Bipolar Plate-Supported Solid Oxide Fuel Cell “TuffCell”

J. David Carter, Deborah Myers, and Romesh Kumar
Chemical Engineering Division

This presentation does not contain any proprietary or confidential information

Argonne National Laboratory
A U.S. Department of Energy Office of Science Laboratory Operated by The University of Chicago
Project Objectives

• To develop an improved solid oxide fuel cell (SOFC) for Auxiliary Power Units and other portable applications

• Addressing the following SOFC issues:
  • Startup time
  • Durability to temperature cycling
  • Vibration and shock resistance
  • Materials and manufacturing cost
Budget

- Total Project Funding, FY’02-FY’04: $550 K
- FY’04 Funding: $250 K
Technical Barriers and Targets

- This project addresses DOE’s Technical Barriers for Fuel Cell Components
  - O: Stack Material and Manufacturing Cost
  - P: Durability
  - Q: Electrode Performance
  - R. Thermal and Water Management

- DOE’s Technical Target is to develop a 3-5 kW\textsubscript{e} Auxiliary Power Unit with the following attributes:
  - Power Density: 150 W/kg and 170 W/L
  - Start-up time, cyclability, durability: 15-30 min, 500 cycles, 5,000 hours
  - Cost: $400/kW\textsubscript{e}
Approaches

- Support cell on metallic bipolar plate to improve durability, cyclability, and shock-resistance
- Minimize thickness of expensive ceramic-containing layers (anode, electrolyte, and cathode)
- Fabricate cell components using powder metallurgy techniques
- Eliminate manufacturing steps to reduce cost
- Develop and test improved SOFC stacks
TuffCell design and fabrication procedure address SOFC shortcomings

- Thin layers of expensive ceramic materials
- Brittle ceramic components are bonded to tough metallic layers
- Single programmed high temperature process
- Single electrical contact plane between stack units
Safety

- Internal safety reviews have been performed for all aspects of this project to address ESH issues
  - Component fabrication
    - *All fabrication is performed in a hood to exhaust vapors of organic solvents and powders*
    - *Used organic solvents and powders are collected and disposed of through the laboratory’s Waste Management Operations*
  - Cell sintering and cell/stack testing
    - *Performed in a hood equipped with hydrogen monitors that trigger automatic shut down of process/test*

- Safety reviews are updated and renewed annually
Project Timeline

12/01
Achieved sintered laminate

2/02
TuffCell has 4x strength of anode-supported cell

8/02
Power max. of 104 mW/cm_

4/02
OCV of 1.14 V 25 mW/cm_

11/02
Power max. of >260 mW/cm_

11/03
Designed and fabricated stack test apparatus

12/03
Fabricated edge sealant material Designed and fabricated a two-cell stack

10/01
Began

12/01
Achieved sintered laminate

4/02
OCV of 1.14 V 25 mW/cm_

11/02
Power max. of >260 mW/cm_

11/03
Designed and fabricated stack test apparatus

12/03
Fabricated edge sealant material Designed and fabricated a two-cell stack

1/04
First stack test

0 50 100 150 200 250 300 350

0 0.2 0.4 0.6 0.8 1.0 1.2

0 100 200 300 400 500 600 700 800 900

U.S. Department of Energy, EERE
Hydrogen, Fuel Cells, and Infrastructure Technologies Program
Current status of TuffCell’s power density

Current Density (mA/cm²)

Cell Voltage (V)

Power Density (mW/cm²)

Apr '02
TuffCell’s superior mechanical properties, cyclability demonstrated

Physical tests:
- Impact test
- 4-point bend test
- Temperature cycling from RT to 800° C at ~10° C/min
TuffCell stack development efforts

• Feb. 2004 Milestone:
  Test two-cell stack on simulated reformate/air

• Stack test requires cell modifications/refinements
  - Individual cell size scale-up from 1”x1” to 2”x2”
  - Gas impermeable bipolar plate
  - Edge sealing for gas manifolding
  - Corner sealing for gas manifolding
  - Coating of chromium-containing cathode flow field
  - Flat flow fields for good electrical contact between cells
Dilatometer study showed problem with bipolar plate binder burn-out

Temperature

434 Stainless Steel

Nickel / TZ8Y

Dimension change (µm)

Temperature (°C)

Time (minutes)

Dilatometer study showed problem with bipolar plate binder burn-out
New binder solved problem of component expansion mismatch during high-temperature processing
Cell fabrication for stack required development of edge sealing procedure

- Metal slip composition was altered to allow metal to be injected into the edges of the flow field tape
A novel and flexible stack test apparatus was designed and built.
A two-cell stack (with edge sealing) was fabricated and tested at 800°C

Bipolar Plate
Cathode Flow Field

TuffCell repeat unit

Anode/Electrolyte/Cathode
Anode Flow Field
Bipolar Plate

Gold foil current collector
Results and lessons learned from stack test

• A realistic open circuit potential was not achieved

• Corner gaskets leaked
  - Composition of gaskets will be altered to reduce porosity

• Metal flow fields caused a large pressure drop through the stack at 1/16-in thickness
  - Increased thickness to 1/8-in while minimizing weight increase by improving metal coating procedure

• Poor contact between adjacent cells
  - Metal flow fields will be ground flat before assembly of stack
Progress vs. FY ’04 Milestones

• Test two-cell stack on simulated reformate/air (2/04)
  - Scaled single cell fabrication from 1x1 in size to 2x2
  - Designed and built stack test apparatus and developed internal manifolding procedure
  - Fabricated first two-cell TuffCell stack and tested it on hydrogen/air

• Complete start-up time and cycle tests (6/04)
  - Once stack sealing issues have been resolved, we will test start-up time and cycle tests

• Obtain a single cell power density of >350 mW/cm_ (9/04)
  - Improved single cell fabrication materials and procedure using dilatometer results. Current status: 260 mW/cm_
Interactions and Collaborations

- Collaboration with Korea Advanced Institute of Science and Technology: Professor Joongmyeon Bae
- Samples will be provided to Motorola for evaluation (Non-disclosure agreement recently signed)
Reviewers’ comments from Berkeley meeting

- Important to demonstrate a two-cell stack
  - Work-in-progress

- Estimate cost of TuffCell and where the opportunities are relative to the $400/\text{kW}_e$ target
  - Anode-supported SOFC Stack Materials: $139/\text{kW}_e$
  - TuffCell Stack Materials: $85/\text{kW}_e$

- May trade some performance for reliability
  - TuffCell should have improved performance due to elimination of resistive bond layers/interfaces
Future Plans - FY’04 and Beyond

• Continue to improve single cell and stack power densities to decrease size, weight, and cost
  - Improve design and fabrication procedure
  - Investigate improved materials for metallic support, anode, and cathode

• Demonstrate that TuffCell stacks can meet DOE Performance Technical Targets for APU application
  - Test start-up time (goal: < 30 min.)
  - Temperature cycling tests (goal: > 500 cycles)
  - Investigate durability (goal: > 5,000 operating hours)
Acknowledgments

- Funding from the U.S. Department of Energy, Energy Efficiency, Renewable Energy: Hydrogen, Fuel Cells & Infrastructure Technologies Program is gratefully acknowledged

- Nancy Garland, DOE Technology Development Manager