Improvement in Lifetime of SOFCs, Utilizing Novel, In-situ Methods to Remove Cathodic Chromium Deposits

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Abstract

Presented are baseline experiments for SOFC cell "poisoning," caused by the deposition of chromium from metallic interconnects into the cathode via the vapor phase. Cell performance was assessed using I-V measurements and corroborated utilizing SEM and EDAX. The analyses demonstrated a decrease in performance due to exposure to chromium vapor species. Two strategies, chemical and electrochemical cleaning, are proposed to remove the Cr deposits, thus reversing the effects of poisoning and increasing cell lifetime.

Introduction

- **Chromium Poisoning (Fig. 1)**

At SOFC operating temperatures, the most prevalent Cr vapor species are CrO_3, $CrO_2(OH)_2$, and $CrO_2(OH)$. They form over Fe-Cr-Mn alloy interconnect, such as Crofer 22 APU/H, and deposit in the cathode causing performance degradation. Increasing the applied current, temperature, and water vapor content increases the rate of poisoning.

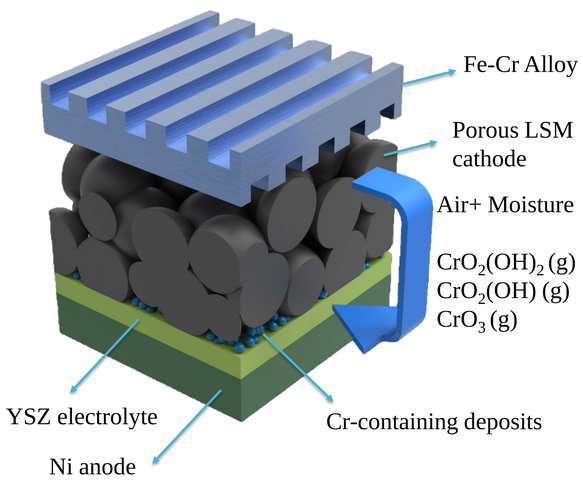

Figure 1. *Cr-Poisoning process in SOFC cathodes*

- **Chemical Cleaning (Fig. 2)**

During chemical cleaning, cells will be placed under open circuit conditions, the temperature will be raised to 850-900°C, and 5-15% water vapor will be added to the air supply. Under these conditions, Cr deposits in the cathode will volatilize, and the poisoning will be mitigated.

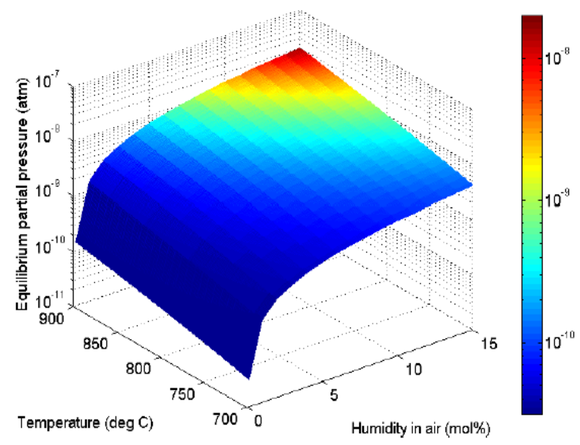

Figure 2. *3D plot showing equilibrium partial pressure of $CrO_2(OH)_2$ (most abundant Cr vapor species) over Cr_2O_3(s) as a function of temperature and air.*

- **Electrochemical Cleaning (Fig. 3)**

During electrochemical cleaning, 0-15% water vapor will be added to the air and 5-20% to the fuel. A small anodic and cathodic bias will be applied on the air and fuel electrodes, respectively. Under such an electrolytic bias, the Cr deposits in the cathode will volatilize as:

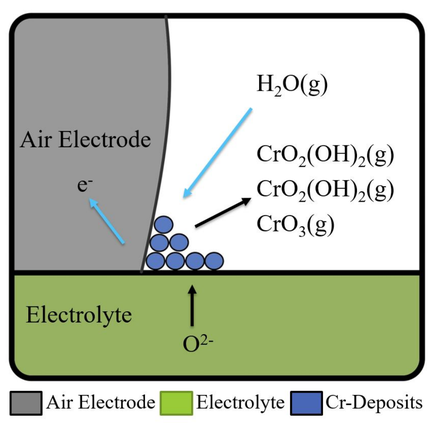

Figure 3. *Electrochemical Cleaning process at TPB (triple point boundary).*

Cr_2O_3(s, air side) + $2H_2O$(g, air side) + $3H_2O$(g, fuel side) = $2CrO_2(OH)_2$(g, air side) + $3H_2$(g, fuel side)

$1.5Cr_2O_3$(s, air side) + $1.5H_2O$(g, air side) + $3H_2O$(g, fuel side) = $3CrO_2(OH)$(g, air side) + $3H_2$(g, fuel side)

Cr_2O_3(s, air side) + $3H_2O$(g, fuel side) = $2CrO_3$(g, air side) + $3H_2$(g, fuel side)

Poisoning Experiment: Setup & Procedure (Fig. 4)

- Cells are activated for 48 hour at 800°C with 0.5 A/cm^2 using 3% humidified H_2, and dry air.
- Poisoning experiments are carried out at 800°C with pre-oxidized Crofer 22 APU strips.
- Cells were poisoned for 70 hours with 0.5 A/cm^2, 3% humidified H_2, and 5% humidified air.

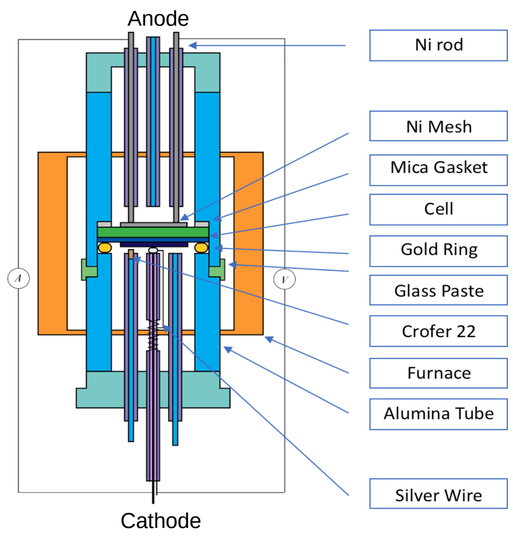

Figure 4. *A schematic of cell test setup.*

Preliminary Poisoning Results

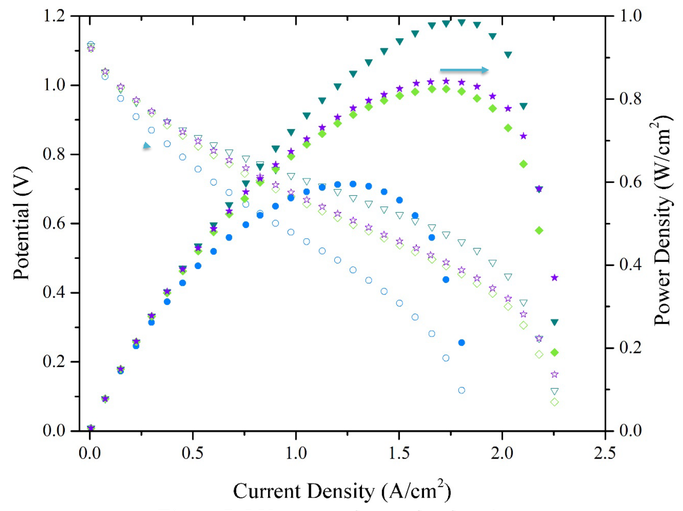

Figure 5. *I-V curves taken under dry air.*

- I-V demonstrates a ~16% decrease in maximum power density due to poisoning over 70 hours (Fig. 5).

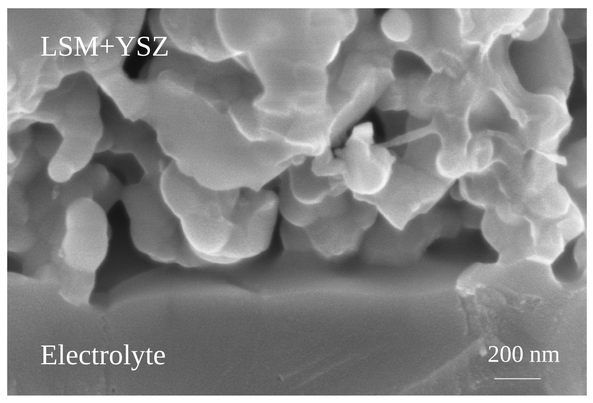

Figure 6. *SEM micrograph of LSM without poisoning.*

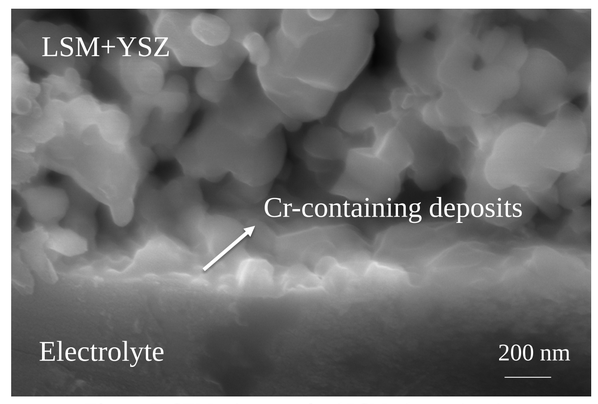

Figure 7. *SEM micrograph of LSM after poisoning.*

- SEM images of cell cross sections show Cr-containing deposition at LSM/electrolyte interface after 70 hours of poisoning (Figs. 6 & 7).

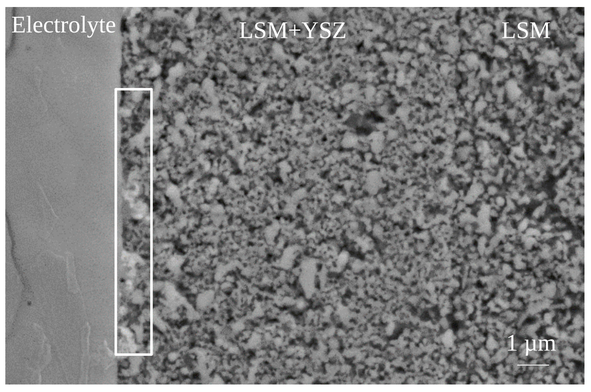

Figure 8. *SEM micrograph of LSM epoxy sample after poisoning.*

Table 1. *EDS quantification result at cathode/electrolyte interface (white rectangular area in Figure 8).*

Element	Wt %	At %
O K	16.6	50.1
SrL	21.2	11.7
LaL	31.2	10.8
CrK	5.3	4.9
MnK	25.5	22.4

- EDS area scan at LSM/electrolyte interface demonstrates Cr presence.

Future Work

- Perform cleaning methods on poisoned cells.
- Utilize quantitative microstructural characterization to compare cleaned and poisoned cells.
- Optimize the experimental conditions for cleaning processes, including temperature, water vapor content, and electrolytic bias.

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