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ADVANCED MATERIALS & ELECTROCHEMICAL TECHNOLOGIES

Metal Interconnect Development

Ceramatec, Inc.

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Challenges

Critical Issue	Approaches tried	Hurdles for success
1. Thermal expansion match	Use of 95Cr-5Fe (Plansee alloy)	Evaporation of Cr is the major source of degradation
2. Oxidation resistance in air, maintaining conductive scale	Cr containing alloys which form conductive Cr_2O_3 scale	Cr evaporation still remains, scale growth continues to occur causing high resistance contribution
3. Conductive scale in fuel atmosphere	Ni coating or cladding	Ni adhesion during thermal cycles Ni CTE
4. Reactivity with electrode materials - deactivation of electrodes	Surface coating, for example using perovskites (LSM, LSCo, LSCr)	Achieving dense layers, spall resistance to thermal cycles
5. Compatibility with anode and cathode environments	Monolithic alloy with surface treatments	Engineering demonstration
	Layered structure engineered for appropriate atmospheres	Engineering demonstration

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Challenges - continued

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

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

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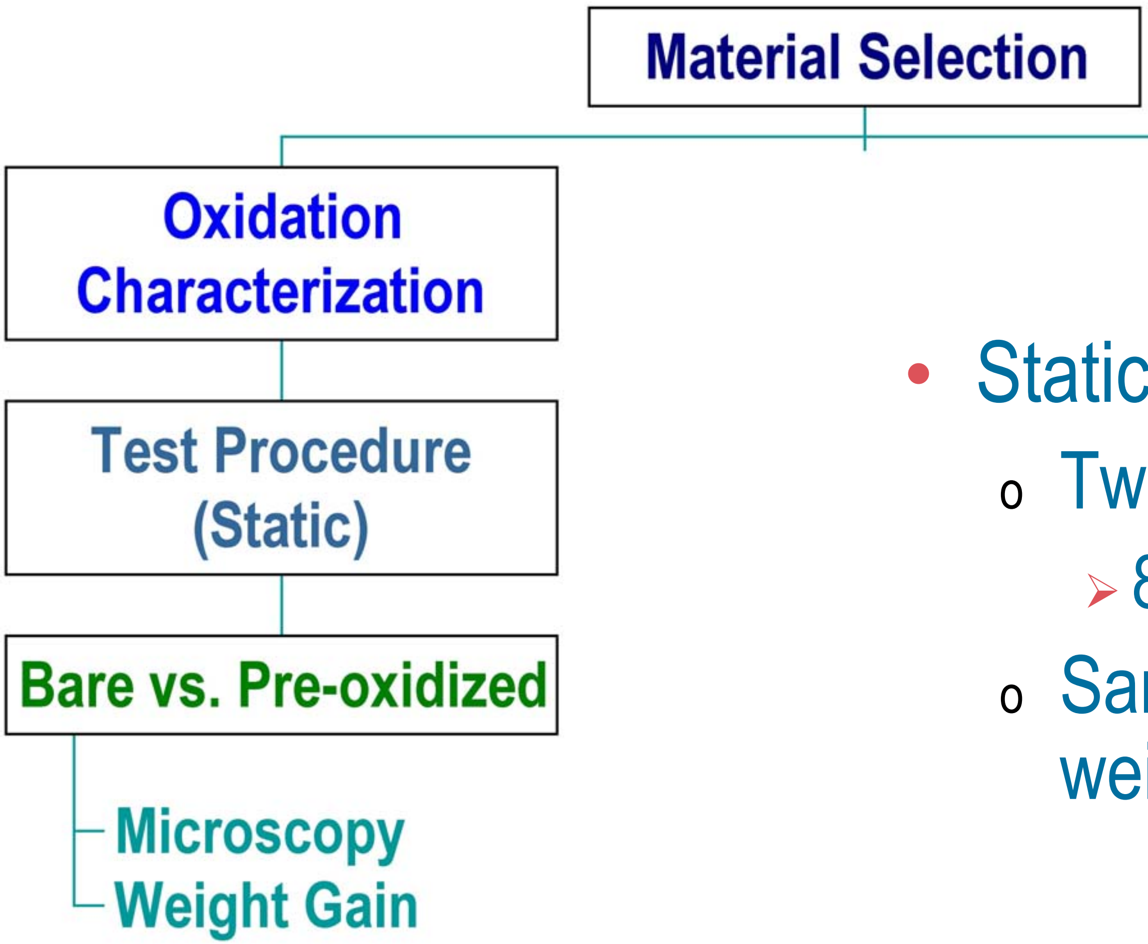
Technical Approach

Material Selection

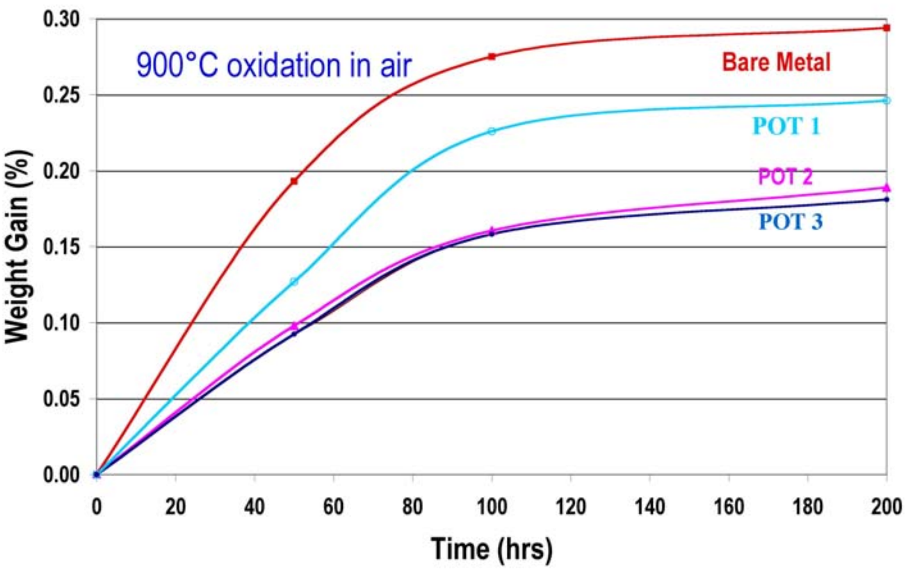
- **Oxidation Characterization**
  - Test Procedure (Static)
    - Bare vs. Pre-oxidized
      - Microscopy
      - Weight Gain
- **Scale Resistance**
  - Test Set-up (Symmetric)
    - Contact layer
      - Stability
      - Microscopy
- **"Electrochemical" Environment Test**
  - Half-cell + interconnects
    - Resistance
      - Stability
      - Thermal Cycle Capability

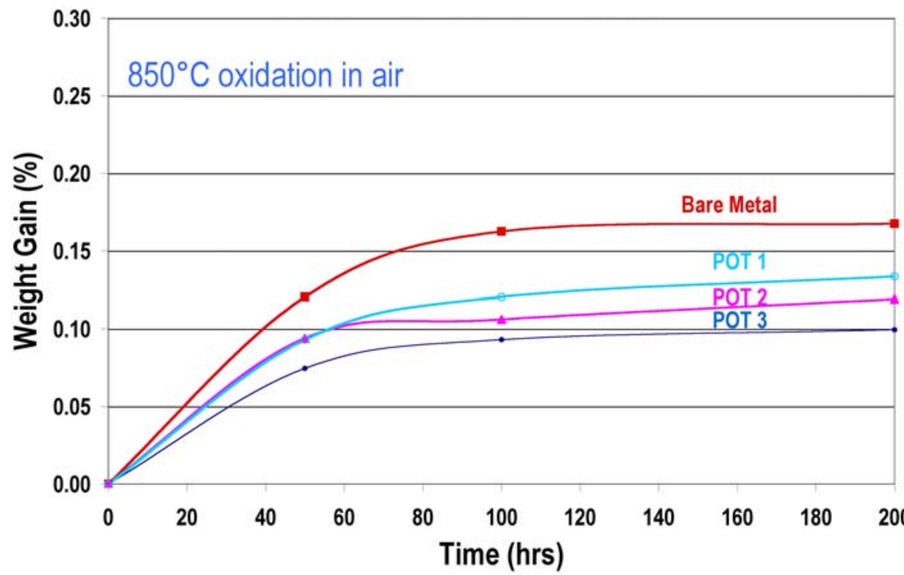
Oxidation in air



- 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

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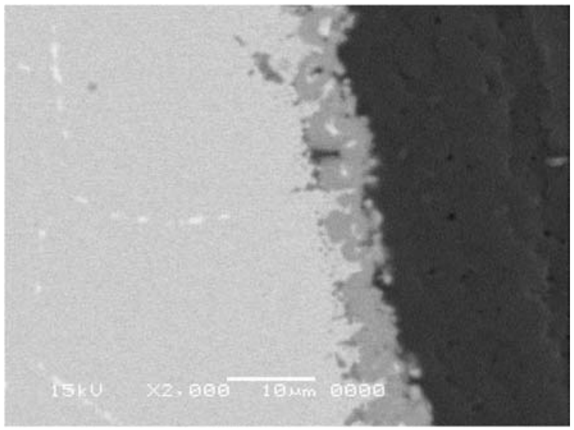
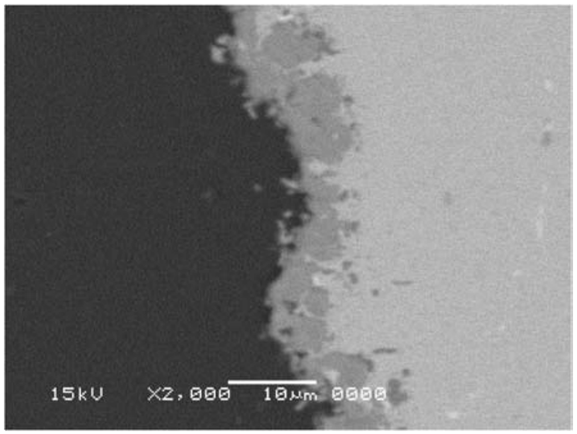
Oxidation Characterization

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

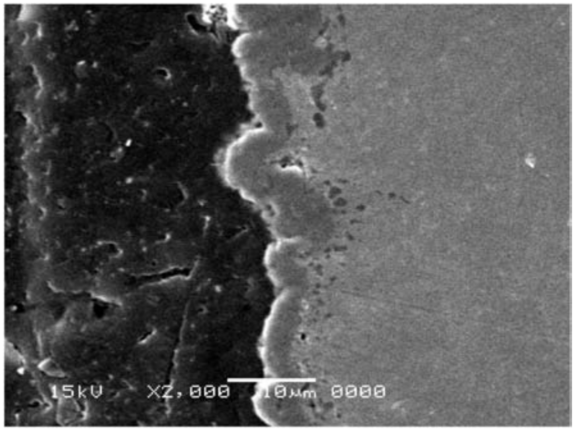
Bare Metal
7 microns

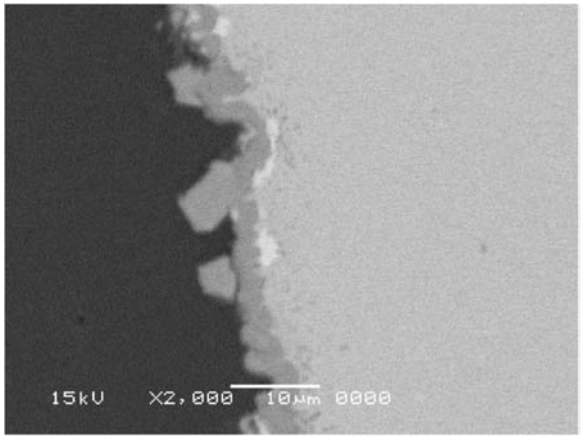




POT 1
5 microns

POT 2
5 microns

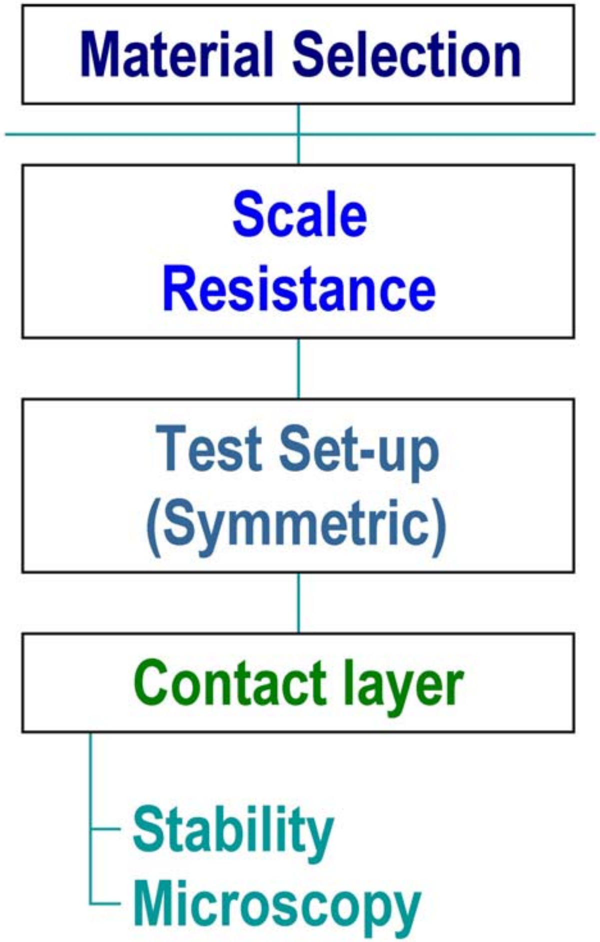




POT 3
3 microns

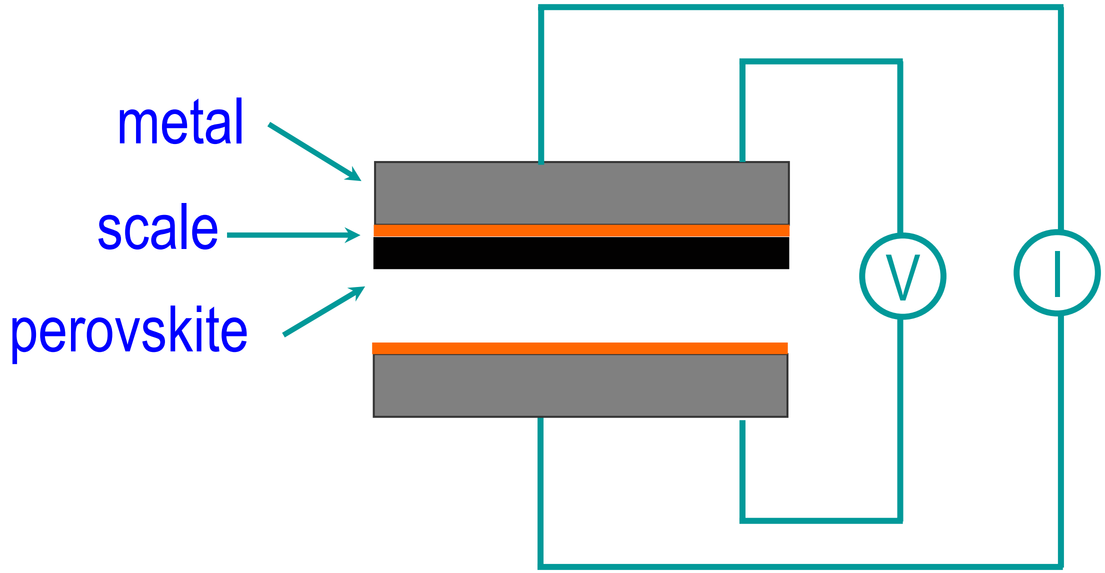
- Scale growth and interface as a function of Pre-Oxidation Treatment

Oxide Scale Resistance



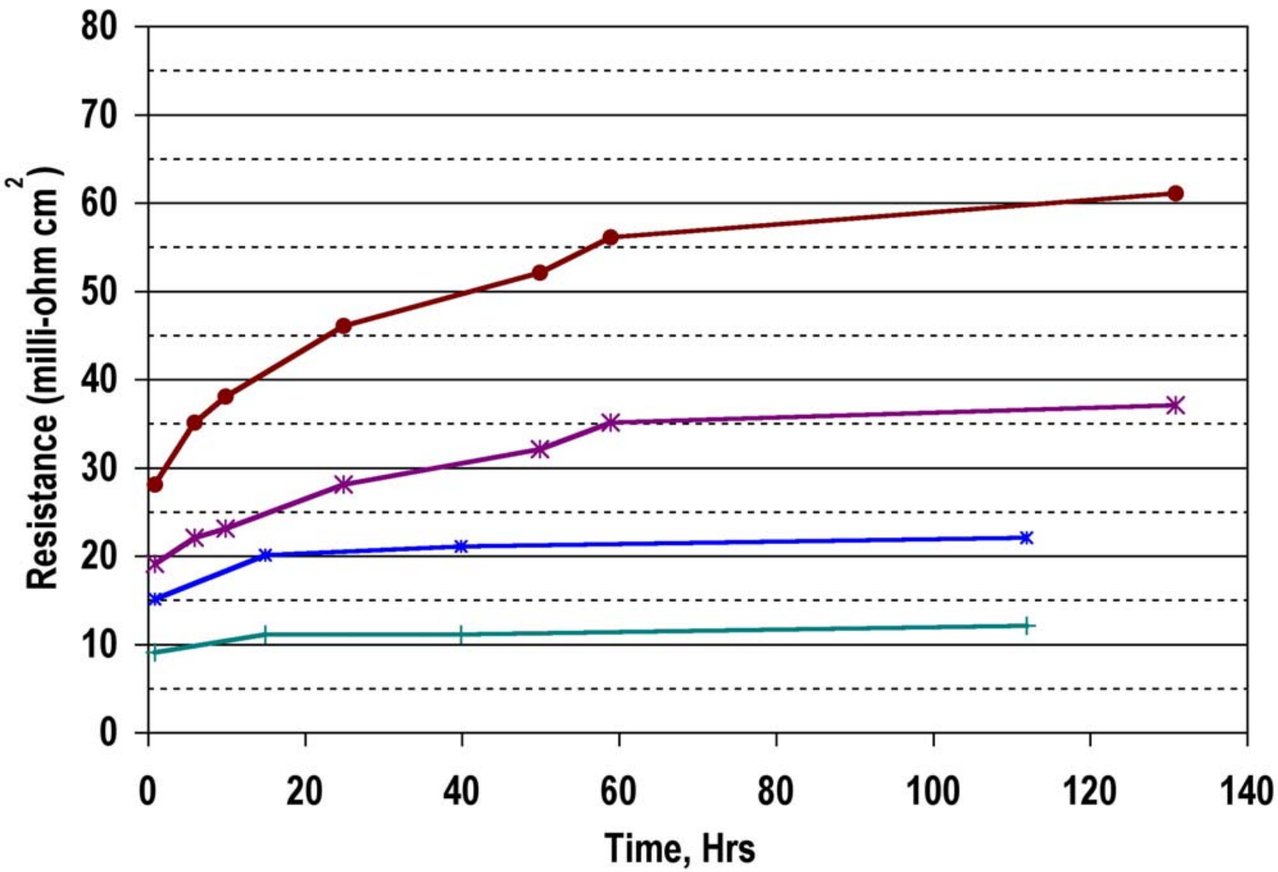
- Symmetric geometry
- Resistance evaluated
    - Function of time and contact layer material

Test Arrangement



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

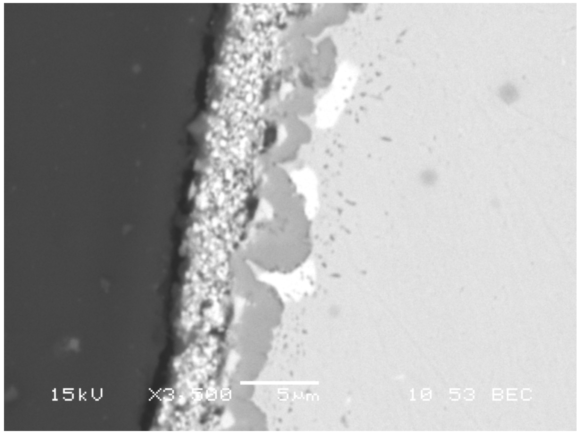
Scale Resistance in Air

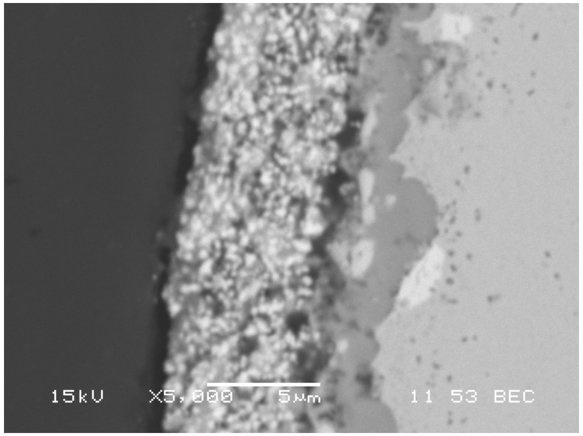


- 10 to 60 milli-ohm.cm^2 in air at 850°C
  - Resistance is a function of perovskite material

Microstructure of scale/interface coating

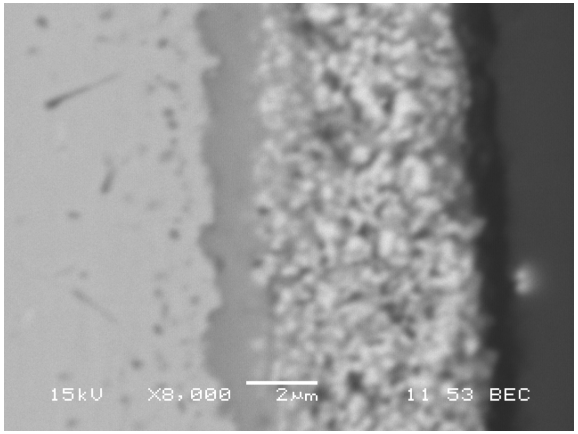
POT 2

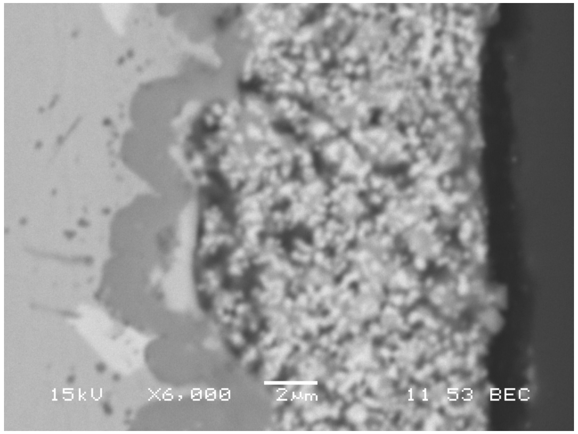




POT 2

POT 3



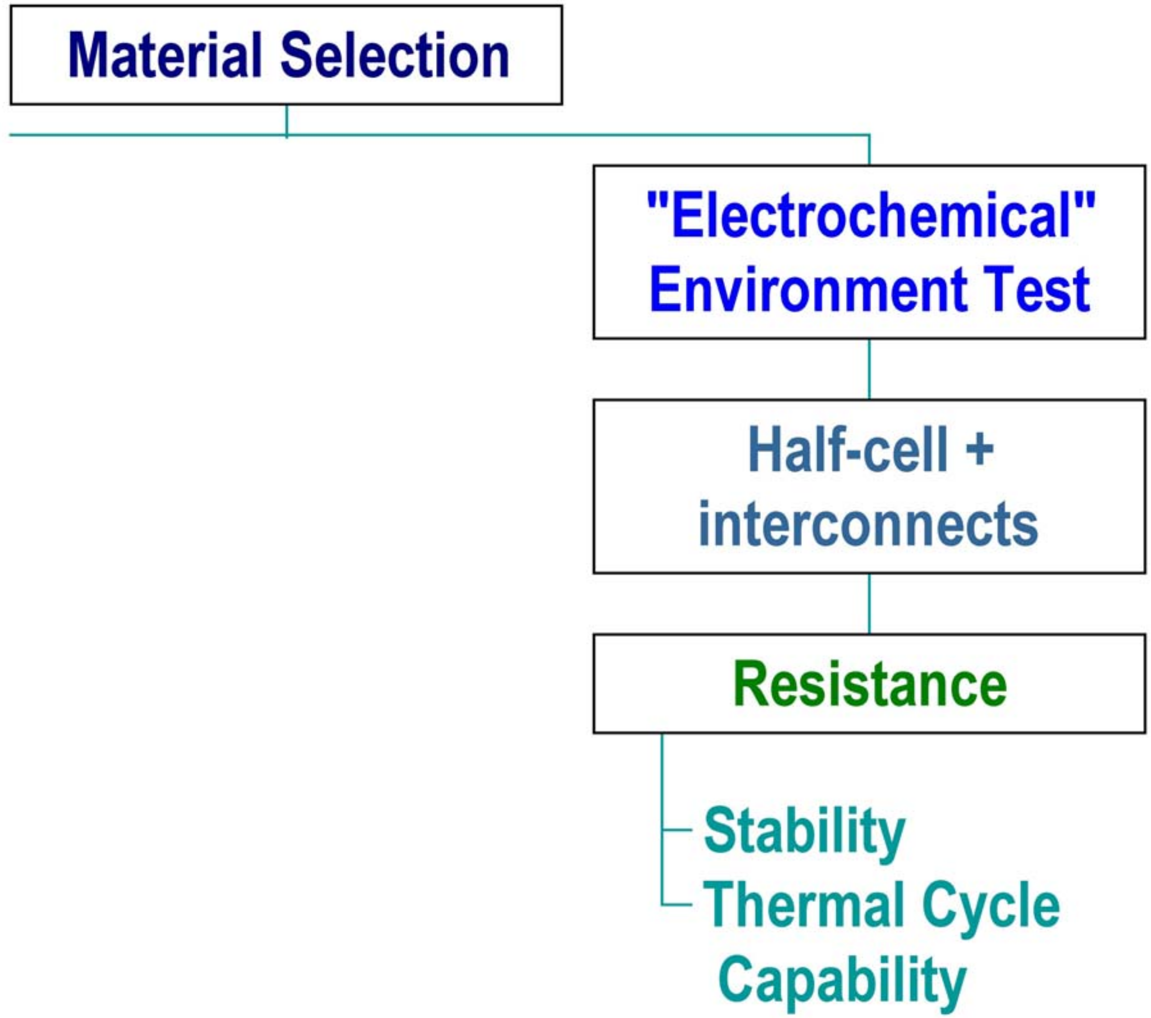


POT 3

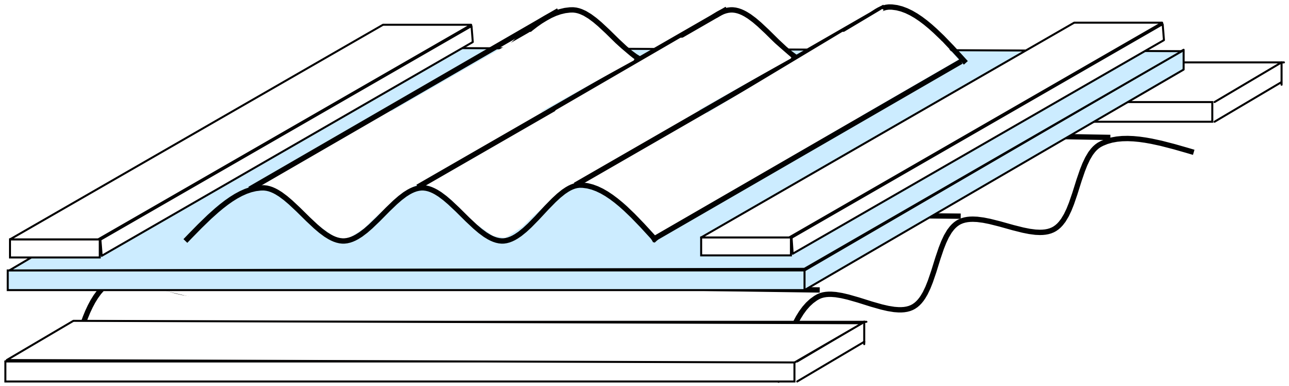
- Interface microstructure depends on both pre-oxidation and the perovskite material

“Electrochemical” Test

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



Interconnect Schematic



- Components
  - Separator plate
  - Flow field (corrugations)

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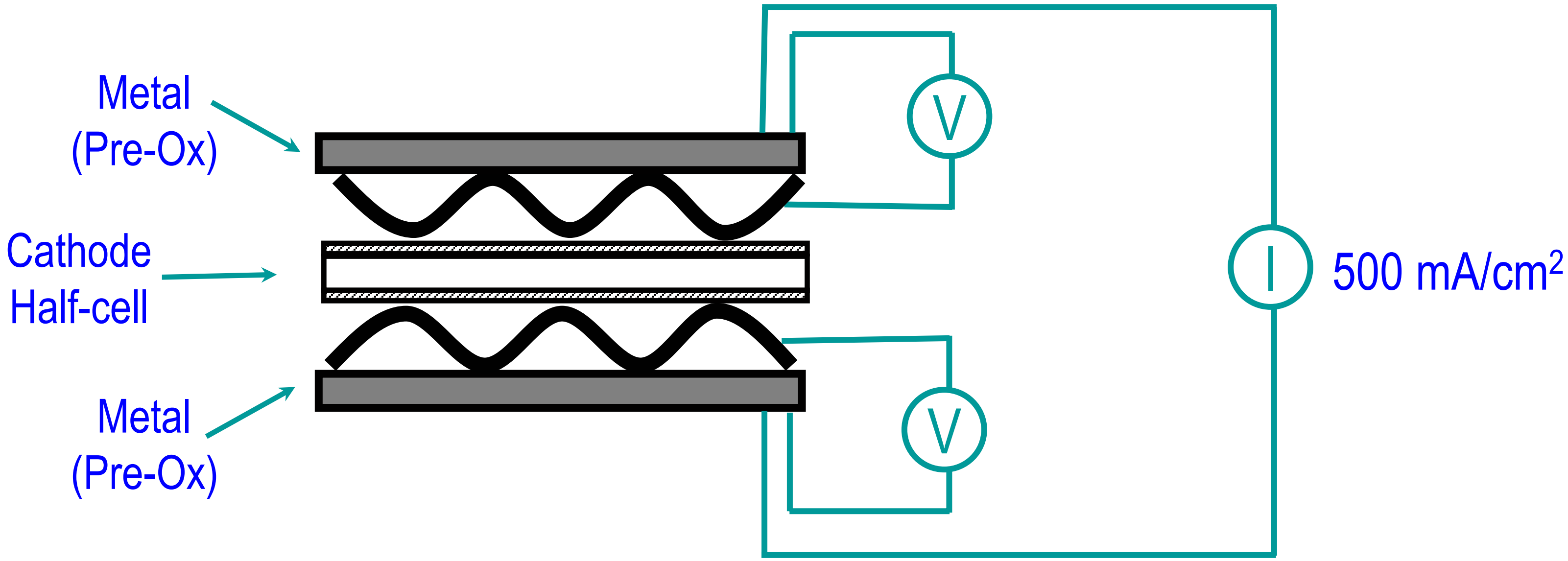
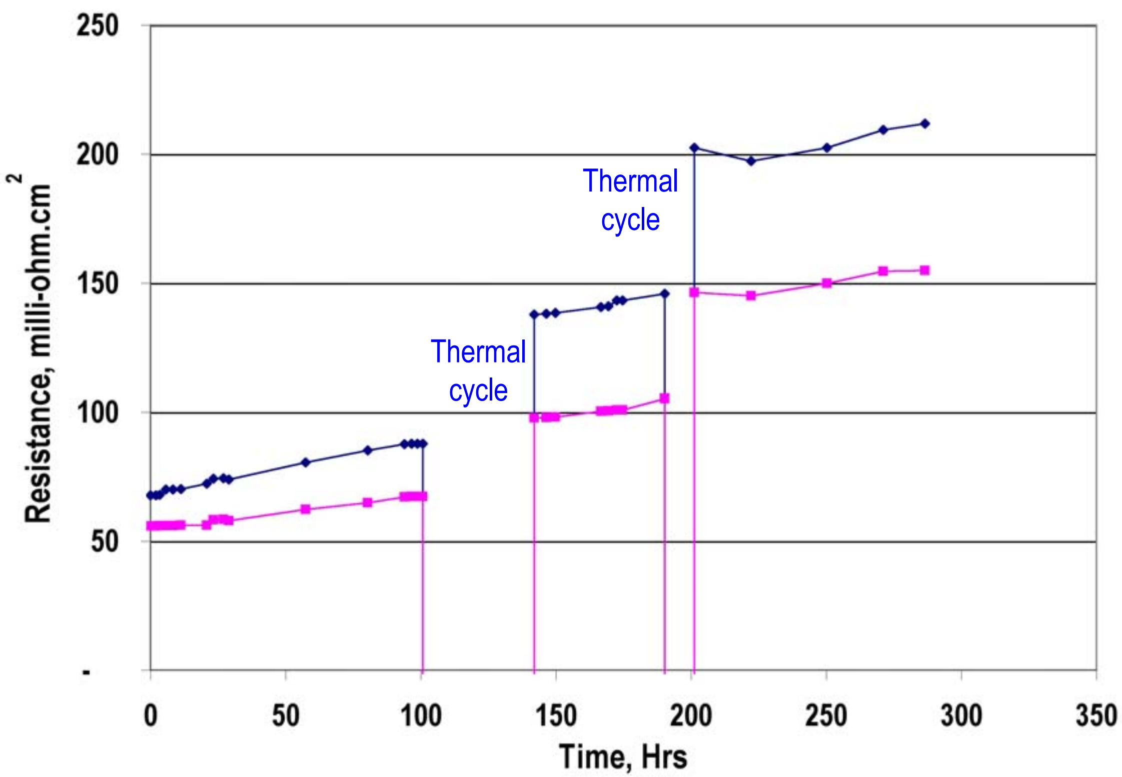
Stability against Cathode - Test Design



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

Stability against Cathode - Initial Results



- Couple at a constant current of 500 mA/cm^2
- Initial value stabilized at 60 - 80 milli-$ohm.cm^2$
- Resistance increased with thermal cycles
- Cause of change?
  - Effect of test geometry?
  - Scale growth?
  - Scale delamination?
  - Poor perovskite adhesion?

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Summary

- Pre-oxidation of commercial alloy reduces high temperature corrosion rate
- Low resistance values of 10 to 50 $ohm.cm^2$ 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?