Abstract

Goals: a) Understand how operating conditions affect the performance of solid oxide fuel cells (SOFCs) with cathodes of lanthanum strontium manganite (LSM, (La1-xSr0.55Mn1.033O3±δ)) and yttria-stabilized zirconia (YSZ, (Zr1±δO2±δ)) at elevated-temperature open-circuit voltage (OCV) (zero current).

1. Reduced O\textsubscript{2} at the cathode, to intensify degradation of cathode performance.
2. Aging tests: to study the effects of service temperature and atmosphere at open-circuit voltage OCV(t) (zero current).
3. Current load cycling: to study the effects of current sweeps and EIS measurements on cell output.

As in the prior work, cells will undergo detailed microstructural characterization, using transmission electron microscopy (TEM), energy-dispersive x-ray spectroscopy (EDXS), and three-dimensional reconstruction (3DR), with sample preparation via focused ion-beam scanning electron microscopy (FIB/SEM), focusing on the following phenomena:

1. Changes in phase fraction and their distribution across the cathode, particularly densification/loss of porosity near the interfaces of the cathode with the electrolyte and the cathode current collector (CCC);
2. Changes in total and active three-phase boundary (TPB) density;
3. Formation and distribution of manganese oxides (MnO\textsubscript{x}), including MnO\textsubscript{3} phases and MnO\textsubscript{3}.

The new studies have the potential to improve the reliability and lifetime of SOFC technology.

Prior work: Durability tests; ASR vs. TPB density

Prior work: 3DR before & after accelerated testing, cathode B

Volume fraction profiles of the YSZ, LSM, and pore phases across the cathode.

As received | 500h Accel test | 624 hrs Accel test
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volume fraction (%) | 29 | 25 | 25
porosity YSZ | 33 | 35 | 37
LSM | 38 | 40 | 38
particle diameter (μm) | 0.45 | 0.5 | 0.46
YSZ | 0.5 | 0.45 | 0.72
LSM | 0.65 | 0.7 | 0.72
normalized surface area (μm\textsuperscript{-1}) | 13 | 12 | 11
YSZ | 16 | 13 | 13
LSM | 9 | 8 | 8
Total TPB (μm\textsuperscript{2}) | 14.5 | 14.8 | 11
Active TPB (μm\textsuperscript{2}) | 13.0 | 12.5 | 10

Microstructural parameters from 3D reconstructions of cathodes.

• All cathodes developed porosity gradients after 500 h of accelerated testing: lower porosity at the cathode / electrolyte interface than at the cathode / current collector interface.

• Cathode B showed less pore coarsening, less loss of pore area, and stabler TPB (total and active) than cathodes A and C.

New aspects of current project

• Possible outcomes from testing at low cathode pO\textsubscript{2}, \textsuperscript{-1}
  - Higher ASR in durability testing
  - Higher cathode overpotentials (higher cathode peaks in Bode plots)

• Aging tests versus durability tests \textsuperscript{2}
  - Independent variables
    - Time at temperature
    - Air versus low pO\textsubscript{2}
    - Operation (durability tests) versus OC
    - Mn excess

• Possible outcomes from current load cycling \textsuperscript{1}
  - Step changes in ASR
  - Step changes in OCV

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References:


Cell details; test conditions

- Button cells: YSZ electrolyte + NiO-YSZ anode
- Cathodes: LSM + YSZ
  - A: (La\textsubscript{0.8}Sr\textsubscript{0.2}O\textsubscript{3−δ})MnO\textsubscript{3} (LSM 80–90)
  - B: (La\textsubscript{0.8}Sr\textsubscript{0.2}O\textsubscript{3−δ})MnO\textsubscript{3} (LSM 80–95)
  - C: (La\textsubscript{0.8}Sr\textsubscript{0.2}O\textsubscript{3−δ})MnO\textsubscript{3} (LSM 80–98)
- Accelerated test conditions: 1000 °C, 760 mA/cm\textsuperscript{2}; ambient air; humidified H\textsubscript{2}, 50 sccm