Performance Degradation of SOFC

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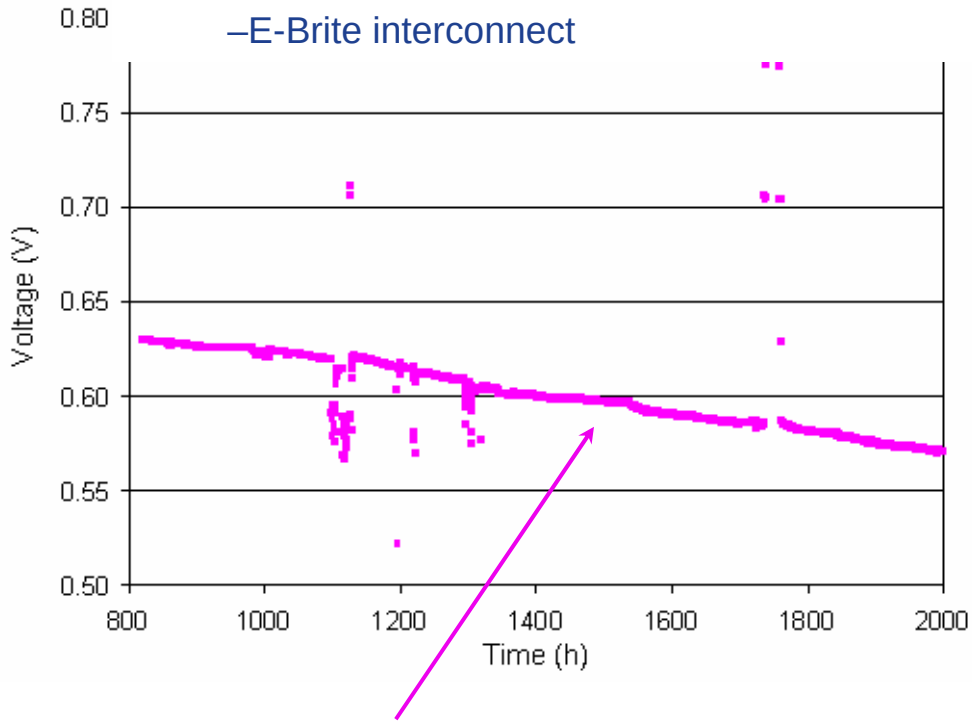
Degradation in SOFC

- Ongoing steady-state reduction in power output at constant operating conditions
- Excluded in current discussion:
  - Transient beginning-of-life performance losses
  - Losses from thermal or power cycling
- Beginning-of-life conditioning is convoluted with degradation

4 " circular cell module @ 800 C in H_2 fuel:
–LSM/YSZ cathode, Ni/YSZ anode, YSZ electro
–E-Brite interconnect

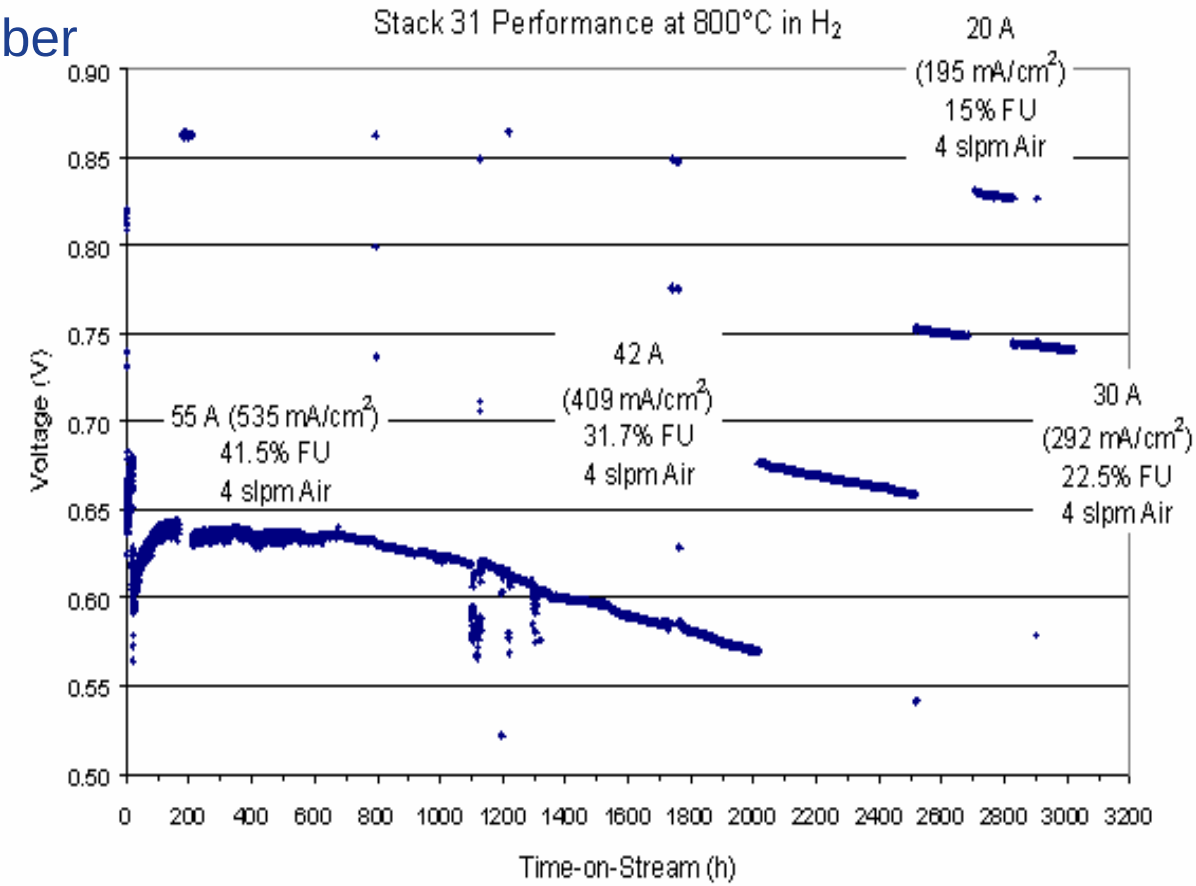


Cell performance degradation under constant-current condition

Factors Affecting Degradation

Performance degradation rate is affected by number of factors including:

- Operating Conditions
  - Current Density
  - Voltage
  - Air Utilization
  - Fuel Utilization
- Materials & Designs
  - Interconnect
  - Cathode and Anode
- Environment
  - Temperature
  - Pressure
  - Gas composition and contaminants



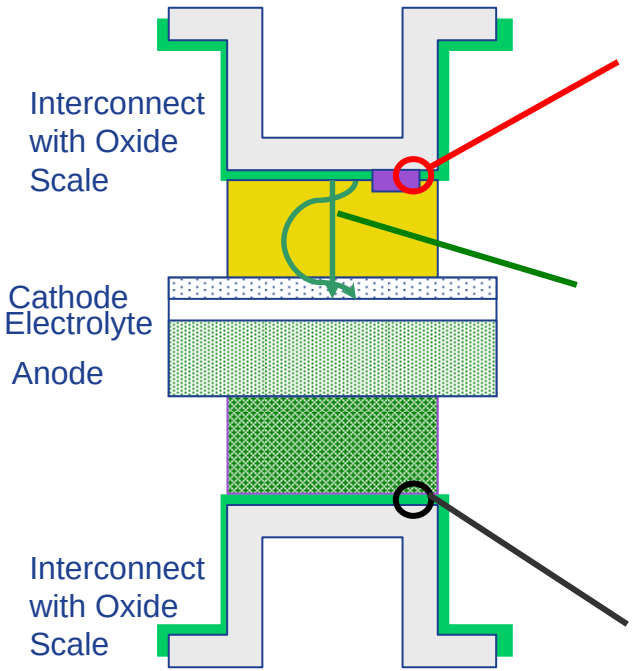
Key Degradation Mechanisms

Increase Resistance

- Interconnect Oxidation
- Interfacial Reactions
- Loss of Bond/contact

Reduce Activity

- ✓ Chromium Cathode Poisoning
- Electrode Coarsening
- Electrolyte Aging
- Coking Deactivation of Anode

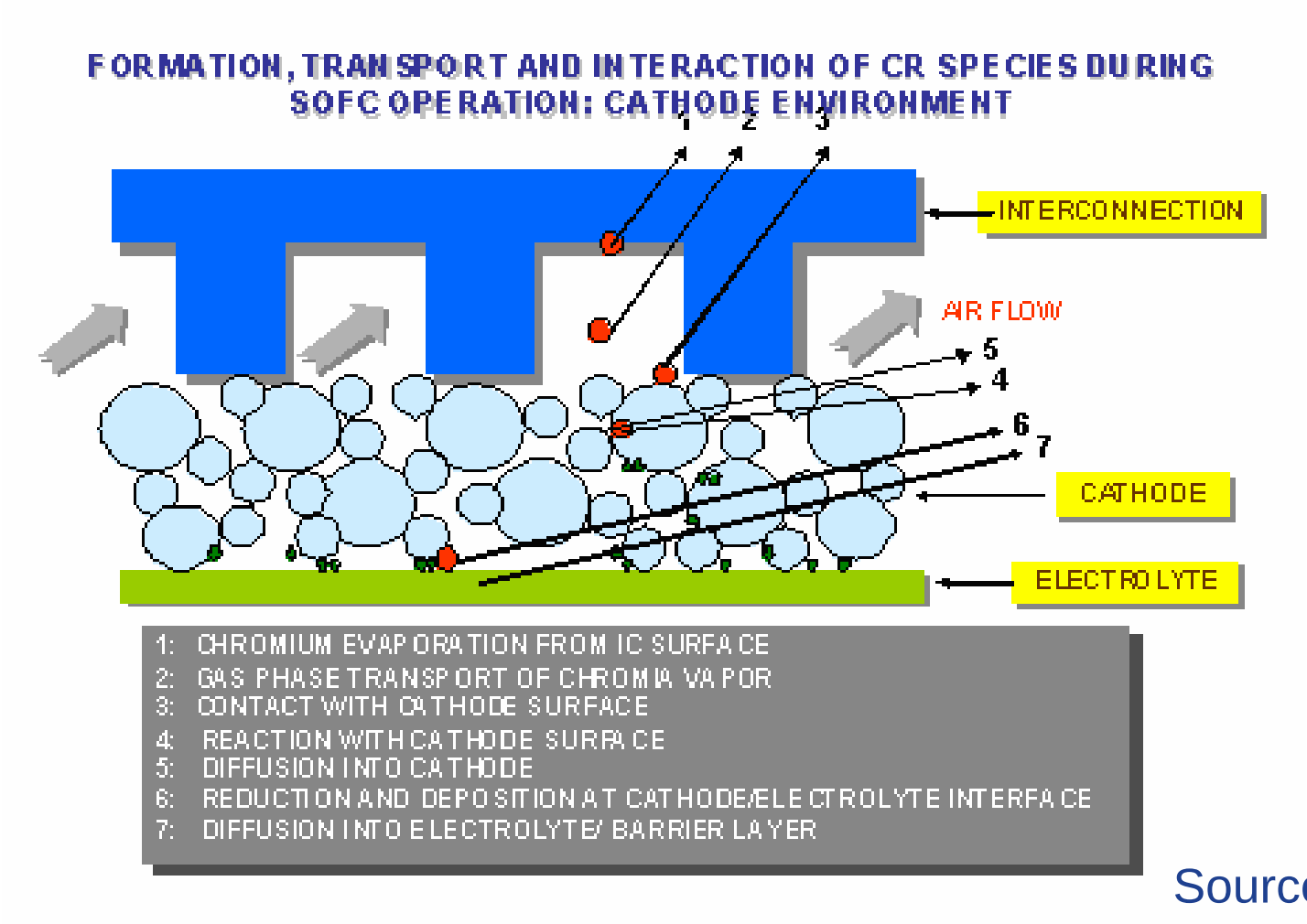


3. Reactions between interconnect and cell material can increase resistance

2. Cr transport to cathode-electrolyte interface: reduces electrochemical activity

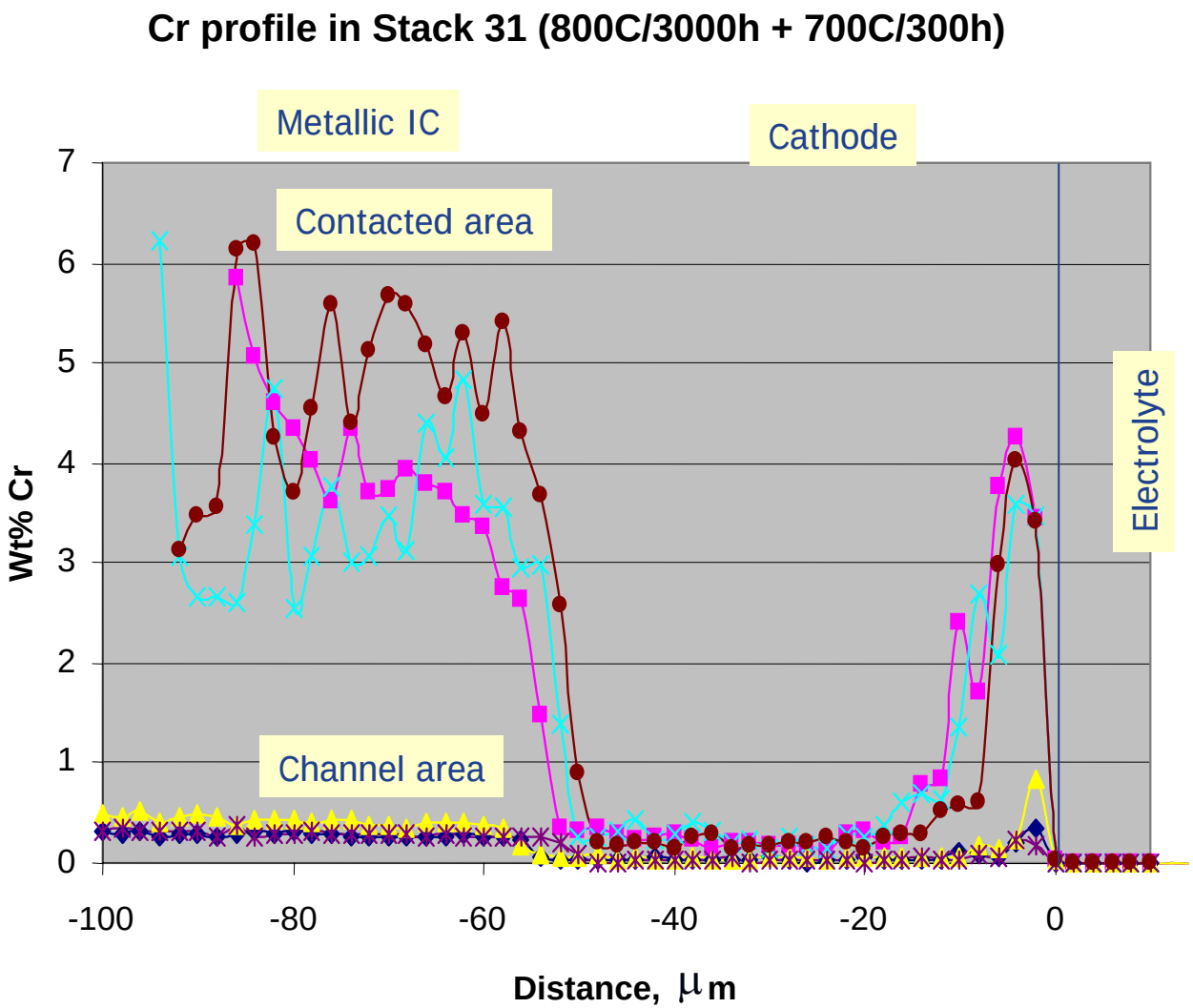
1. Oxide scale increases electrical resistance

Potential Steps in Cr Poisoning of SOFC Cathodes



Source: PNNL

Chromium Deposition in SOFC Cathodes



- 4+ wt.% Cr at cathode-electrolyte interface
- Higher Cr concentration at contacted areas
- Less deposition observed in 700 C experiments

GE-PNNL-ANL Joint Project

Objectives

- Determine under what conditions, if any, chromium transport has a detrimental effect on LSM-based cathodes
- Determine if the Cr transport is predominantly vapor phase and/or solid state
- Determine nature of Cr compounds formed at interfaces and correlate Cr observed at interfaces vs. observed performance degradation (if any)

Experiments – Common Basis and Plan

- Basis and Common Experimental Conditions
  - Common cell test vehicle
  - InDEC cells, E Brite and/or Au interconnects
  - Identical experimental parameters
    - air and fuel flow rate,
    - temperature,
    - Other test parameters such as current densities etc.

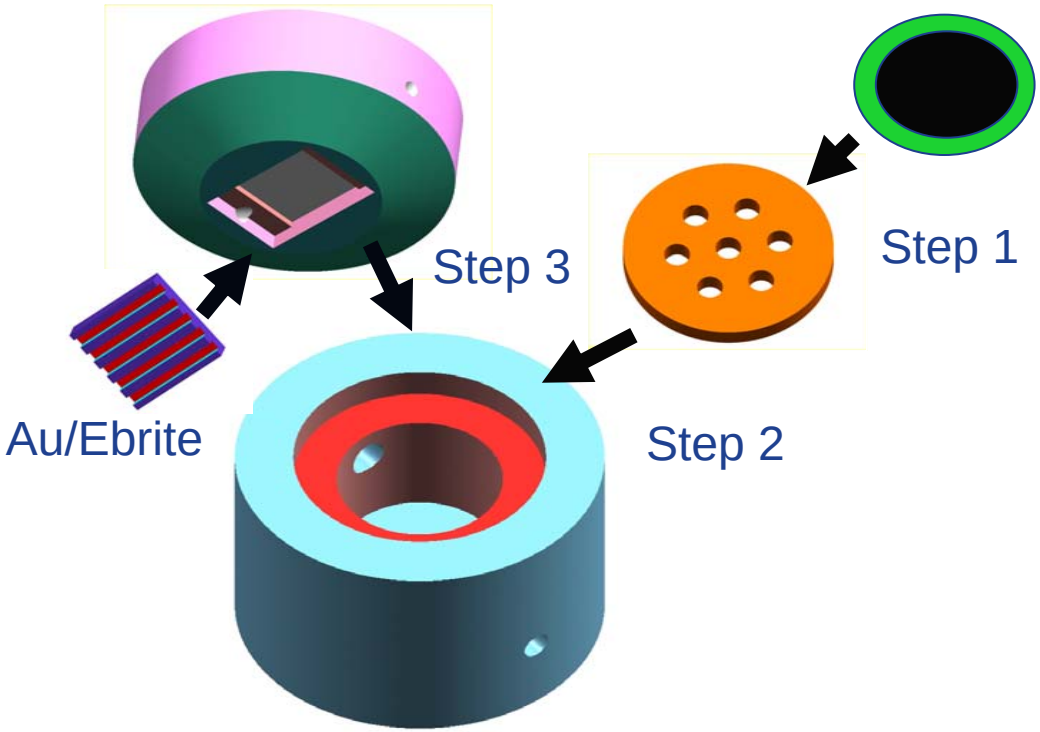
- Degradation tests under realistic stack conditions
  - Uncovered E Brite interconnects (GE)
  - Au IC, Cr vapor dosing realistic conc. (PNNL)
  - Preferentially covered E Brite interconnect flowfields (ANL)

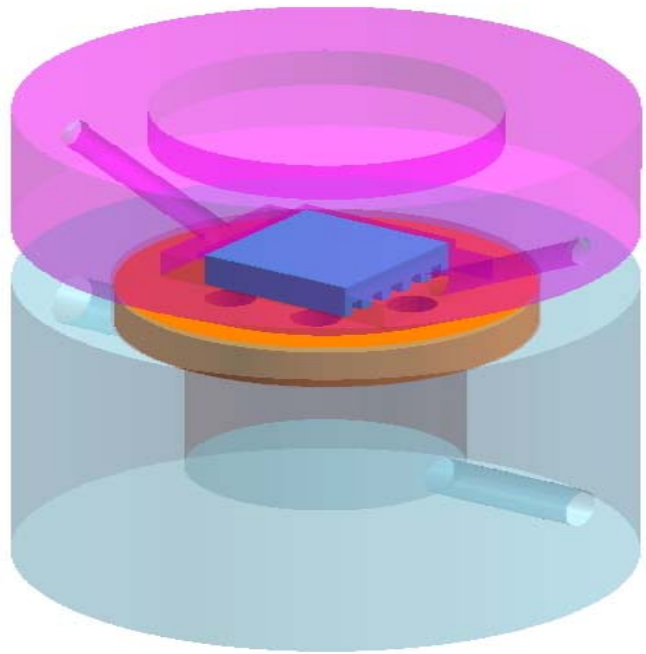
- Analysis

  - TEM/SEM/EDS - conc. of Cr at channels and ribs cathode areas

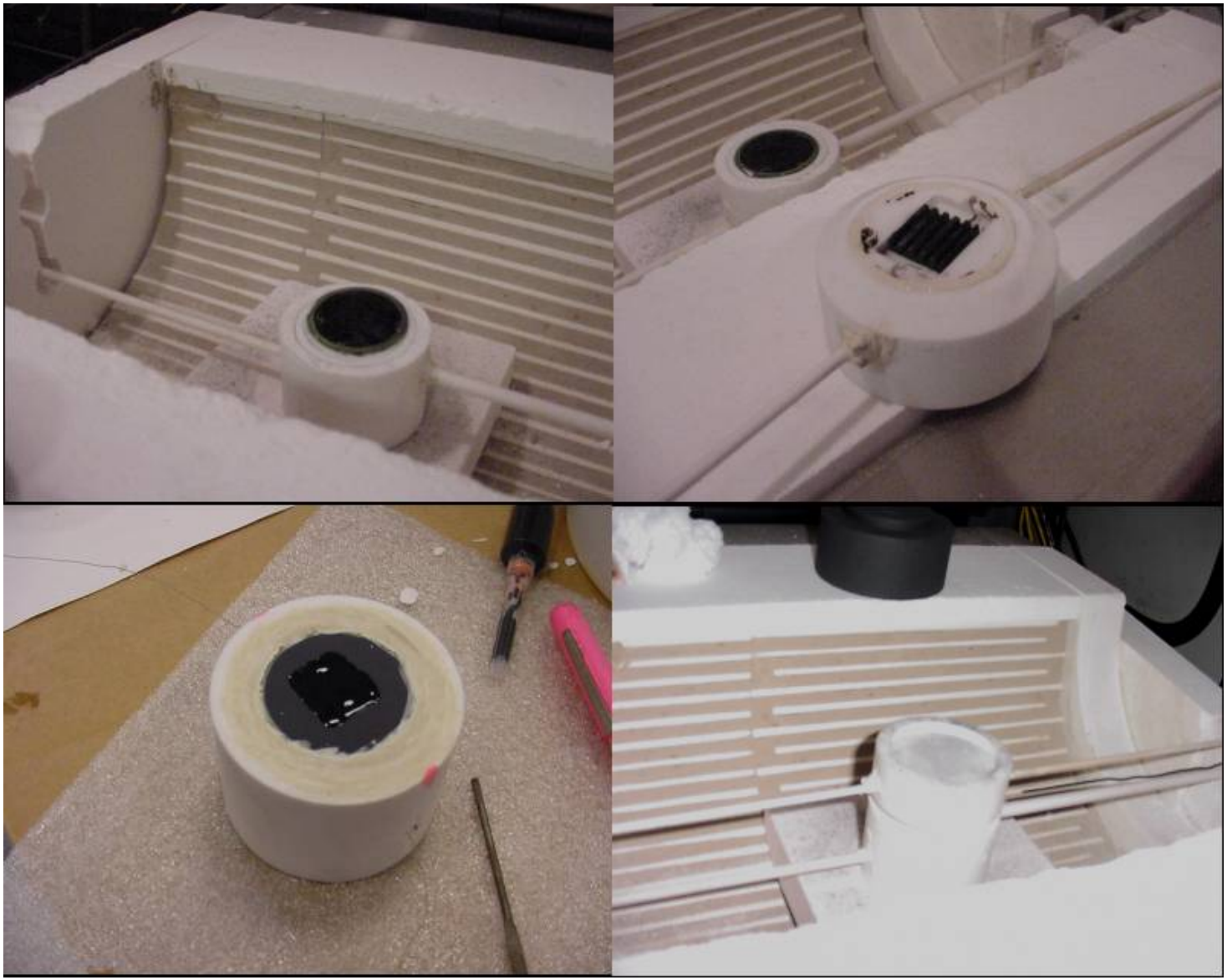
  - Auger, XPS, SIMS and Rutherford back scattering (as appropriate) – on cathode top surface

Assembly of Ceramic Fixture

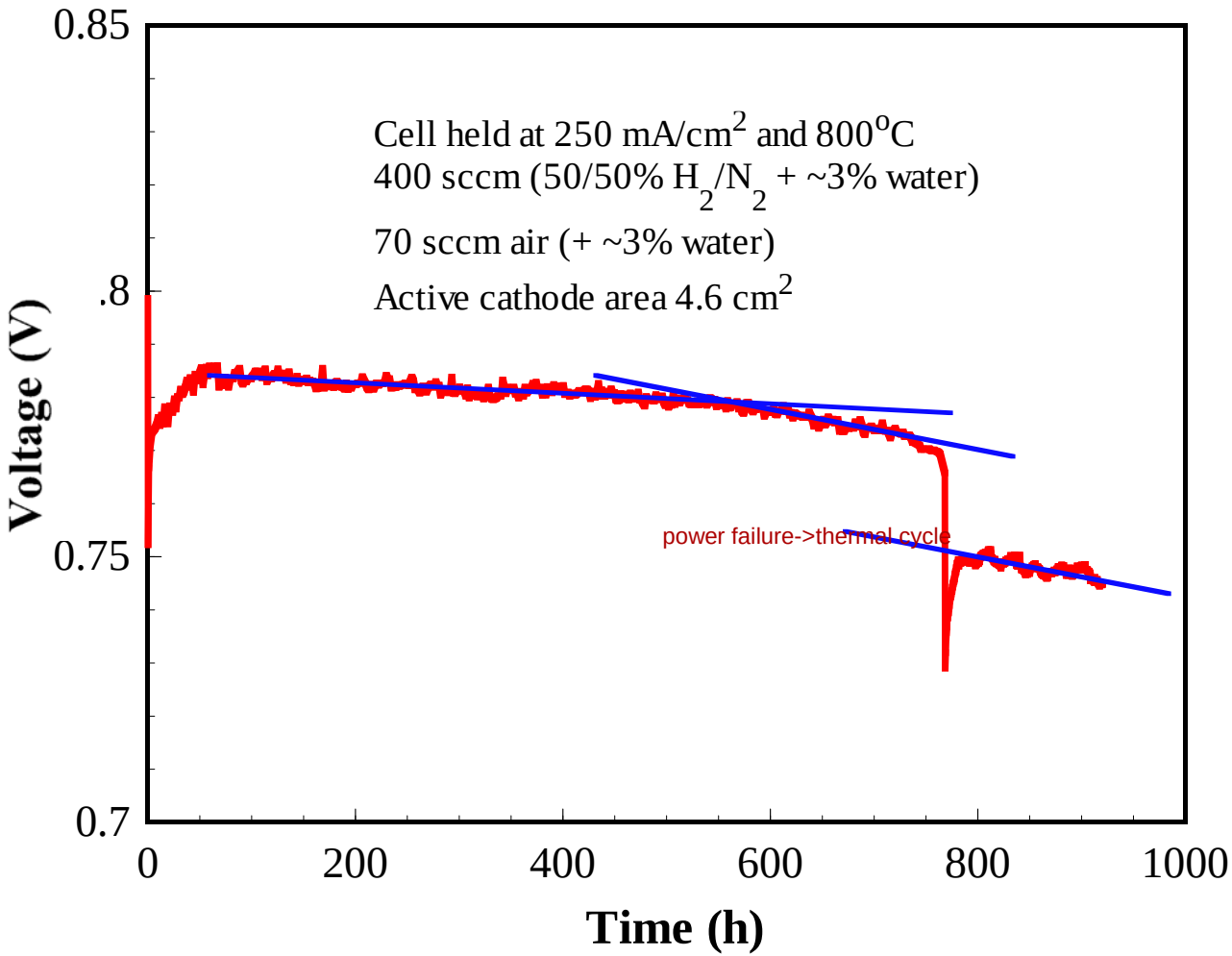


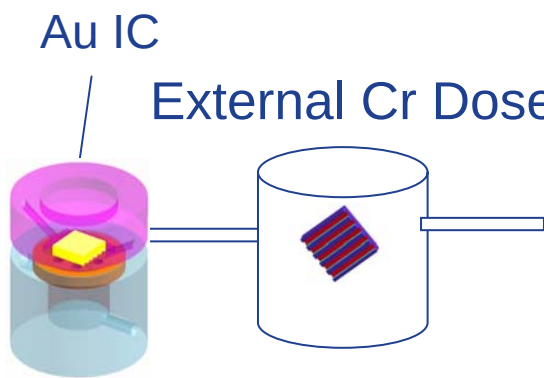


Assembly of Ceramic Fixture



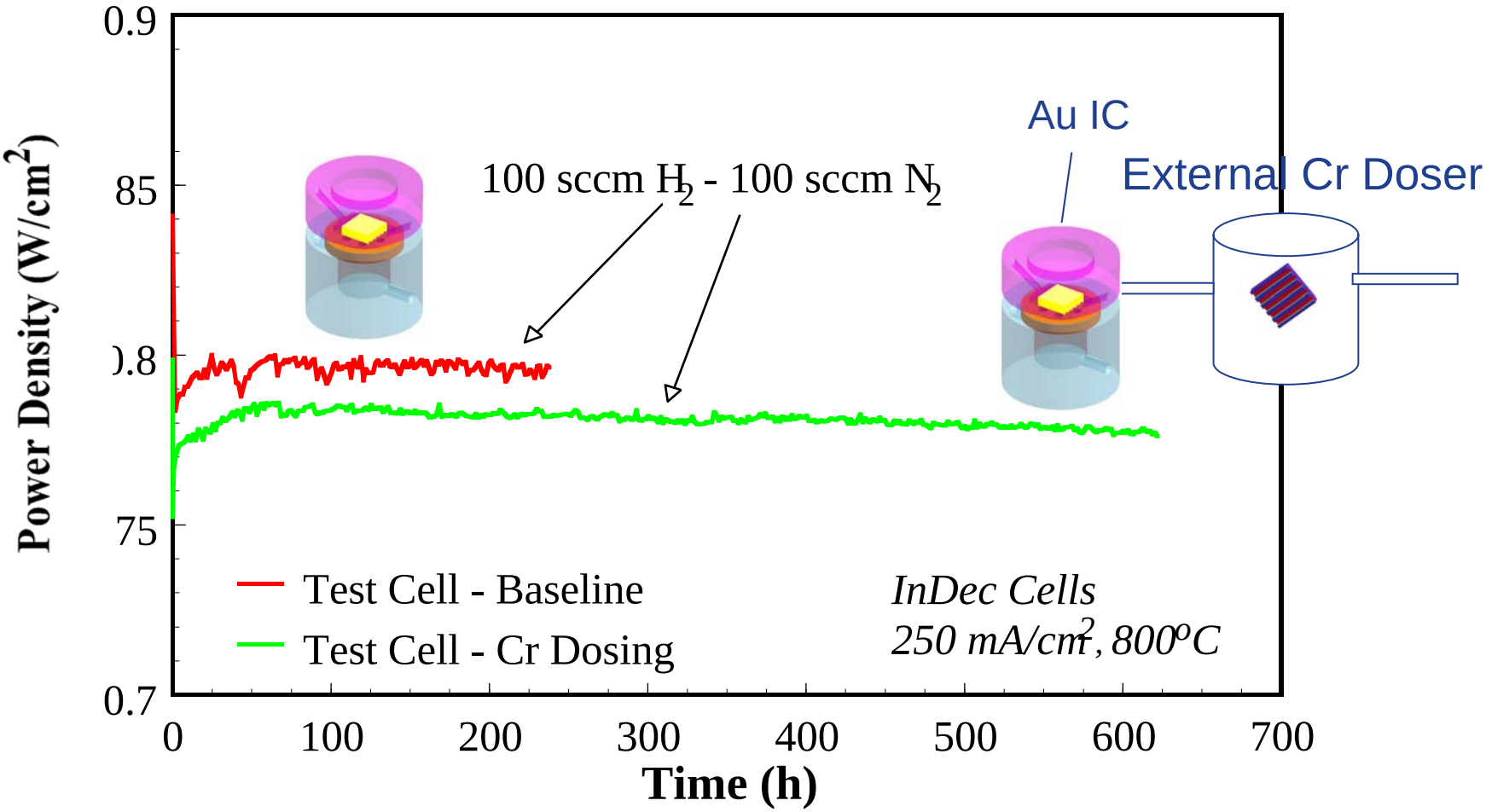
Long Term Performance Test @ PNNL





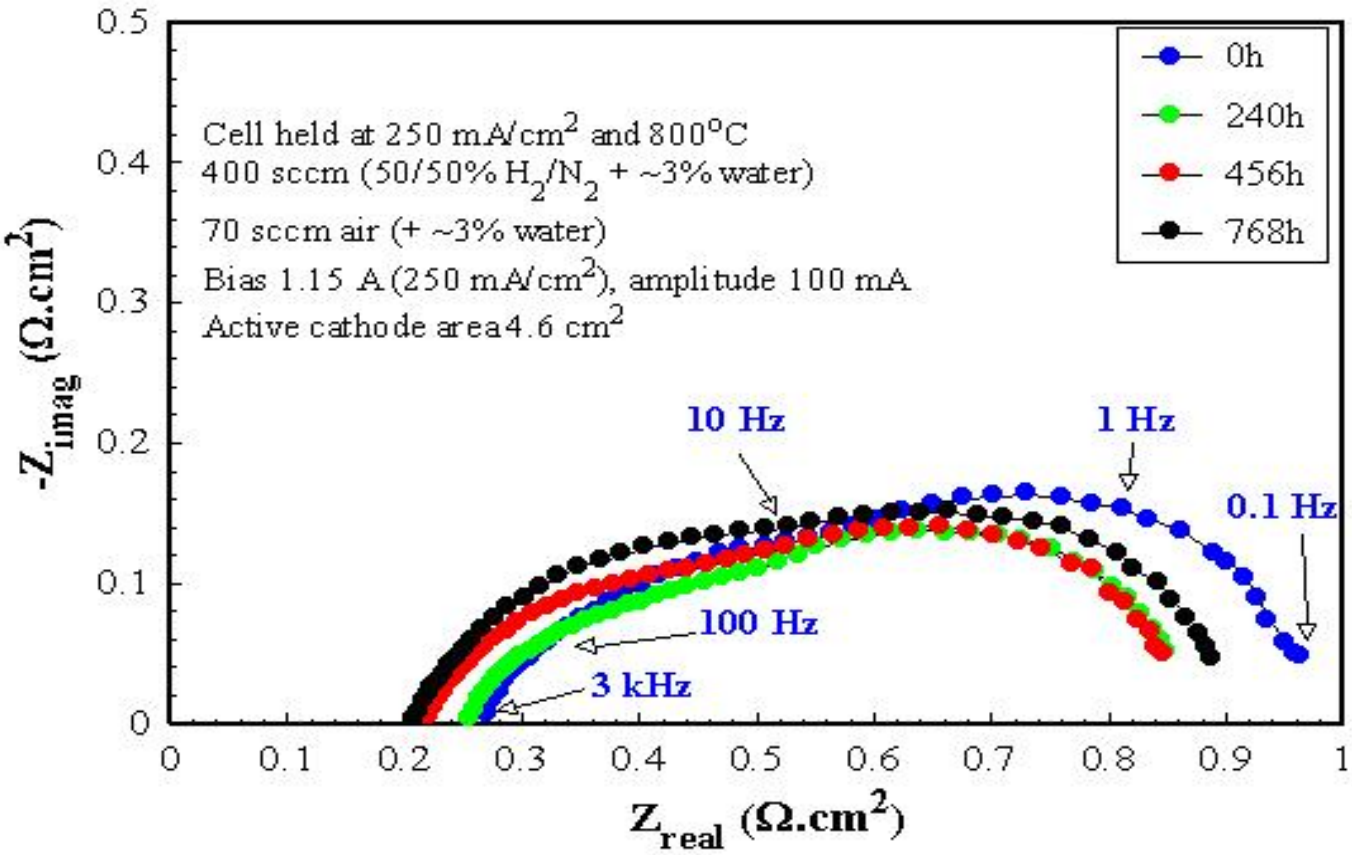
- Observed degradation rate = ~16 mV/1000 hr

Comparison of "Cr Vapor Dosed" Sample With Baseline @ PNNL



- Observed degradation rates are identical up to 240 hrs

Cell Impedance Behavior During Long Term Tests @ PNNL

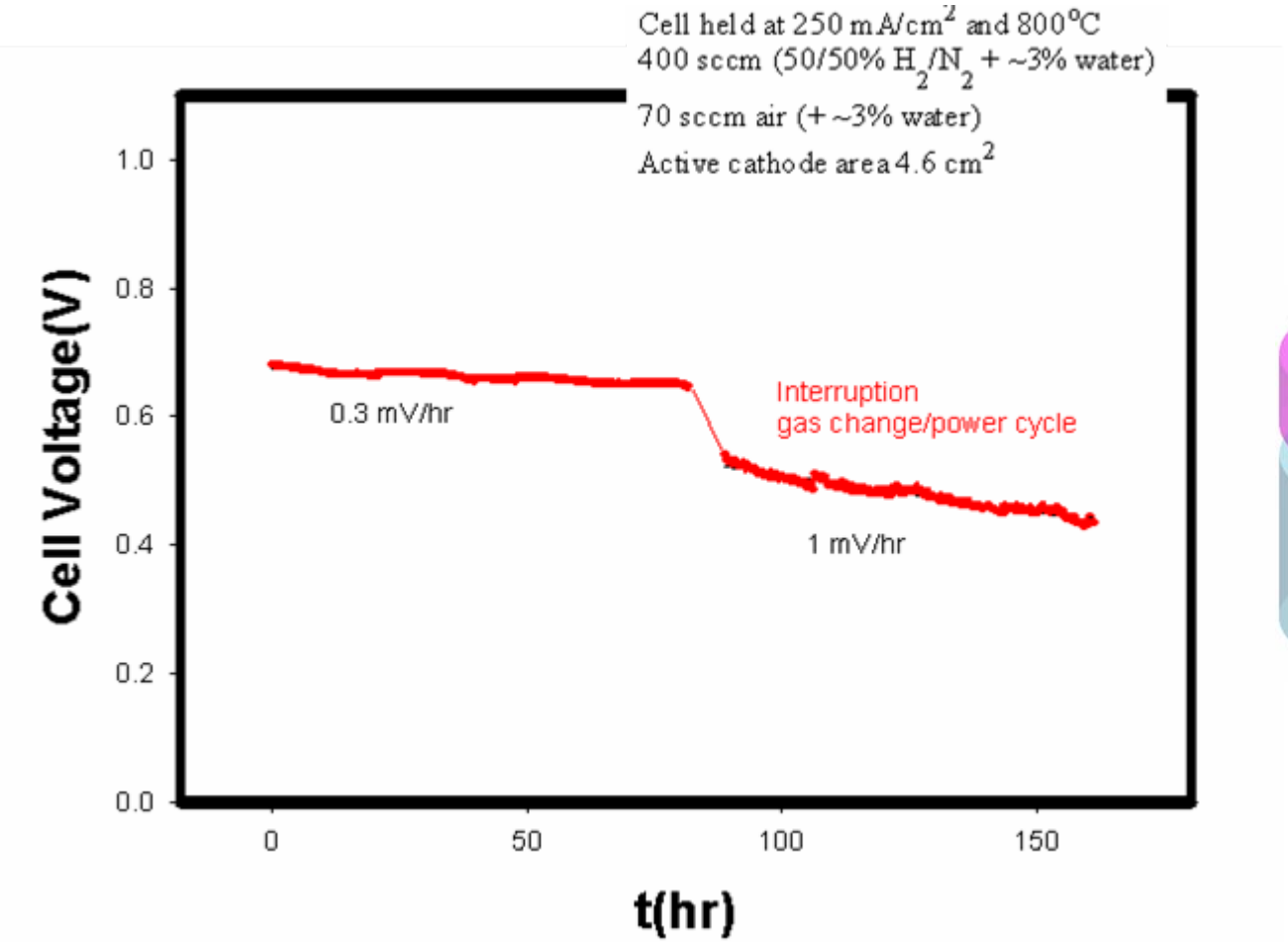


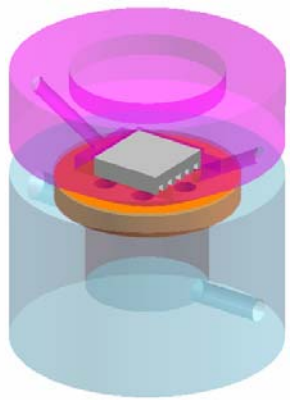
Cell Performance improved over 0 - 240 hrs

Cell Performance degraded between 240 – 770 hrs

- Electrode activity decreases during long term test

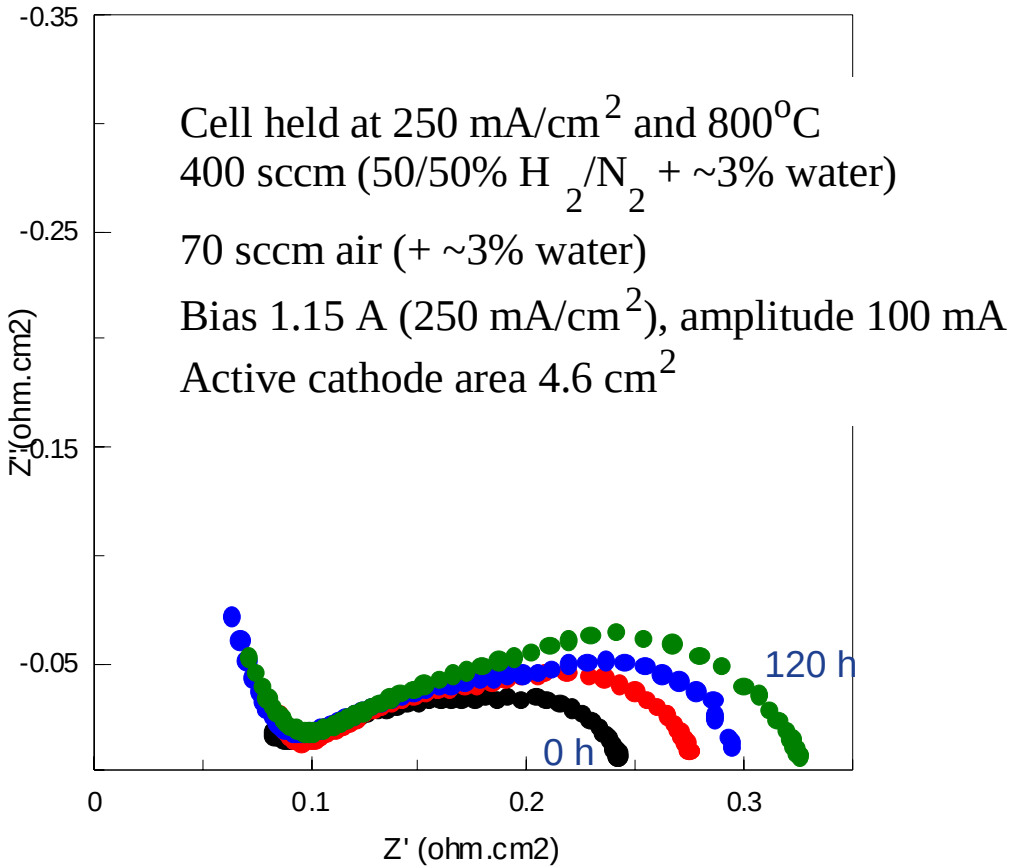
Long Term Performance Test @ GE





- Observed degradation rate = 300 – 1000 mV/1000 hr

Cell Impedance Behavior During Long Term Tests @ GE

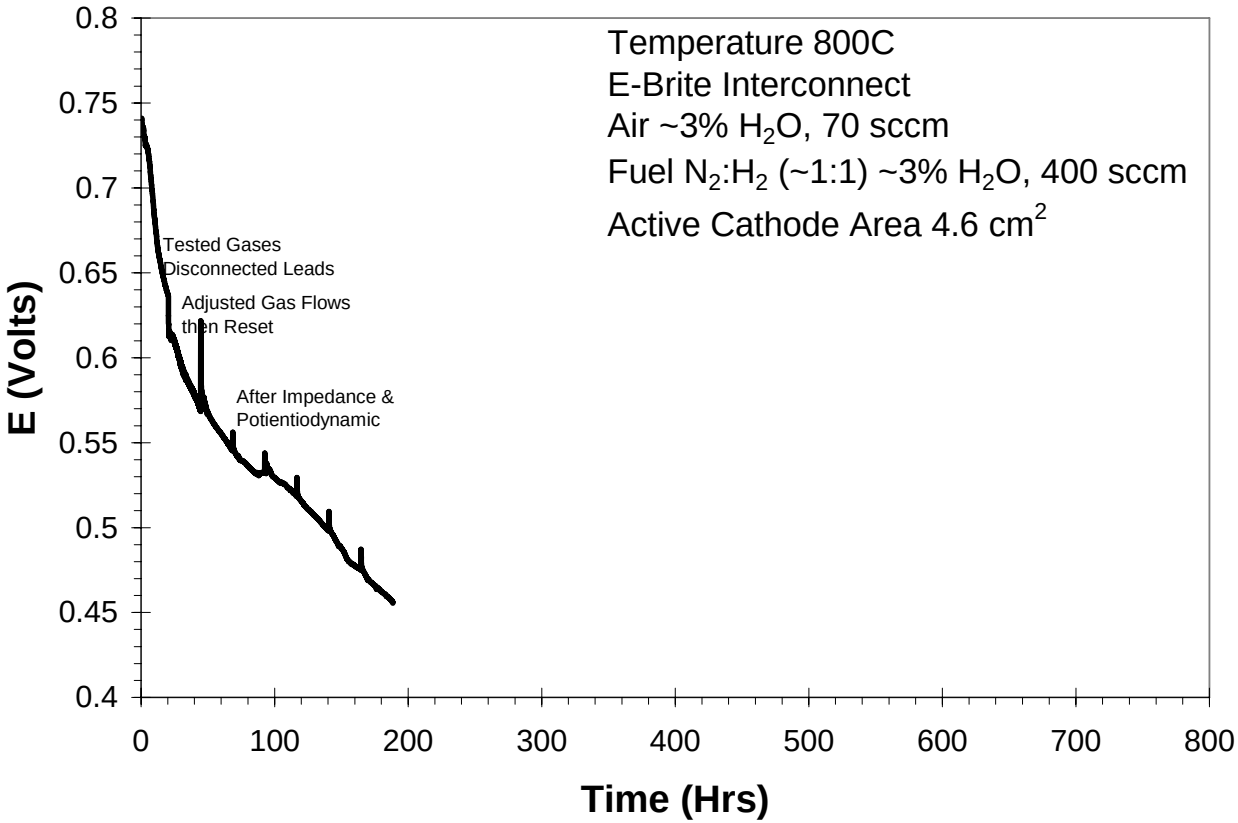


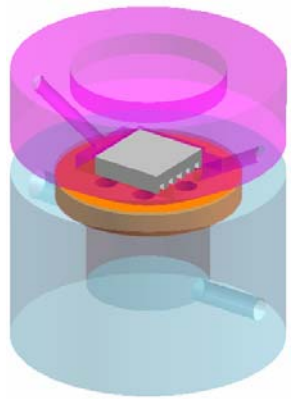
No Cell Performance improvement observed

Cell Performance degraded with time

- Electrode activity decreases during long term test

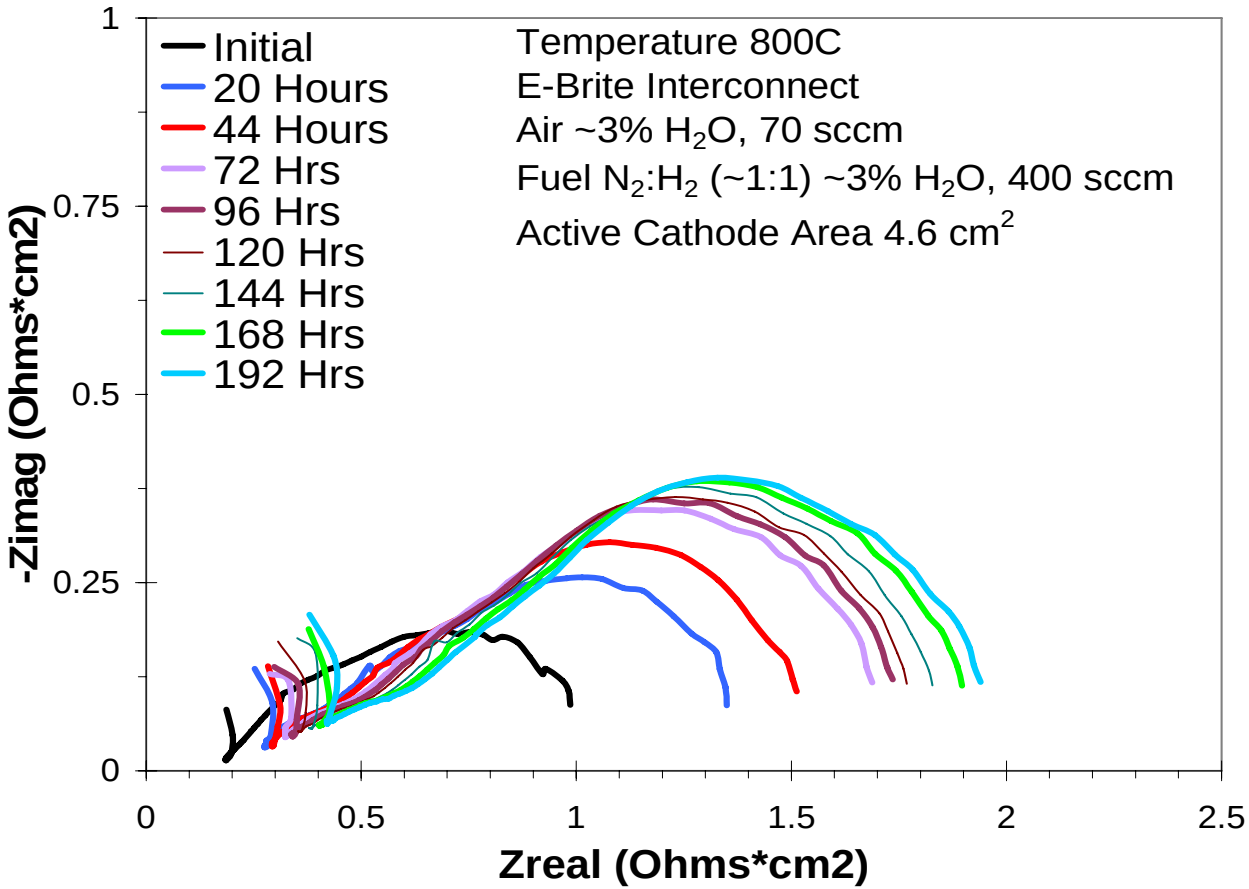
Long Term Performance Test @ ANL





- Observed degradation rate = ~ 1000 mV/1000 hr

Cell Impedance Behavior During Long Term Tests @ ANL



No Cell Performance improvement observed

Cell Performance degraded with time

- Electrode activity decreases during long term test

Summary

- Initial round of testing is under way
  - Low degradation rate observed in “Cr vapor dosing” experiment at PNNL
  - Higher degradation observed in Ebrite flow field experiments at GE and ANL

- 1st round of testing, including post-test analysis, should be completed by end of calendar year
- Next round of tests will include
  - lower temperature (700ºC)
  - higher current densities (500 mA/cm2)

Acknowledgements

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