Metal Interconnect Development

Ceramatec, Inc.
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## Challenges

<table>
<thead>
<tr>
<th>Critical Issue</th>
<th>Approaches tried</th>
<th>Hurdles for success</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Thermal expansion match</td>
<td>Use of 95Cr-5Fe (Plansee alloy)</td>
<td>Evaporation of Cr is the major source of degradation</td>
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<td>2. Oxidation resistance in air, maintaining conductive scale</td>
<td>Cr containing alloys which form conductive Cr$_2$O$_3$ scale</td>
<td>Cr evaporation still remains, scale growth continues to occur causing high resistance contribution</td>
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<td>3. Conductive scale in fuel atmosphere</td>
<td>Ni coating or cladding</td>
<td>Ni adhesion during thermal cycles</td>
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<td></td>
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<td>Ni CTE</td>
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<td>4. Reactivity with electrode materials - deactivation of electrodes</td>
<td>Surface coating, for example using perovskites (LSM, LSCo, LCr)</td>
<td>Achieving dense layers, spall resistance to thermal cycles</td>
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<td>5. Compatibility with anode and cathode environments</td>
<td>Monolithic alloy with surface treatments</td>
<td>Engineering demonstration</td>
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<td>Layered structure engineered for appropriate atmospheres</td>
<td>Engineering demonstration</td>
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## Challenges - continued

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<th>Critical Issue</th>
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<td>7. Uniformity in contact</td>
<td>Machining and/or lapping to achieve required flatness</td>
<td>Fabrication cost?</td>
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<td></td>
<td>Use of corrugated layers</td>
<td>Selection of appropriate layer materials</td>
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<td>8. Thermal cycle capability</td>
<td>Limited information</td>
<td>Scale spalling</td>
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<td>CTE mismatch</td>
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<td>9. Cost</td>
<td>Use of commercial alloy</td>
<td>Must meet all other requirements</td>
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Metal Interconnects

- Program Goal
  - Demonstrate stable stack performance using metal interconnects

- Phase I Objective
  - Surface treatment of commercial alloys
    - Conductive, adherent scale with long term and thermal cycle stability
  - Verification in air and fuel environments
Technical Approach

Material Selection

- Oxidation Characterization
  - Test Procedure (Static)
  - Bare vs. Pre-oxidized
    - Microscopy
    - Weight Gain

- Scale Resistance
  - Test Set-up (Symmetric)
  - Contact layer
    - Stability
    - Microscopy

- "Electrochemical" Environment Test
  - Half-cell + interconnects
  - Resistance
    - Stability
    - Thermal Cycle Capability
Oxidation in air

Material Selection

Oxidation Characterization

Test Procedure (Static)

Bare vs. Pre-oxidized

Microscopy

Weight Gain

- Static test selected
  - Two temperatures
    - 850 and 900°C
  - Sample cooled and weighed periodically
Oxide Scale Growth - Static Test

- Temperatures selected to increase oxidation rates
- Oxide scale growth rate is a function of Pre-Oxidation Treatment (POT)
  - Significant reduction in oxide scale growth by the choice of pre-oxidation technique
Oxidation Characterization

Static Test: Scale Thickness: 200 hours in air at 900°C

- Bare Metal
  - 7 microns

- POT 1
  - 5 microns

- POT 2
  - 5 microns

- POT 3
  - 3 microns

- Scale growth and interface as a function of Pre-Oxidation Treatment
Oxide Scale Resistance

• Symmetric geometry
• Resistance evaluated
  ○ Function of time and contact layer material
Test Arrangement

- Symmetric couple used to measure conductivity through the conductive interface layer and the oxide scale in air
Scale Resistance in Air

- 10 to 60 milli-ohm.cm\(^2\) in air at 850°C
  - Resistance is a function of perovskite material
Microstructure of scale/interface coating

- Interface microstructure depends on both pre-oxidation and the perovskite material
“Electrochemical” Test

- Symmetric Cell
  - Cathode Half-cell
  - Pre-Ox Metal
Interconnect Schematic

- Components
  - Separator plate
  - Flow field (corrugations)
Stability against Cathode - Test Design

- Cathode half-cell (cathode/electrolyte/cathode) sandwiched between Pre-Ox interconnects (separator/corrugation)

500 mA/cm²
Stability against Cathode - Initial Results

- Couple at a constant current of 500 mA/cm²
- Initial value stabilized at 60 - 80 milli-ohm.cm²
- Resistance increased with thermal cycles
- Cause of change?
  - Effect of test geometry?
  - Scale growth?
  - Scale delamination?
  - Poor perovskite adhesion?
Summary

• Pre-oxidation of commercial alloy reduces high temperature corrosion rate
• Low resistance values of 10 to 50 ohm.cm² in air at 850°C can be achieved
• Thermal cycle properties need further investigation
Planned Activities

- Additional long-term/thermal cycle tests with cathode half-cells to deduce mechanism of degradation
- Thermal spray of perovskite to improve adhesion/thermal cycle stability
- Dual atmosphere test?