Low Cost Multi-layer Fabrication Method for Solid Oxide Fuel Cells

DE-AC26-00NT40707

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Background of TMI

- Organized in 1990 to commercialize low cost planar SOFC technology
- Engineered compact, integrated, systems.
- Designed for multi-use applications and simplified field service.
- Operated on common fuels- multiple 100 Cell stacks on CH₄ /JP-8
Overall Program Objectives

- Large demand for low cost SOFC systems.
- Multi-Pass Screen Printing - mature, low cost fabrication technique adapted to the TMI SOFC radial-flow design.

Timeline:

- 2000: Preliminary Cost Studies
- 2001: Binder Selection and Compatibility, Printing Trials
- 2002: Multi-pass Cell Tests
TMI Cell Design

- Simple Geometry
- Small, central seals
- Radial Co-flow
- Low Cost (vs. Performance)
Compatible Flow Strategy

A Common Planar Design

TMI Design

1.0 - 1.5 mm
(0.040-0.060”)

Electrolyte

Separator

Gas Channel

Gas Channel

Separator

Porous Flow-field

Electrolyte
Low Cost Manufacturing Strategy

Low Cost Screen Printing
Rapid Cure Catalyst
Flow-field
Electrolyte Substrate

Automated Commercial Screen Printer
Task 1. Cost/Benefit Estimate

• Cost Build-up:
  – Direct Materials, Labor and Overhead
  – Indirect
  – Amortization of Capital Costs

• Benefits
  – Reduced Stack Cost
  – Increased Power Density (volume and weight)
Lower Per-Unit Costs

Base Approach
Multilayer Approach
% Reduction in Cost

Production Rate (MW/YR)
% Cost
0 10 20 30 40 50 60 70 80 90 100

Cost (%)
0 250 500 750 1000
Production Rate (MW/YR)
Task 2. Binder Systems

- Identified Candidate Binders
- Characterized Seven different systems
  - Reactivity/Contamination
  - Sensitivity/Hardness
- Four systems ranked by Compatibility.
Reactivity Analysis

<table>
<thead>
<tr>
<th>Binder</th>
<th>Cathode Powder</th>
<th>Seal Glass</th>
<th>Anode Powder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample S1*</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Sample C1**</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Sample C2</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Sample P1</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Sample P2</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Sample P3</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Sample P4</td>
<td>Slight</td>
<td>Slight</td>
<td>Slight</td>
</tr>
</tbody>
</table>

* Reacted > 24 hrs with Cathode  
** Reacts in ambient conditions
Cell Performance
(a Contamination Indicator)

<table>
<thead>
<tr>
<th>Binder</th>
<th>% Loss on Ignition</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>0.13%</td>
</tr>
<tr>
<td>P2</td>
<td>0.19%</td>
</tr>
<tr>
<td>P3</td>
<td>0.20%</td>
</tr>
<tr>
<td>S1</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

200 mA/cm²
H₂ + 6% H₂O
900°C

0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

0 50 100 150 200

Time under Test (hrs)
Task 3. Ink Curing Quality

- Curing quality & rate depends on powder, thickness, and catalyst

- Challenges
  - Voids / Pockets
  - Incomplete curing
Current Challenges

• Trade-offs among rate of cure, thickness, and catalyst.
• Multi-pass Printing
Low Cost Strategies

Adv. Separators
DE-FG02-00ER83109

Multilayer Printing
“Manufacturing”
DE-AC26-00NT40707

Integrated Hot Assembly
(Internal)

Multi-Module Operation
DE-FC26-00NT41009
Summary

• Completed Cost Estimate.

• Identified Binders
  • Reactivity and Contamination Studies Initiated.
  • Trade-offs among rate of cure, thickness, and catalyst.

• Multi-pass tests (Phase III).