Recent Progress in Coal Syngas Contaminant Effect Studies on SOFC Anodes at West Virginia University

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Objectives

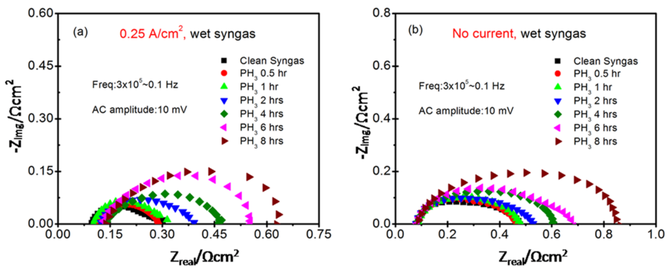
- Micro structural and electro chemical characterization of contaminant effects.
- Continuum level modeling to Predict the lifetime of the anode for a given impurity level.
- Propose remedies for impurity effects .

Methodology

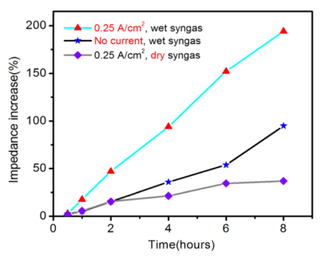
- Multi-scale, multi-disciplinary approach.
- In-house half and full cell test and fabrication of high performance solid oxide fuel cells.
- Combining In-situ electrochemical testing with the ex-situ material characterization methods to analyze the degradation.
- SEM and SIMS techniques to characterize cross section surface morphology and elemental maps.
- HRTEM to characterize microstructure origins of degradation
- In-situ concentration measurements using mass spectrometry
- Numerical modeling for analysis of degradation mechanisms and prediction of cell life at low impurity levels.
- Advanced ceramic anode materials to replace Ni as alternative electro-catalysts for fuel oxidation.
- Large Fuel Cell Testing at WVU

Electrochemical Characterization

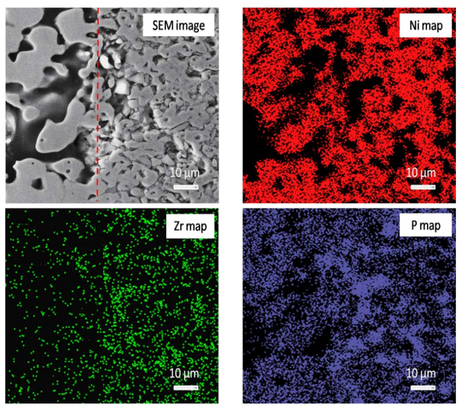
- Verified that Ni migration in Ni-YSZ is induced by electrostatic force and chemical potential gradient of phosphorous
- Rate of migration is much less when the cell is not loaded.



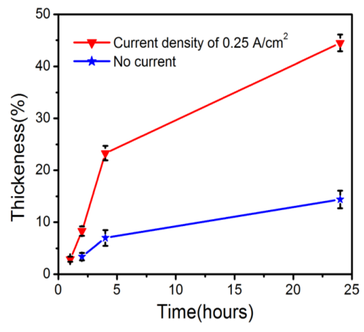
Nyquist plots of the impedance spectra taken from the half cells operated at 800° C in coal-syngas with 5 ppm PH_3 : (a) at current density of 0.25 A/cm² (b) without current load .



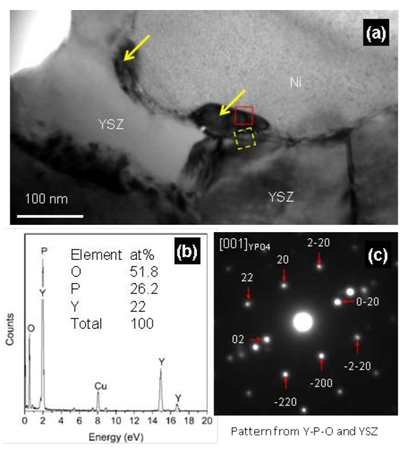
Polarization impedance as a function of operation time (5 ppm PH_3 at 800°C)



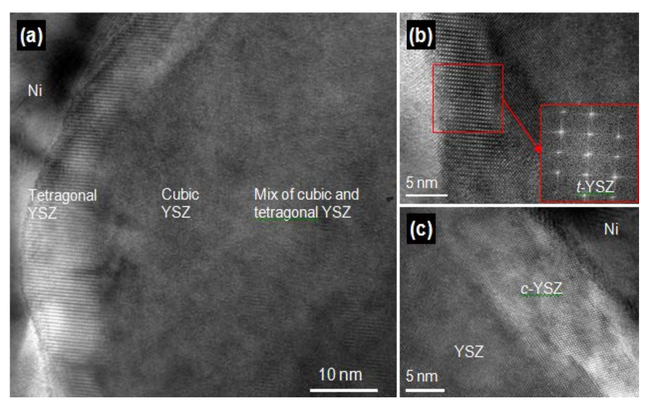
Elemental maps collected from the cross-sections of the fuel cells. Ni converted to Ni-P secondary phases in the anode exposed to 5 ppm for 24 hours at a current density of 0.25 A/cm².



Ratio of the top Ni-P compound layer thickness to the whole anode thickness as a function of time of exposure to 5 ppm PH_3-containing coal-syngas at 800 °C.

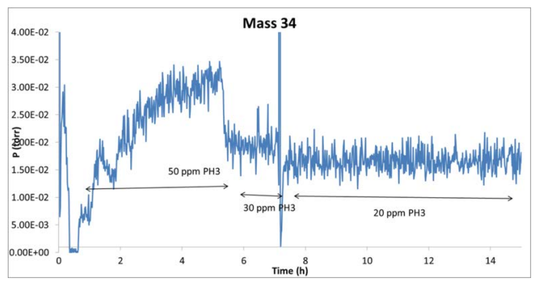


(a) the presence of Y-P-O precipitates growth at YSZ/YSZ/Ni triple grain junctions, (b) the spectrum and chemical composition of these precipitates, (c) the diffraction pattern taken from the area with Y-P-O phase and YSZ phase.



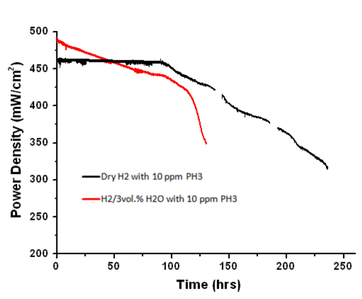
The *t*-YSZ ribbon phase and c-YSZ domain along the Ni/YSZ interface for the sample operated in syngas with phosphine for 117 h.

- HRTEM revealed that YSZ crystalline structure is also affected by phosphine.
- in-situ mass spectrometer measurements found no evidence that PH_3 and H_2S impurities convert to oxidized forms.
- Air leaks were detected in the test stands.

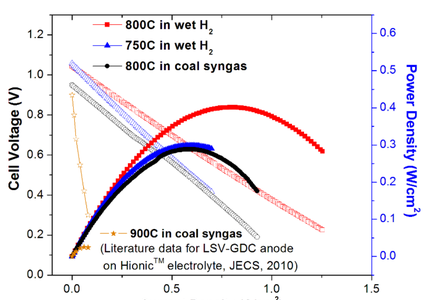


In Situ Gas Concentration: Measurements Partial pressure of mass 34 as a function of PH_3 concentration in a hydrogen stream.

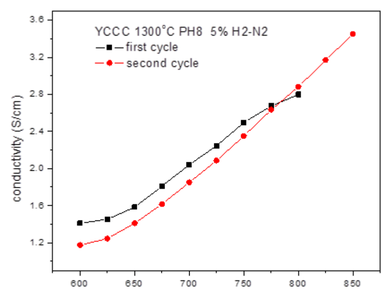
Anode Materials Development and Cell-Testing



Phosphine induced degradation under wet and dry fuel conditions.

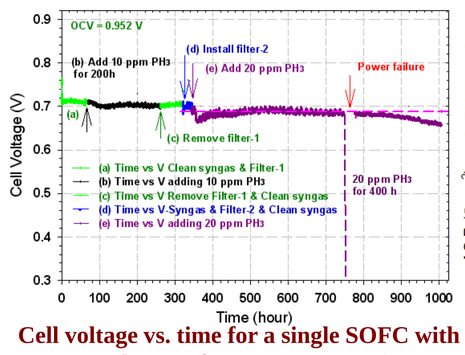


Performances of LSGM-supported Ni-free SOFC with LSV-SDC

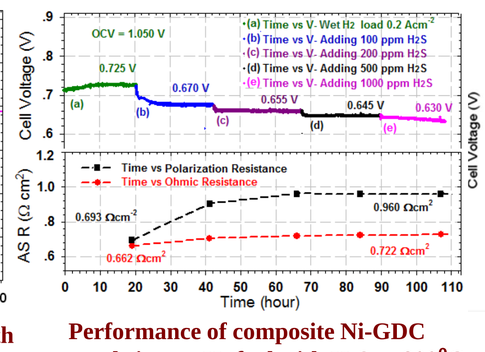


Conductivity of YCCC in air

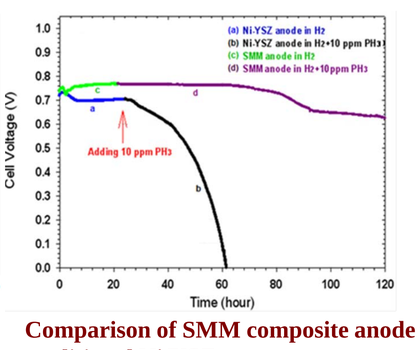
- Rate of cell degradation is strongly dependent on the steam concentration
- Synthesized SOFCs with $La_{1-x}Sr_xV_{1-y}M_yO_3$ and SDC anode, LSGM electrolyte and LSCF cathode which showed higher performance than similar cells in literature.
- Synthesized alternative YCCC anodes with high red-ox stable conductivity.
- Extended the lifetime of cells exposed to PH_3 using a pre-filter which is estimated to last upwards of 10,000 hrs in 2ppm PH_3.
- Ni-GDC anodes with Ni-GDC barrier are resistant to H_2S even at 1000 ppm.
- Synthesized an all ceramics SOFC using $Sr_2MgMoO_{6-\delta}$ (SMM) and $Ce_{0.9}Gd_{0.1}O_2$ (GDC) anode which resistant to PH_3 poisoning.



Cell voltage vs. time for a single SOFC with over 1000 hours of exposure to PH_3 in syngas.

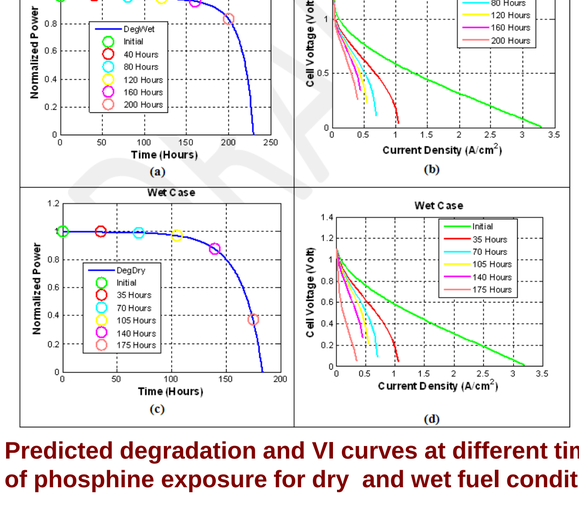


Performance of composite Ni-GDC anode in wet H_2 fuel with H_2S at 800°C.



Comparison of SMM composite anode to traditional Ni/YSZ cement

Modeling



Predicted degradation and VI curves at different times of phosphine exposure for dry and wet fuel conditions

- Simulated the experimentally observed sensitivity of PH_3 induced degradation to steam concentration.
- Developed modeling tools to simulate polarization and impedance responses of the cells at different times after impurity exposure.

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