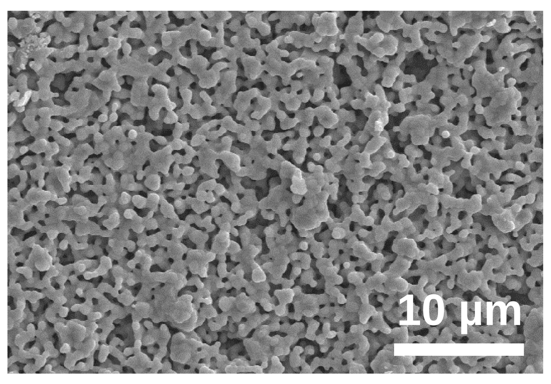
Conclusion

- Scalable fabrication process of thin-film SOFC was developed
- Tape casting, reactive sputtering and screen printing methods were utilized
- Design of AFL layer is important to have thin film electrolyte
- Almost theoretical OCV and good performance were obtained

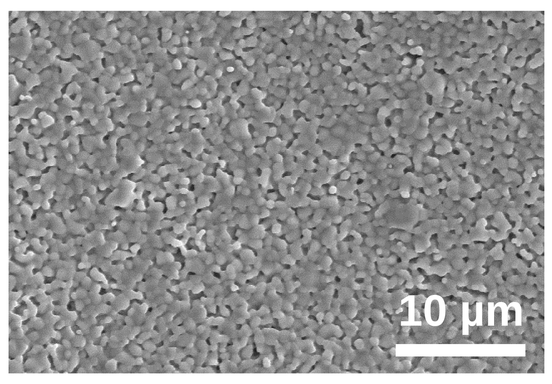
Result and discussion

▪ Optimization of NiO-YSZ anode mechanical support

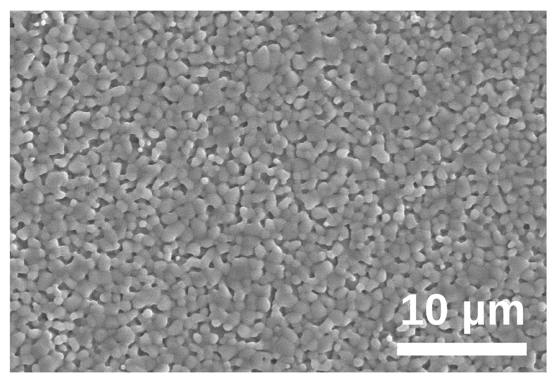
- Slurry composition: Target materials + Pore former
- Azeotropic composition of solvents → linearize de-airing process
- Pre-sintering tape and coating AFL layer
- Co-sintering tape-AFL assembly (figures below)



co-sintered at 1250°C



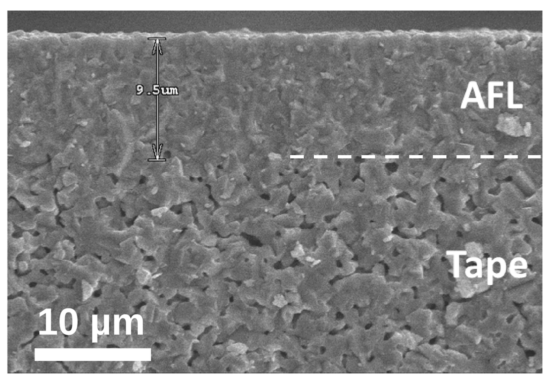
co-sintered at 1300°C



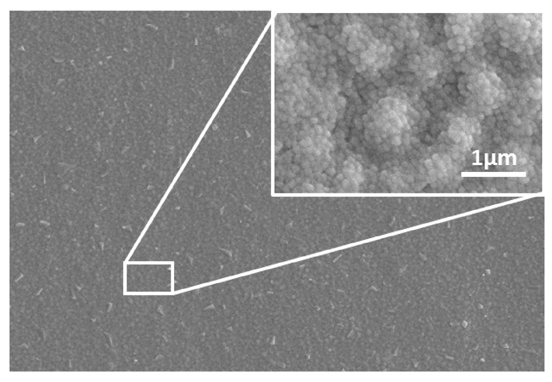
co-sintered at 1350°C

▪ Micromorphology analysis

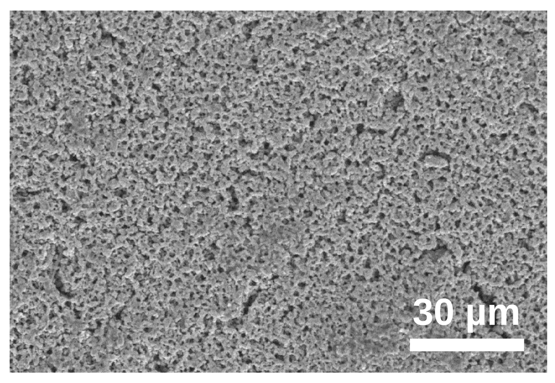
− AFL surface is important for thin film electrolyte deposition
− Uniform and dense electrolyte thin film by sputtering
− Porous LSCF-GDC cathode layer



Substrate cross-section



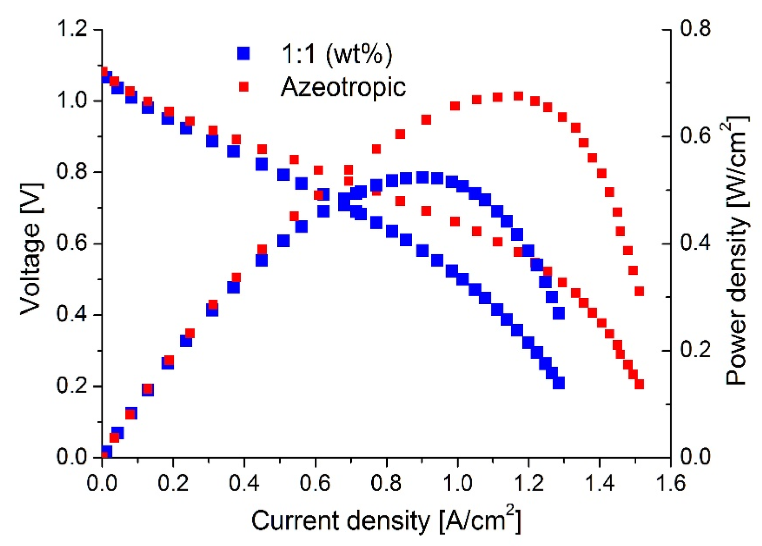
Thin-film electrolyte surface

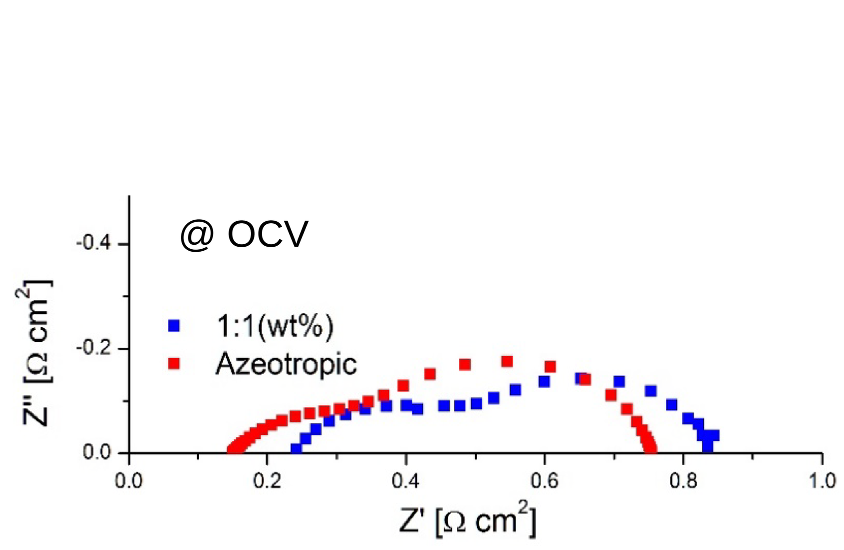


Cathode surface

▪ Electrochemical performance of thin-film SOFC

− 700 °C operation with wet hydrogen and dry air (active area = 0.8 cm^2)
− Electrolyte thickness: 500nm YSZ, 500nm GDC
− OCV = 1.08 V, Power = 670 mW/cm^2, ASR_{ohm} = 0.18 Ωcm^2





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