Electrode Contamination Studies

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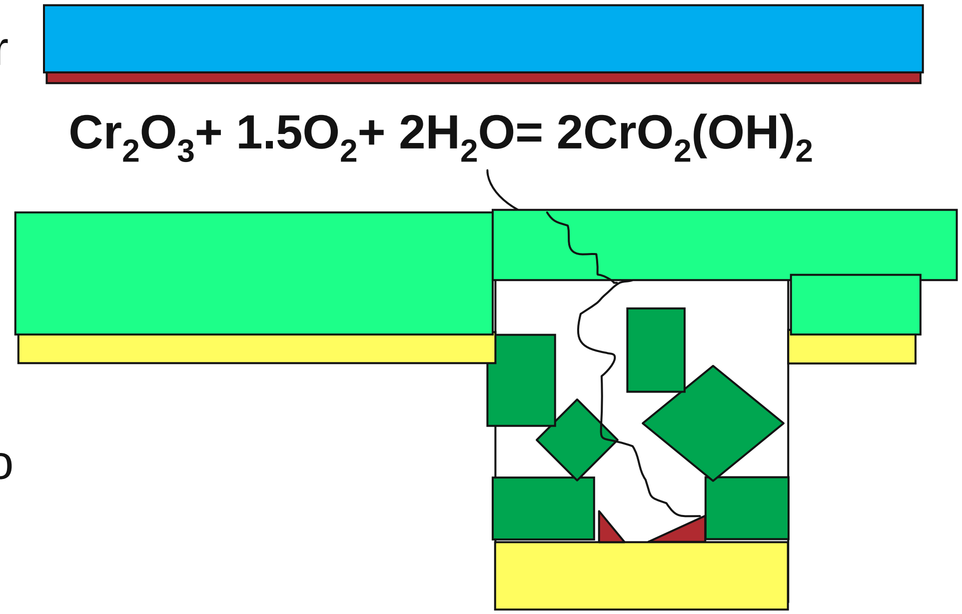
The Chromium Contamination Issue

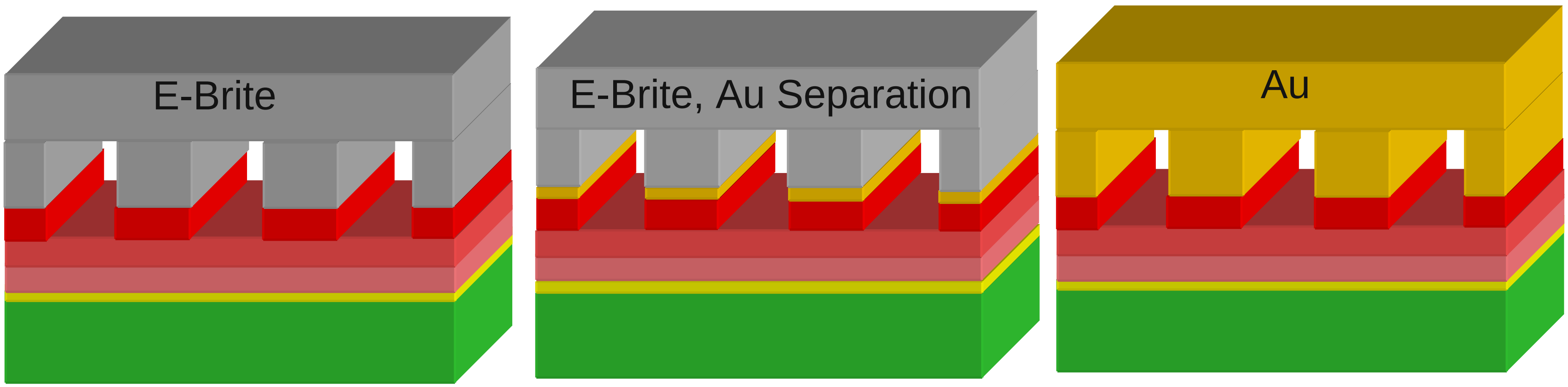
- Metallic bipolar plates for planar SOFCs contain chromium
- Chromium forms a volatile oxy-hydroxide
- The oxy-hydroxide is reduced to chromium oxide at the cathode
- The chromium oxide deposits affect the cell performance



$$Cr_2O_3 + 1.5O_2 + 2H_2O = 2CrO_2(OH)_2$$

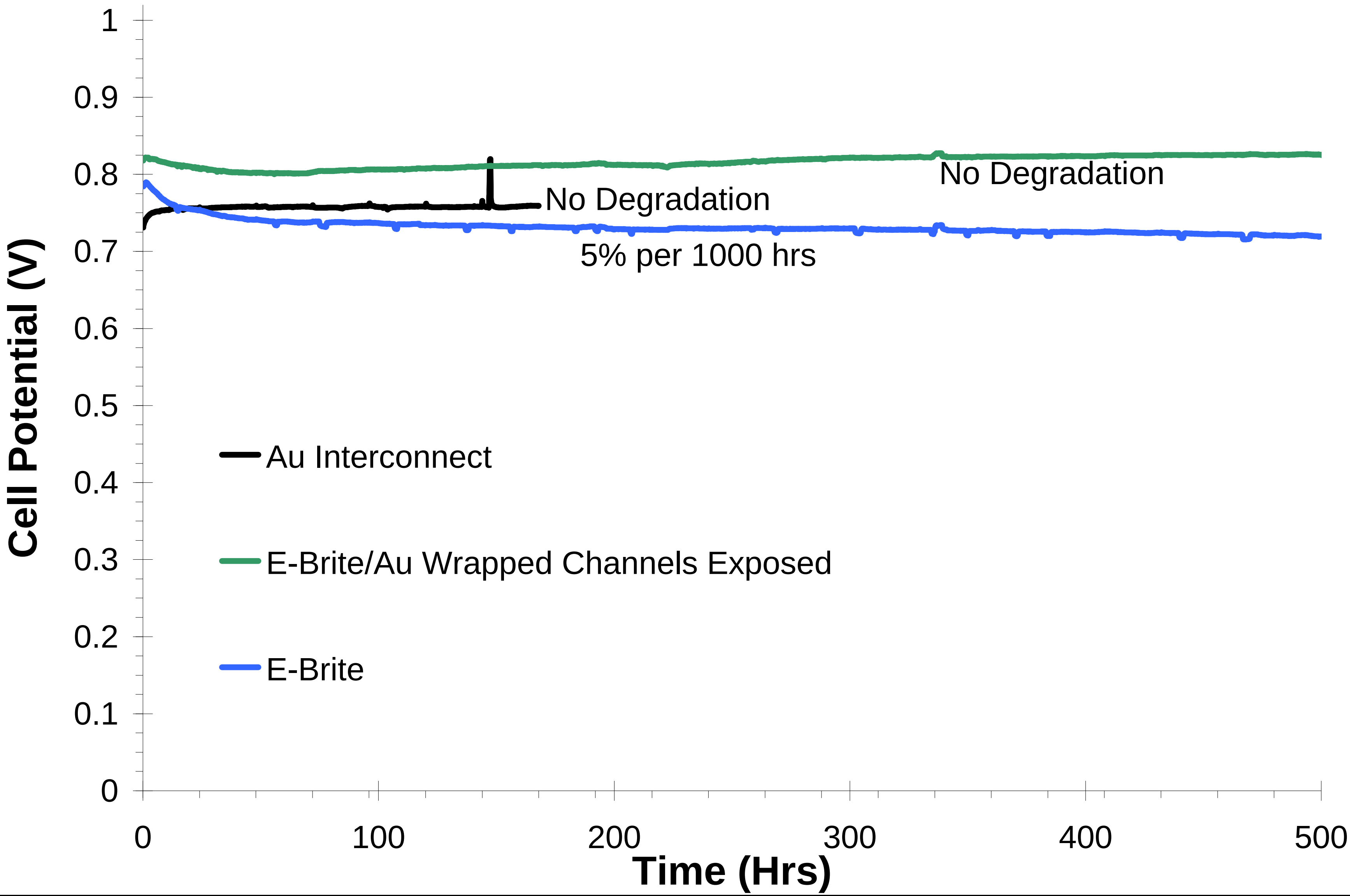
$$2\ CrO_2(OH)_2 + 6e^- + 3V_o^{\cdot\cdot} = Cr_2O_3 + 3O^{2-}\ 2H_2O$$

Three Cell Configurations Were Tested

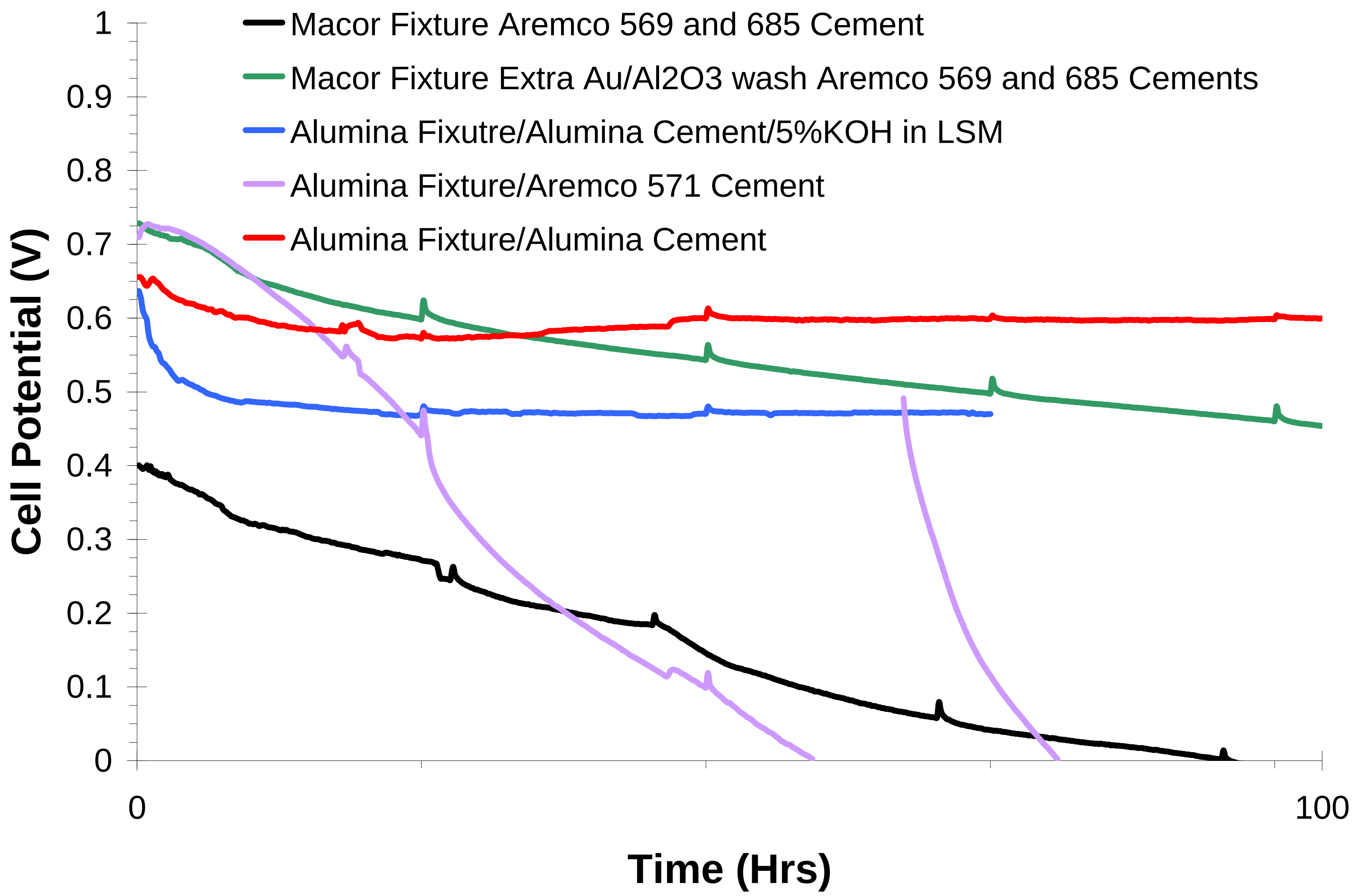


With and without external dosing

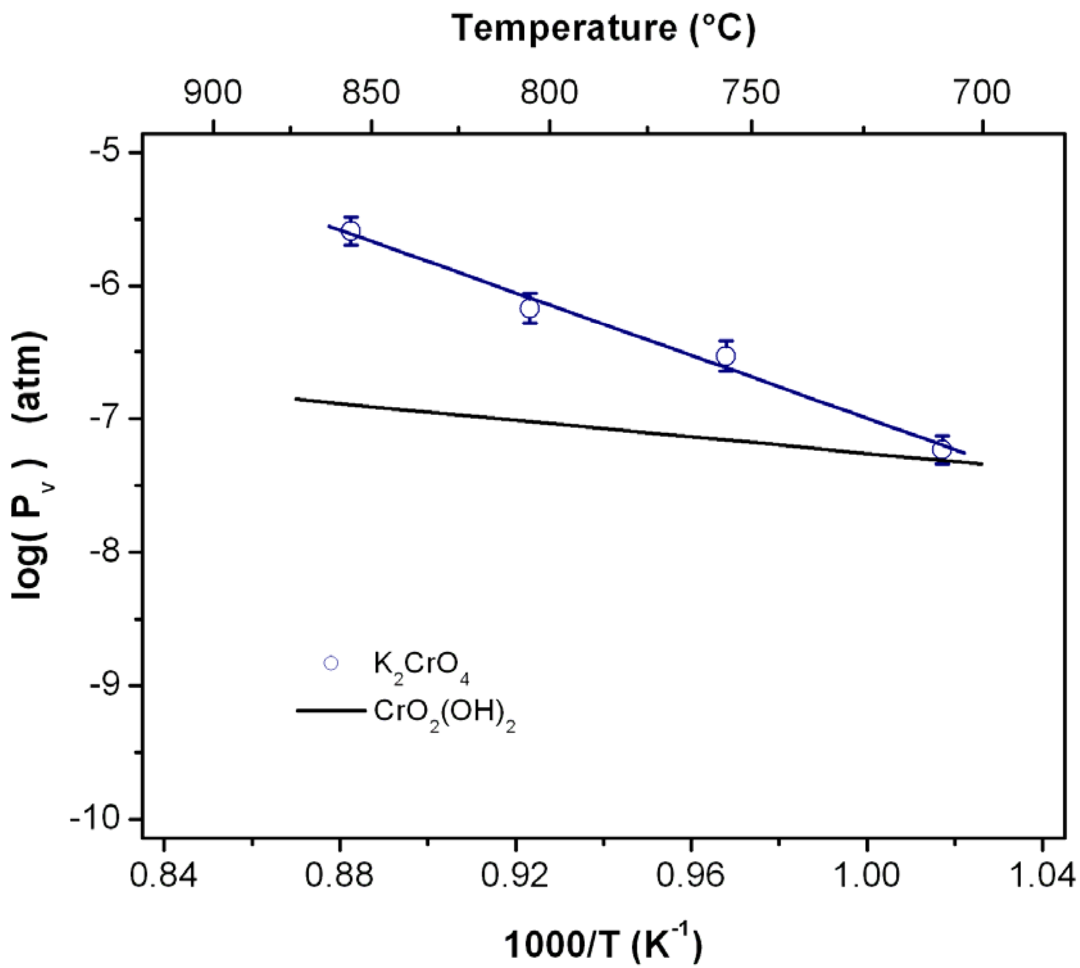
Cells Run at 800°C Effect of Contact



Effects of Alkali Metals at 800°C



Vapor pressure of K_2CrO_4



Incremental Chromium Transport Mechanisms

Surface of interconnect

normal: $Cr_2O_{3(s)} + {}^3/_2\, O_{2(g)} + 2H_2O \rightarrow 2CrO_2(OH)_{2(g)}$

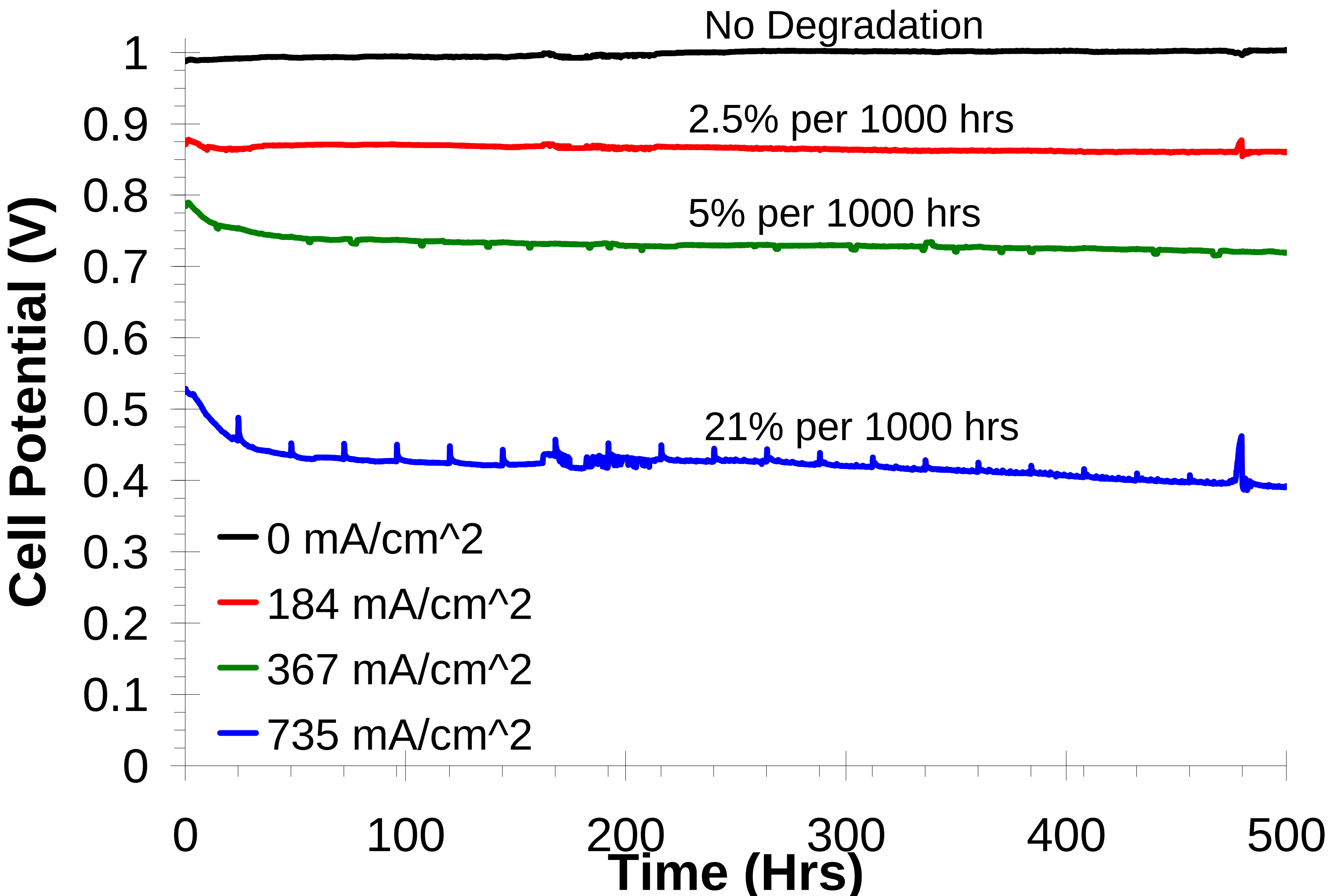
incremental: $Cr_2O_{3(s)} + {}^3/_2\, O_{2(g)} + 4KOH \rightarrow 2K_2CrO_{4(g)} + 2H_2O_{(g)}$

Cathode interface

$2CrO_2(OH)_{2(g)} + 6e^- \rightarrow Cr_2O_{3(s)} + 2H_2O_{(g)} + 3O^{2-}$

$2K_2CrO_{4(g)} + 6e^- \rightarrow Cr_2O_{3(s)} + 2K_2O_{(g)} + 3O^{2-}$

Degradation of cell potentials at 800 C and different current densities



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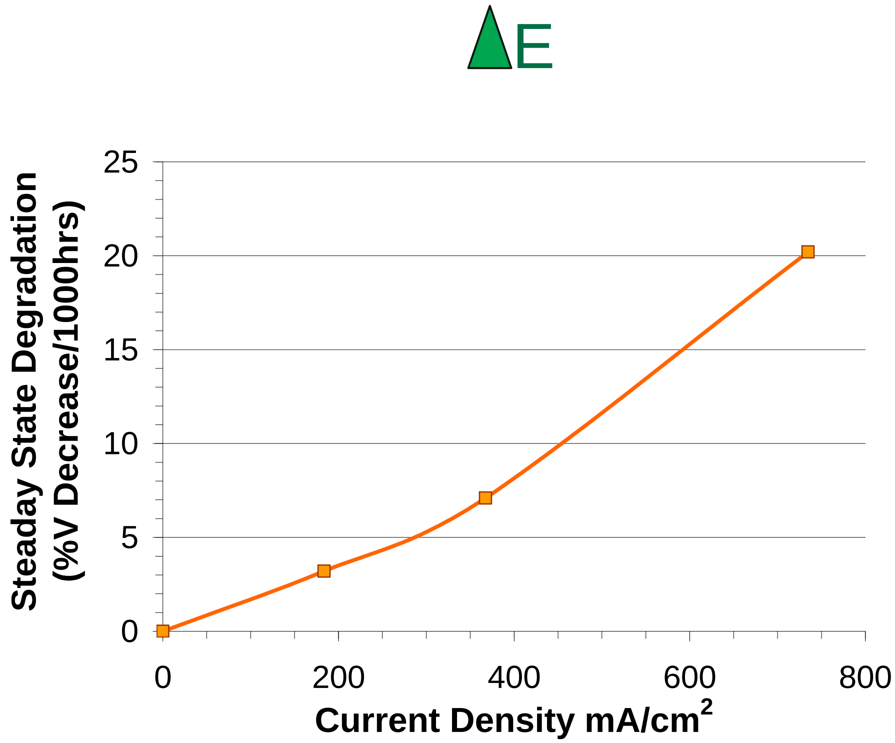
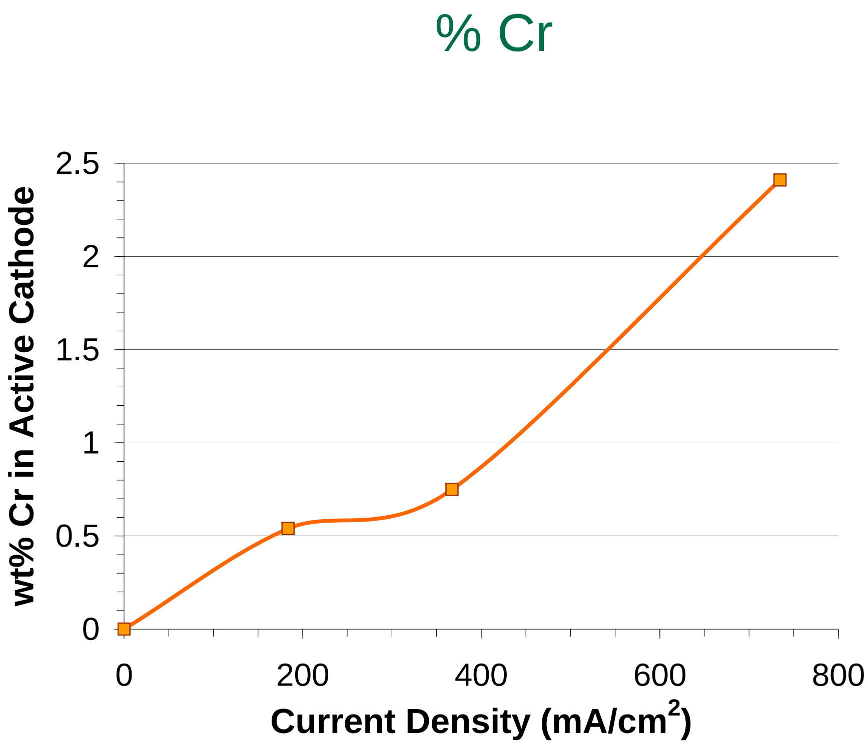
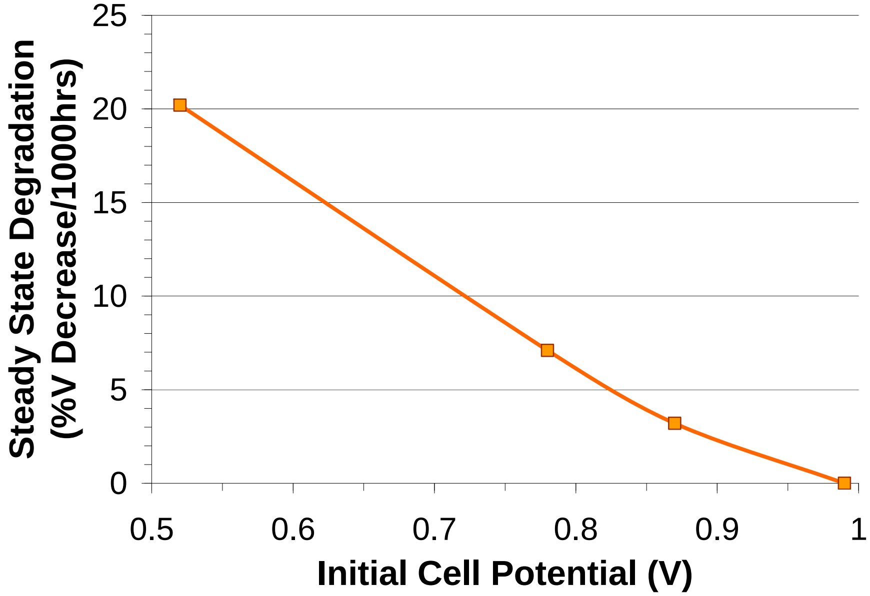
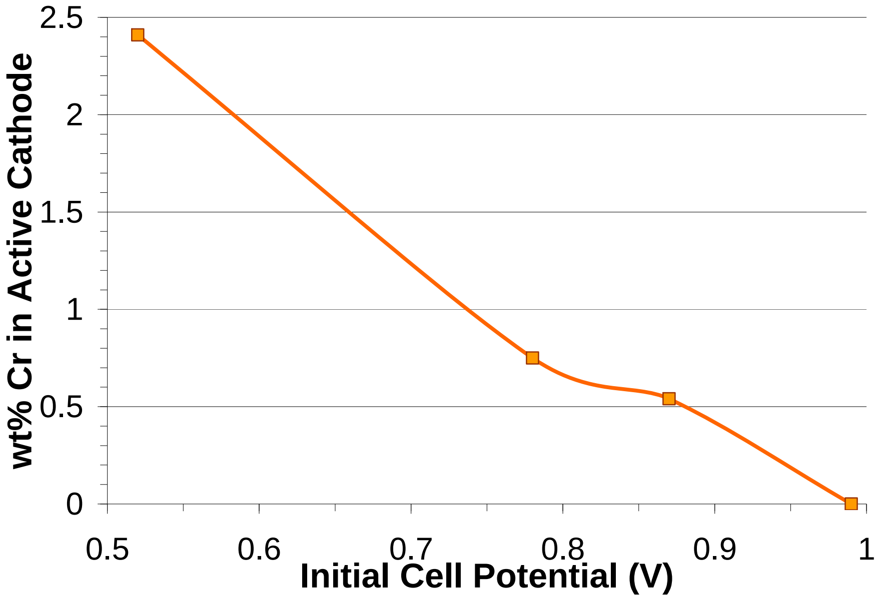
Effect of Current Density at 800°C





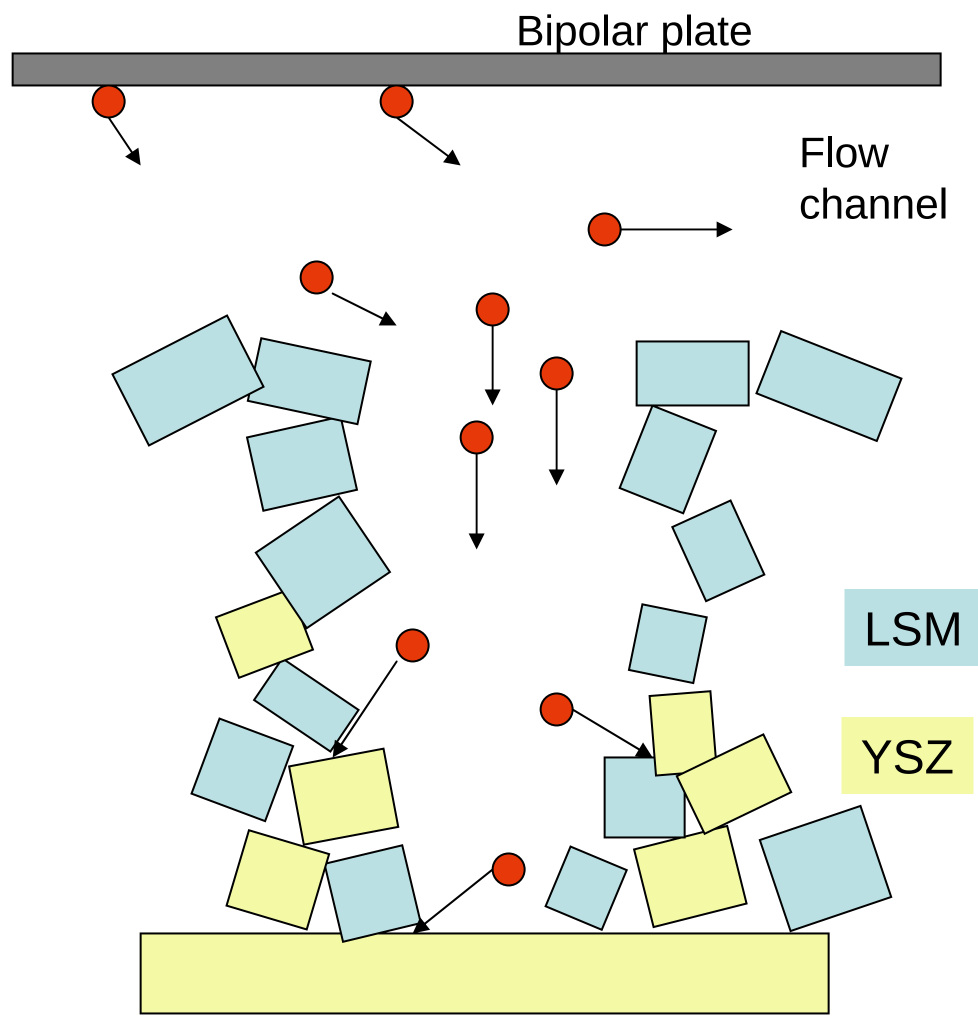
Effect of Cell Potential at 800°C

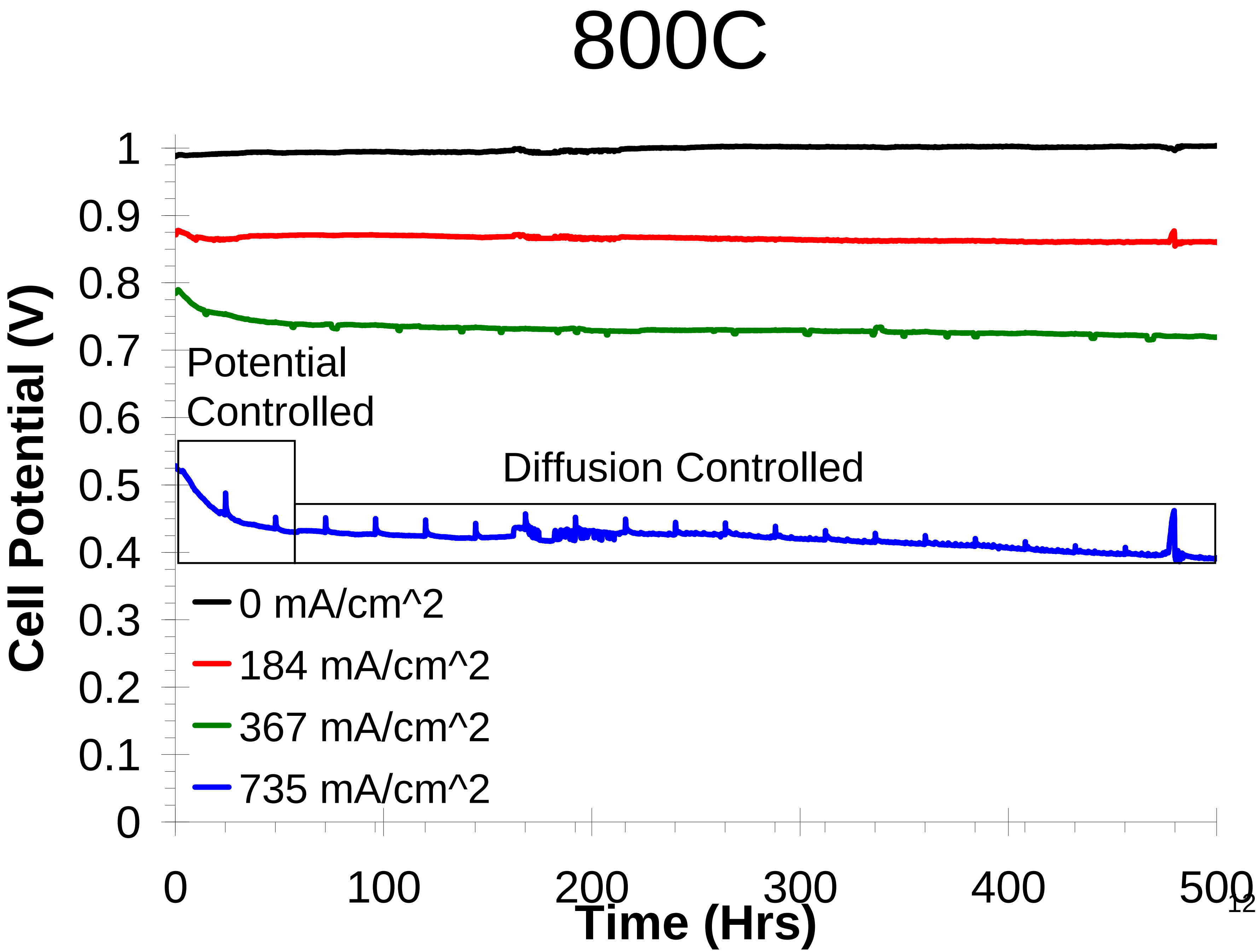




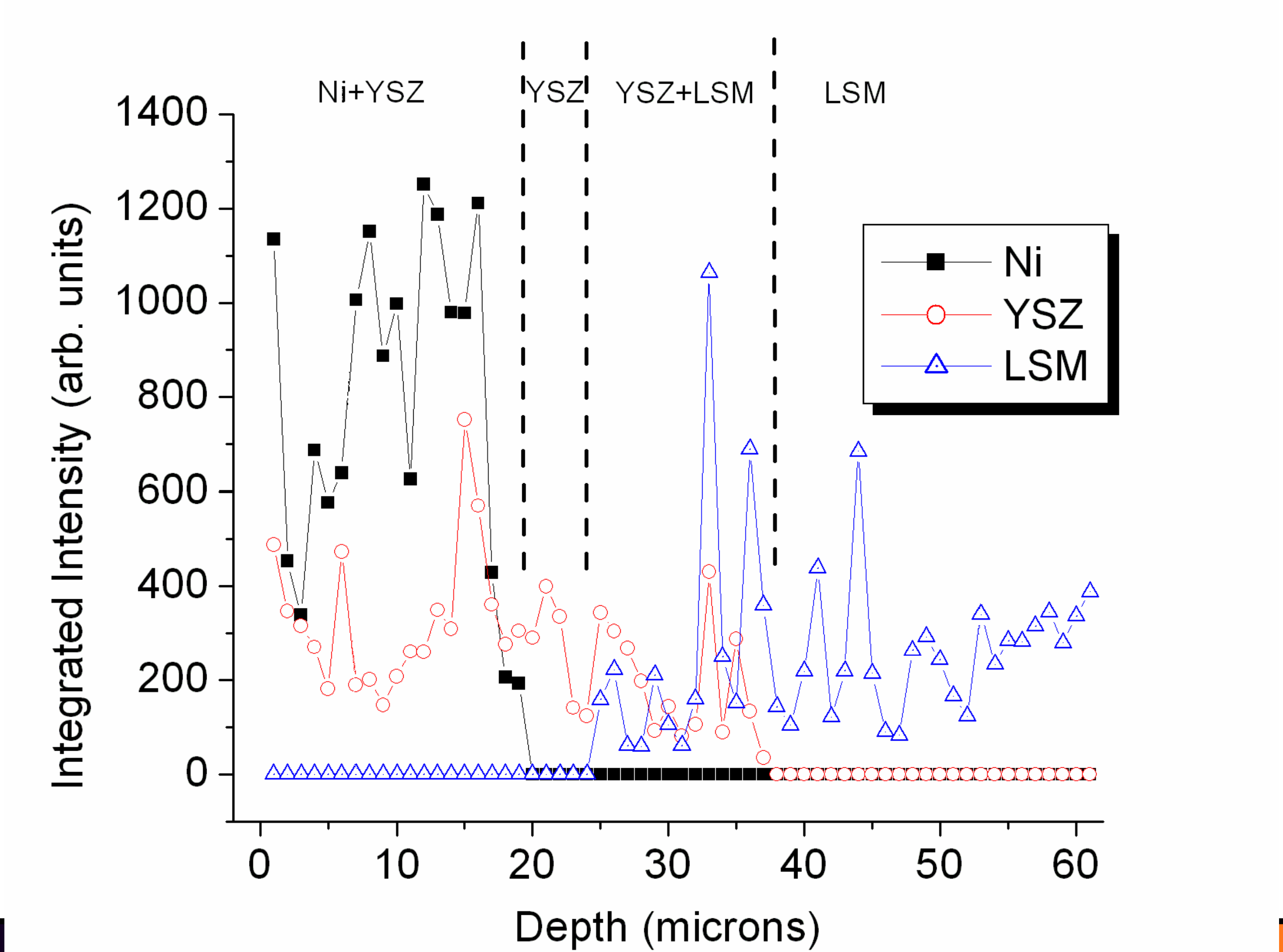
Factors affecting Chromium Migration

- Rate of oxyhydroxide formation
- Hydrodynamics
- Diffusion in cathode pores
- Rate of reduction

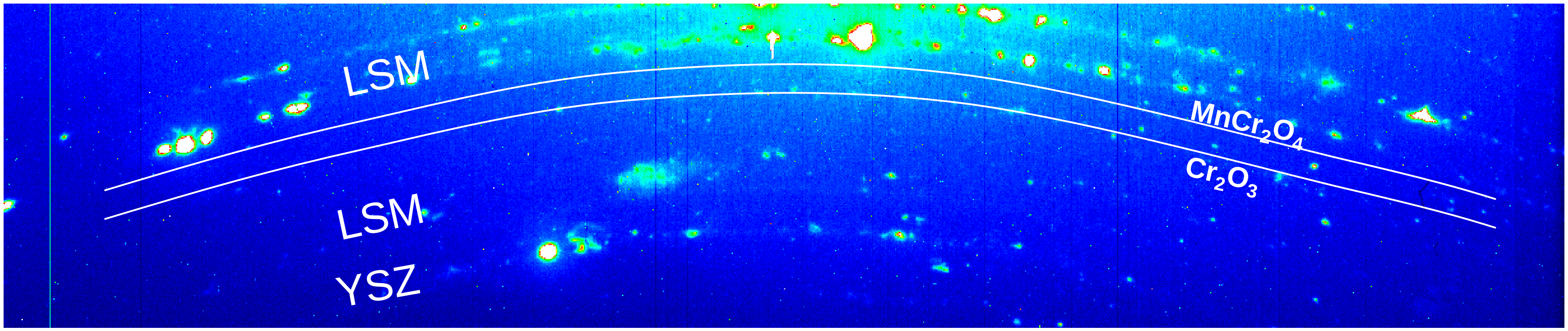



800C
Cell Potential (V)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Potential
Controlled
Diffusion Controlled
0 mA/cm^2
184 mA/cm^2
367 mA/cm^2
735 mA/cm^2
0
100
200
300
400
500
Time (Hrs)

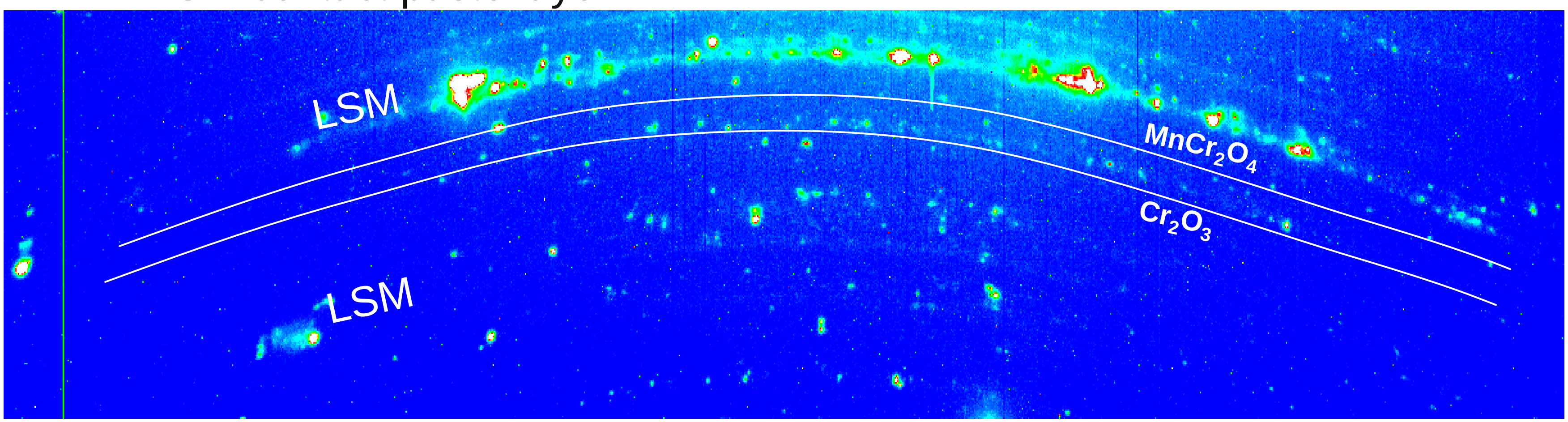
Phase distribution from 0.5micron beam x-ray diffraction at APS



Cathode (LSM + YSZ) layer

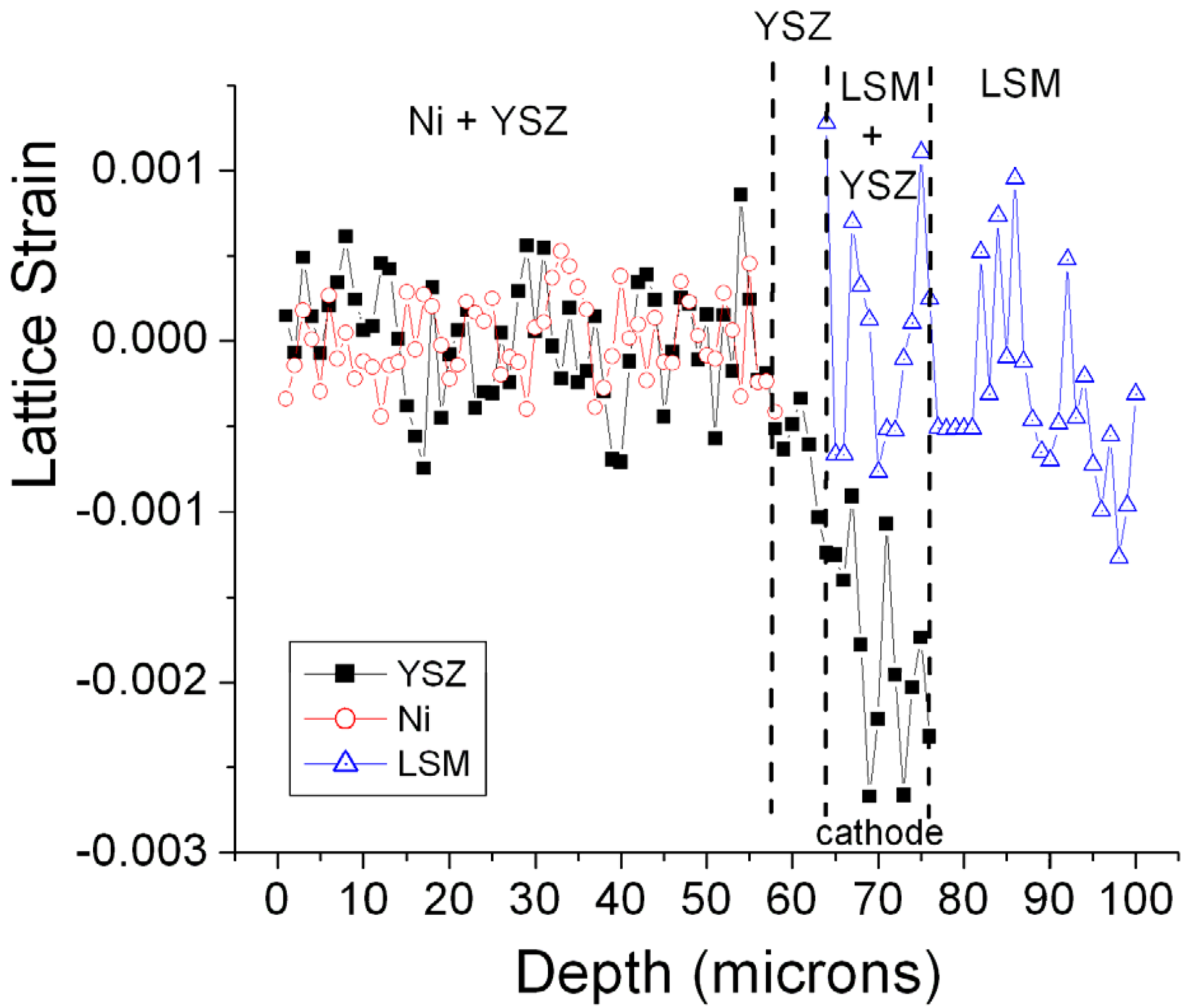


LSM contact paste layer

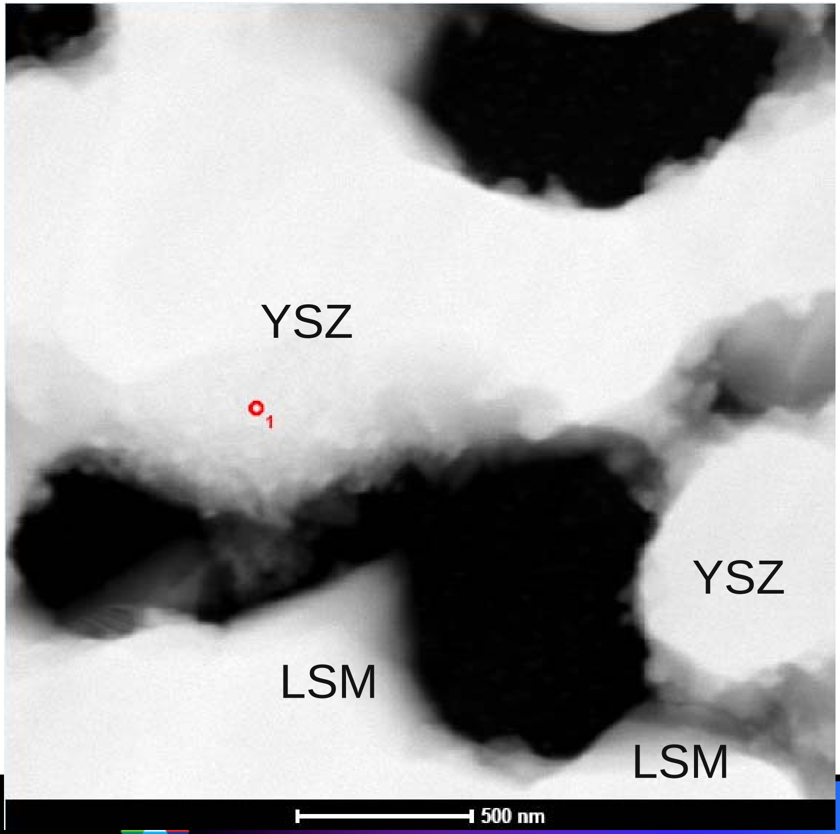


Very weak diffraction peaks of $MnCr_2O_4$ and Cr_2O_3 phases were observed. Cr_2O_3 is relatively more abundant in the contact paste.

Strain Distribution

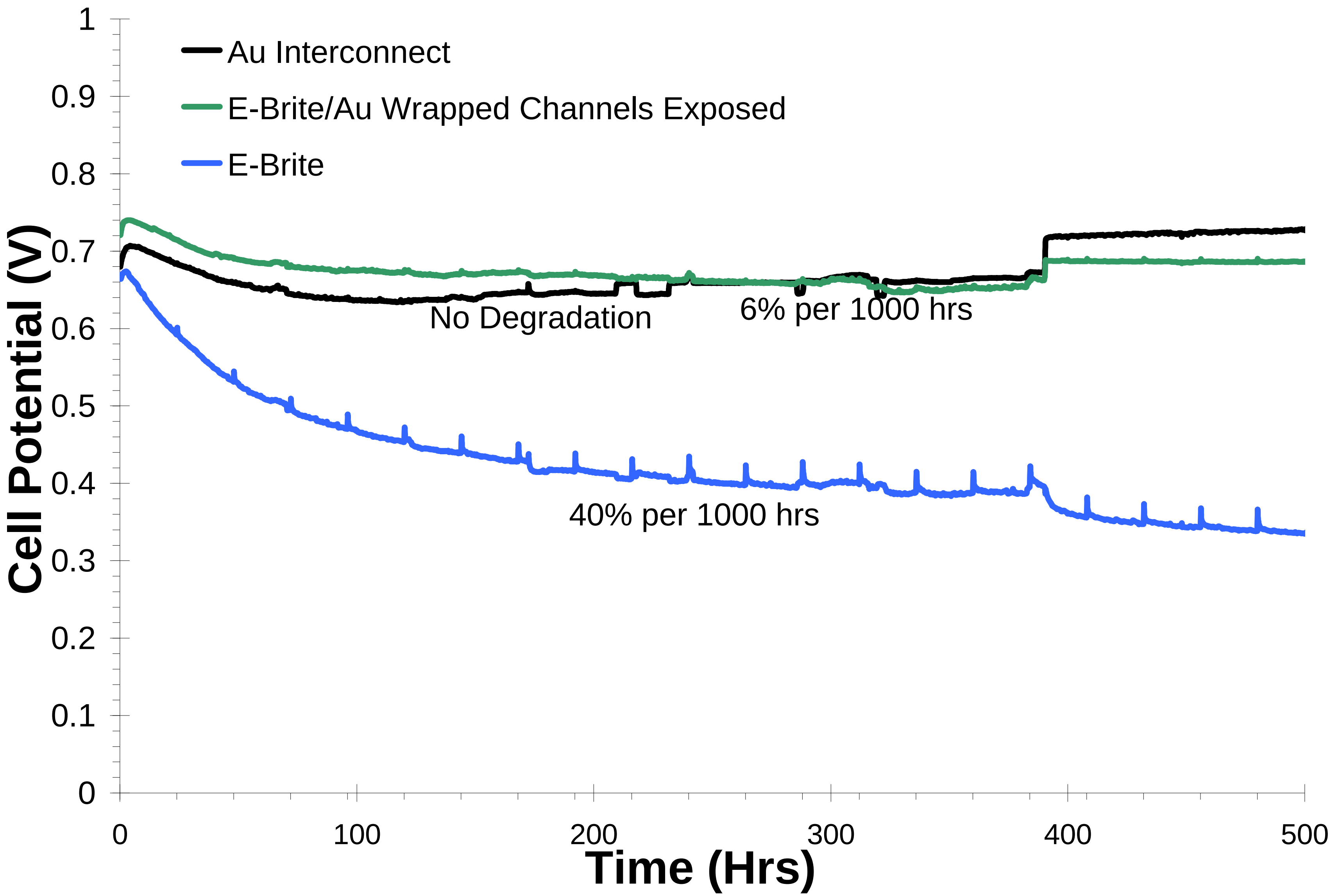


Cr_2O_3 Growing on YSZ
in cell operated at 800°C, 500 Hours, 1.15A

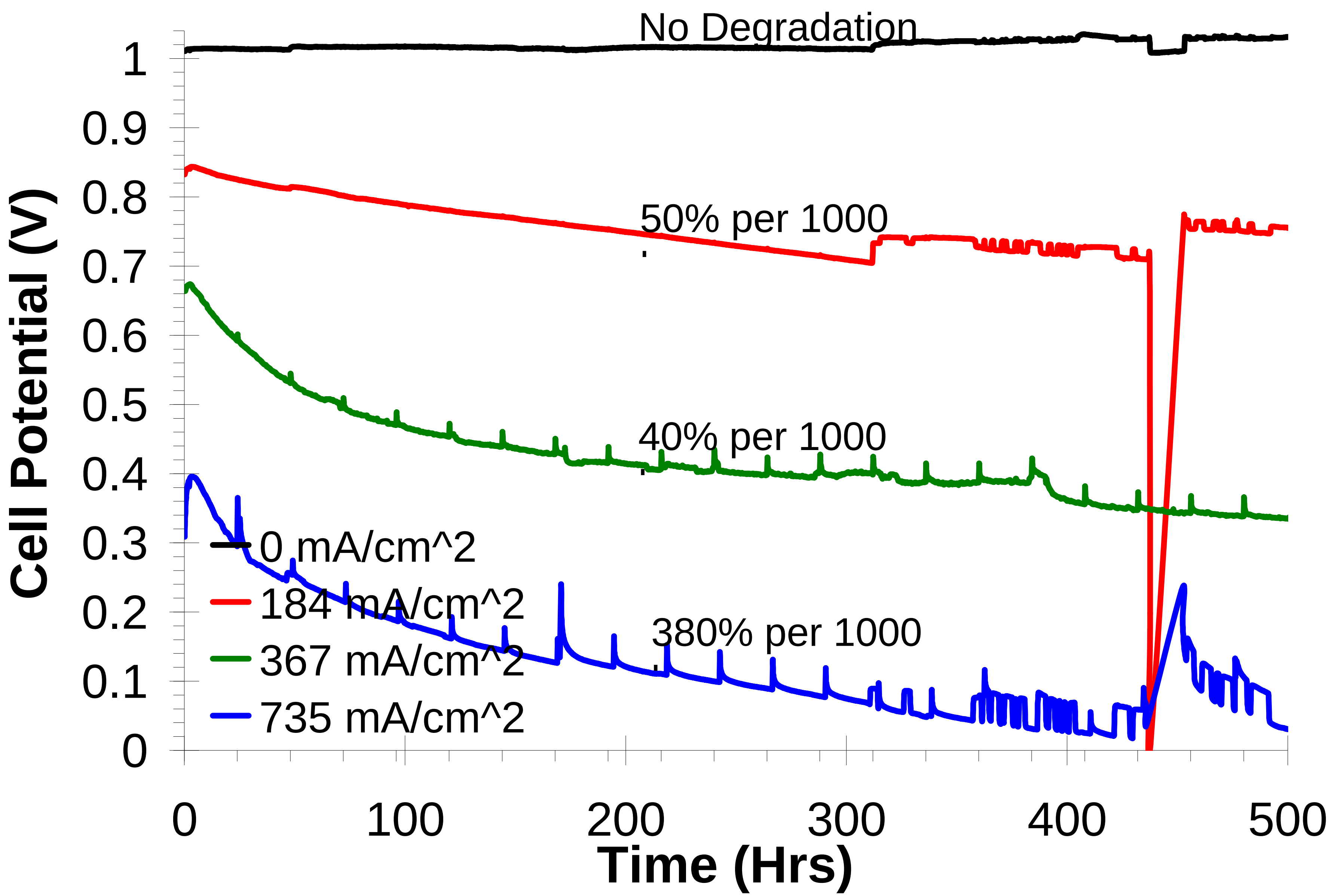


- Cr_2O_3 particles grow on YSZ.
- Traces of Mn associated with.
- LSM Typically clean.
- Some trances of spinel, but limited.
- Pores still open.

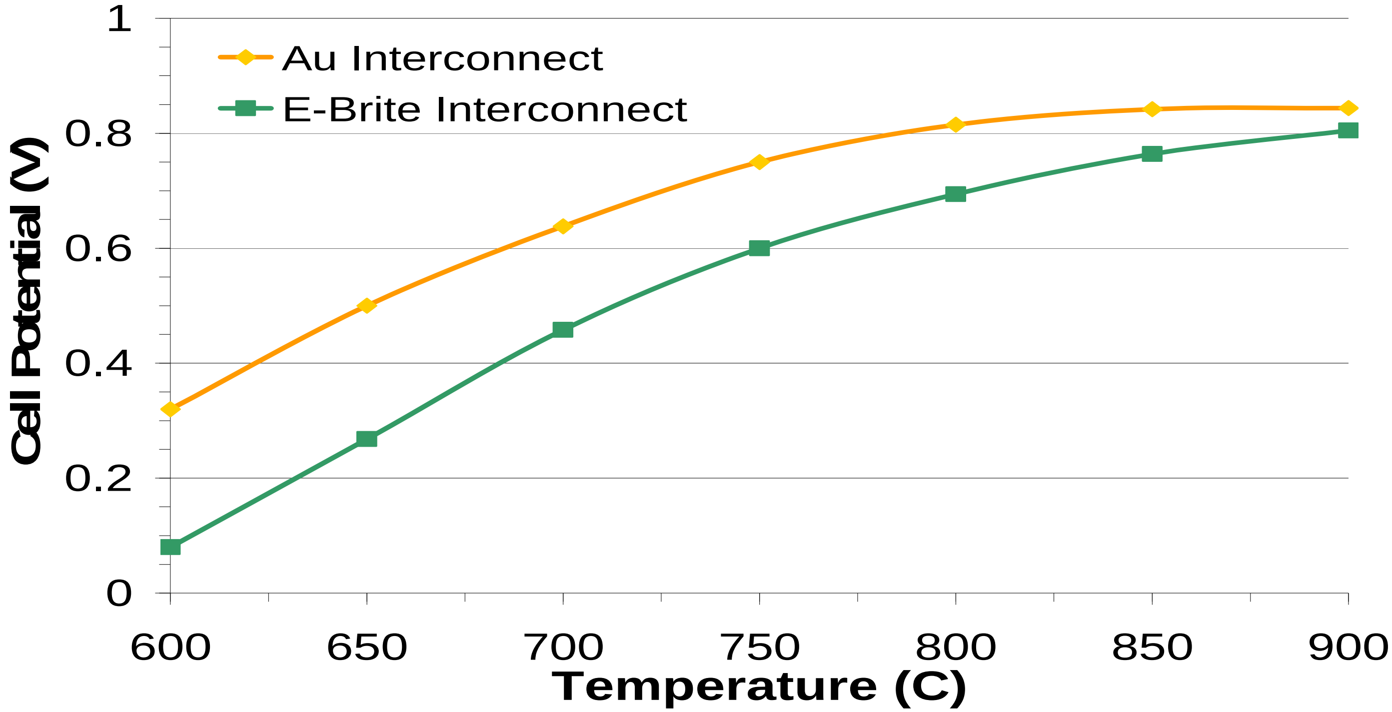
Cells Run at 700°C Effect of Contact



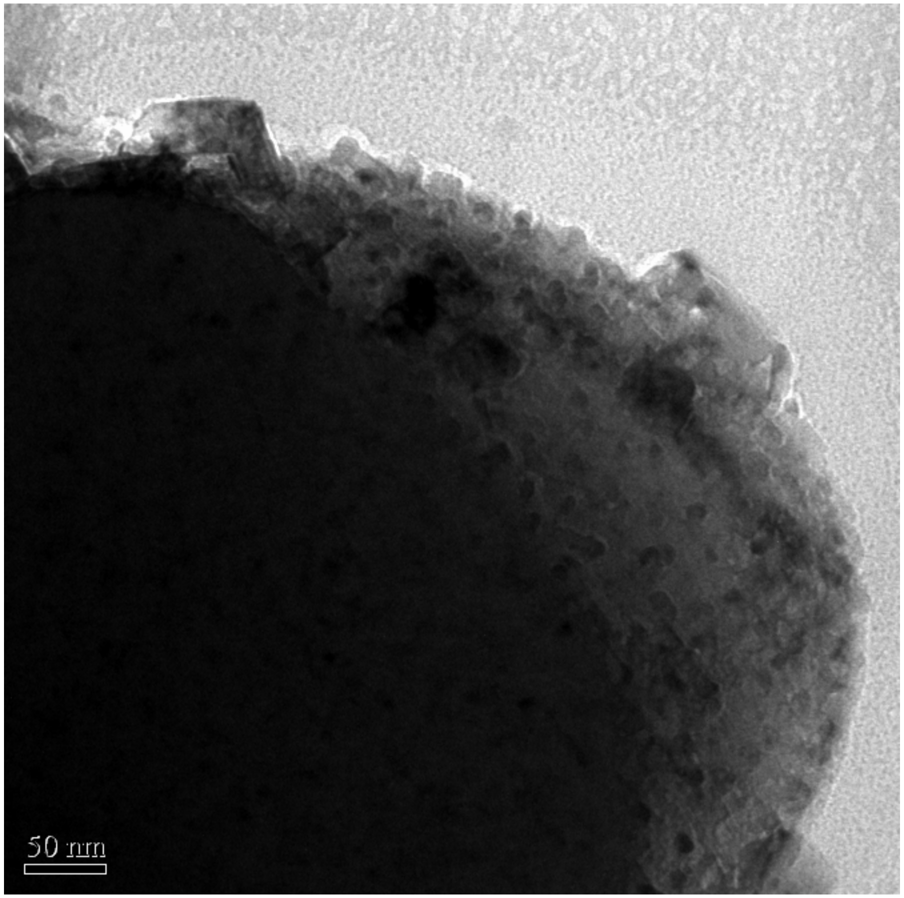
Degradation at 700C



Effects of temperature on cell potentials after 500 hours of operation



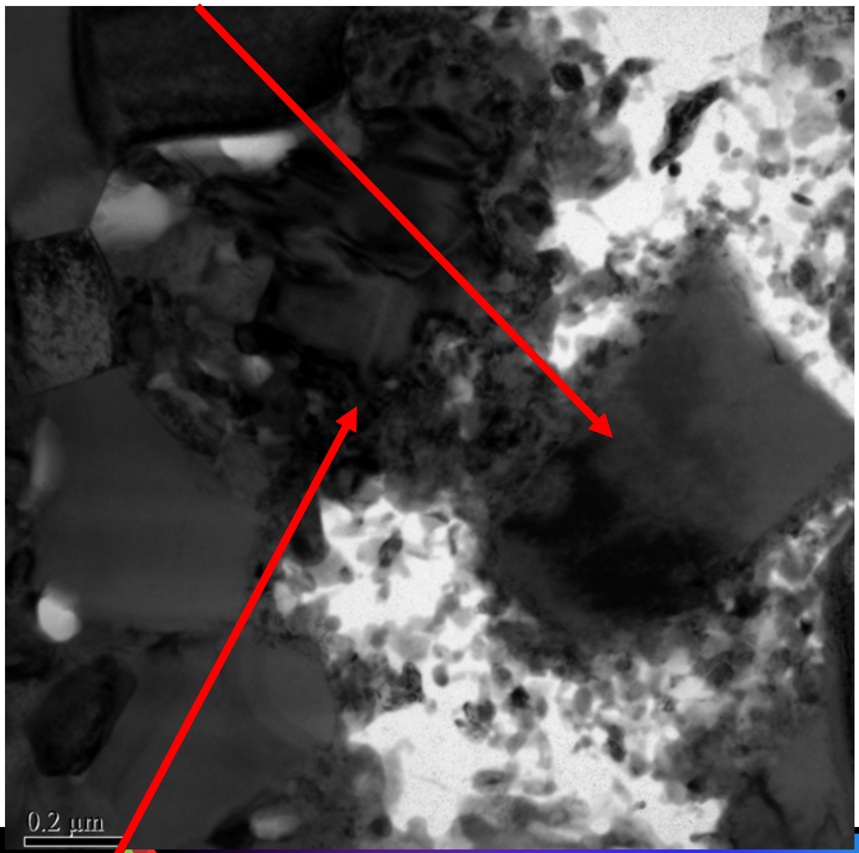
$MnCr_2O_4$ Growing on YSZ in cell operated at 700°C, 500 Hours, 1.15A

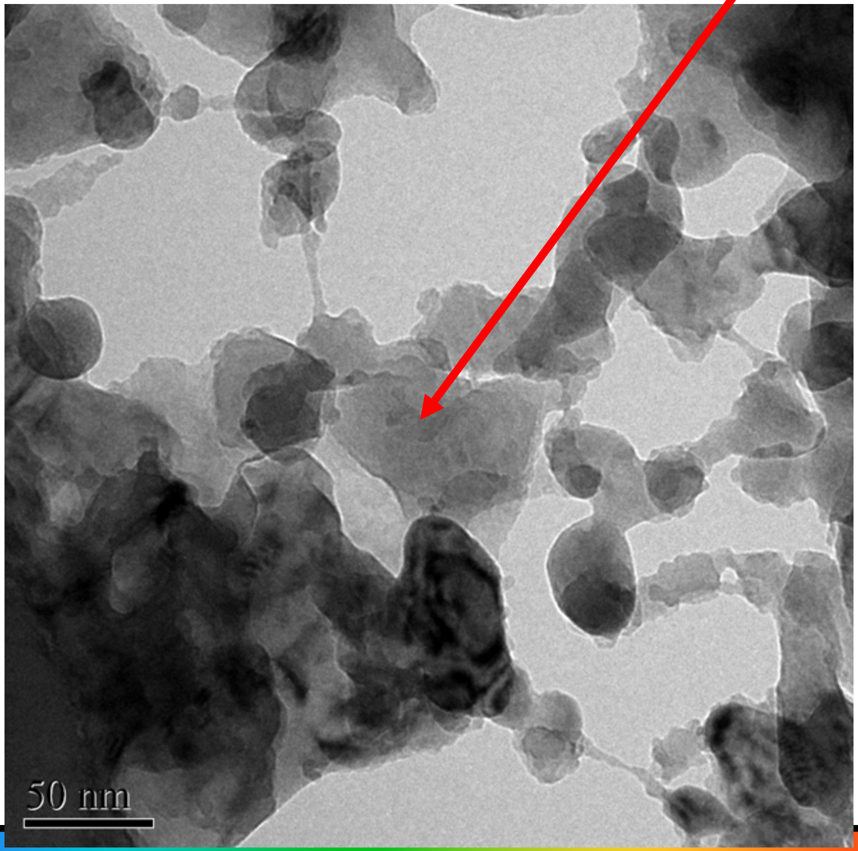


$(Mn,Cr)_3 O_4$ Nano-particles Filling Pores in cell at 700°C, 500 Hours, 1.15A

YSZ Particle

$(Mn,Cr)_3O_4$ Nano-Particles





Decomposed

The vacancy concentration affects the Cr^{6+}/Cr^{3+} equilibrium potential and also the degree of blockage

$$2CrO_2(OH)_2 + 3V_O^{\bullet\bullet} + 6e^- \leftrightarrow Cr_2O_3 + 3O_O^{\times} + 2H_2O$$

$$E = E^\circ - \frac{RT}{nF}\ln\frac{\left(a_{H_2O}\right)^2}{\left(a_{CrO_2(OH)_2}\right)^2 * \left(a_{V_O^{\bullet\bullet}}\right)^3}$$

$$E = E^\circ - 0.03 * \ln\left(10^6 * \left[V_O^{\bullet\bullet}\right]^{-3/2}\right)$$

$\therefore$ Doubling $[V_o^{\bullet\bullet}]$ increases E by ~32 mV

Acknowledgements

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