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A small solid oxide fuel cell demonstrator for microelectronic applications

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Abstract

A key question relating to the application of solid oxide fuel cells (SOFCs) is the size of the smallest device which can be usefully operated. Previous studies have suggested that 1 kW_e is the smallest power output that is reasonably attainable, with most applications in the larger power range around 200 kW_e. In this paper we demonstrate that smaller SOFCs can be built, with possible applications to microelectronics and communications at remote sites where gas is available but batteries are expensive. Experiments are described on a three-cell device powered by butane. This was warmed up in minutes at a flow rate of 80 ml/min of butane to give an electrical output between 0.1 and 1 W. The cells were made of zirconium oxide extruded in thin-walled tube form, with nickel cermet anodes and lanthanum strontium manganite cathodes. © 1998 Elsevier Science S.A.

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1. Introduction

Solid oxide fuel cells (SOFCs) have generally been designed for large power applications. For example, Westinghouse have aimed for a multi-MW system powering a gas turbine [1]. Ceramic Fuel Cells Ltd. are building a 200-kW system for combined heat and power uses. Sulzer have made a 10-kW SOFC for domestic heat and power application [2]. Our objective was to build much smaller SOFCs.

The smallest SOFCs are those used as oxygen sensors in automobile, boiler and food storage applications [3]. These provide a signal which measures oxygen differential across the ceramic electrolyte. Power for heating the device and driving the system must normally be provided from another source. Our objective in the present work was to devise a small SOFC power generator which could be operated completely by available gas, for example butane, to heat the electrolyte, process the fuel, drive the system and provide around 1 W_e of power for microelectronic and communications equipment. The design of the device was based on studies carried out at Keele over the past 5 years [4–8].

2. Design of micro-SOFC

The design of the micro-SOFC system is shown in Fig. 1. A butane gas supply was fed through a control valve, past an air premix orifice, and along a rubber tube connecting to the cell inlet manifold. This divided the fuel/air premix into the three tubular cells which were enclosed in a glass tube surrounded by ceramic fibre insulation. Electrical power from the cells was brought out through the manifold and used to drive an electronic load.

Fig. 2a illustrates the arrangement of the cells inside the SOFC unit. The premix was warmed as it approached the cell electrodes at the centre of the insulation. Partial oxidation of the fuel occurred at this stage. The fuel then passed through the cell and exited into a catalytic combustion region where a platinum-coated honeycomb provided heat for the device. Combustion air entered at the base of the block, flowed around the glass tube and exited at the upper exhaust. Clean air for the cathodes passed up inside the glass tube and exited at the top of the device.

Fig. 2b shows a single cell tube. This was made by extruding a plastic paste of 8Y-zirconia through a tube die, to form 2-mm diameter tubes with 200 μm wall thickness. After drying and firing to 1400°C, nickel cermet ink was injected down the inside of the tube with

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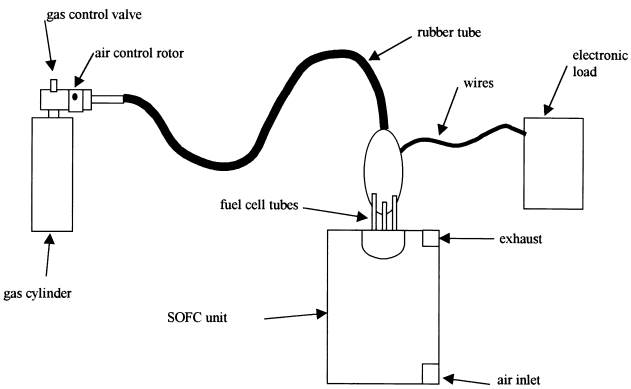

Fig. 1. System composed of fuel supply, SOFC unit and load.

a syringe and lanthanum strontium manganite ink was painted on the outside. The cells were then fired at 1300°C. A nickel wire picked up the anode current and brought it out through the plastic manifold to connect with the neighbouring cell cathode collector, which was led out along the tube.

3. Results

The device was switched on by opening the butane gas valve and igniting the gas near the catalyst in the centre of the SOFC unit. The flame rapidly warmed up the SOFCs as shown in Fig. 3. The gas valve was adjusted to control the final temperature of the fuel cells near 700°C. The results were obtained with an initial flow rate of 80 ml/min which was reduced to 25 ml/min after 10 min. Although the thermal inertia of the system gave a 20-min heating time, it was possible to heat the individual cells to operating temperature in a few seconds without damage by increasing the initial fuel flow rate.

The voltage–current curve is plotted in Fig. 4, showing that significant power could be drawn from the cells. This was used to operate an electronic calculator and other electronic devices. After running the system for several hours, it was shut down and allowed to cool. The device was cycled 12 times with no apparent decrease in electrical performance. After 8 h the anode surfaces inside the tubes were inspected and no sign of carbon deposits was found. Longer-term tests are now being undertaken.

4. Conclusions

A small SOFC system has been built to drive microelectronic applications using butane as fuel. A three-cell unit made from extruded zirconia tubes provided between 0.1 and 1 W_e of power at 700°C. The benefits of the small tubes were:

- they were mechanically robust and did not crack;

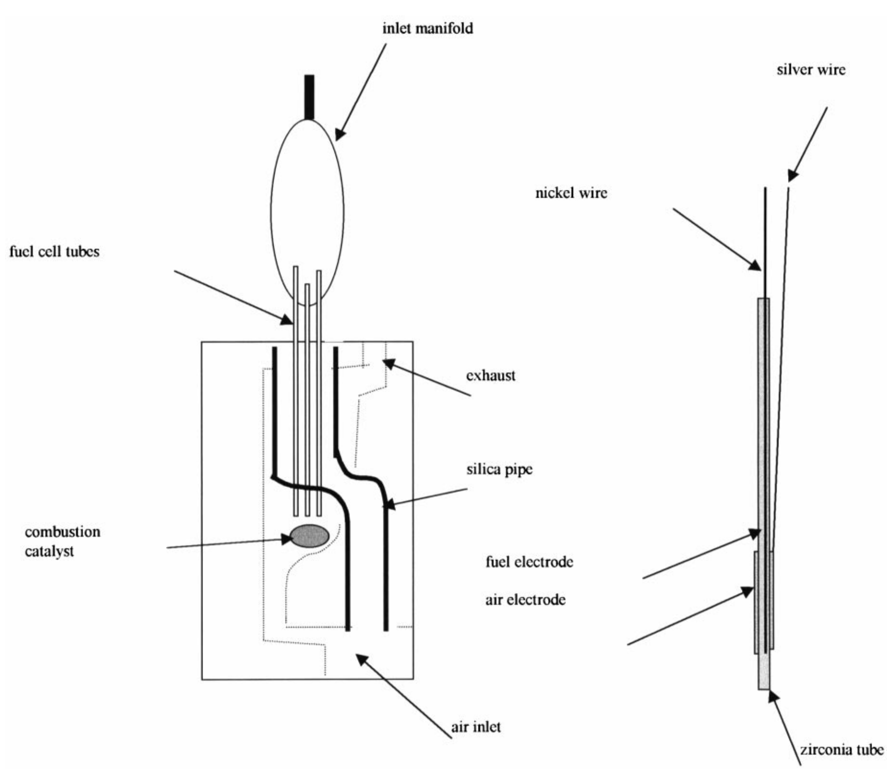

Fig. 2. (a) Arrangement of the SOFC unit. (b) Structure of individual cell.

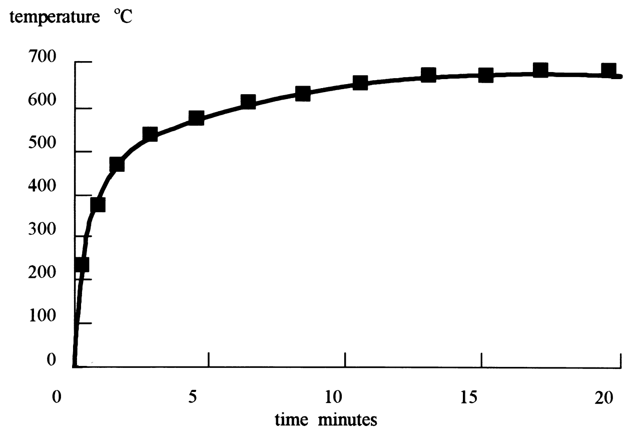

Fig. 3. Warm-up time for the SOFC unit.

- they were highly resistant to thermal shocks;
- they were heated in minutes to the operating temperature;
- they were sealed and connected outside the hot zone; and
- they operated on a butane/air premix without coking.

It is believed that such small SOFCs could provide power for electronic devices and communications in remote locations where gas is available but batteries are expensive.

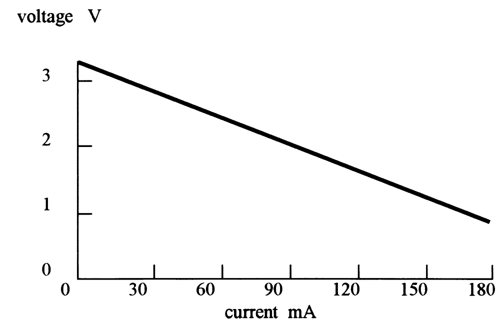

Fig. 4. Current–voltage curve for the 3-cell unit at 700°C; total cell area 2.25 cm^2.

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