Metal Interconnects for Solid Oxide Fuel Cell Power Systems

SECA Core Technology Program

Ceramatec, Inc.

Supported in part by

DOE-NETL

Presented at

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Technical Issues Addressed

- Technical Requirements for Metal Interconnects
  - CTE match
  - No gas permeation
  - High temperature corrosion resistance
  - Scale conductivity
  - Scale adhesion
  - Stability in atmosphere (physical, chemical, microstructure, conductivity)
  - Stability against electrode/bond layer (poisoning effect)
  - Electrical contact with cells
  - Thermal cycle capability

Risks and Challenges

- Alloys with exceptional corrosion resistance form non-conductive scales (e.g., alumina formers)
- Chromia formers provide a conductive scale
  - Continued scale growth during operation
    - Increased electrical resistance
    - Loss of adhesion
    - Porosity at interface
  - Chromium vaporization
    - Electrode Poisoning
  - Electrode compatibility
    - High resistance phase formation with electrode cations (spinel)

R&D Objectives

- Controlled growth of conductive scale to achieve
  - Electronic conductivity
  - Low cation (metal) and anion (oxygen) diffusivity
  - Good adhesion ('native' scale)
- Application of conductive layers
  - Application techniques
    - Screen printing
    - Thermal spraying

Approach

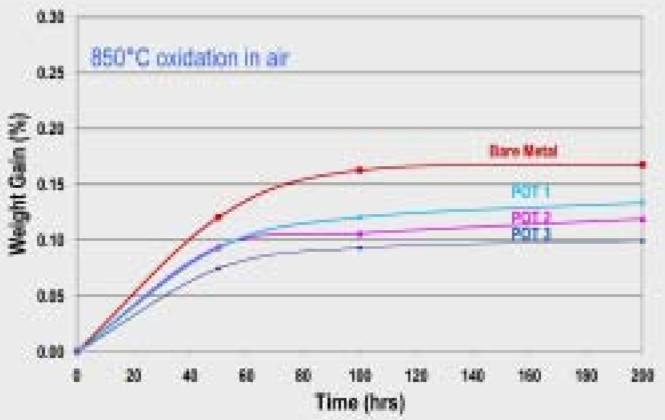
- Alloy Selection — Fe-Cr based ferritic SS
  - CTE Match
  - Conductive scale (chromia former)
  - Choice of minor alloying elements

- Pre-treatment
  - Growth of selective oxide scale
    - Control P, T, X_i and t
  - Scale characterization

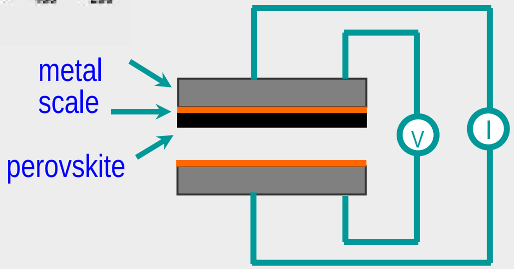
Assessment Criteria

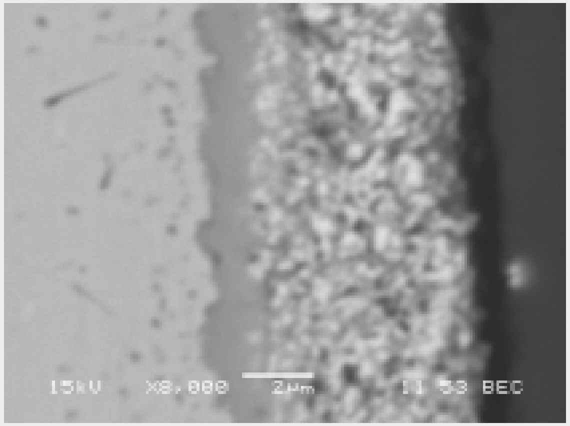
- Weight gain with time at temperature
- Scale thickness
- Electrical resistance
- Thermal cycles
- Exposure to relevant atmospheres

Summary of Results - 20Feb03



Weight gain

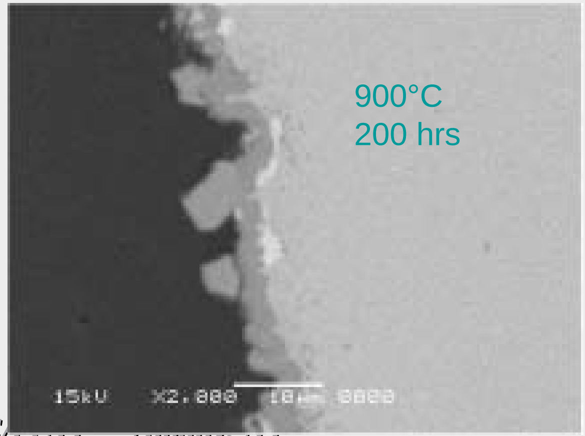


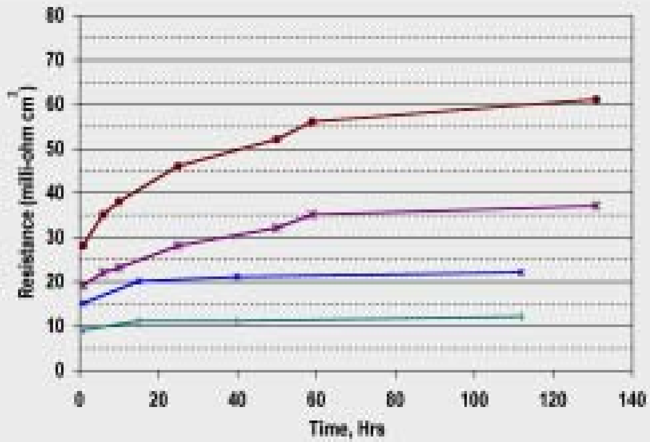


Scale adhesion

Scale growth

Scale resistance



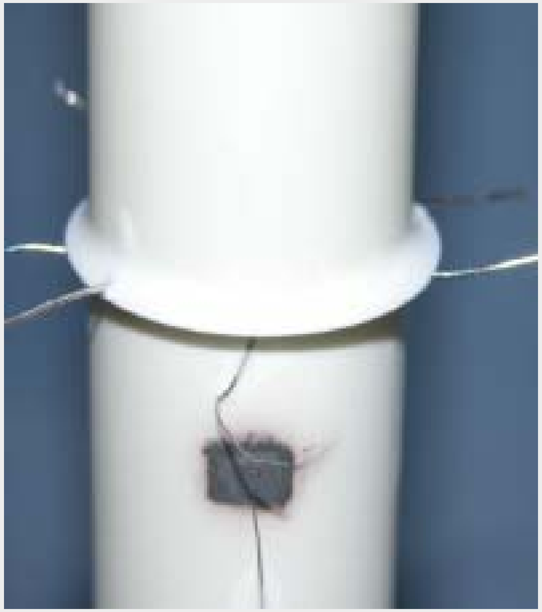


SECA Team Recommendation

- Feedback
  - Relevancy of temperature
  - Effect of atmosphere on air-side scale
    - moisture in air
    - dual atmosphere
- Revised Plan
  - Test temperature 750°C
  - Characterization at various exposure conditions

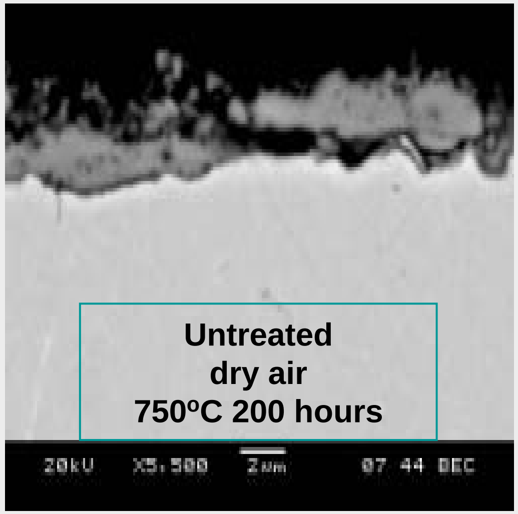
Revised Experimental Plan

- Exposure conditions (750°C 500 hours)
  - Dry air / dry air
  - Dry air / wet hydrogen
  - Wet air / wet hydrogen
  - Wet air / wet air
  - Wet hydrogen / wet hydrogen
- Characterization
  - Static weight gain
  - Scale Morphology & Composition
  - Conductivity / thermal cycle tests

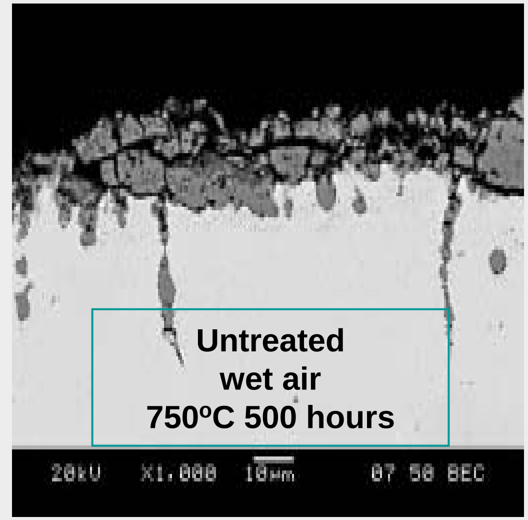


Test arrangement to monitor fuel pO_2 during dual atm. exposure

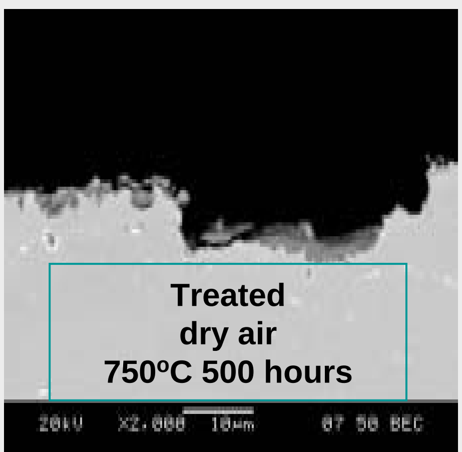
Scale Morphology



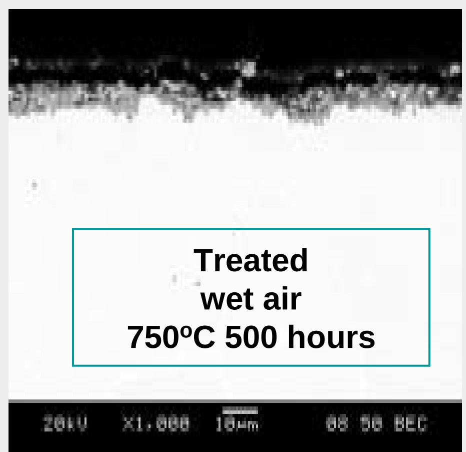
Untreated
dry air
750°C 200 hours



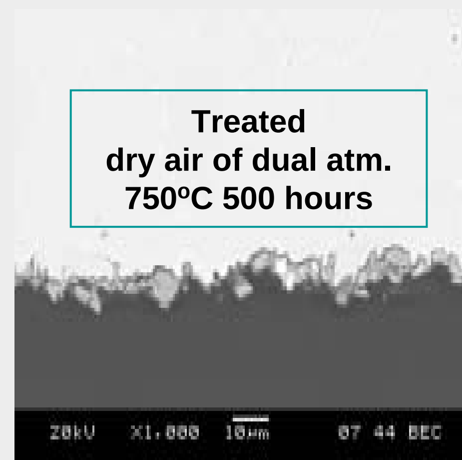
Untreated
wet air
750°C 500 hours



Treated
dry air
750°C 500 hours

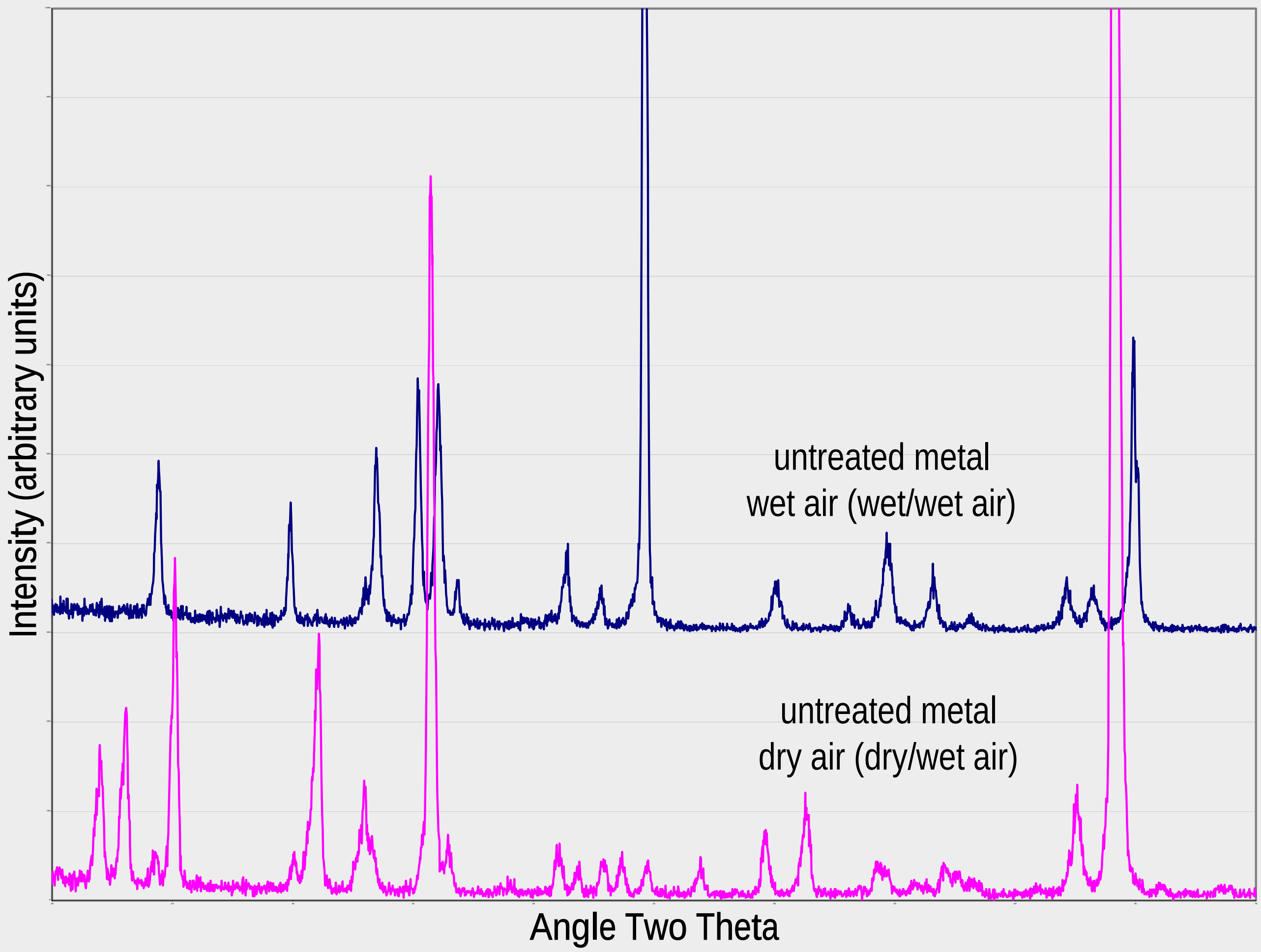


Treated
wet air
750°C 500 hours

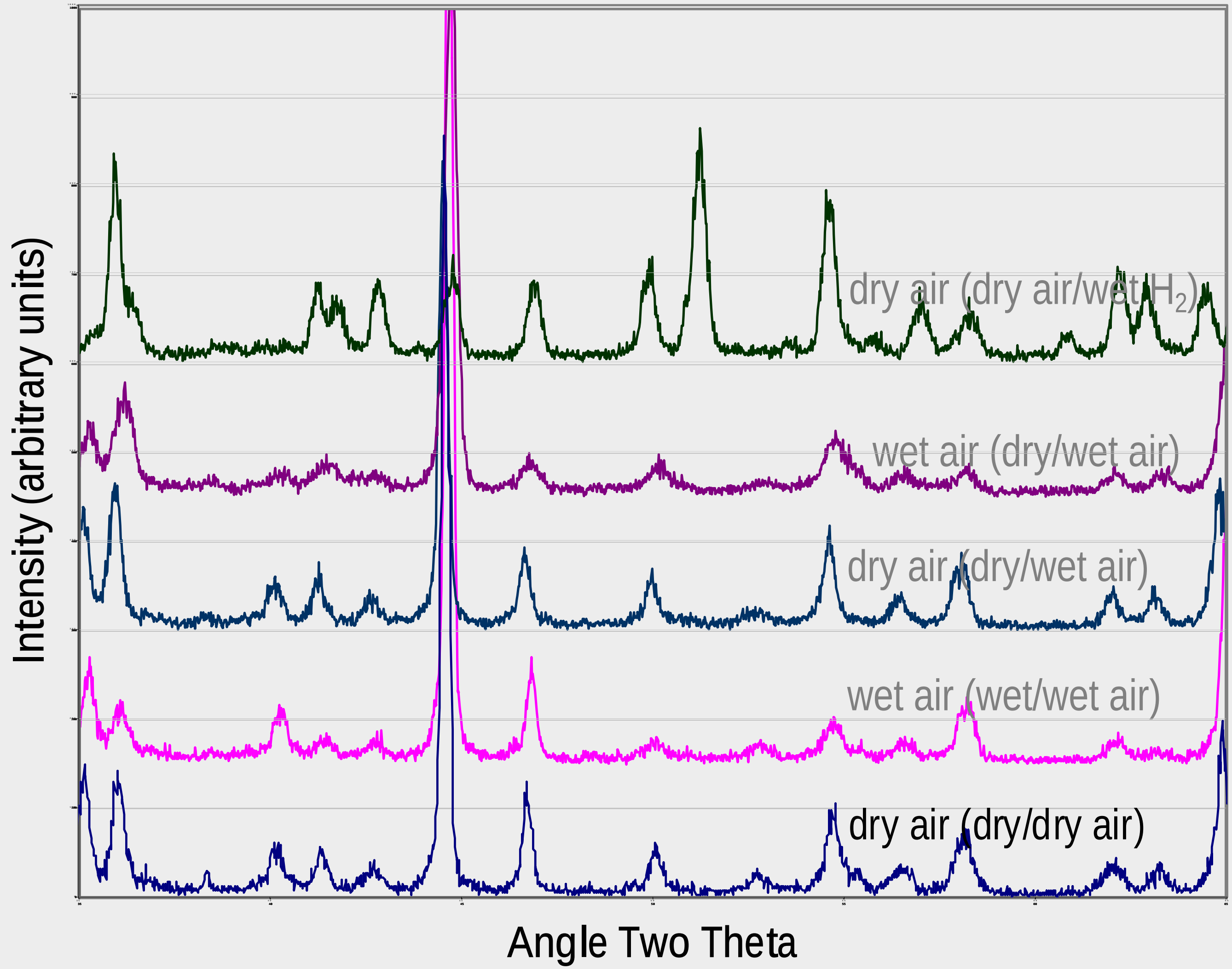


Treated
dry air of dual atm.
750°C 500 hours

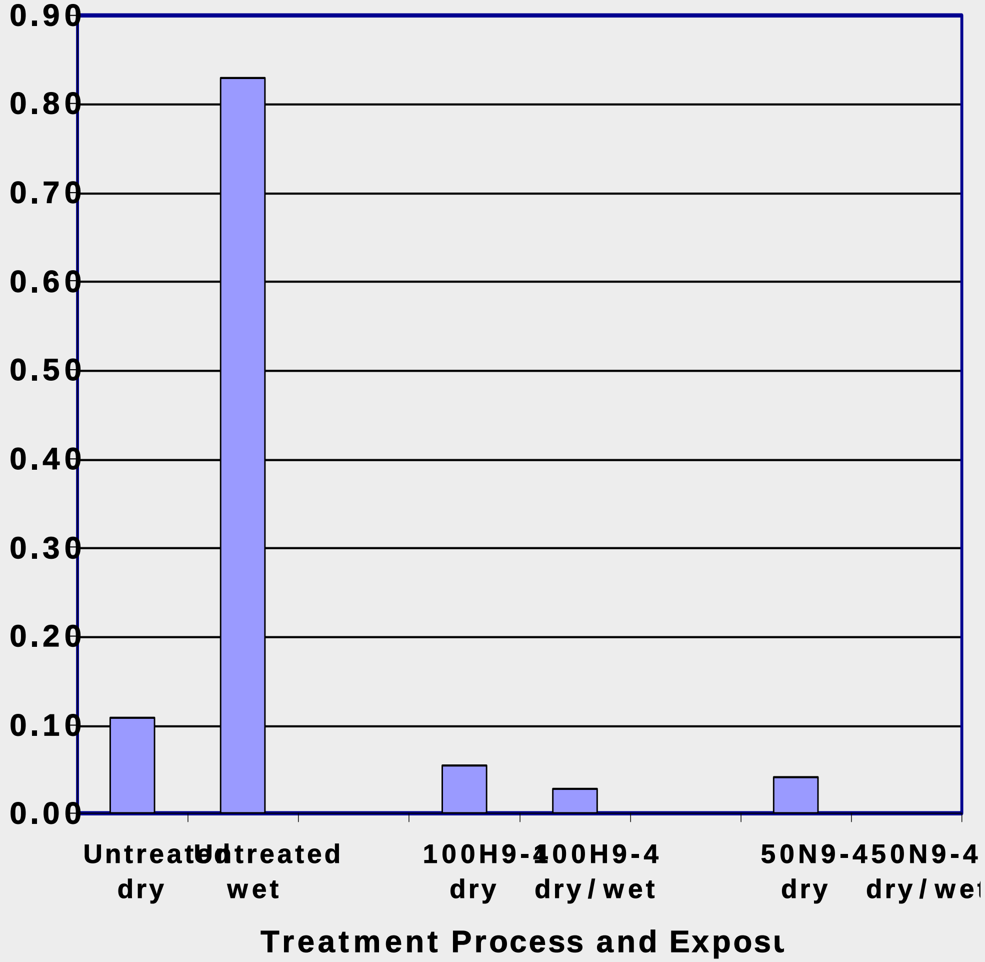
Untreated Metal - 500 hrs at 750°C



Treated Metal - 500 hrs at 750°C



Static Weight Gain



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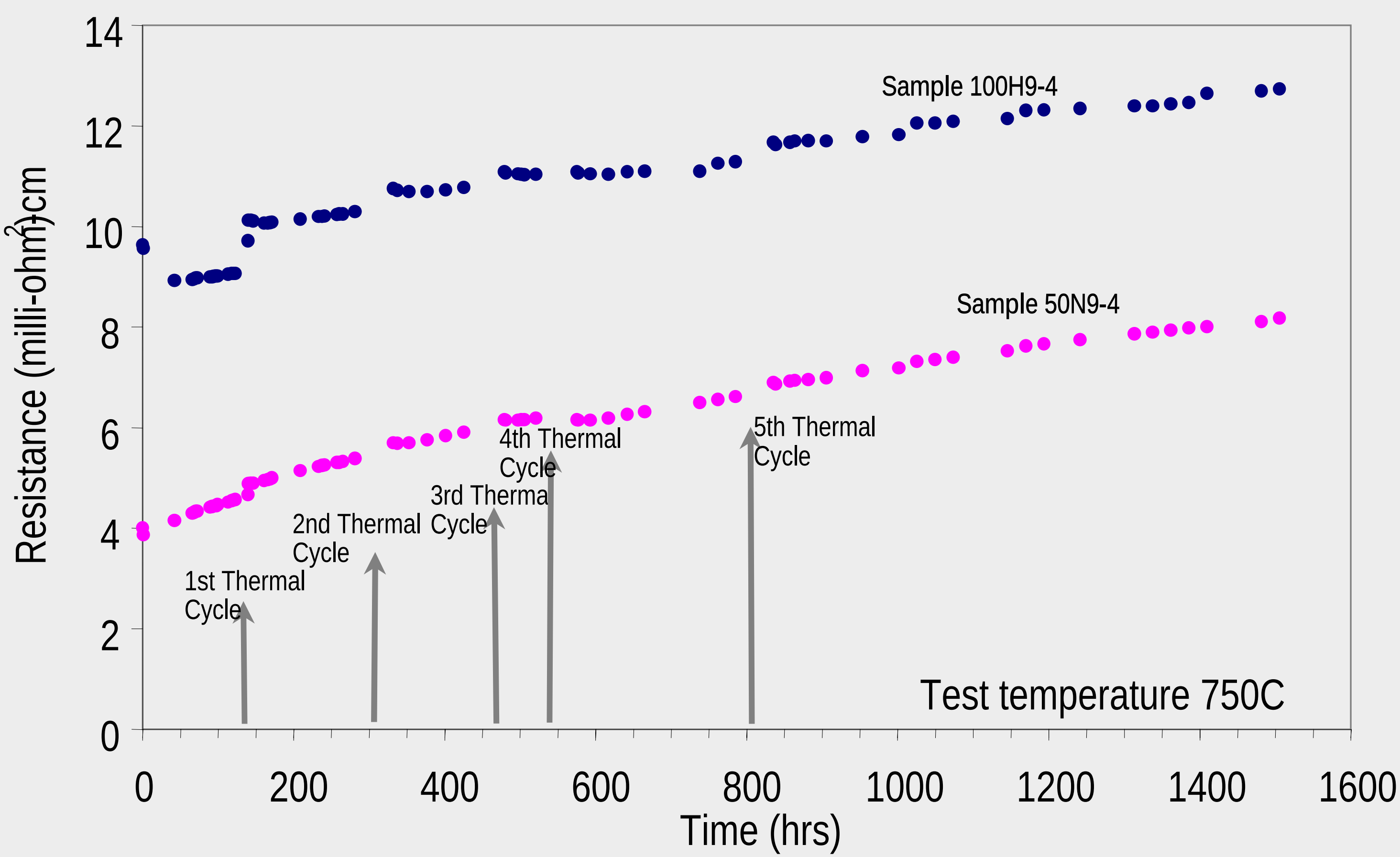
Scale Resistance



Phase I Summary

- Commercial stainless steel characterized for applicability
- Demonstrated an appropriate treatment to achieve
  - Low resistance interface
  - stable morphology
  - Proper scale composition
  - Thermal cycle capability (up to five) demonstrated
- Selected optimization parameters for additional improvements in properties

Applicability to Industrial Teams

- Present approaches by the SECA industrial teams
  - Electrolyte supported co-fired planar
  - Anode supported planar
  - Cathode supported re-designed tubular
  - Anode supported thin cylinder
- Technical applicability
  - Metal interconnects
  - High temperature current collectors, bus bars
- Commercial applicability
  - Low cost materials and processes
  - Process flexibility to suit materials chemistry of mating surfaces

Activities for the next 12 Months

- Additional improvements to pre-treatment process
- Determine scale growth kinetics
- Process development for conductive coating
- Scale - coating interaction study
- Effect of SOFC relevant atmospheres

Optimization Pre-treatment Process

- Objective
  - Selection of optimal pre-treatment process conditions
- Approach
  - Iterative modification of process conditions based on initial and after 500 hour exposure at 750°C (dry & wet air, wet hydrogen)
    - Scale composition - full scale development after pre-treatment
    - Microstructure evolution
    - Interface electrical resistance

Scale Growth Kinetics

- Objective
  - Measure the rate of scale growth by thermogravimetry in air and humidified hydrogen atmospheres
- Approach
  - TGA of baseline and treated samples in relevant atmosphere to establish kinetic parameters

Process for Conductive Coating

- Objective
  - Determine the optimal powder characteristics and process parameters to obtain thin dense coating - Process selection applicable to a variety of powder compositions
- Approach
  - Iterative evaluation of particle morphology, size distribution and specific surface area and deposition conditions.
  - SEM, EDS, conductivity

Scale-Conductive Coating Interaction

- Objective
  - Determine the chemical interaction between the conductive coating and the scale, and the effect on scale growth and morphology
- Approach
  - Scale composition and morphology after 500 hour exposure
  - TGA for scale growth

Evaluation in SOFC Relevant Atm.

- Objective
  - Determine the scale properties at various SOFC relevant atmosphere
    - Scale chemistry, morphology, and adhesion
- Approach
  - Study the effects of
    - Wet air
    - Dual atmosphere
    - Hydrocarbon fuel (simulated reformed methane)
    - S-bearing fuel (up to 5 ppm H_2S)

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Key Tasks for Year 1

Tasks	Q1	Q2	Q3	Q4
1. Optimization of Pre-treatment Process				
2. Determination of Scale Growth Kinetics				
3. Process Optimization for Conductive Coating				
4. Evaluation scale and conductive coating interaction				
5. Evaluation in SOFC Relevant Atmospheres				

Acknowledgement

- Ceramatec team
- DOE-SECA project managers
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- SECA industrial teams