V.I.2 Advanced Materials for RSOFC Dual Operation with Low Degradation

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Fiscal Year (FY) 2011 Objectives

The objective of project is to advance reversible solid oxide fuel cells (RSOFCs) cell stack technology in the areas of endurance and performance.

Technical Barriers

This project addresses the following technical barriers from the Hydrogen Production section of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan [1]:

(G) Capital Cost
(H) System Efficiency
(I) Grid Electricity Emissions (for distributed power)
(J) Renewable Electricity Generation Integration (for central power)

Technical Targets

Technical targets will be achieved through RSOFC materials development and reversible stack design. The project objectives are to meet the following performance and endurance targets in a kW-class RSOFC stack demonstration:

- RSOFC dual mode operation of 1,500 hours with more than ten SOFC/solid oxide electrolysis cell (SOEC) transitions.
- Operating current density of more than 300 mA/cm^2 in both SOFC and SOEC modes.
- Overall decay rate of less than 4% per 1,000 hours of operation.

Meeting those performance and endurance technical targets will be the key RSOFC cell stack technology development step towards meeting DOE's Technical Targets for Distributed Water Electrolysis Hydrogen Production by an RSOFC system.

FY 2011 Accomplishments

- Developed 12 candidate cell material systems, of which five systems exceeded both performance (area specific resistance [ASR] <0.3 Ω-cm^2) and endurance (degradation rate less than 4% per 1,000 hours) targets in both fuel cell and electrolysis modes.
- Validated cell material systems through electrolysis/fuel cell cyclic operation. Over 100 daily cycles were demonstrated over 2,500 hours. The degradation rate is less than 1% per 1,000 hours.
- Completed stack design and component down select, conducted a kW-class RSOFC stack development test for over 5,000 hours.

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Introduction

RSOFCs are energy conversion devices. They are capable of operating in both power generation mode (SOFC) and electrolysis modes (SOEC). RSOFCs can integrate renewable production of electricity and hydrogen when power generation and steam electrolysis are coupled in an "energy storage system" that can turn intermittent solar and wind energy into "firm power," or can enable intermittent power to aide in the selective arbitrage between peak power rates and power company resource deployment and turndowns. In order to address the technical and cost barriers, DOE funded a number of research projects over the past ten years [2]. Although significant progress was made in those projects, further development is required, especially in the areas of RSOFC performance and endurance. In this project, Versa Power Systems (VPS) is addressing performance and endurance issues for RSOFC cell and stack.

Approach

VPS has identified four task areas in an effort to improve the performance and endurance of RSOFC systems: degradation mechanism study, cell material development,

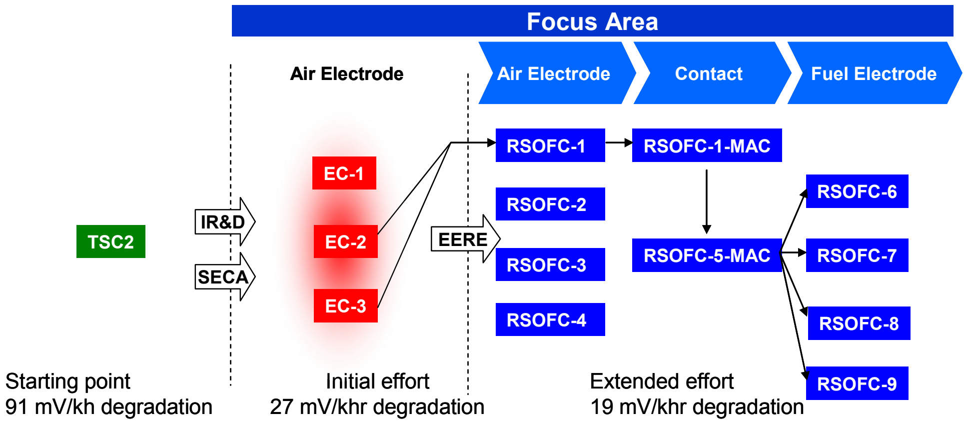

FIGURE 1. RSOFC Cell Development Path at VPS

interconnect material development, and stack design and demonstration. A stage-gate project management process is employed with a quantitative Go/No-Go decision point. The scope of the work has been carried out by:

- Building on VPS' strong SOFC cell and stack baseline, and leveraging cell and stack advancements from the DOE Solid State Energy Conversion Alliance program.
- Carrying out parallel materials development activities and integrating them with cell production technology development.
- Conducting RSOFC stack and process designs to address durability, performance, and cost in both fuel cell and electrolysis operating modes.

Results

The development path for RSOFC cell technology at Versa Power Systems can be summarized in Figure 1. Twelve material systems have been developed in the project.

Table 1 summarizes the RSOFC cell technology at the project Go/No-Go decision point. The best cell material system–RSOFC-7–demonstrated 223 and 224 mΩ-cm^2 ASR values in electrolysis and fuel cell modes, respectively, at 750°C compared with the target of less than 300 mΩ-cm^2. The degradation rate of the RSOFC-7 in steady-state electrolysis mode was 1.5% per 1,000 hours compared with a target of less than 4% per 1,000 hours for over 1,000 hours.

TABLE 1. Summary of RSOFC Performance and Endurance Status at Project Go/No-Go Decision Point

	Target	Status
Performance (area specific resistance in both SOFC and SOEC operating modes)	<0.3 Ω-cm^2	0.223 Ω-cm^2 in SOFC 0.224 Ω-cm^2 in SOFC
Degradation (Overall decay rate)	<4% per 1000 hours of operation	~1.5% per 1,000 hours of operation
Operating Duration	>1,000 hours	1,005 hours (as of Oct. 29, 2010)
Operating Current Density	>300 mA/cm^2	500 mA/cm^2

RSOFC cell material systems have been further developed in fuel cell/electrolysis cyclic operation. A cyclic test profile was designed and implemented to simulate an integrated reversible SOFC/solar power system. The test runs a 24 hour cycle with 10.5 hours in electrolysis, 12.5 hours in fuel cell operation, and the balance for transitions. Figure 2 depicts the cell voltage against time over 105 simulated day-night cycles of electrolysis and fuel cell operation. The performance decay, calculated from fuel cell mode, was 0.21 mV/cycle (0.89% per 1,000 hours) over 105 days (or cycles, representing over 2,500 hours).

A number of RSOFC stacks were built and tested in parallel for cell and interconnect materials development. A kW-class stack test (Figure 3) demonstrated over 5,000 hours of stable electrolysis operation with a split between constant current and constant voltage operation. This kW-class stack design and RSOFC-7 cell materials system have been chosen for the end-of-the-project stack metric test. The performance decay, calculated from fuel cell

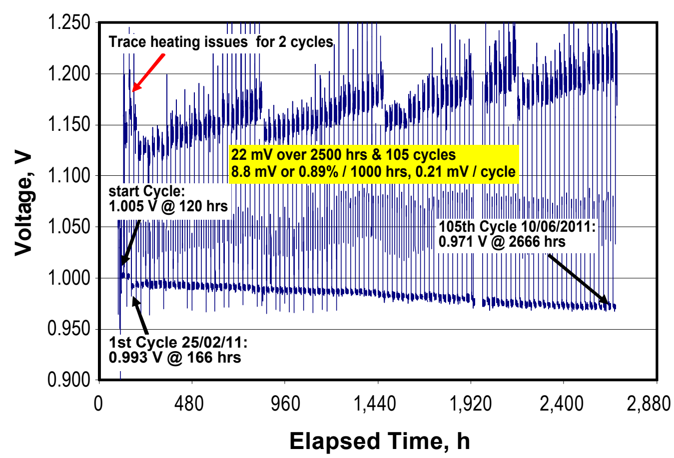

FIGURE 2. Fuel Cell and Electrolysis Cyclic Testing of a RSOFC-7 Cell

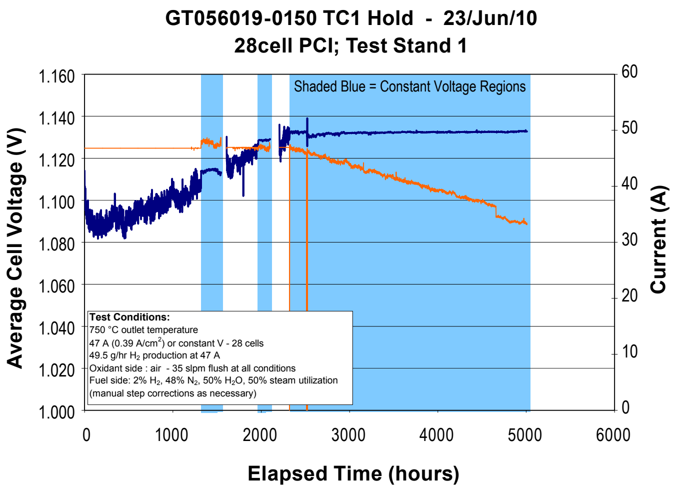

FIGURE 3. GT056019-0150 kW-Class Stack Electrolysis Tests in Both Constant Current and Constant Voltage (shaded blue) Conditions

mode, was 0.21 mV/cycle (0.89% per 1,000 hours) over 105 days (or cycles, representing over 2,500 hours). The test is on-going and will be updated as testing continues.

Conclusions and Future Directions

In the coming year, the project team will continue on the current development path. This work includes:

- Continuation of the RSOFC cell and stack development and testing.
- Completing the end-of-the-project kW-class RSOFC stack metric test.

FY 2011 Publications/Presentations

1. An oral presentation for this effort was made at the 2011 DOE Hydrogen and Vehicle Technologies Programs Annual Merit Review and Peer Evaluation Meeting.

References

1. DOE EERE Multi-Year Research, Development and Demonstration Plan, Page 3.1-7 (2007).

2. J. Guan et al., High Performance Flexible Reversible Solid Oxide Fuel Cell, Final Technical Report, DOE DE-FC36-04GO14351.