High Temperature Electrochemistry Center - HiTEC

Core Program

Tampa Bay, FL

January 27, 2005

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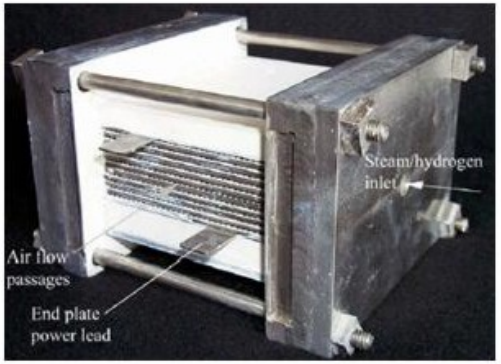
DG Systems Program Areas (R&D Activity)

FY05 Budget in Millions

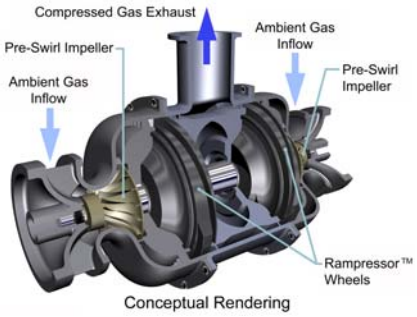
Innovative Concepts SECA $54.2



Advanced Research $12.2 High Temperature Electrochemistry Center (HiTEC)

Vision 21 Hybrids $5.0 (SWPC)

Systems Development $2.9 (FCE)

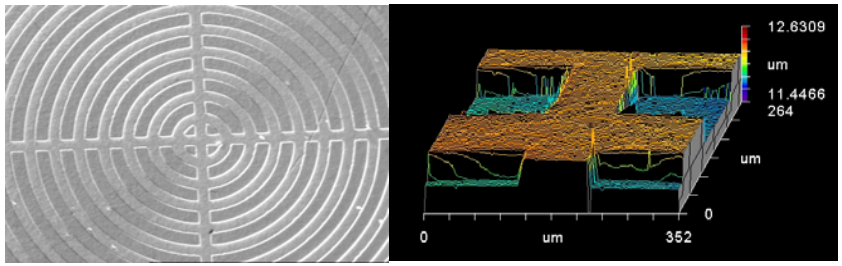


Novel Generation $3.0 (Ramgen)

High Temperature Electrochemistry Center

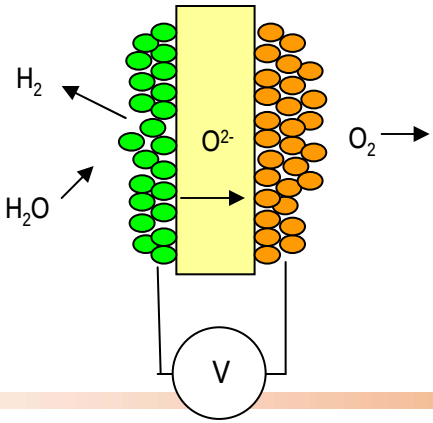
Organization

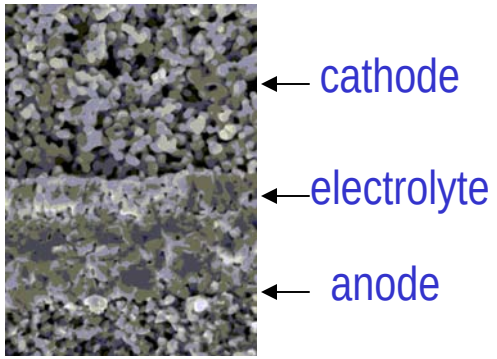
- Located at PNNL with Satellite Universities currently at Montana State Universities and University of Florida
- Funding Agencies: DOE NETL, DOD, NASA, DARPA, ORL, ONR
- Contractors: University of Utah, Cal Tech, Ion America, TBD
- Focus to support Energy Security, Hydrogen Economy and FutureGen, DOD and Space Applications



Novel electrode structures allow role of microstructure and catalytic activity to be distinguished.

"Reversible" solid oxide fuel cell could produce hydrogen from water during periods of excess grid capacity, and produce electricity later from the stored hydrogen.





HITEC Mission

The mission of HiTEC is:

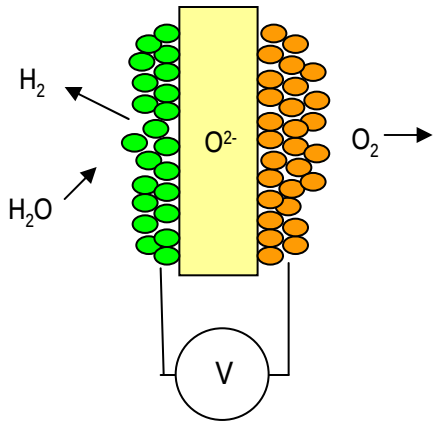
1) to advance the solid oxide technology, such as solid oxide, high temperature electrolysers, reversible fuel cells, energy storage devices, proton conductors, etc., for use in DG and FutureGen applications, and

2) to conduct fundamental research that aids the general development of all solid oxide technology.

HiTEC Extending Solid Oxide Technology Potential

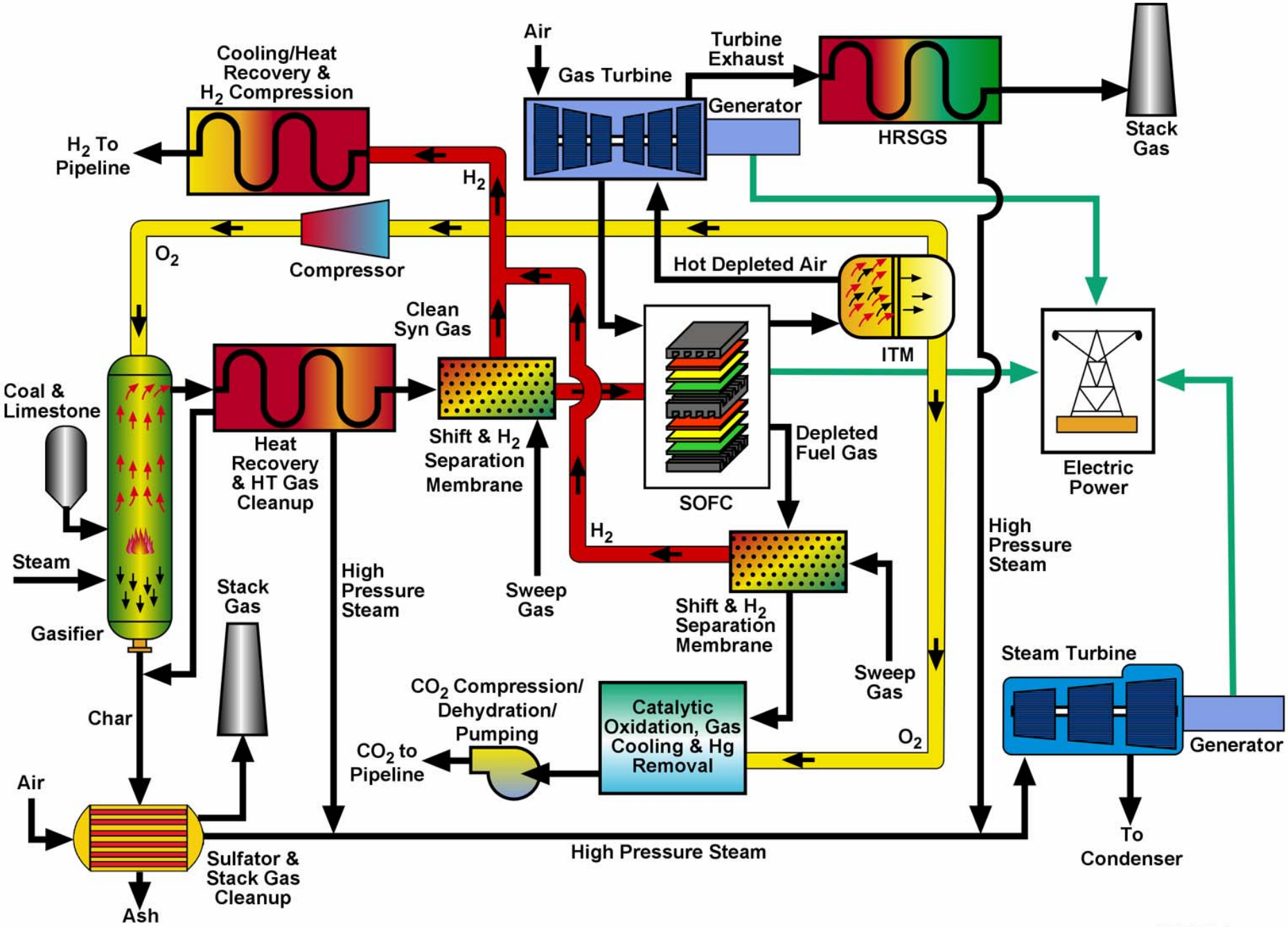
- **Fuel cells**
  - Proton conductors – cerates and zirconates
  - Next generation higher power density (DoD and NASA)
- **Energy storage devices**
  - Flow batteries
- **Regenerable fuel cells**
  - Strontium titanate working anode
- **Electrolyzers**
  - Elly Zone
  - High efficiency utilizing waste heat
- **Membranes**
  - Hydrogen
  - Oxygen
  - Carbon dioxide
- **Reformers**
- **Thermelectrics**
- **Sensors**

"Reversible" solid oxide fuel cell could produce hydrogen from water during periods of excess grid capacity, and produce electricity later from the stored hydrogen.



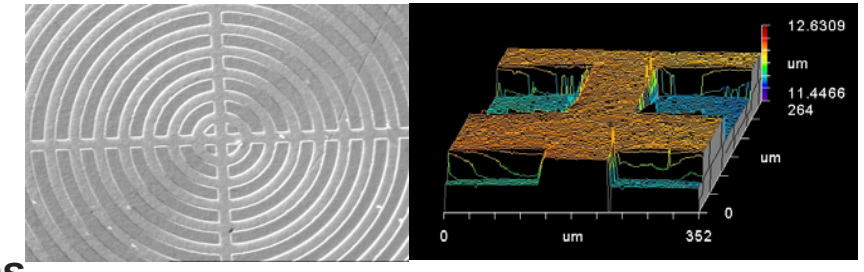
HiTEC Extending Solid Oxide Technology Applications

- **Power Generation**
  - DG
  - FutureGen
- **Hydrogen Production**
- **Reformation**
  - Syngas, NG
- **Hydrogen fueling stations**
  - Co-production –H2, Electricity, Thermal
- **Oxygen Production**
- **Transportation fuel cells**
  - SOFC (baseload) + ICE (peak)


Air
Gas Turbine
Turbine Exhaust
Generator
HRSGS
Stack Gas
Cooling/Heat Recovery & H_2 Compression
H_2 To Pipeline
H_2
O_2
Compressor
Hot Depleted Air
ITM
Clean Syn Gas
Coal & Limestone
Heat Recovery & HT Gas Cleanup
Shift & H_2 Separation Membrane
SOFC
Depleted Fuel Gas
Electric Power
High Pressure Steam
Steam
Gasifier
Stack Gas
High Pressure Steam
Sweep Gas
H_2
Shift & H_2 Separation Membrane
Sweep Gas
Steam Turbine
Char
CO_2 Compression/ Dehydration/ Pumping
Catalytic Oxidation, Gas Cooling & Hg Removal
O_2
Generator
CO_2 to Pipeline
Air
Sulfator & Stack Gas Cleanup
High Pressure Steam
To Condenser
Ash
IG0404008.1

HiTEC Research Areas and Participants

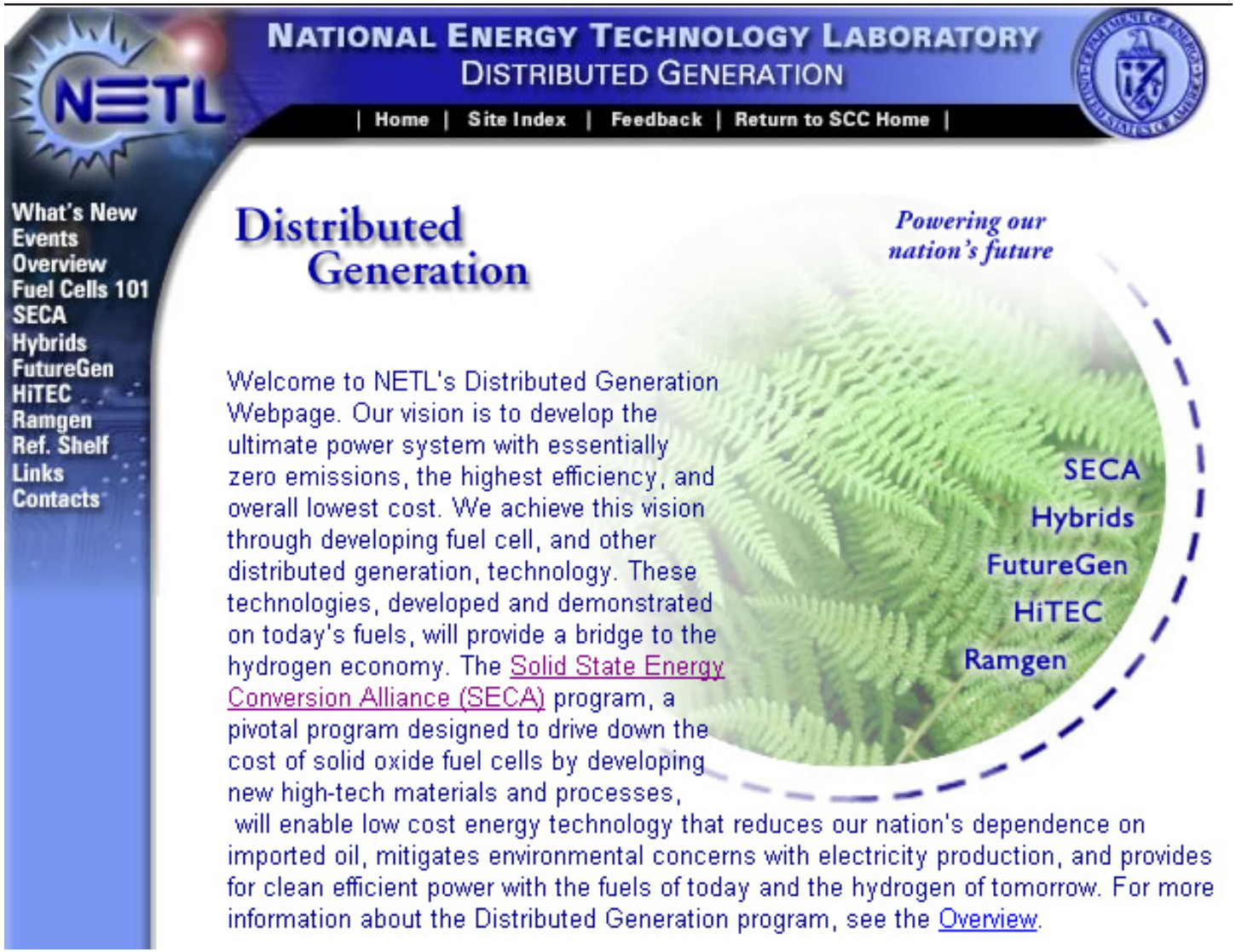
- ***Study of Buried Interfaces in Fuel Cell Structures***
  (Montana State University)
- ***Development of Corrosion-Resistant Layers on SOFC Interconnects***
  (Montana State University)
- ***Determination of Cathodic Inefficiencies in SOFCs Using Patterned Electrodes***
  (University of Utah)
- ***Reversible Solid Oxide Fuel Cells***
  (PNNL, Ion America)
- ***Proton Conductors/Hydrogen Membranes***
  (University of Florida, CalTech, PNNL)
- ***Atomistic modeling of defects using molecular dynamics***
  (University of Florida)



HiTEC Events

- **HiTEC Solicitation**
  - $2.0MM
  - Awards, September ’05
  - Possible topics include: energy storage, electrolyzers, reversible fuel cells, thermoelectrics, and other selected cross-cutting research areas

- **HiTEC Workshop, August ‘05**
  - Selection of HiTEC Steering Committee
    - DOE, NASA, DARPA, ONR, ORL



http://www.netl.doe.gov/dgfuelcells

mark.williams@netl.doe.gov gary.mcvay@pnl.gov

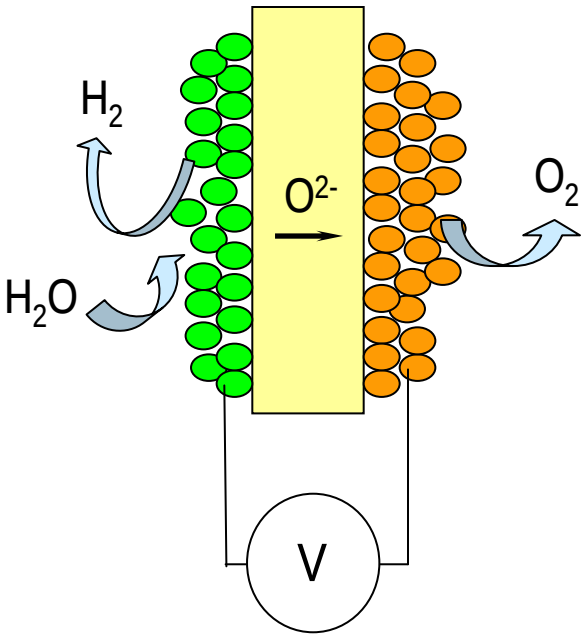
Electrode Development For Reversible Solid Oxide Fuel Cells

Olga Marina, Greg Coffey, Carolyn Nguyen, Larry Pederson, Peter Rieke, and Ed Thomsen
Pacific Northwest National Laboratory
Richland, Washington 99352 USA

Mark Williams
National Energy Technology Laboratory
Pittsburgh, Pennsylvania USA

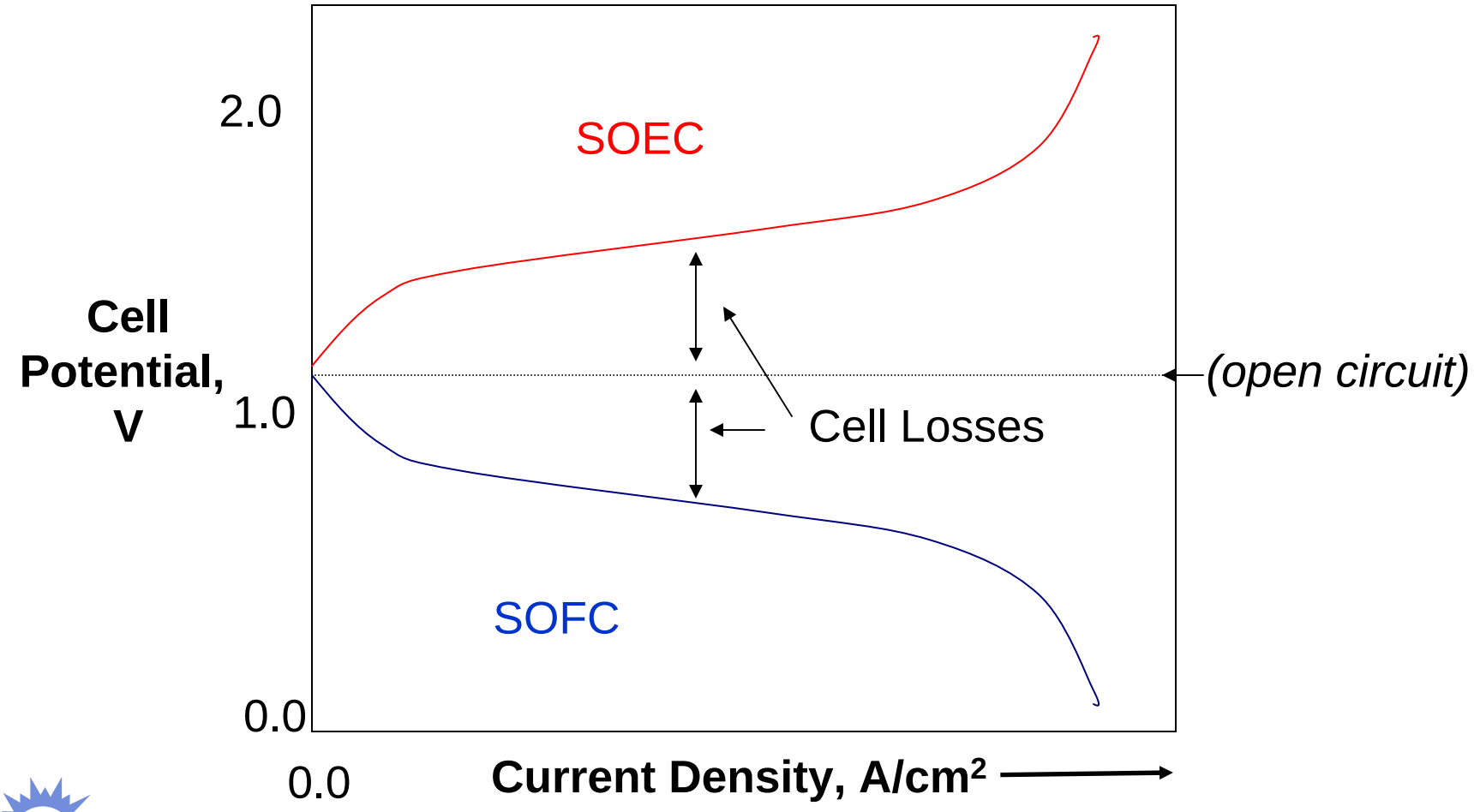
2004 Joint International Meeting
Honolulu, Hawaii
October 3-8, 2004

Steam Electrolysis in a Reversible SOFC, or "SOFC/SOEC"

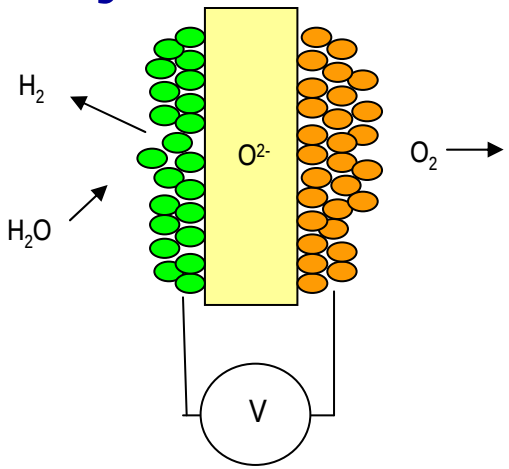


- **A "reversible" solid oxide fuel cell could produce hydrogen from water during periods of excess grid capacity, and produce electricity later from the stored hydrogen.**
- **High temperature steam electrolysis potentially more efficient than liquid water electrolysis at low temperature.**
- **Potential cost advantages in combining functions in single device versus separate electrolyzer and fuel cell.**
- **Barriers include electrode losses, stability, heat integration, hydrogen storage.**

Schematic Current-Voltage Characteristics for SOFC/SOEC



High Temperature Electrochemistry Center (HiTEC)



FY2005 Key Advanced Research Project Milestones

- **Description of Impact**
  - Investigate interconnect coatings/materials.
  - Develop Reversible SOFCs.
  - Solicitation for additional universities 12-15 awards ($2.25MM)

- **Benefit to Product Area**
  - Advance high temperature solid oxide electrochemical technologies, such as solid oxide, high temperature electrolyzers, reversible fuel cells, energy storage devices, proton conductors, etc., for use in DG and FutureGen applications, and to conduct fundamental research that aids the general development of all solid oxide technology.

Participant or Team	Place of Event	Milestone Date
PNNL	Richland, WA	FY05 by 4th Qtr
Montana State	Bozeman, MT	FY05 by 4th Qtr
Univ. Utah	Salt Lake City, UT	FY05 by 4th Qtr
Ion America	Moffett Field, CA	FY05 by 4th Qtr
Univ. Florida	Gainesville, FL	FY05 by 4th Qtr
Cal Tech	Pasadena, CA	FY05 by 4th Qtr
HiTEC Solicitatioin	NETL	FY05 by 4th Qtr