Effect of Syngas Trace Contaminants on SOFC Anode Performance

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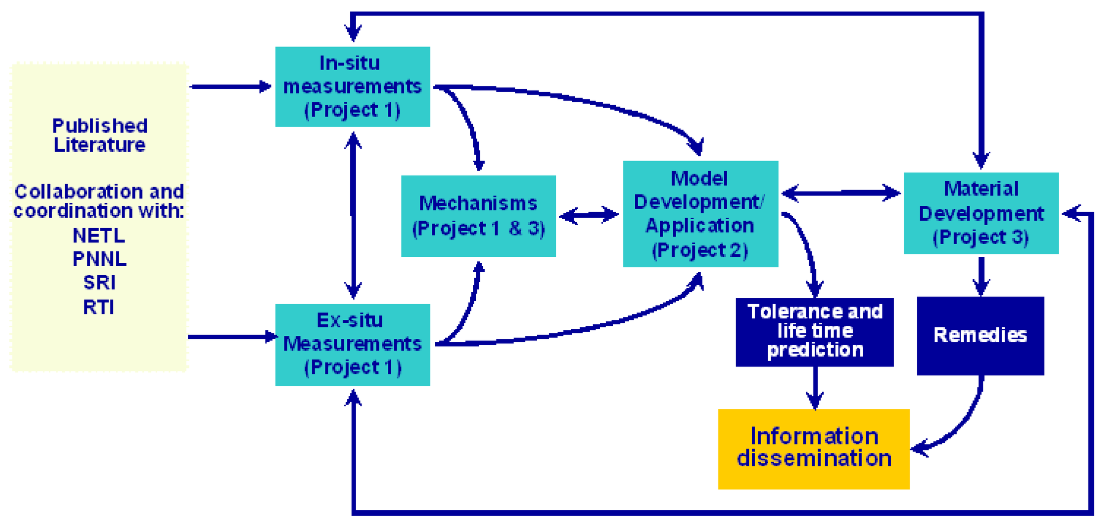
Objectives

- Identify the tolerance limits of SOFCs for trace impurities in syngas.
- Predict the lifetime of the anode for a given impurity level.
- Propose remedies for impurity effects.
- Develop and Implement new SOFC characterization methods.

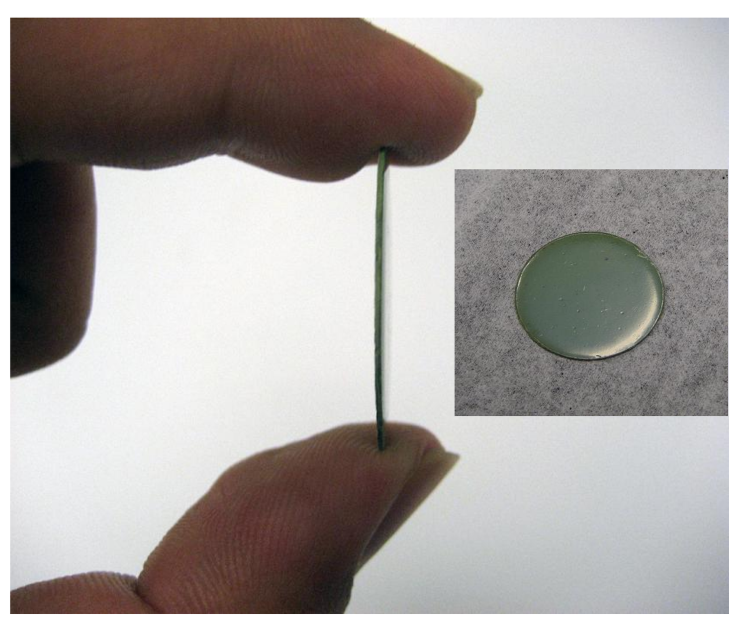
Methodology

- Multi-scale, multidisciplinary approach.
- In-house fabrication of high performance solid oxide fuel cells.
- Characterization of contaminant effects using in situ and ex-situ techniques
- Numerical modeling for analysis of degradation mechanisms.
- Validation and calibration of models using accelerated tests.
- Prediction of cell life time during long operation at very low impurities levels.
- Improve tolerance of SOFC anode to sulfur and phosphorus containing syngas.

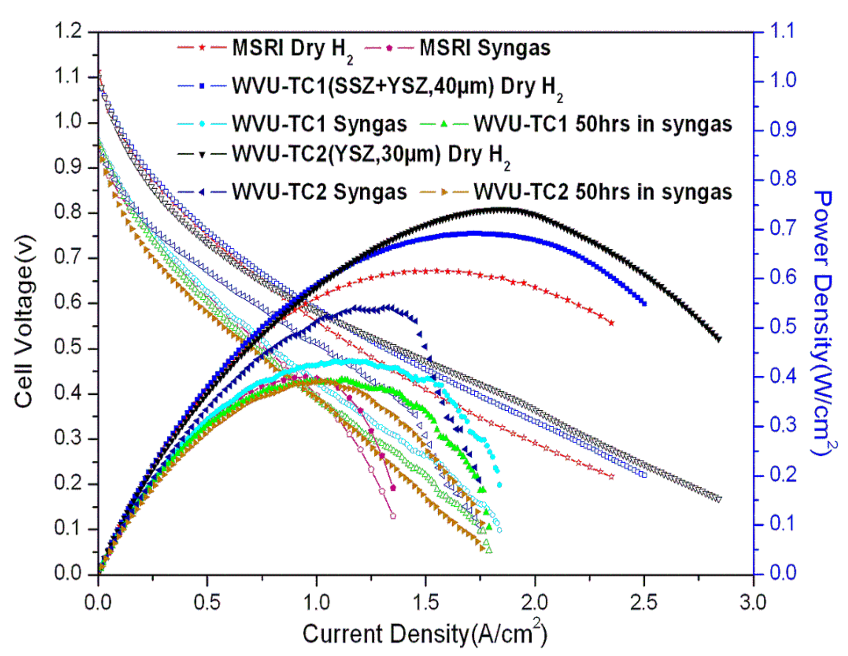


Anode Materials Development

- Improvement in performance is achieved for in-house button cells.
- Sulfur tolerance of anode supported cell was improved by impregnation of doped ceria.
- Large planar cells are being manufactured for testing under realistic stack conditions.



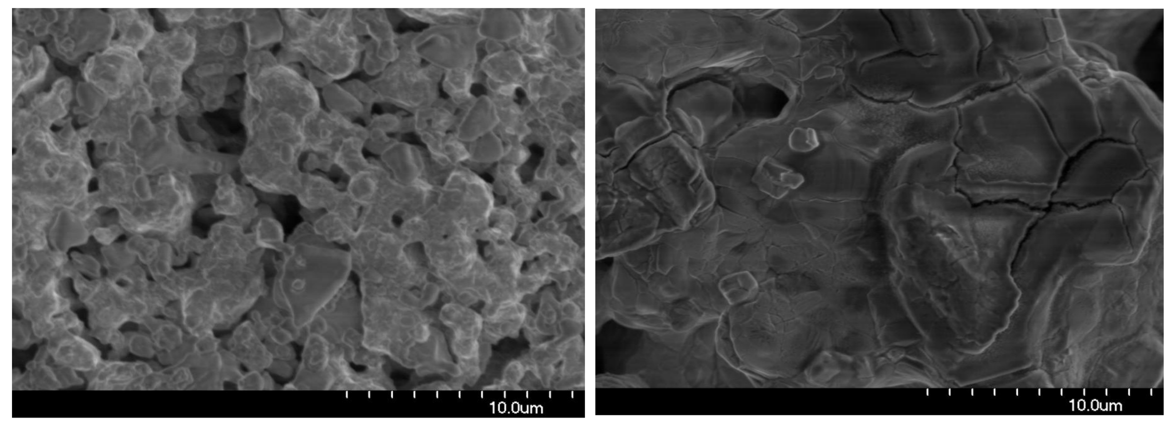
Co-sintered anode supported cell fabricated at WVU



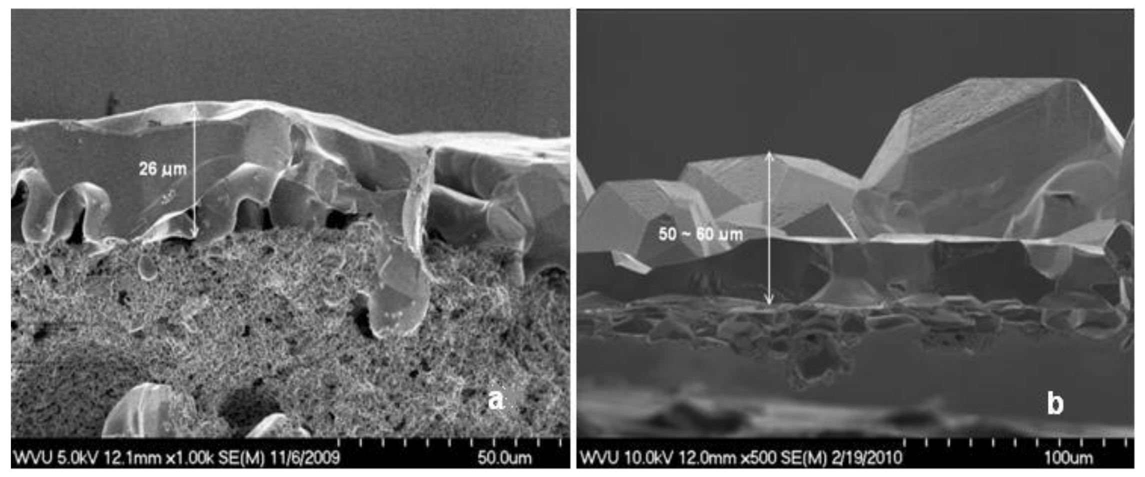
Button cells manufactured at WVU showed performance comparable to that of commercial cells

Characterization of Contaminant Effects

- Experiments were conducted to study degradation of SOFC anode due to three different impurities: P, S and Cl.
- The degradation rate due to PH_3 is larger at higher temperatures.
- The dominant phases of Ni_xP_y on the cell anode are believed to be Ni_5P_2 with H_2O and $Ni_{12}P_5$ without H_2O.

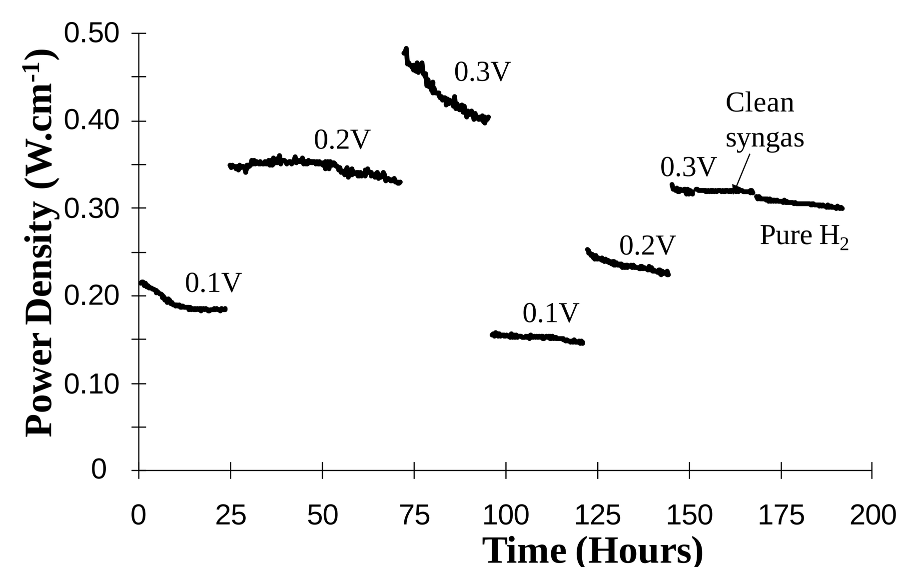


SEM images of the Ni/YSZ electrode surface (a) after 24 h of exposure to the clean syngas at 900 ºC, (b) after 48 h of exposure to 10 ppm PH_3 at 90 0ºC. Above images reveal that one possible reason for cell degradation due to PH3 is the effect P has on the anode microstructure.

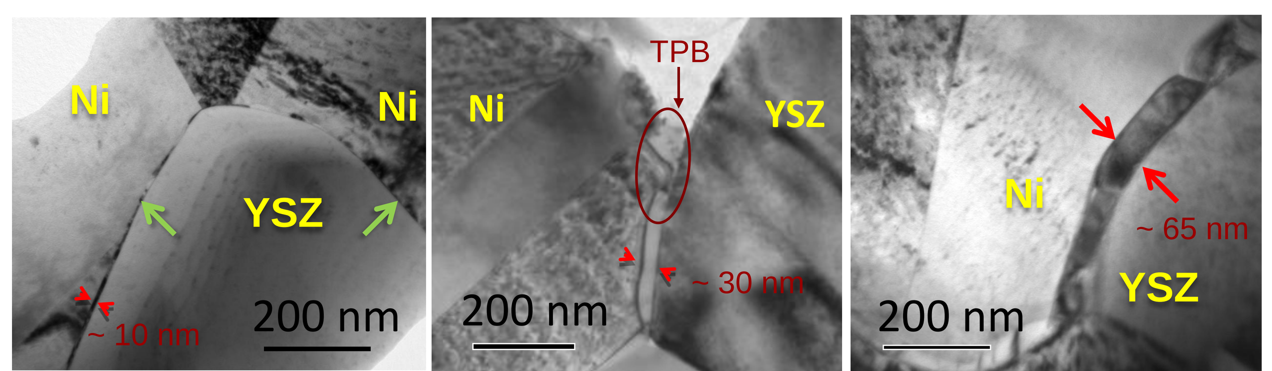


SEM micrographs of the top anode cross-section after exposure to dry H_2 with 10 ppm PH_3 at 800ºC. (a) The cell with 0.5 A cm^{-2} load for about 120 h at 1000x magnification, (b) the cell without load for about 140 h at 500x magnification. The thickness of secondary phase layer is more for no (no H_2O) load case.

- In situ Van der Pauw measurements showed no significant change in the anode conductivity when exposed to PH_3.
- TEM characterization of SOFC anodes showed existence of secondary phases at Ni-YSZ interface



Power density vs time at constant cell voltage. Rate of power loss is not a definite function of the cell over voltage when cell is operated under syngas + 10 ppm PH_3

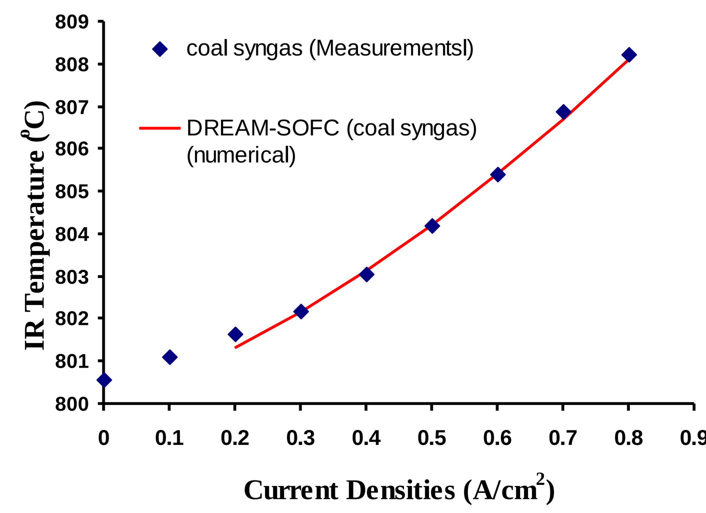


FC-1, MSRI cell, 10 microns electrolyte, ~24 h electrochemical load, 97% H2, then stopped.	FC-2, MSRI cell, 20 microns electrolyte, ~45 h electrochemical load, syngas, stopped due to crack.	FC-3, MSRI cell, 20 microns electrolyte, 550 h electrochemical load, syngas+10 ppm Hg, no degradation according to electrochemical data

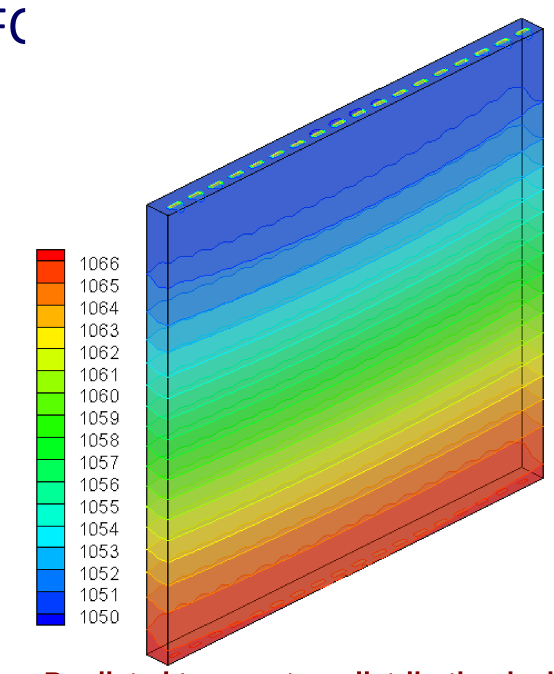
NiO ribbon grains observed at the interface of Ni and YSZ

Modeling

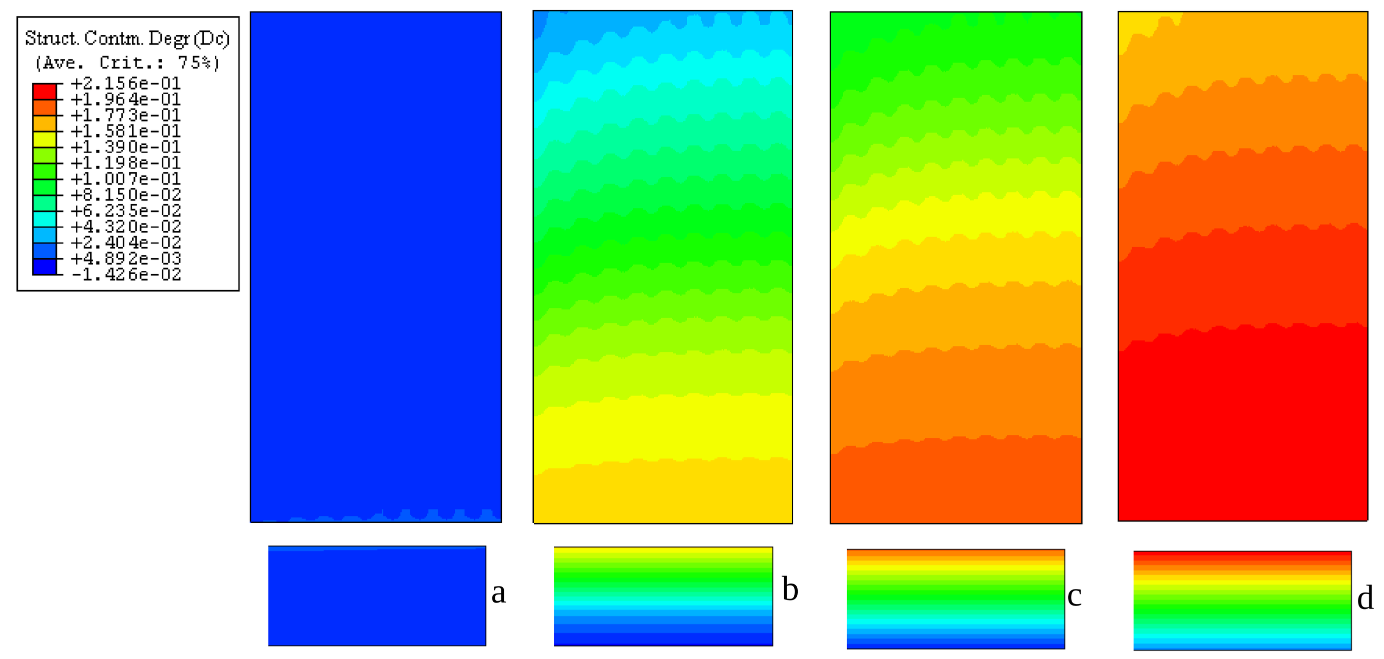
- Parametric studies were conducted using in-house simulation tools to predict the electrochemical and structural performance of SOFC



Model validation: Predicted SOFC surface temperature plotted along with measurements from in-situ experiments.

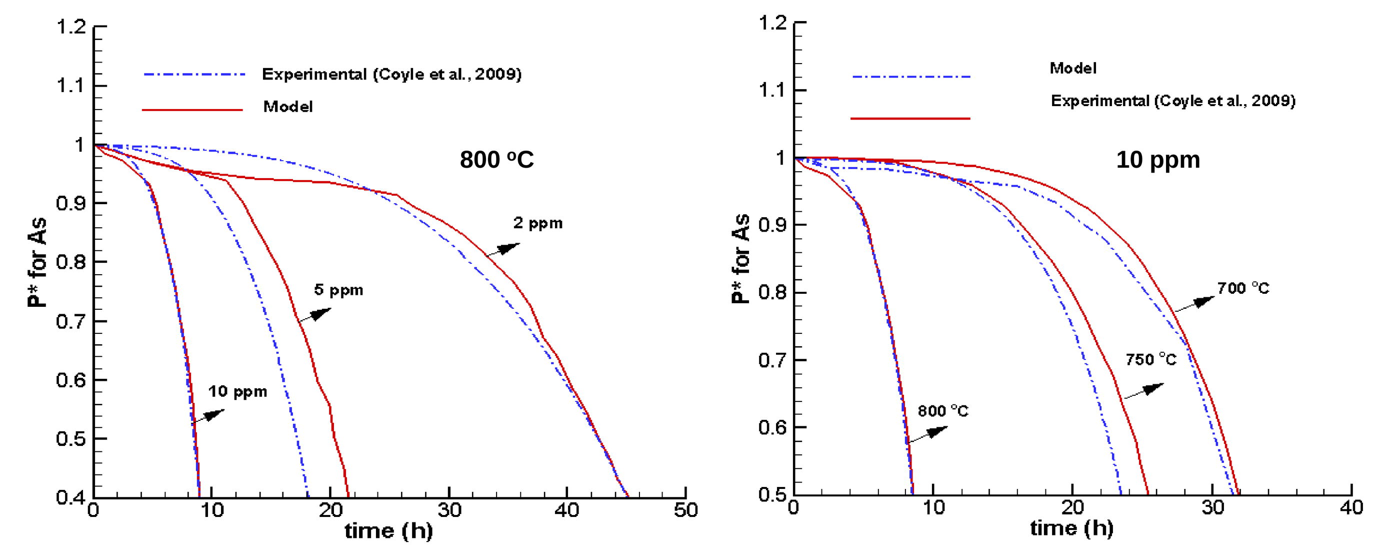


Predicted temperature distribution inside a counter-flow planar SOFC.



Predicted degradation of anode material in a planar cell due to contaminant along the fuel flow and across anode thickness under 5ppm of PH3 exposure (a) 510h (b) 7410h (c) 12410h (d) 19410.

- A new phenomenological model is developed to simulate the typical SOFC anode degradation due to syngas trace impurities.
- The degradation model is shown to accurately predict the long term performance when calibrated with the accelerated tests.



Predicted Performance degradation due to AsH_3 exposure: Modified power density vs time at 0.05A/cm². Degradation model closely emulates the characteristic behavior of SOFC anodes at different temperatures and concentrations.

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