PROJECT SUMMARY NO PS210

Development of innovative metal-supported IT-SOFC technology

OBJECTIVES

The aim of this project was to develop and demonstrate cells and stacks based on the innovative metal supported Solid Oxide Fuel Cell technology developed by Ceres Power, and to perform detailed design studies on options for micro-CHP systems at the 5 kW_e scale. The project had the following targets:

- Cell power density to be increased, from 80mWcm^{-2} at 600°C at the project start, to 200mW cm^{-2} at 550°C by the project end.
- Single cell to be demonstrated for 1,000 hours with less than 3% degradation.
- Single cell to be demonstrated with less than 5% performance degradation after 5 thermal cycles.
- Short stack to be demonstrated for 1,000 hours with less than 5% performance degradation.
- Short stack to be demonstrated with less than 10% performance degradation after 5 thermal cycles.

Figure 1: 10-layer Ceres Power short stack prior to testing. This stack delivered 160W at 600°C.

- 100W_e short stack to be demonstrated operating at 550°C.
- 5kW_e natural-gas fired micro-CHP system to be simulated capable of delivering more than 35% electrical efficiency.
- 5kW_e stack concept to be developed, with the potential for volume production at a cost of less than \$400/kW_e.

SUMMARY

- All original project objectives met or exceeded.
- Major improvement in cell power density achieved from 80mWcm^{-2} at 600°C at start of project to 250mWcm^{-2} at

JANUARY 2005

550°C/ 400mWcm^{-2} at 600°C by end of project.

- Single cell tested for over 1000 hours with 2.3% performance degradation.
- Short stack tested for 3300 hours with less than 5% performance degradation per 1000 hours operation.
- Short stack thermally cycled 6-times with 4% performance degradation in total.
- Stack demonstrated producing 107W_e at 550°C, and 160W_e at 600°C.
- Natural-gas fuelled CHP system simulated, delivering 35% overall electrical efficiency at full power, and 80% overall efficiency at the 5kW_e scale.
- By the use of low-cost production methods for the forming of metallic components, the costing study for the 5kW_e stack demonstrated that at mass-production scale it should be possible to achieve the cost target of <US$400k$W_e^{-1}$.

CONTRACTOR

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COST

The total cost of this project is £600,000, with the Department of Trade and Industry (DTI) contributing £300,000, and Ceres Power Ltd. the balance.

DURATION

12 months – August 2003 to November 2004.

BACKGROUND

Ceres Power Limited is developing a new concept in fuel cell technology, the metal-supported Intermediate Temperature Solid Oxide Fuel Cell (IT-SOFC). This offers the potential for robust, low-cost fuel cells which can run on a variety of currently-available hydrocarbon fuels as well as hydrogen.

The Ceres fuel cell is a ceramic solid-oxide fuel cell, but unlike traditional SOFCs, the ceramic layers are fired onto a porous steel substrate which acts as a robust mechanical support, and minimises the mass of expensive ceramic required. The use of a steel substrate also allows conventional metal-joining techniques to be used to form a gas seal around the cell, eliminating the need for fragile ceramic-to-metal seals. Ceres unique technology also allows operation of the fuel cell stack at temperatures of 550-600°C, well below normal SOFC operating temperatures.

The provision of DTI financial support has accelerated the development of a number of key technologies required to demonstrate that Ceres Power fuel cell technology is commercially viable

THE WORK PROGRAMME

Cell development

During the course of the project major improvements were made to the cell fabrication process, particularly for the anode and electrolyte. The resulting improvements resulted in cells which could be produced at the hundreds-off scale with a performance level of:

- 350-400mWcm-2 maximum power density at 600°C on moist hydrogen/ air.
- 200-250mWcm-2 maximum power density at 550°C on moist hydrogen/ air.
- 200-250mWcm-2 maximum power density at 570°C operating on moist hydrogen diluted 50% with argon/air.

This level of performance is believed to be viable for commercial demonstration.

The improvement in cell power density over the course of the project is illustrated in figure 2.

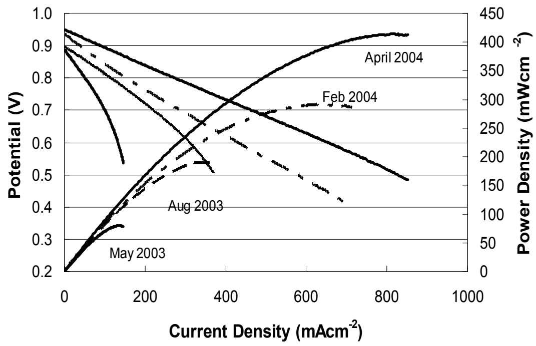

Figure 2: VI and power curves for Ceres Power fuel cells operating at 570°C, showing improvement in power density over the duration of the project.

In addition several cells were tested for over 1000 hours under constant load with 2.3% voltage degradation over this period. One cell was thermally cycled 20 times from room temperature to operating temperature and back again with 3% loss in maximum power density, a significant achievement when compared to the thermal cycling performance of other planar SOFC technologies.

Stack development

During the course of the project several iterations of a short-stack concept were developed. This was based around the use of ferritic stainless-steel interconnect plates. The cells were incorporated into the interconnect plates by laser-welding the steel substrates to the plates, thus avoiding the difficult ceramic-to-metal sealing issues inherent in other planar SOFC technologies.

The electrical isolation and sealing between plates was provided by the use of compressive gasket seals, and cathode current collection was by means of low-cost stainless-steel meshes. A short-stack was tested for 3300 hours of continuous operation with less than 5% performance degradation per 1000 hours, and another short stack was thermally cycled 6 times with 4% degradation in total. Finally a larger stack of 107We power output at 550°C was demonstrated, and operated for 960 hours at 35% fuel utilisation on simulated reformate with 4.2% loss in performance over that period.

System concept development

A number of possible concepts for an IT-SOFC based 5kWe CHP system were evaluated by computer modelling. A fully dynamic model of one preferred system concept was developed and simulations were undertaken at 100% and 50% rated power. In both cases the electrical efficiency was predicted to be in the range 33-35%, and the overall efficiency in the range 78-82%. The control system was demonstrated to be effective at keeping the system stable under dynamic operating conditions such as a load change.

Costing study

By the use of low-cost production methods for the forming of metallic components, the costing study for the 5kWe stack demonstrated that at mass production scale it should be possible to achieve the cost target of <US$400kWe-1 for the stack.

CONCLUSIONS

Ceres Power Ltd. is developing a novel metal-supported SOFC technology which has significant advantages in a number of key areas

- Significantly lower temperature of operation.
- Ease of stack fabrication, avoiding the use of brittle glass-ceramic seals.
- Low fabrication and materials cost.
- Mechanical robustness.

All the initial objectives in this project were met or exceeded, specifically:

- Cell power density was increased, from 80mW cm^{-2} at

600°C at the project start, to 250mW cm^{-2} at 550°C by the project end.

- A single cell operated for 1,000 hours with 2.3% degradation.

- A single cell was thermally cycled 20 times with 3% degradation.

- A short stack operated for 3,300 hours with less than 5% performance degradation per 1000 hours.

- A short stack was thermally cycled 6 times with 4% performance degradation.

- A stack was demonstrated which achieved a power output of 107We at 550°C, and was operated for 960 hours with 4.2% performance degradation.

- A 5 kWe natural-gas fired micro-CHP system was simulated capable of delivering 35% electrical efficiency with external steam reforming.

- A 5 kWe stack concept was developed, with the potential for volume production at a cost of less than $400/kWe.

POTENTIAL FOR FUTURE DEVELOPMENT

It has been demonstrated in this project that metal-supported Ceres cells can be successfully produced, tested, and incorporated into stacks, and that these display many attractive operating characteristics. Whilst this is very encouraging, considerable development work remains to enable the successful commercialisation of the technology. A number of key development areas are listed below;

- Further improvement in cell power density on a range of fuels.
- Demonstration of thermally self sustaining stacks.
- Demonstration of systems incorporating Ceres stacks.
- Scale up of cell manufacturing.
- Development of internal reforming technology to increase stack efficiency
- Extended durability and thermal cycle testing over a range of operating conditions and fuel compositions.
- Further work on design for manufacture.

Further renewable energy information from the DTI Technology Programme: New and Renewable Energy, and copies of publications, can be obtained from:
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