Manufacturing of Metal Foam Supported SOFCs with Graded Ceramic Layer Structure and Thin-film Electrolyte

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Motivation and Objectives

1. Demonstration of the feasibility of the metal foam supported cell concept and design.

2. Deposition of gas-tight thin-film electrolyte (~3 µm thick) layers to ensure low ASR.

3. Development of metal foam supported SOFCs in combination with desired materials and catalysts to address issues of SOFC technologies: sulfur poisoning, redox stability……
DLR state-of-the-art Metal-supported SOFC (MSC)

**Conventional**

**Metal foam**

Replacement

Full plasma sprayed cell

Cathode

Electrolyte

Anode

Porous metal

2000 hours tests degradation rate <1.5%/kh

Electrolyte Manufacturing Routes on MSC

Thick VPS electrolyte
Prototype, low-risk and experienced approach

Challenges:
1. Robust substrate
2. Gas-tight electrolyte
3. Efficient functional anode layer

Thin PVD electrolyte
High-risk and high impact approach

Challenges:
1. Well-defined surface structure
2. Gas-tight thin electrolyte
3. Thermal stability of the multi-layers [1]


[Thicker electrolyte image: 200 µm]

[Thinner electrolyte image: 10 µm]
Performance on ASC cells with thin electrolyte


1.8 A/cm²@600°C

Cathode size 4 cm x 4 cm
Up-scaling size 9 cm x 9 cm

ASR < 0.05 Ω cm² @ 650 °C
Manufacturing of current collecting support

Engineering of pore size

Pore size distribution of calcined NiCrAl alloy substrates with impregnated LST.
Example of graded layer structure

Intermediate YSZ layer
Mesoporous

Anode
Macroporous

Surface Engineering

Top view SEM: (a) NiCrAl foam, (b) NiCrAl foam with impregnated LST, (c) LST-GDC anode functional layer, (d) dip-coated YSZ layer
Surface Engineering for supporting PVD GDC
A Way to Thin Electrolyte

Electrolyte

NiCrAl Metal foam

Anode

LST

NiCrAl Metal foam

YSZ

GDC

Anode: LST + GDC
Dense and Gas-tight PVD GDC Electrolyte

SEM of LST-GDC/YSZ/GDC interfaces: (a) cross section, (b) elemental mapping
Leakage rate of half cells with PVD electrolyte

Leak rate of half cells

- GDC as deposited
- co-fired @1000 °C

50mm

State-of-the-art half cells

Gas-tightness is crucial for cell performance

7x10^{-4} \text{ (hPa} \text{ dm}^3) / (\text{s cm}^2)
Thermal Stability of bi-layer Electrolyte
Thermal Treatment @ 1000°C on Half Cells with PVD GDC
Cell processing route with graded layer structure and PVD electrolyte

**Challenges:**
- Defect-free anode layer
- Adhesion of layers
- Thermal stability
Conclusion

i. Half cells have been fabricated on substrates consisting of NiCrAl alloy foam as structural support and impregnated LST ceramic as anode material.

ii. Thin-film YSZ-GDC bi-layer electrolytes were made of dip-coated 1 µm thick YSZ layer and 2 µm thick PVD GDC layer.

iii. Despite the thin electrolyte, the leakage rate of the half cells with thin-film YSZ-GDC bi-layers has been measured as low as $7 \times 10^{-4}$ (hPa dm$^3$)/(s cm$^2$), demonstrating an good gas-tightness.

iv. Further optimization and electrochemical tests of the cells will follow in future work.

v. Potentials for other application fields requiring low ASR at low temperature: SOECs, co-electrolysis, methanation, and etc.
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Thanks for Your Attention