Bipolar Plate-Supported Solid Oxide Fuel Cell "TuffCell"

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Argonne, IL

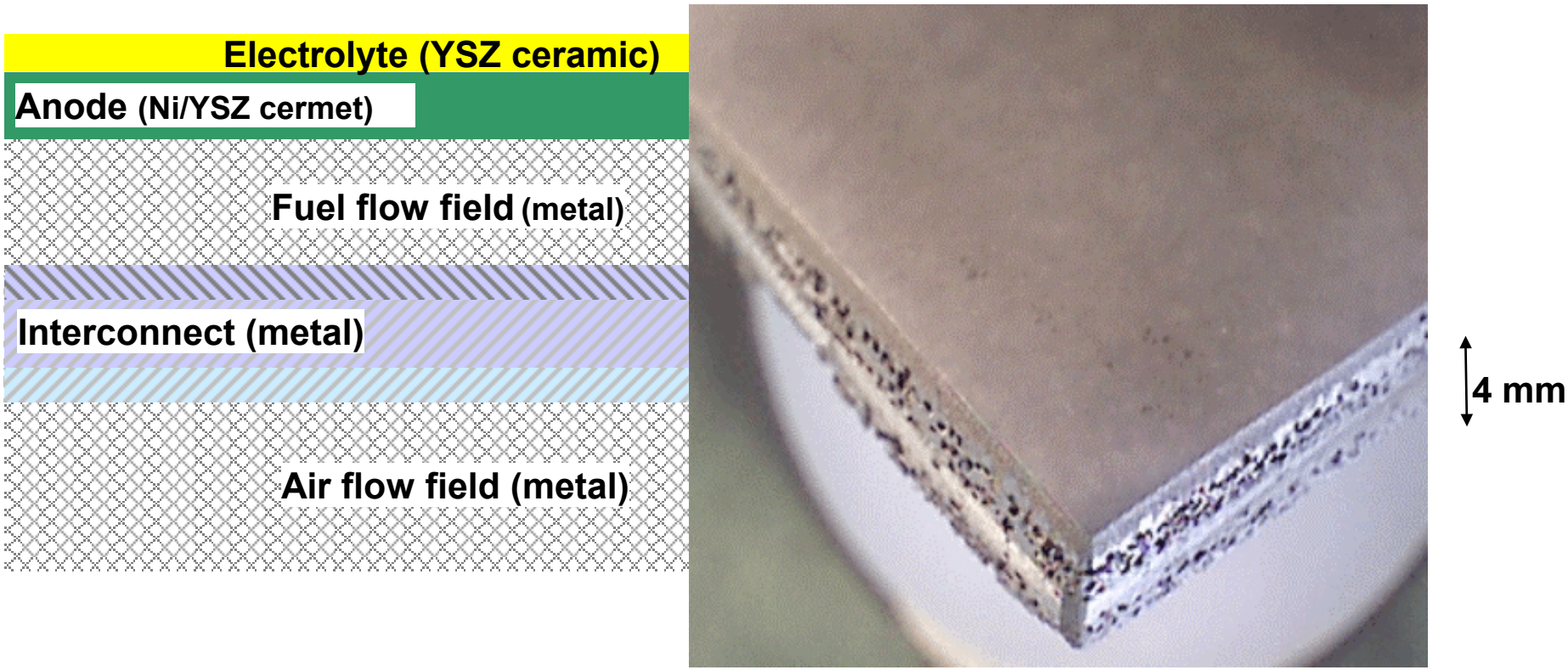
2003 Annual Review
DOE Fuel Cells Program
May 19-22, 2003

Relevance/Objective

- Relevance: DOE's Technical Target is to develop a 3-5 kW_e Auxiliary Power Unit (APU) at 150 W/kg and 170 W/L
  - This work addresses technical barriers D, L, M, O, P, and Q

- Objective: Develop an improved SOFC for APUs
  - SOFC advantages
    - High power density and efficiency
    - Fuel versatility/simplified fuel processing
    - Well-suited to duty cycle of APU
  - SOFC issues
    - Startup time, temperature cycling, and durability
      - Status: 2-3 hours, 10 cycles, 100 hours lifetime
      - Goal: 15-30 min, 500 cycles, 5,000 hours
    - Vibration and shock resistance
    - Cost
      - Status: >$2,000/kWe, goal: $400

Metallic Bipolar-Plate-Supported SOFC Design (TuffCell)

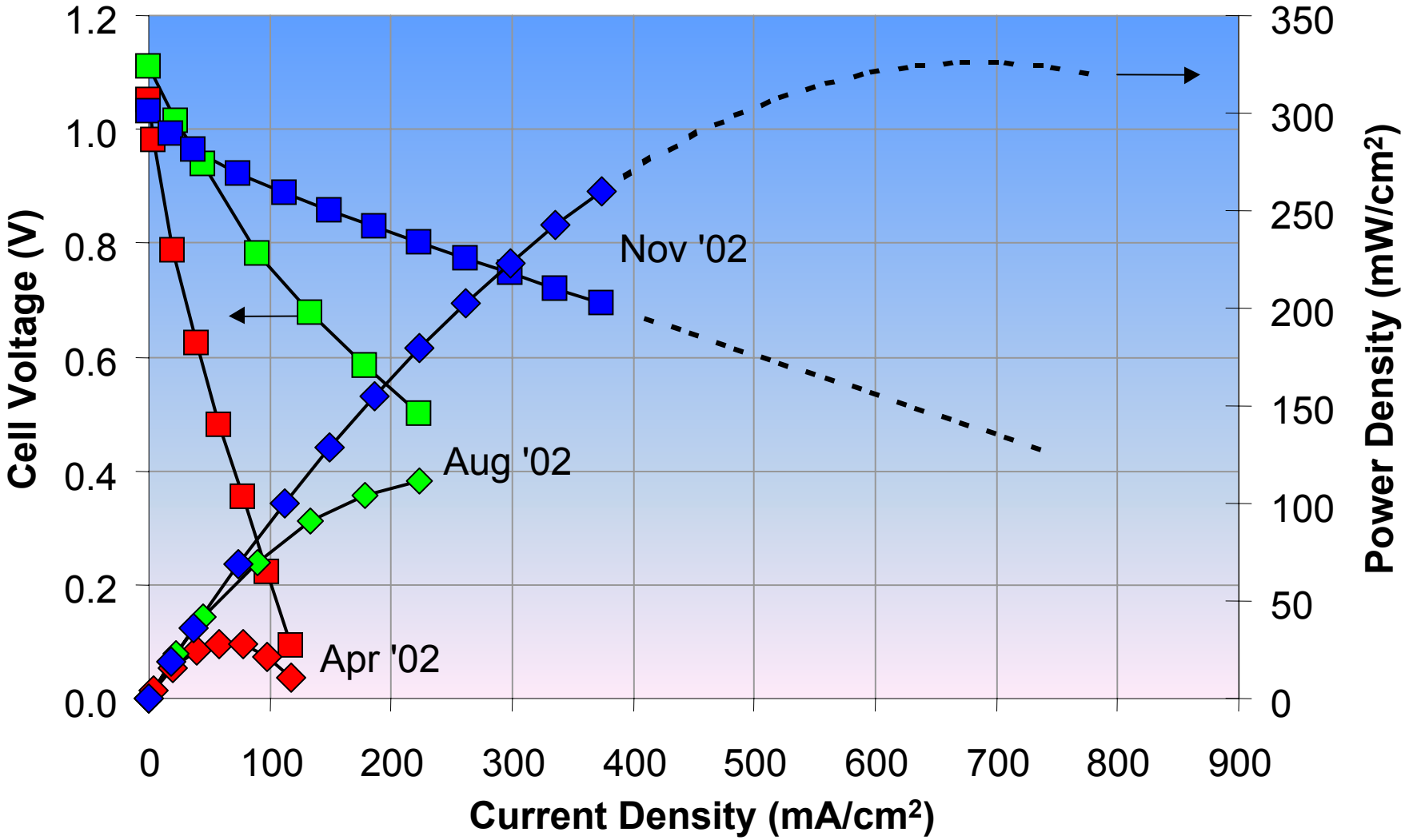


Essential stack elements integrated into a multilayer composite

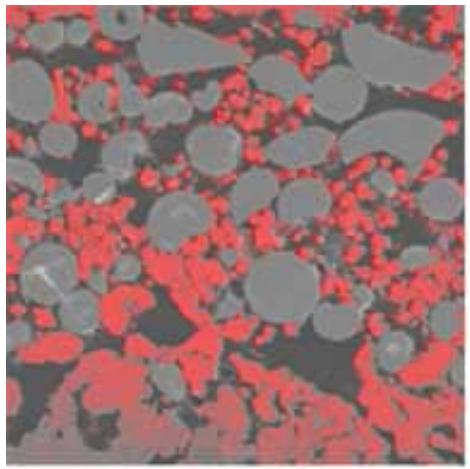
Metallic Bipolar-Plate-Supported Design Addresses SOFC Shortcomings for APUs

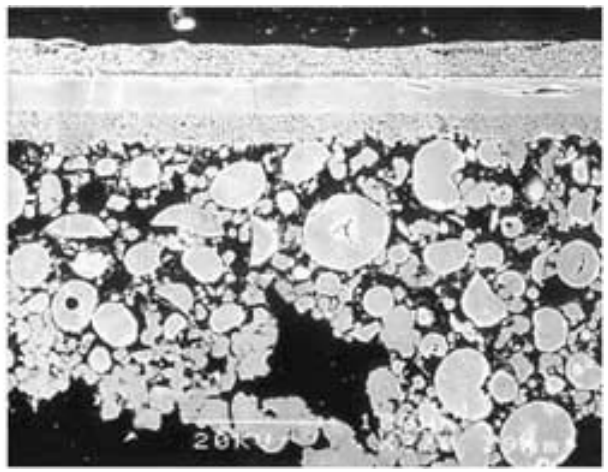
- Oxide and metal slurries are tape-cast into films, then films are laminated
- Metallic bipolar plate, anode, and electrolyte are sintered together in a single high-temperature process
- Cathode is slurry-coated onto electrolyte and sintered *in situ*
- Advantages:
  - Brittle ceramic components are bonded to tough metallic layers
  - Single high-temperature process lowers cost
  - Single electrical contact plane reduces interfacial impedance
  - Simplified gas sealing
  - Allows compositionally graded bipolar plates

Power Density of TuffCell Improved by an Order of Magnitude

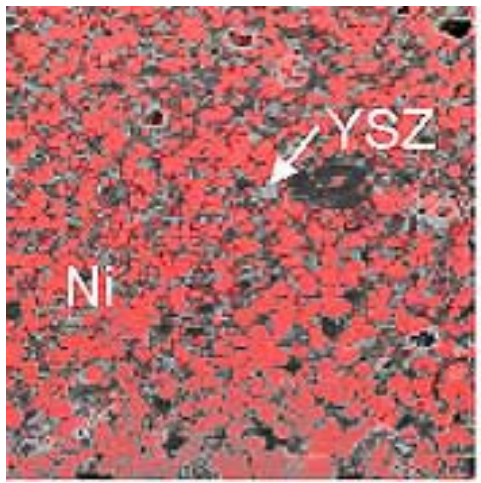


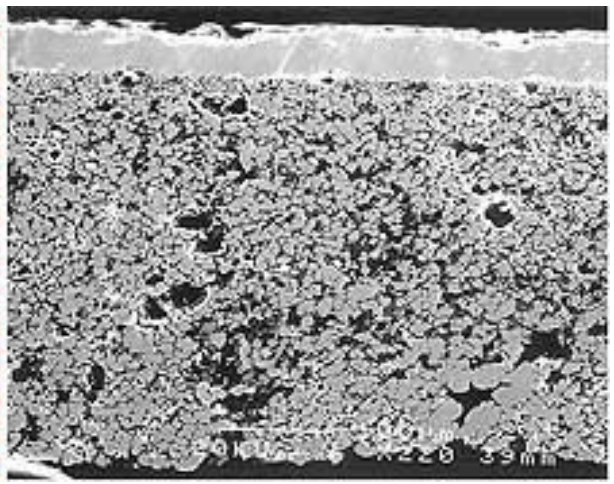
TuffCell Anode Microstructure Improved





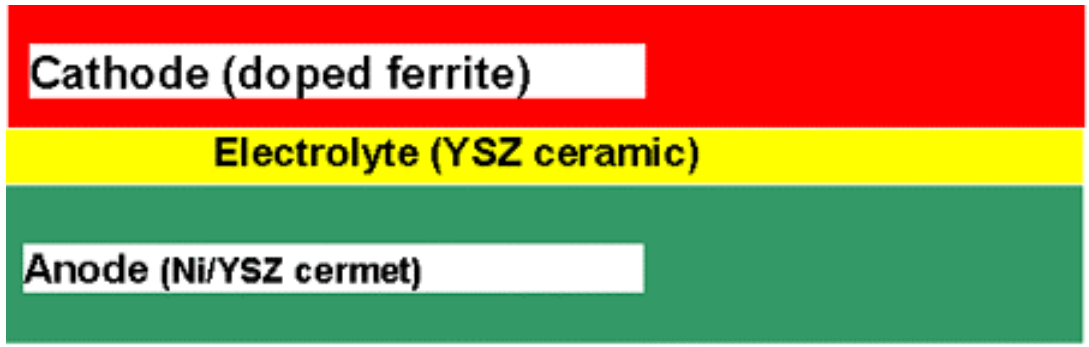
Apr ‘02





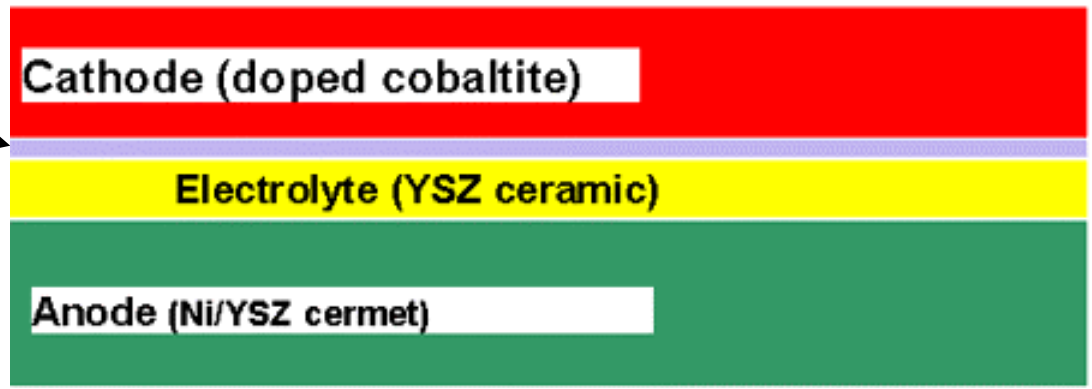
Aug ‘02

TuffCell Cathode Improved



Aug '02

Barrier Layer
(CGO ceramic)

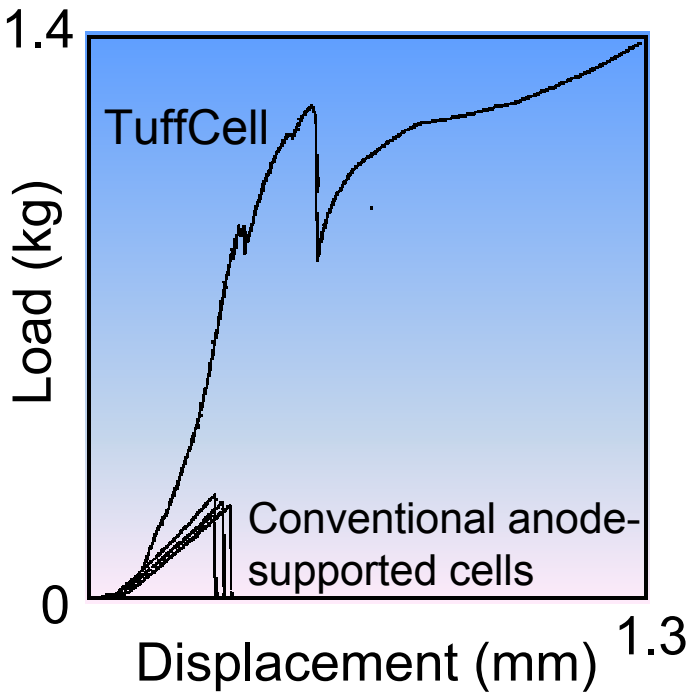


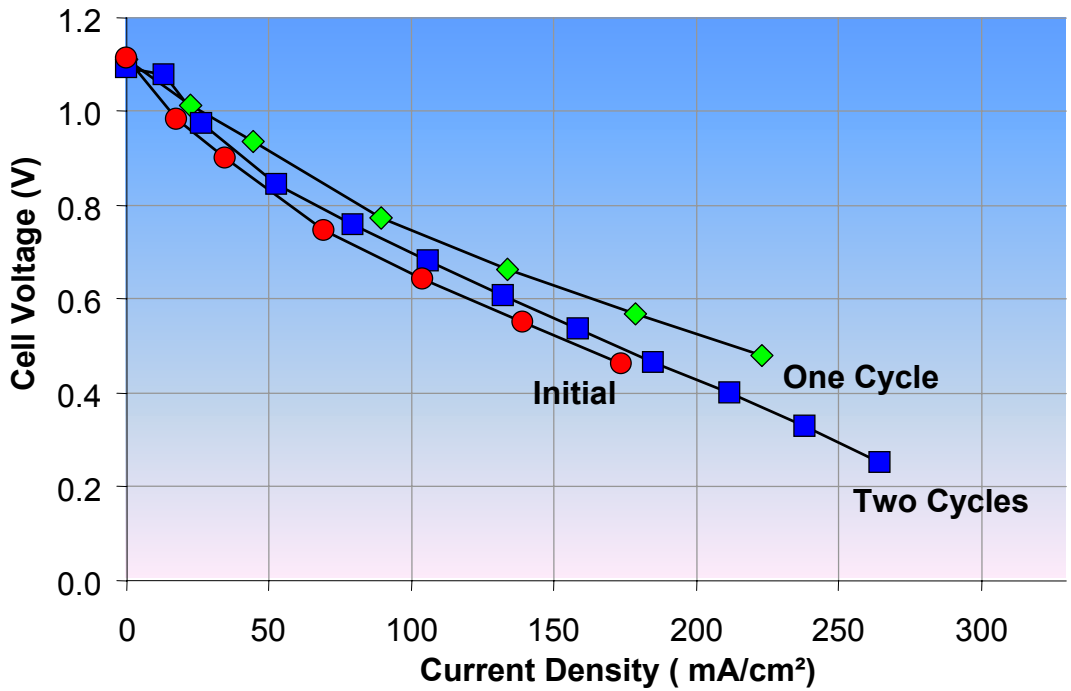
Nov '02

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





Project Timeline

12/01
Achieved sintered laminate

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

4/02
OCV of 1.14 V
25 mW/cm²

8/02
Power max. of 104 mW/cm²

11/02
Power max. of >260 mW/cm²

9/03
Design and fabricate a TuffCell short stack (2 cells) to achieve open circuit potential >90% of theoretical

10/01
Began

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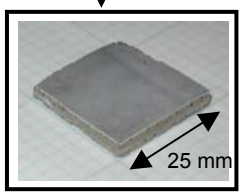
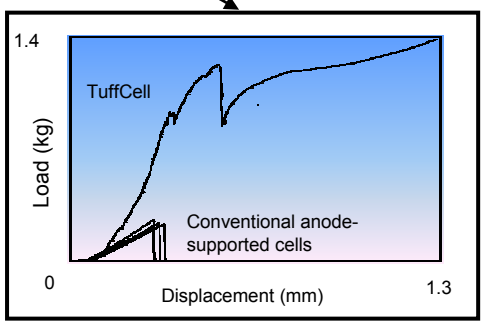
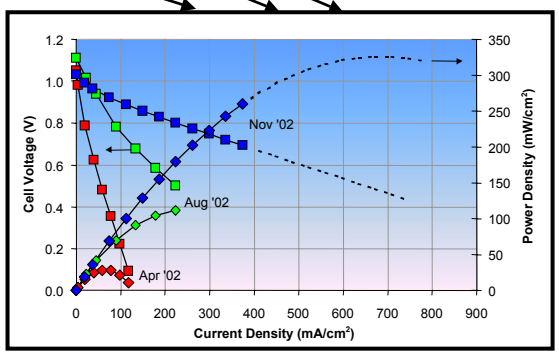
FY '02

FY '03

DOE's APU Goals - 2010:
150 W/kg, 170 W/L, $400/kW$_e$, 500 cycles, 5000 h durability, 15-30 min startup







Reviewers' Comments--2002 Annual Review

- Incorporate more materials science in project; need CTE data
  - Published CTE data for conventional materials used for early cell fabrication. A dilatometer was purchased in FY '03 for determining cell component expansion and sintering behavior
- Evaluate start/stop data; demonstrate durability
  - Temperature cycling from RT to 800°C did not cause degradation in cell performance
- Improve current density
  - Current density at 0.7 V improved from 30 to 380 mA/cm²
- Scale up fabrication
  - Currently fabricating two-cell stack

Milestones

- Obtain TuffCell power density of 0.3 W/cm^2 with H_2/air

  Target: 02/03
  Achieved: >0.26 W/cm² 11/02

- Design and fabricate a TuffCell short stack (2 cells) to achieve open-circuit potential >90% of theoretical (hydrogen/air)

  Target: 09/03
  Currently fabricating stack and manifold

Future Plans

- Test two-cell stack on simulated reformate/air
- Test startup time, cyclability, and durability
- Investigate improved materials for metallic support, anode, and cathode
- Improve fabrication procedure
- Collaborate with universities, industry, and other national laboratories

Benefits of This Project

- A TuffCell based auxiliary power system is:
  - Fuel-flexible
  - Compact
  - Rugged and durable
  - Faster-starting than current SOFCs
  - Cost-effective
    - Lower manufacturing cost
    - Lower materials cost
  - Highly efficient