Metal Interconnects for Solid Oxide Fuel Cell Power Systems

SECA Core Technology Program

Ceramatec, Inc.

Supported in part by

DOE-NETL

Presented at

Boston, MA

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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

- **Chromia formers preferred to 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 in scale
  - Low cation (metal) and anion (oxygen) diffusivity
  - Good adhesion ('native' scale)

- Application of conductive layers
  - Application techniques
    - Thermal spraying (INEEL FWP)

Approach

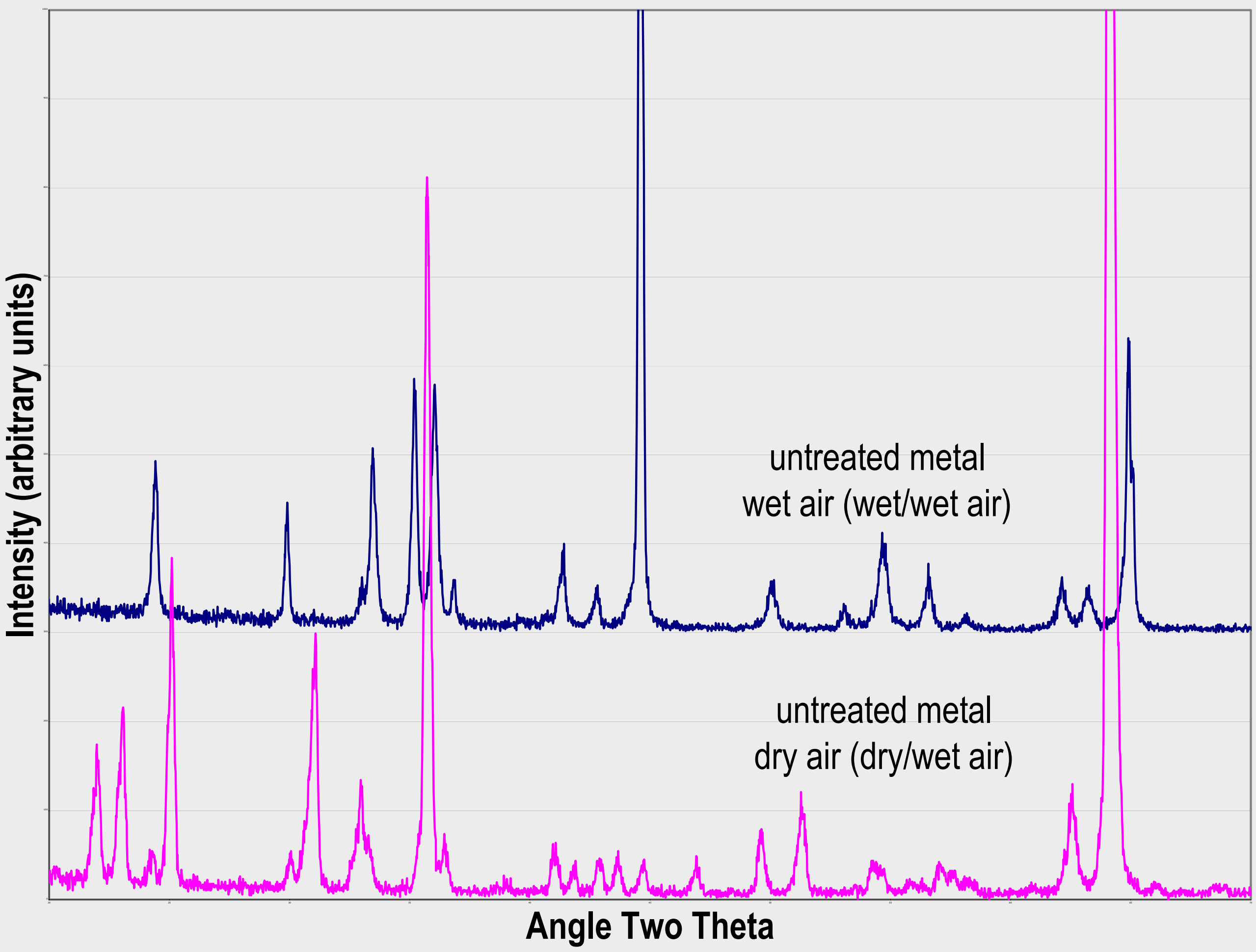
- Alloy Selection (Fe-Cr based ferritic SS)
  - CTE Match, Conductive scale (chromia former)
  - Choice of minor alloying elements

- Surface Treatment & Oxidation
  - Growth of selective oxide scale
    - Control P, T, X_i and t
  - Scale characterization

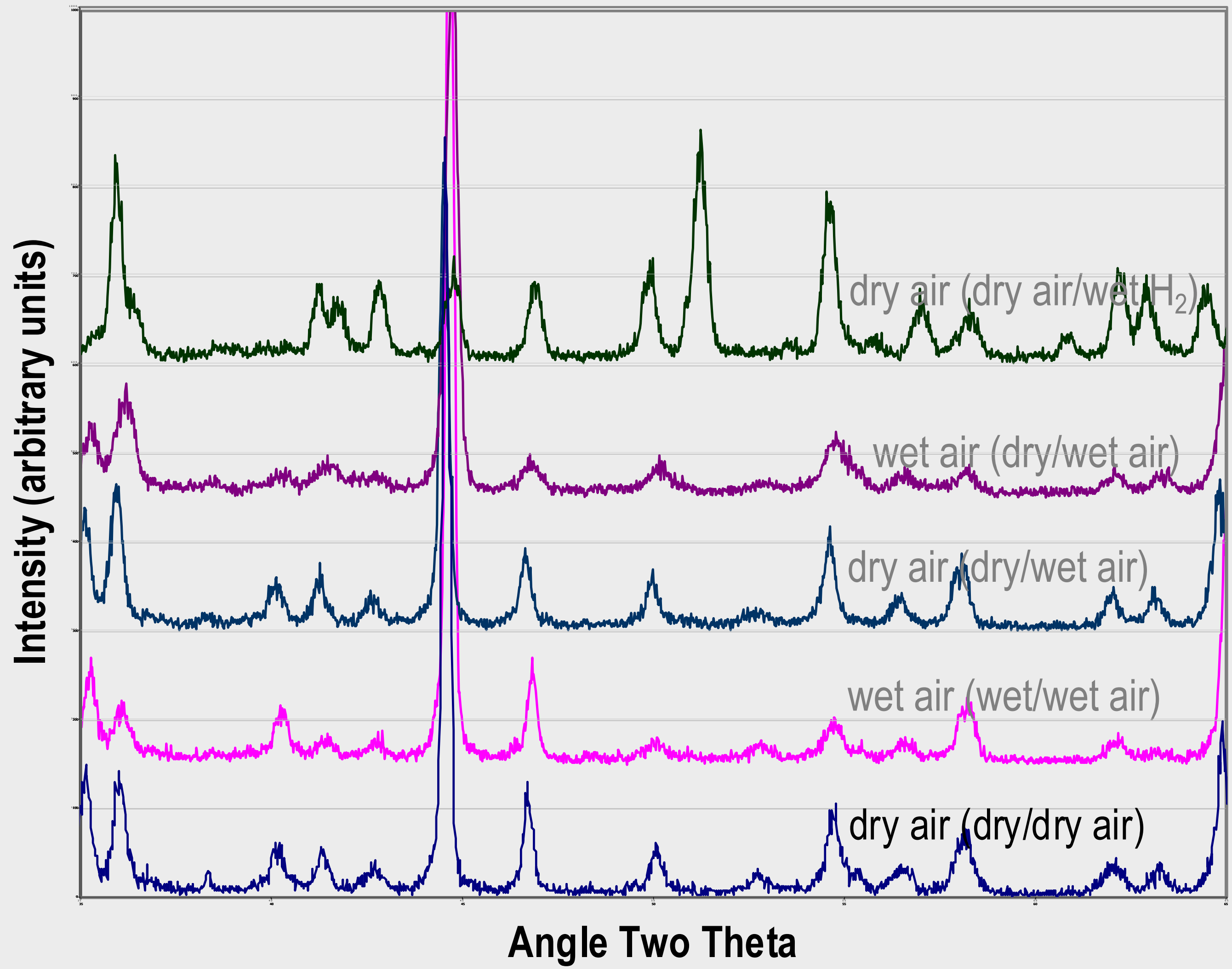
Assessment Criteria

- Weight gain with time at temperature
- Scale thickness, morphology, composition
- Electrical resistance with thermal cycles
- Exposure to relevant atmospheres

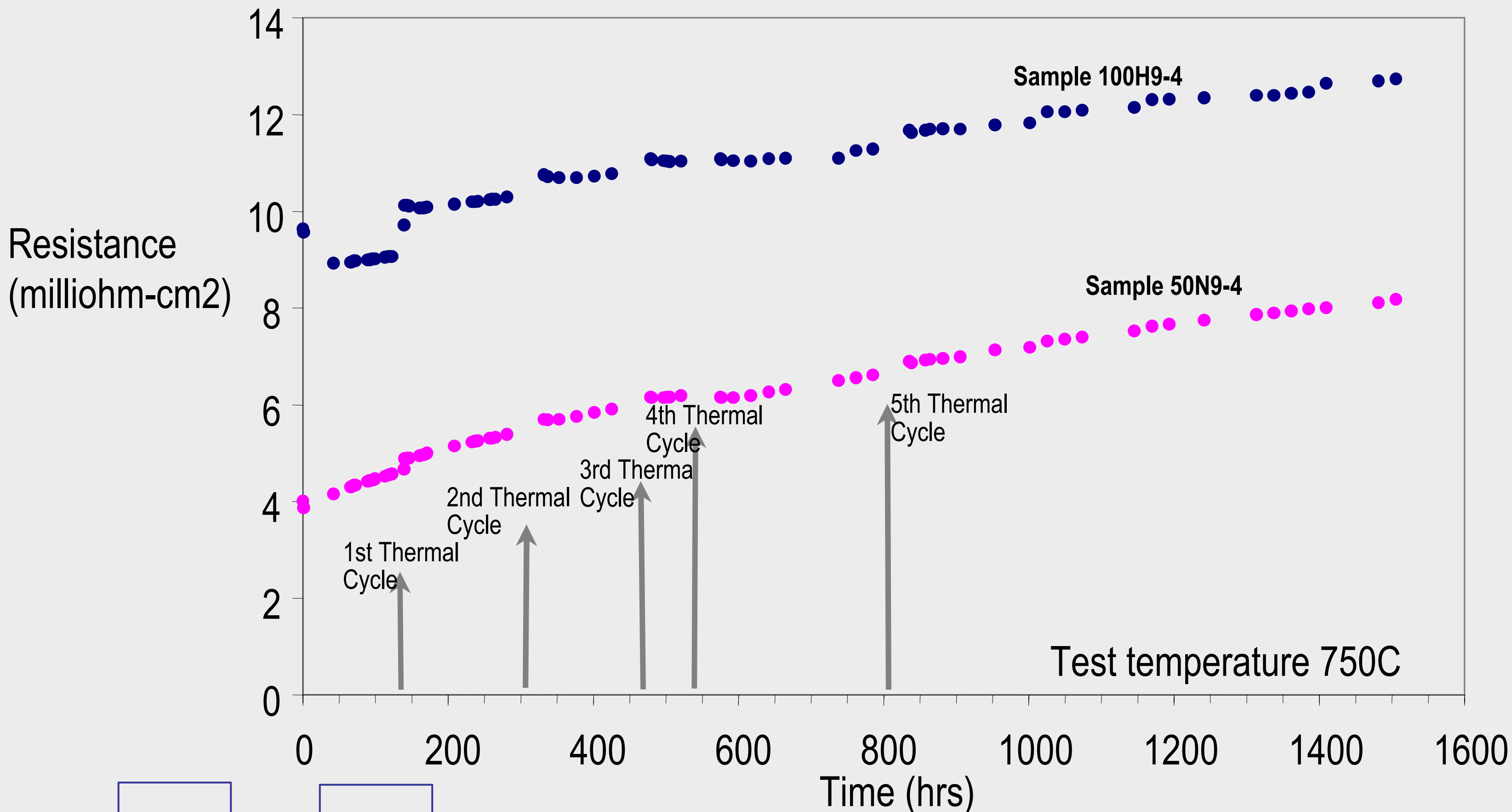
Untreated Metal - 500 hrs at 750°C

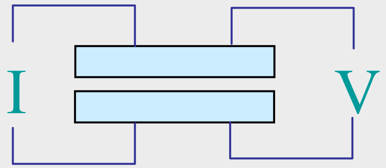


Treated Metal - 500 hrs at 750°C

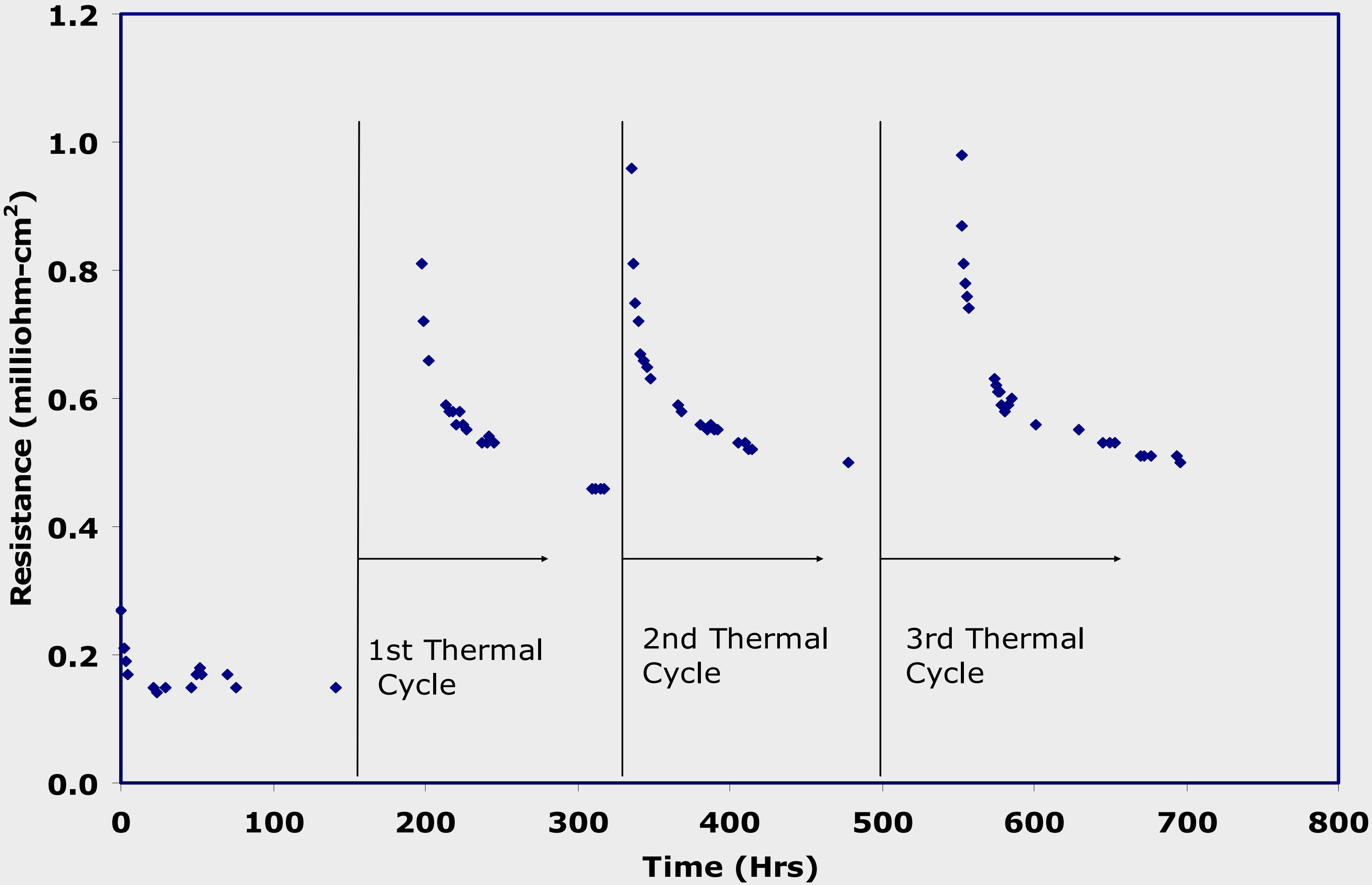


Scale Resistance in Air (coupon couples)

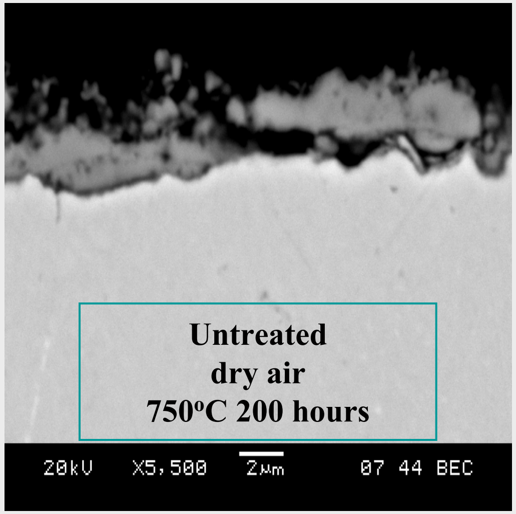


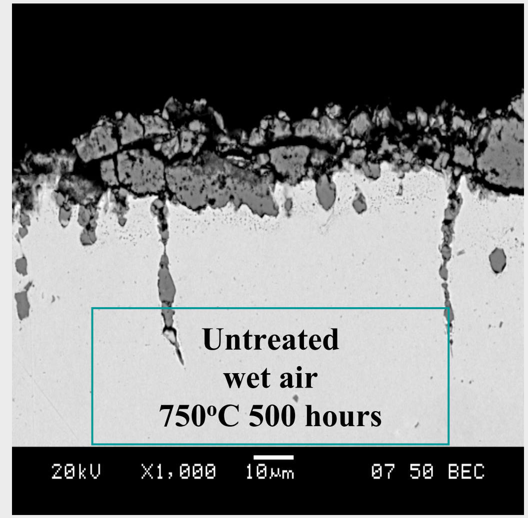


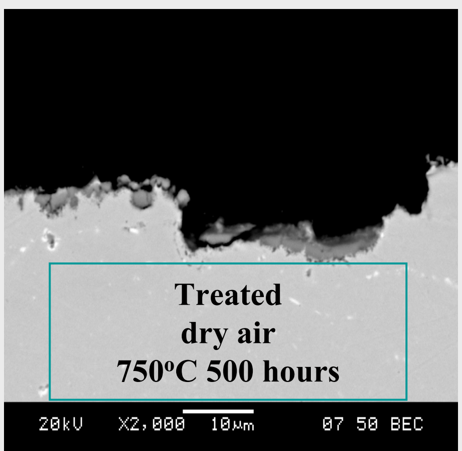
Scale Resistance in H_2/H_2O

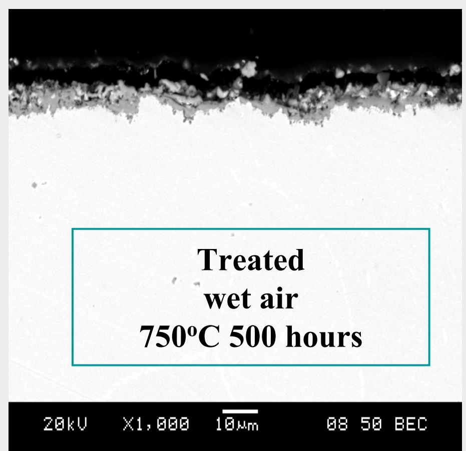


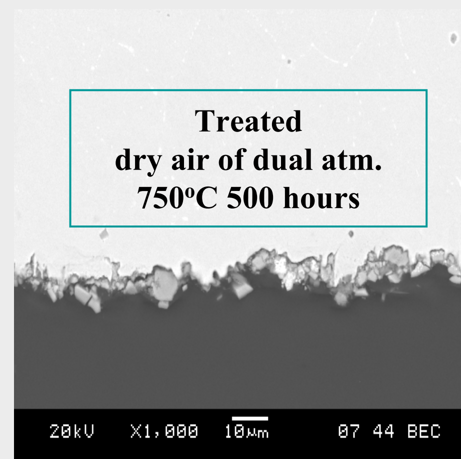
Scale Morphology











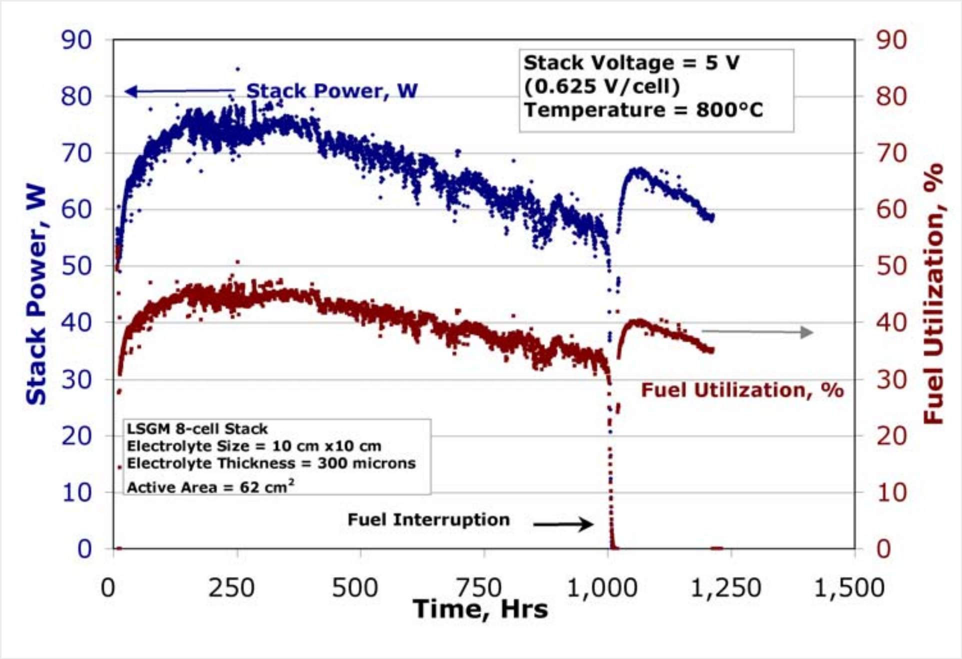
Phase I Summary

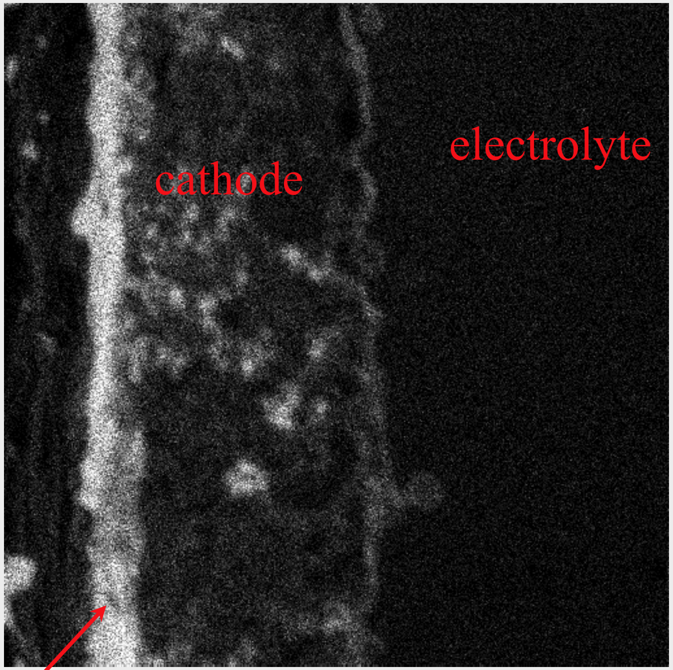
- Commercial stainless steel characterized for applicability
- Demonstrated an appropriate treatment to achieve
  - Low resistance interface
  - stable morphology
  - Proper scale composition
  - Thermal cycle capability (up to five) demonstrated
- Selected optimization parameters for additional improvements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

Phase II Tasks

- Treatment process optimization
- Scale growth kinetic parameter evaluation (TGA)
- Contact layer
  - Application process
  - Chemical interaction
- SOFC relevant atmosphere
  - Effects carbon species, dual atmosphere, sulfur
- Cr evaporation

Stack Evaluation (SBIR Project)





Sr,Cr
rich

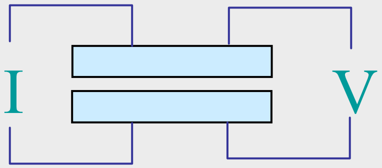
- A treatment process with low resistance in coupon tests evaluated (screen printed contact layer)
- Post-test: Sr-Cr rich phase on La(Sr)CoO_3 cathode

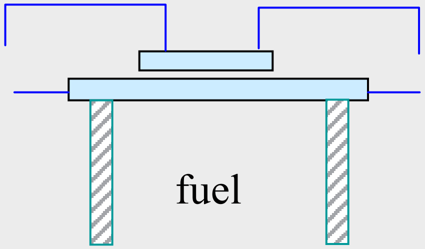
Phase II Evaluations

- Approaches to surface treatment optimization
  - Modify intrinsic scale
    - surface treatment and thermal process
    - Objective: Limit scale growth
  - Apply extrinsic layer
    - low Cr activity composition (~$LaCrO_3$)
    - Objective: Limit Cr evaporation
  - Combine the two layers
    - graded composition

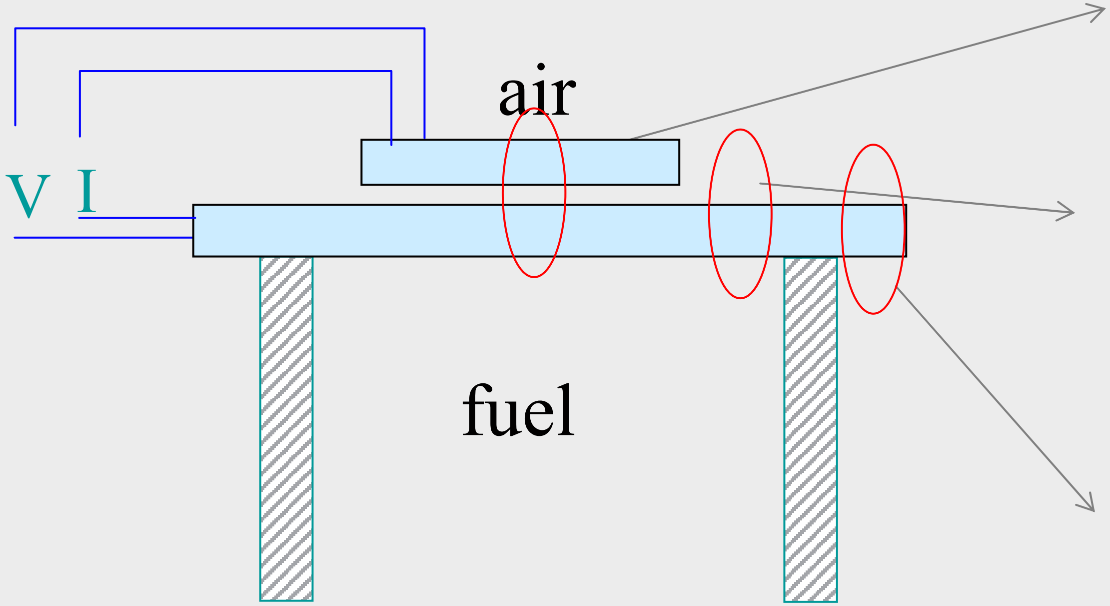
Experimental Arrangement

TGA	Coupon Couples	Dual atm. couples	Stack
• Single atmosphere • No contact / electrode layers • No current • Isothermal	•Single atmosphere •Contact layer •Intermittent current •Isothermal	• Dual atmosphere • Continuous current • Contact layer • Isothermal	• Dual atmosphere • Continuous current • Contact/electrode layers • In-plane thermal, current density gradients





Dual atmosphere couples



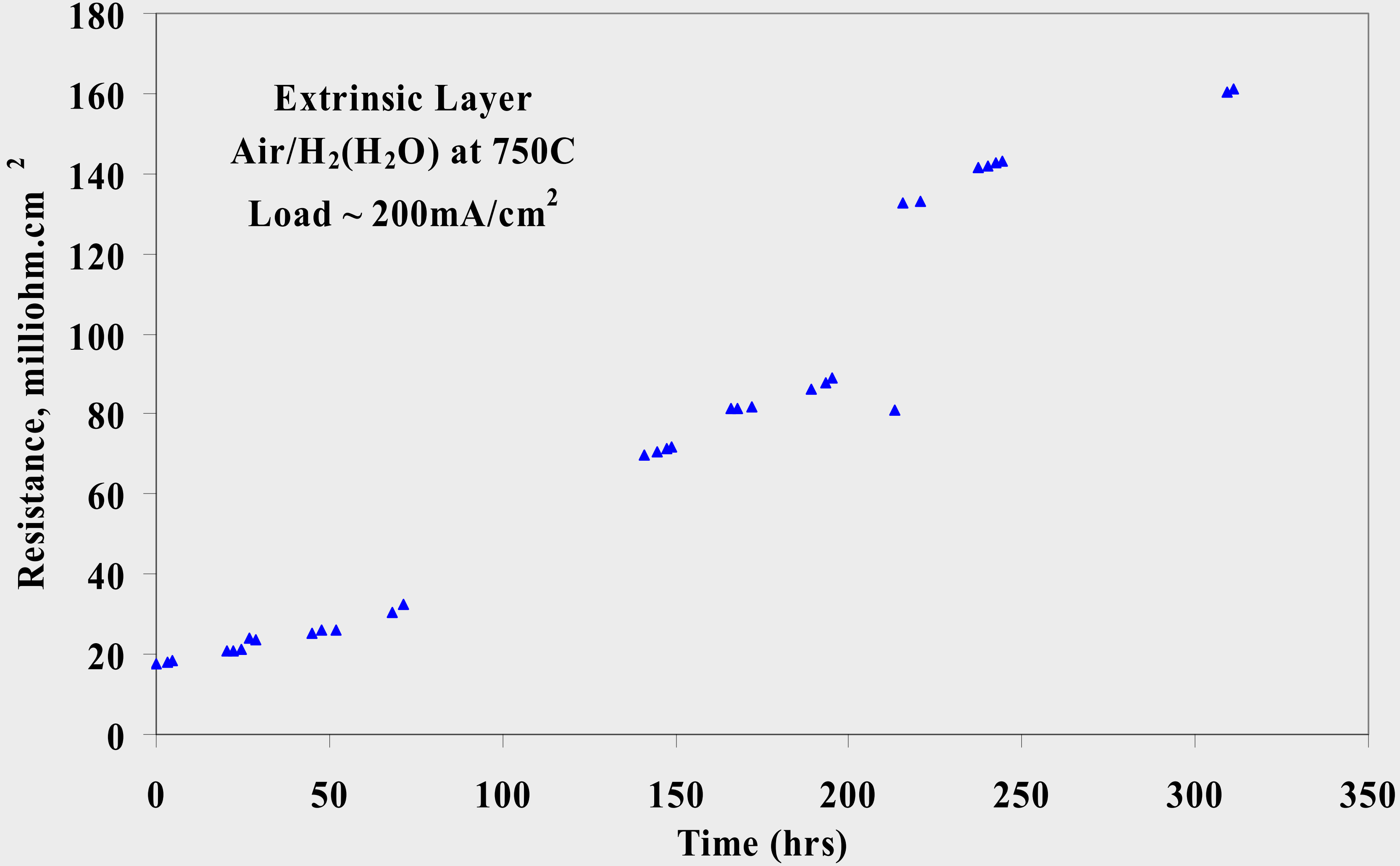
- Dual atmosphere
- Contact layer
- Continuous load (constant current)

- Dual atmosphere
- No contact layer
- No current

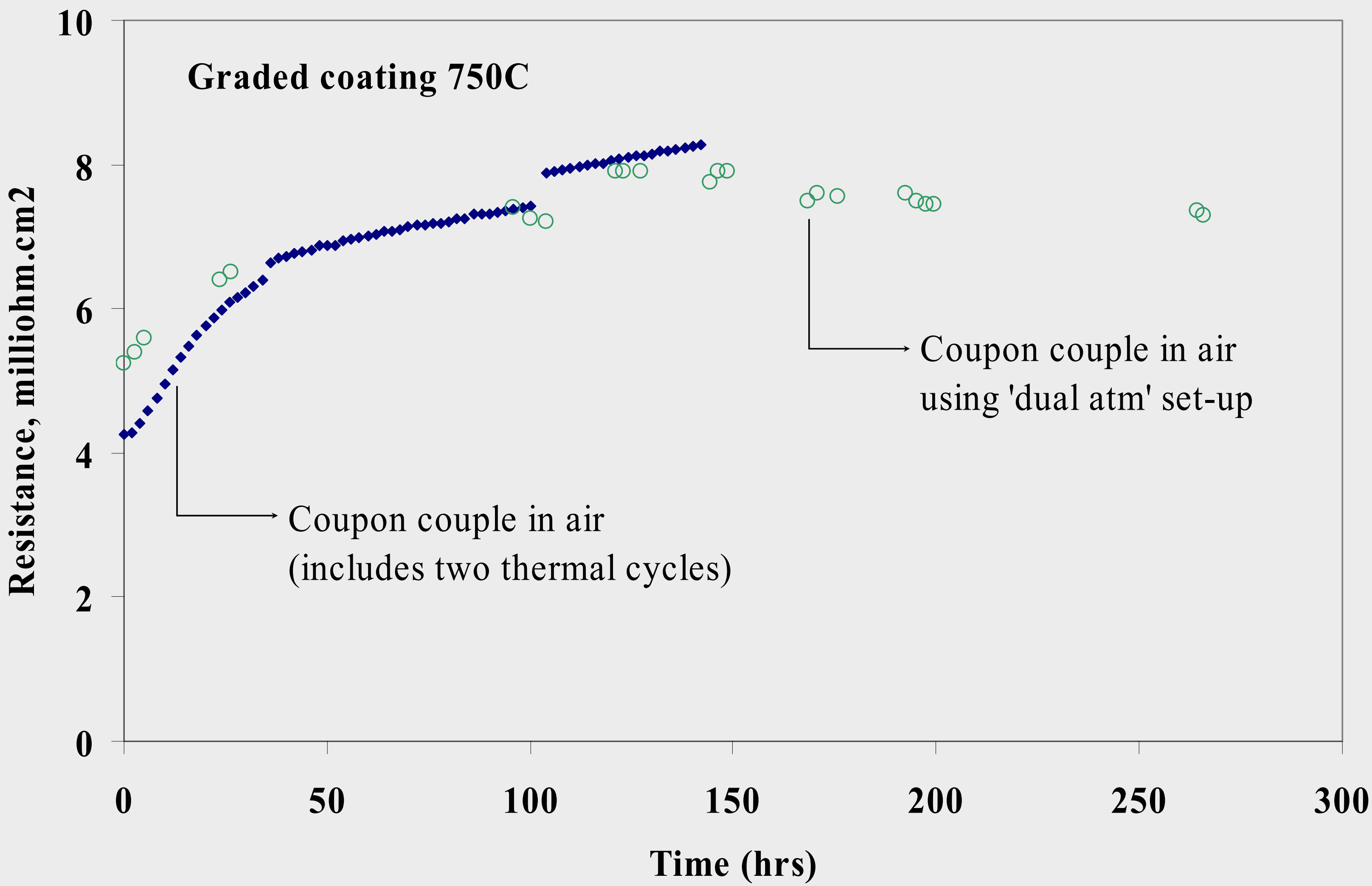
- Air atmosphere
- No contact layer
- No current

1x1 cm coupon on a larger (3.5x3.5 cm) blank
Identical treatment on mating surfaces
Contact layer: cobaltite

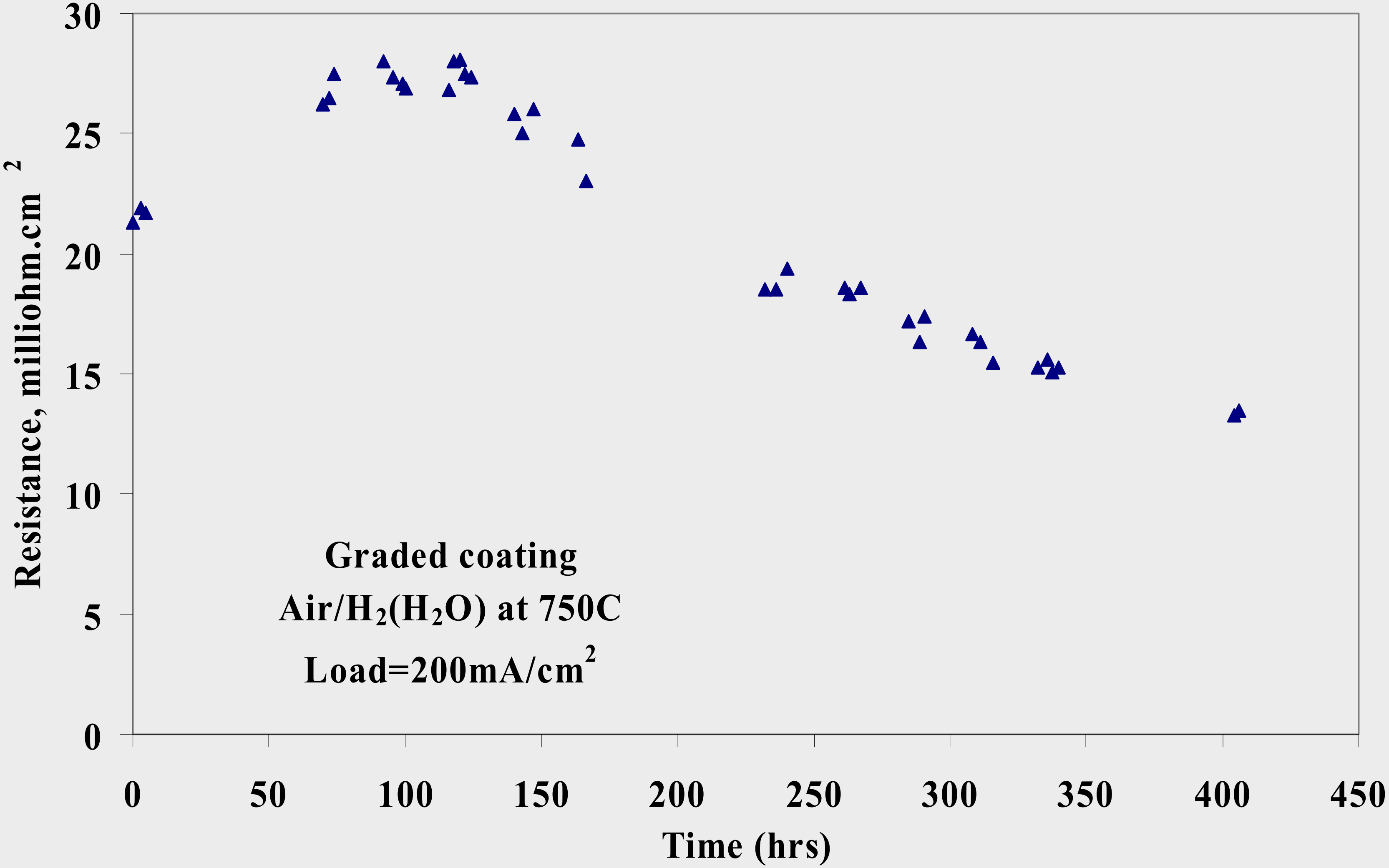
Extrinsic Layer - Dual atmosphere



Rig Validation: Graded Coating in air



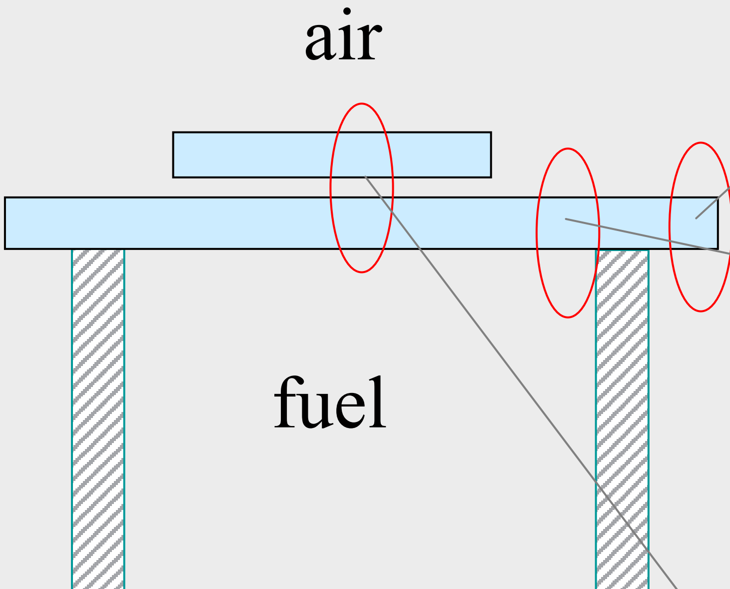
Graded Coating: Dual atmosphere

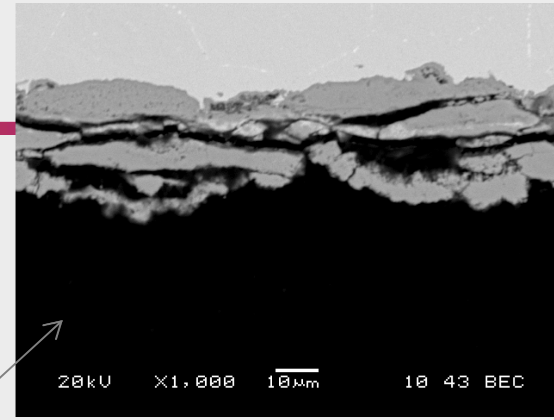


Extrinsic layer

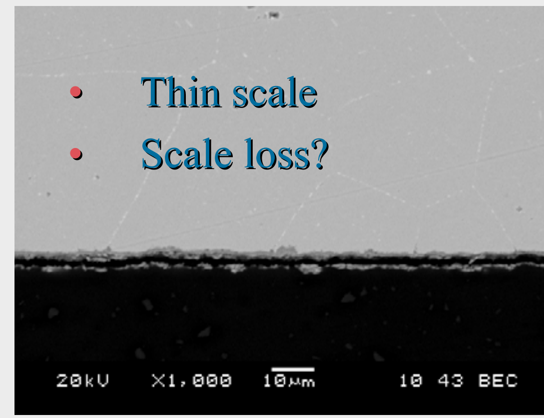
200 mA/cm^2, ~350 hrs

140 milliohm.cm^2

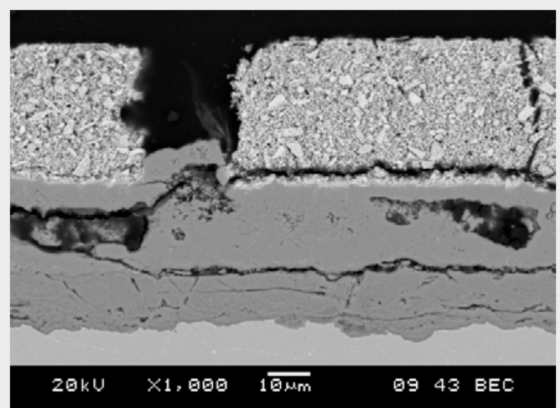




- Thick scale
- Poor adhesion



- Thin scale
- Scale loss?

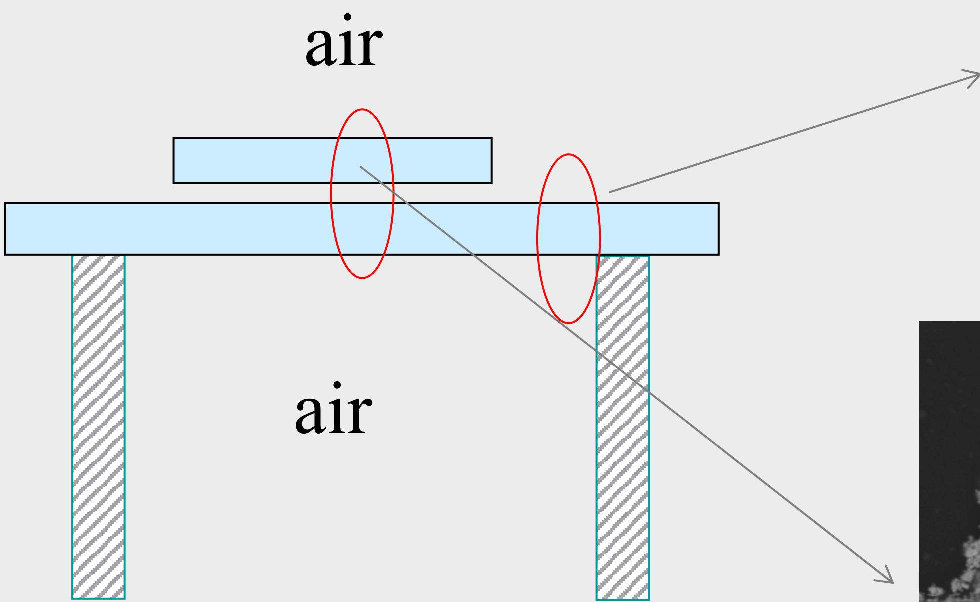


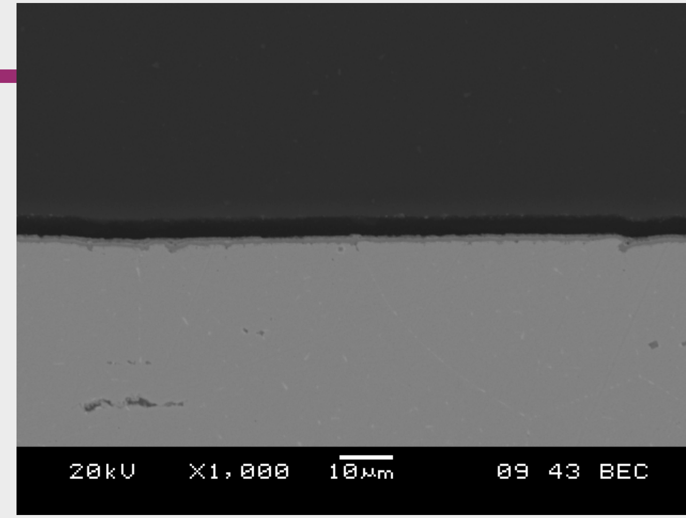
- Thick scale under contact layer
- Sr-Cr rich interface

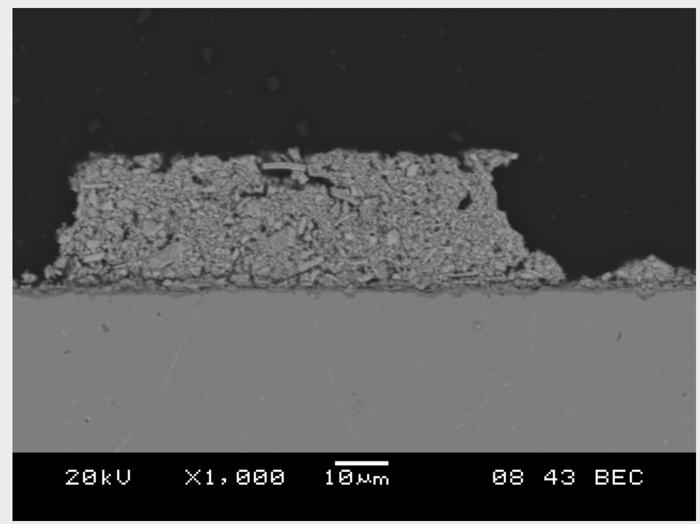
Graded Coating

200 mA/cm^2, ~300 hrs

7 milliohm.cm^2



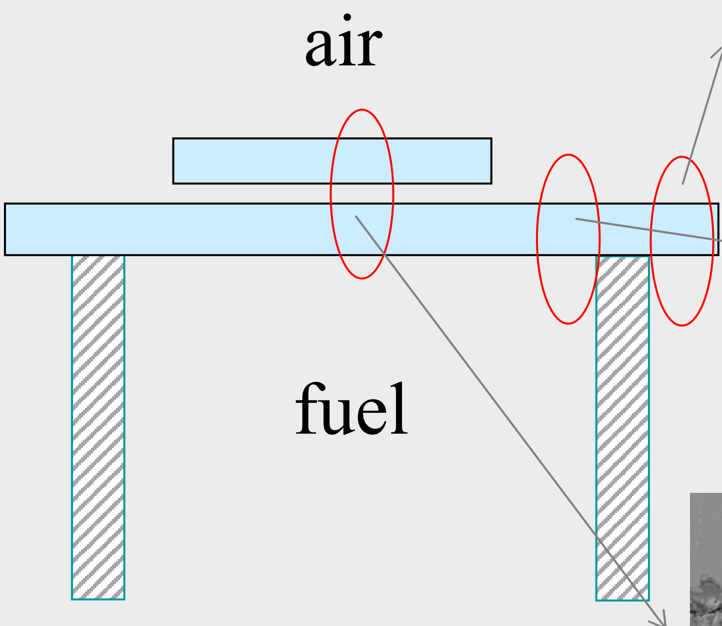


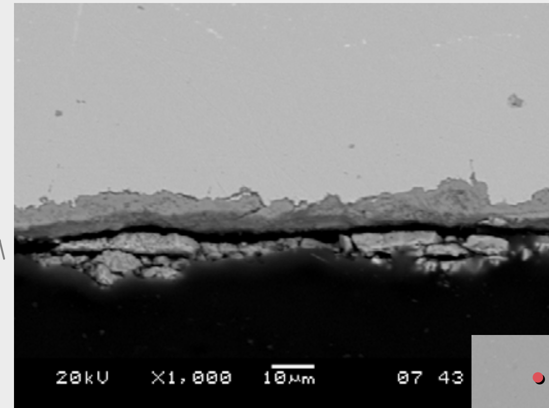


- Thin scale (1 µm) in both regions
- No Sr-Cr rich phase

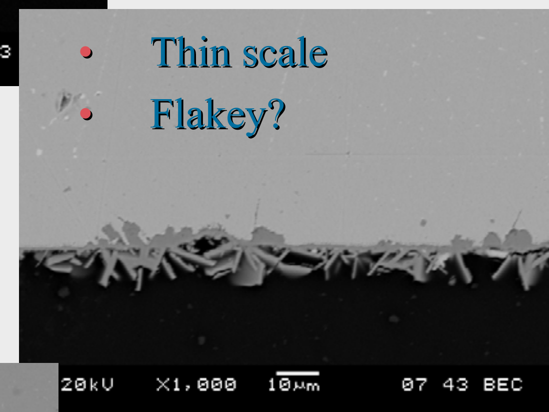
Graded coating - dual atm.

200 mA/cm^2, ~400 hrs
15 milliohm.cm^2

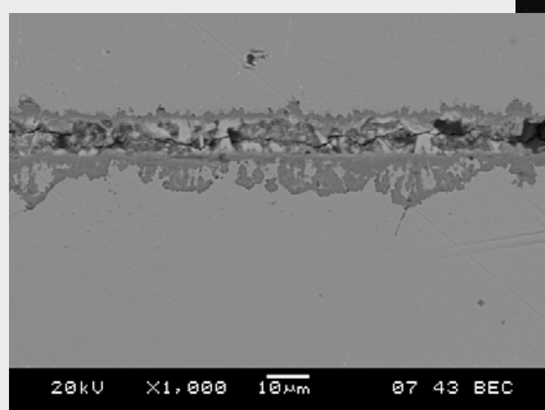




- 6 µm scale
- Influence of dual atm. away from the region?



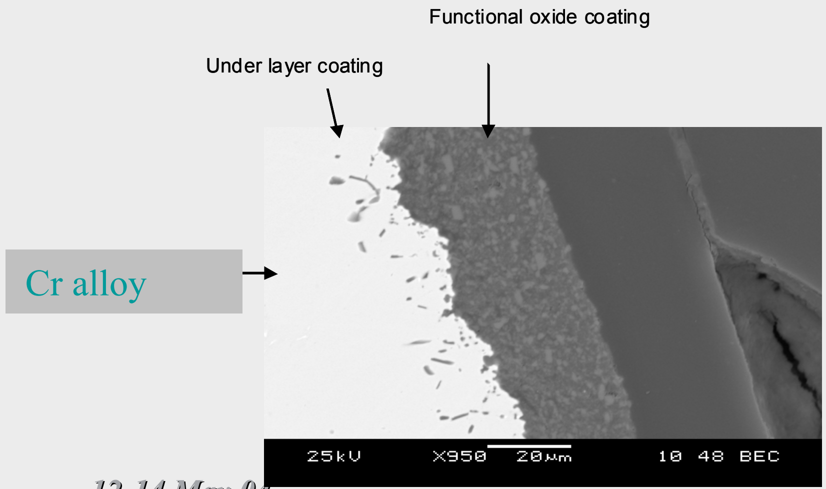
- Thin scale
- Flakey?



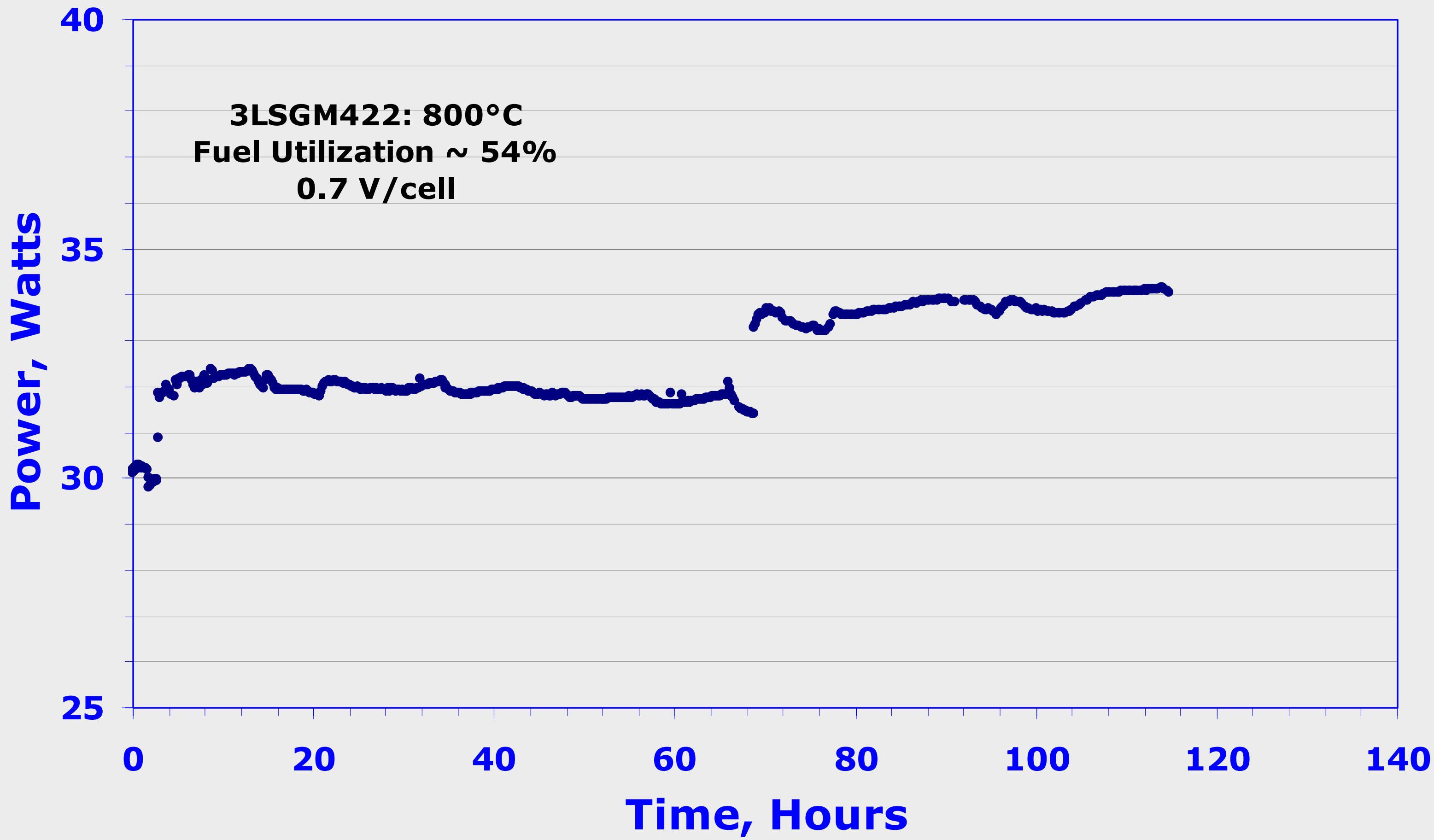
- Thin scale under contact layer
- No Sr-Cr phase at the scale

LSGM Short Stack Test (SBIR)

- Changes Made
  - Modified surface treatment of interconnect (low resistance in air and not optimal in dual atm)
  - Lower Sr-containing contact layer
  - Coated fuel and air feed tubes; metal manifolds
    - Environmental Barrier Coating from DOE-SBIR



3-Cell LSGM Stack



- 500 hour test planned

Summary

- New test arrangement
  - Allows resistance measurement in dual atm. exposure
  - Allows continuous load
- Graded coating provides low resistance and thinner oxide scale in initial tests
- Additional work planned
  - Effect of coating variations
  - Effect of current density
- Stack test validation in parallel programs

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
  - Graded coating
- Determine scale growth kinetics
  - TGA - a new unit with controlled atmosphere capability installed this month
- Process development for conductive coating
  - FWP at INEEL
- Scale - coating interaction study
- Effect of SOFC relevant atmospheres
  - Hydrocarbon fuel (simulated reformed methane)
  - S-bearing fuel (up to 5 ppm H_2S)

Acknowledgement

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