PERFORMANCE OF REDUCED-TEMPERATURE SOFC STACKS

Nguyen Q. Minh and Kurt Montgomery
AlliedSignal Aerospace Equipment Systems
2525 West 190th Street
Torrance, California 90504-6099, USA

ABSTRACT

AlliedSignal has been developing low-cost, high-performance solid oxide fuel cells (SOFCs) operating at reduced temperatures (600° to 800°C). The technology is well suited for use in a variety of power systems, ranging from commercial cogeneration to military mobile power plants. The AlliedSignal SOFC design is based on stacking thin-electrolyte cells (made by tape calendering) with metallic interconnect assemblies to form a lightweight, compact structure. This SOFC technology is not only cost effective but also suitable for scaleup in high-volume production using commercially available equipment. To date, the feasibility of fabrication and operation of stacks based on this technology has been demonstrated. Excellent stack performance has been achieved (e.g., 670 mW/cm² at 800°C) with stack power density exceeding 1 kW/kg. This paper discusses the technical status of the design, manufacture, and performance of AlliedSignal reduced-temperature SOFC stacks.

INTRODUCTION

AlliedSignal has been developing high-performance solid oxide fuel cells (SOFCs) operating at reduced temperatures (600° to 800°C) for a broad spectrum of power generation applications (1). This reduced-temperature SOFC technology has the potential of low material and manufacturing costs. The AlliedSignal concept is based on incorporating thin-electrolyte single cells with thin-foil metallic interconnect assemblies to form a lightweight, compact device. Thin-electrolyte cells are produced by a process based on the tape calendering method (2). Thin-foil metallic interconnect assemblies are fabricated by conventional forming techniques. Efficient operation at reduced temperatures of SOFC stacks based on this technology has been demonstrated. This paper discusses the technical status of the design, manufacture, and performance of AlliedSignal reduced-temperature stacks.
STACK DESIGN

The AlliedSignal stack concept for reduced-temperature operation is a flat-plate (planar) design that places ceramic cells in a compliant metallic housing. In this design, single cells are connected in electrical series via metallic fins and interconnects (interconnect assemblies). Metallic fins and interconnects are made from thin cross-section foils. The fins, attached to the interconnects, form flow channels for fuel and oxidant gases. A crossflow version of this design is schematically shown in Figure 1. This design concept has two key features:

- Single cells used in this design contain supported thin (5 to 10 micrometer) electrolytes. Thin electrolyte layers reduce component weight, improve cell performance, and minimize internal resistance, allowing efficient operation at reduced temperatures.
- The metallic interconnect assembly, made from thin foils, is designed to provide sufficient compliancy to minimize thermal expansion mismatch stresses and form a compact, lightweight structure. The thin-foil structure reduces material weight and cost.

This stack design has the potential of having low material and fabrication costs and can produce more than 1 kW/kg and 1 kW/L while maintaining high efficiency at reduced temperatures.

STACK FABRICATION

Procedures have been developed for assembling multicell stacks based on this design. The procedures consist of the following key steps:

(i) Cell preparation: Thin-electrolyte cells having the desired footprint area are first inspected to ensure no defects. Defect inspection is focused on detecting cracks in the cell and pinholes in the thin electrolyte.

(ii) Interconnect assembly preparation: Interconnect assemblies having the desired dimensions are prepared. Assembly flatness and fin uniformity are the key acceptance criteria.

(iii) Stacking: Single cells and interconnect assemblies are stacked in proper order and orientation. Visual and optical microscopic examination is performed to ensure adequate contact between different components.

(iv) Sealing and manifolding: Seals are applied to the edges of the assembled stack, and gas manifolds are attached. The stack is then checked for any gas leakage.

Figure 2 shows, as an example, a photograph of an assembled ten-cell stack.
STACK PERFORMANCE

Numerous multicell stacks have been tested to demonstrate performance and efficient operation at reduced temperatures. The testing has been carried out with hydrogen as fuel and air as oxidant. Stack performance has been evaluated in terms of open circuit voltage, voltage under load (voltage/current relationship), power output, and stack power density. The results obtained to date are summarized below:

(a) Open circuit voltage: Tested stacks have shown excellent open circuit voltages (OCVs). Typically, the OCV of two-cell stacks is on the order of 2.0 to 2.2 V at 800°C, and that of five-cell stacks is 5.0 to 5.3 V. The OCV of a ten-cell stack is 10.2 V at 800°C with hydrogen fuel and air oxidant. These values are very close to the theoretical values.

(b) Voltage/current relationship: Figure 3 shows voltage/current and power density curves of three two-cell stacks (footprint area of 25 cm²) at 800°C. As can be seen from the figure, the area-specific resistance of the stacks is about 0.75 ohm-cm² (0.38 ohm-cm² per cell). The maximum power density is about 670 mW/cm² at 800°C. The power density obtained at different temperatures is given in Figure 4.

(c) Power output: Figures 5 and 6 show voltage/current curves and power outputs of a five-cell stack (footprint area of 100 cm²) at 800°C and 700°C, respectively. The stack produced peak power of about 270 W at 800°C and 185 W at 700°C.

(d) Stack power density: Although the design has not been optimized, stack power densities achieved are exceeding or close to the goals of 1 kW/kg and 1 kW/L (Figure 7).

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Figure 1 Stack Design

Figure 2 Ten-Cell Stack
2.5 Voltage, v
Fuel: Hydrogen
Oxidant: Air

Stack A A.S.R. = 0.69 Ohm.cm²
Stack B A.S.R. = 0.72 Ohm.cm²
Stack C A.S.R. = 0.85 Ohm.cm²

0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4
Current Density, A/cm²

Figure 3 Voltage/Current and Power/Current Curves of Two-Cell Stacks at 800°C

Figure 4 Power Density of Two-Cell Stack

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Figure 5  Power Output of Five-Cell Stack at 800°C

Figure 6  Power Output of Five-Cell Stack at 700°C
Figure 7 Stack Power Densities