SOFC Core Development Activities at PNNL

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Technology Focus Areas

- Cell / Stack Materials and Fabrication Processes
- Stack and System Performance Modeling
- Related SOFC Development Programs at PNNL

Cell/Stack Materials and Fabrication Processes Development

Technology development

- Tape casting and co-sintering
- Ni base anode electrode
- Non Ni red/ox tolerant anode
- High performance cathode
- Corrosion resistant interconnection

Low cost tape casting and co-sintering processes

Anode formulations consisting of Ni - ZrO_2 - Al_2O_3

- CTE match with the electrolyte
- Cost reduction- substitution of ZrO_2 by Al_2O_3
- Dimensional control & less warpage

Co-sintering of the anode and electrolyte layers in air

- Bi-layer composites fabricated and tested
  - 5 to 10 uM dense YSZ &~ 600 to 1000 uM porous Ni- Cermet

Advanced red/ox tolerant anode development

Goal : Develop alternatives to Ni-based anodes that offers higher tolerance to oxidizing environments to allow fuel to be turned off during shut down.

- *Limited choice of materials*
- *Selected Perovskites, fluorites,Spinels, Pyrochlores identified with:*
  - *High electrical conductivity*
  - *Chemical and structural stability - oxidizing / reducing environments*
  - *Good TEC match*
  - *Very slow redox kinetics*

Development Status

- *Mixed valence transition metal oxides.*
- *Measured conductivity : 1-300 S/cm at 1000°C at $pO_2 = 10^{-18}$ atm.*
- *TECs : 10 -12 x 10^{-6} C^{-1} during Oxidation & Reduction Cycles.*
- *Full reduction-oxidation cycles demonstrated.*

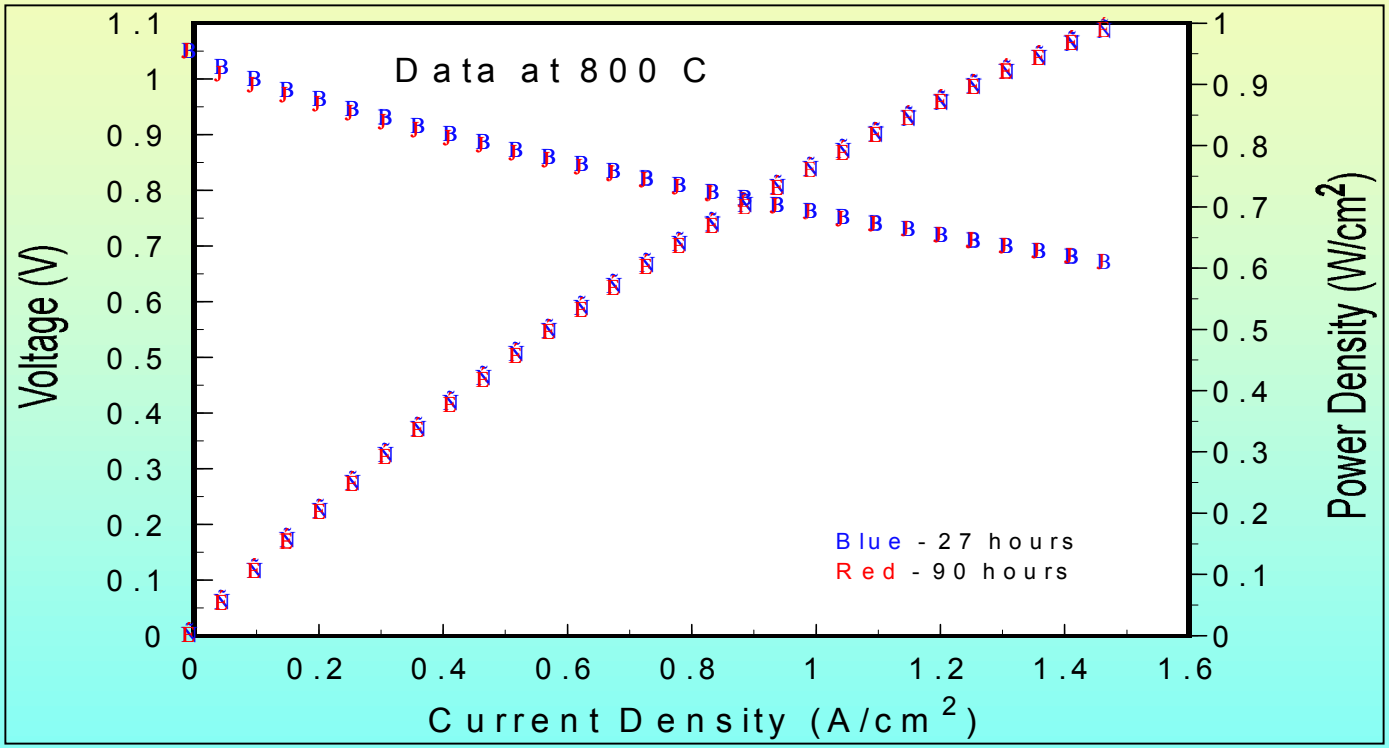
Further Characterization and cell tests in progress.

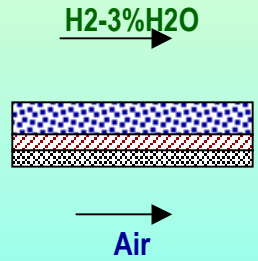
High Performance Cathode

Goal : Develop and optimize intermediate temperature chemically stable cathode for high power density operations under isothermal and thermal cyclic exposure conditions.

- *A large historical data base available on doped ABO_3 Perovskites*
- *Improved performance & stability demonstrated for $La_{1-x}Sr_xFeO_3$*
- *Structural and compositional optimizations (bulk and interfacial modifications) in progress*

Improvements in Cell Performance





Anode – $Ni\text{-}Al_2O_3\text{-}ZrO_2$ (600uM) Cathode – $La_{.8}Sr_{.2}FeO_3$(50uM) Electrolyte - YSZ(10 uM)

SOFC interconnection development

Two fold objective:

- *Identify degradation processes*
- *Develop a cost effective material (bulk and /or coatings) for intermediate temperature operation.*

SOFC exposure conditions remain complex:

- ***Multi component gas streams (H_2O, CO_2, O_2 etc.)***
- ***Changing fuel composition (fuel utilization)***
- ***Simultaneous fuel and oxidant gas exposures***
- ***Isothermal and thermal cyclic exposures***

SOFC interconnection development

Status:

- *Identified corrosion processes :*
  - *Conjoint attack*
  - *Molecular diffusion through scale imperfections / defects*
  - *Oxide defect chemistry - anion or Cation stoichiometry*
  - *Short circuit diffusion*
  - *Vaporization*

- *Developed metallurgical data base :*
  - *Oxidation and oxide properties (conductivity, PB ratio, defect structure)*
  - *Joinability and fabricability (hot & cold rolling, welding, brazing)*
  - *Carburization & sulfidation behavior (metal dusting, low mp eutectic)*

Approach

- **Pre-Screen Evaluation**
  - Thermal expansion coefficient
  - Linear rate of oxide scale growth at 800°C
  - Creep rate at 800°C
  - Potential for hydrogen embrittlement
  - Potential for corrosion due to sulfidation
  - Initial estimate of raw materials costs
- **Screen Testing**
  - Electrical Screen
  - Chemical Screen
  - Mechanical Screen
  - Fabrication Screen
  - Cost Analysis
- **Collaborative Development Effort**
  - National Laboratories
  - SOFC Manufacturers
  - Materials Manufacturers
  - Academia

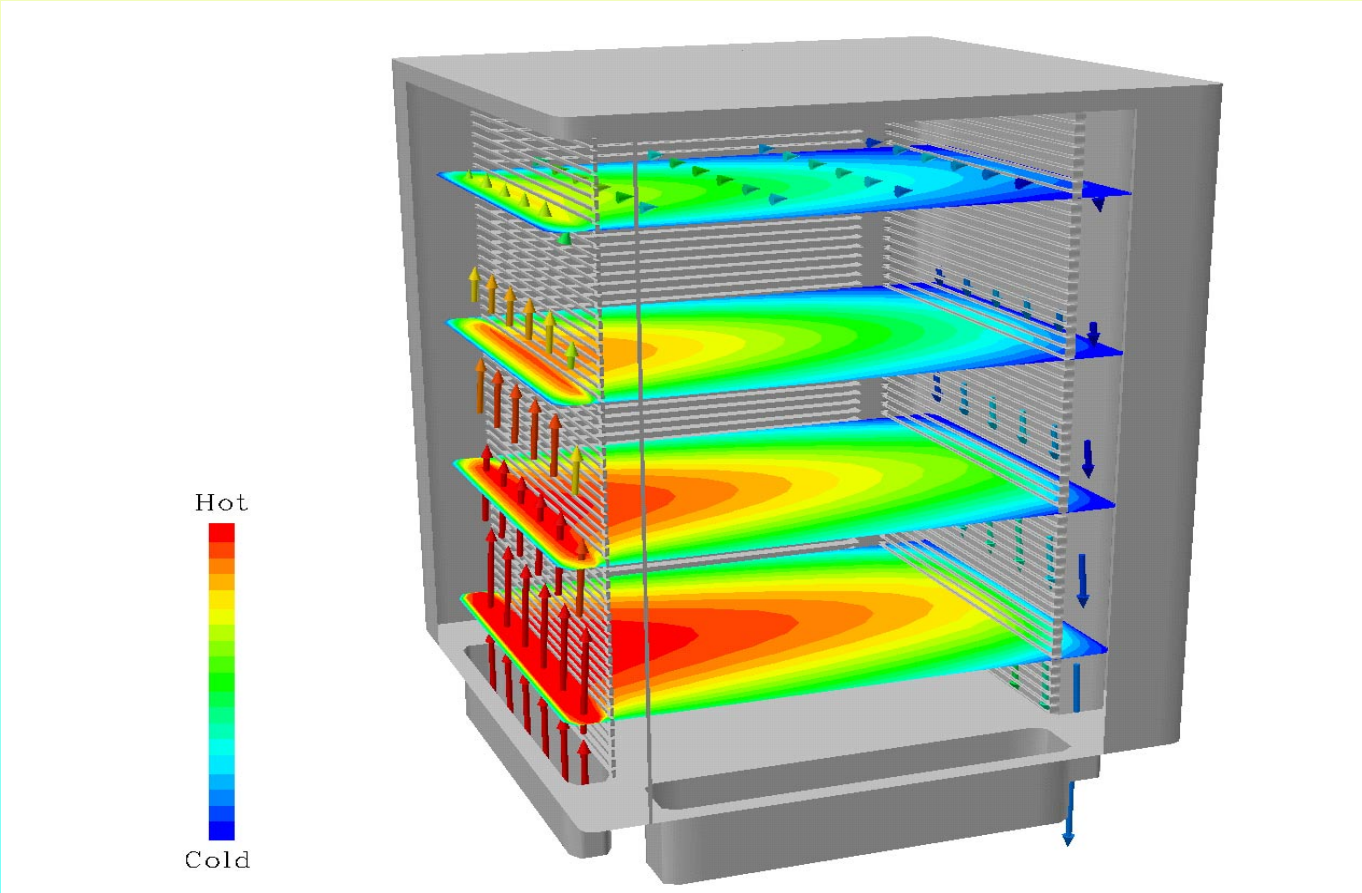
Stack and System Performance Modeling

Goal : Develop and optimize advanced engineering modeling tools and cell and stack designs.

Predict thermal, stress, flow and electrical performance during cell / stack startup and cool down as well as steady state and transient operation (Electro-thermo-chemical analysis)

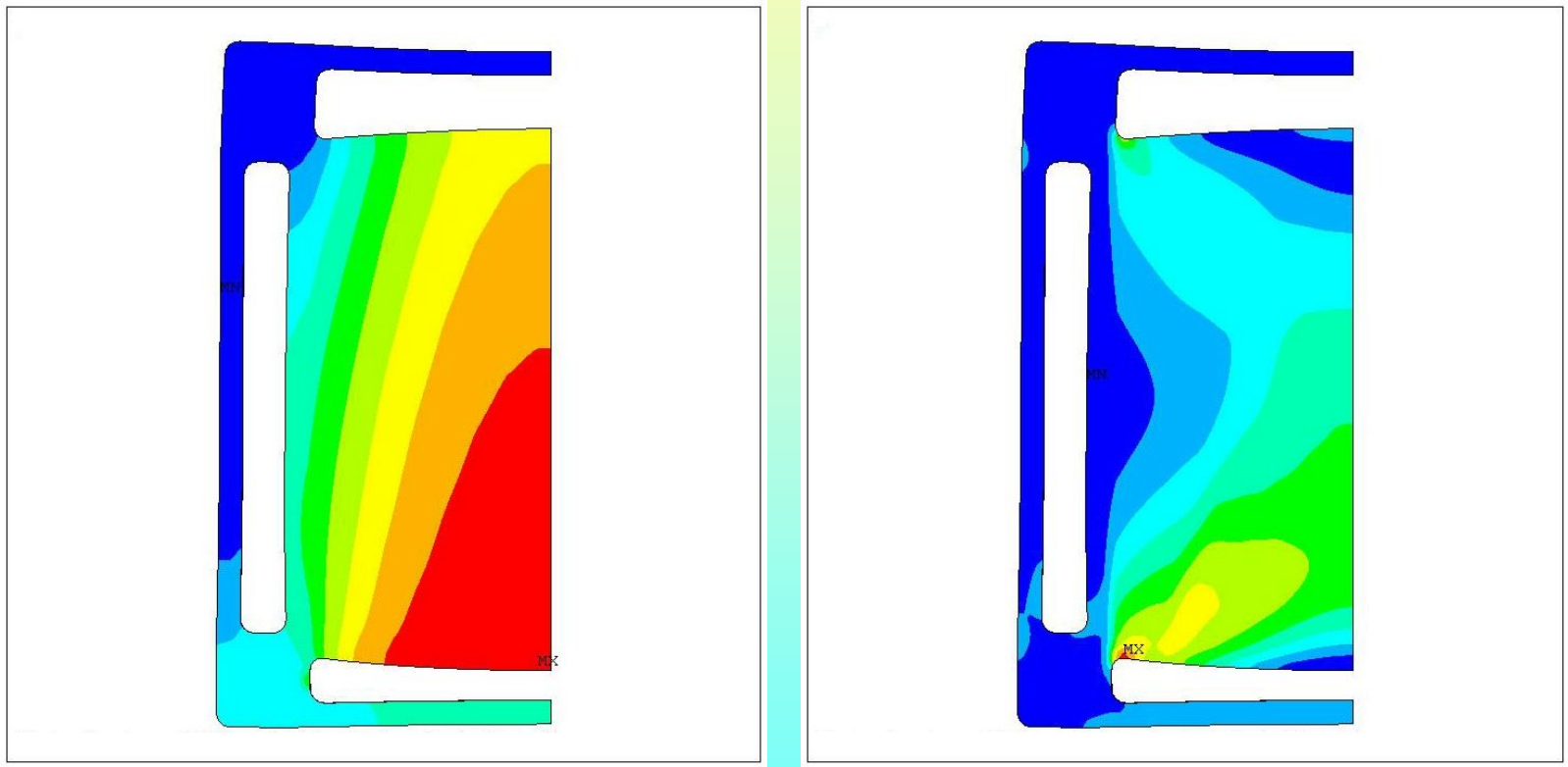
- *Stress analysis*
- *Computational flow analysis*
- *Electrochemical analysis*

Thermal-Fluids Model



Prediction of flow and temperature distribution.

Thermal-Structural Model:



Prediction of thermal stresses and planar deflections

Animation of stack heat up

Related SOFC Development Programs at PNNL

LDRD :

- *Fuel Cell Observatory*
- *Advanced FC Systems & Functional Integration*

AR&TD :

- *Basic Electro-ceramic Materials for Fuel Cells and Gas separation membranes, Glass seals*

CRADA :

- *Collaborative SOFC Technology development with Delphi Automotive for Automotive Auxiliary Power*

DARPA :

- *Collaborative SOFC Technology Development with Honeywell for "Palm Power"*

SOFC Stack Observatory Concept

Solid oxide fuel cell stack observatory