MICRO SOLID OXIDE FUEL CELL

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ABSTRACT

The Alberta Research Council Inc. (ARC) is developing a tubular micro solid oxide fuel cell (μSOFC). Small diameter SOFC has two main potential advantages, substantial increase in the electrolyte surface area per unit volume of a stack and also quick start up. Since fuel cell power is directly proportional to the electrolyte surface area, a μSOFC stack has high potential to substantially increase the power per unit volume. Simple calculation shows a decrease of tube diameter from 22 mm to 2 mm will increase the electrolyte surface area in a stack approximately eight times. Due to its thin wall, a μSOFC has extremely high thermal shock resistance and low thermal mass. These low thermal mass and high thermal shock resistance characteristics are fundamental to reducing start up and turn off time for the SOFC system.

INTRODUCTION

The Alberta Research Council Inc. (ARC) is developing the design and manufacturing process for a high surface area micro solid oxide tubular fuel cell (μSOFC). This small diameter tubular fuel cell has a wall thickness in the micrometer range; therefore, it has a low mass together with high thermal shock resistance. The combination of these two characteristics, high thermal shock resistance and low mass, are the key in reducing start up and turn off time of these ceramic-based fuel cells. Another major advantage of μSOFC is a significant increase in the volumetric power density. High volumetric power density translates to smaller devices, which is vital for portable application.

EXPERIMENTAL

Samples are fabricated using sequential electrophoretic deposition (EPD) technique. Sequential EPD technique, Sarkar and Nicholson (1-3), was developed to fabricate laminated ceramics. Present work has an electrolyte layer made from Tosoh's 8 m/o yttria-stabilized zirconia (YSZ). Single cells are anode supported. The anode layer is a mixture of Ni and YSZ, starting material is approximately 50 w/o NiO. The cathode layer is made of La0.8Sr0.2MnO3.

Microstructural examinations were conducted on a cross-sectional fracture surface by SEM on sintered and reduced samples. Current-voltage-power (IVP) characteristics of the single cells were measured using Keithley SourceMeter 2400, the temperature range
was 700° to 800°C, using 30% H₂ + He mixture. Typically, fuel gas before entering the cell passes through water and approximately 3% moisture is added to fuel gas. Schematic of the fuel cell test system is shown in Figure 1.

![Schematic drawing of the fuel cell test system.](image)

**RESULTS AND DISCUSSION**

Siemens Westinghouse (SWH) is the world leader in tubular SOFCs. The diameter of the SWH tubes is ~22 mm and length is ~1500 mm. A fuel cell stack containing 22 mm diameter tubes has electrolyte surface area of approximately 0.1 m²/L; now if the diameter of the tube is reduced to 2 mm then this surface area is ~0.8 m²/L which is eight times of the surface area of 22mm tube. If we consider that changes in the diameter will not effect the power density per unit area and this value is 0.250 W/cm² then a stack containing 2 mm diameter tube will produce ~2,000 W/L power (See Table 1). In Table 1, surface area ratio is calculated using 22 mm as reference. As the tube diameter gets smaller, the stack’s predicted surface area gets very high. In this case it may not be possible to have 0.25 W/cm² output, that is why no value is assigned in the estimated power column.

**Table 1. Single cell diameter and corresponding estimated stack surface area and power output.**

| Single Cell Diameter (mm) | Surface of the Stack (m²/litre) | Surface Area Ratio | Estimated Power (W/litre) |
|--------------------------|---------------------------------|--------------------|--------------------------|
| 22 (22,000 µm)           | 0.1                             | 1                  | 250                      |
| 2 (2,000 µm)             | 0.82                            | 8.2                | 2,050                    |
| 1 (1,000 µm)             | 1.64                            | 16.4               | 4,100                    |
| 0.1 (100 µm)             | 16.4                            | 164                | -                        |
Figure 2 is the single cell schematic and the insert is a photograph of three ~2 mm diameter single cells. These are anode supported single cells and are fabricated by EPD. A SEM micrograph of cross-sectional fracture surface of a single cell is shown in Figure 3. The electrolyte layer of the cell is <10 μm and anode functional layer is ~5 μm.

Figure 4 shows the current-voltage (IV) and current-power (IP) plots of a single cell at three different temperatures. 30% hydrogen and helium mixture was used as the fuel gas. The fuel gas was bubbled through 25°C water; therefore, the final fuel gas composition had 3% moisture. The fuel gas flow rate was 30 SCCPM. This cell has produced theoretical open circuit voltage. Figure 4 shows, at all three temperatures, activation
polarization is absent. Concentration polarization was not observed in the measurement range. Approximately a 2 cm length of the cell was coated with cathode; this is the active length of the cell during measurement. At 800°C, peak power output is over 300 mW with a corresponding voltage and current at ~0.5 V and ~600 mA, respectively. At 750°C, peak power is ~255 mW and at 700°C, peak power is ~215 mW.

![Figure 4. Voltage and power of cell as a function of current at 700°C, 750°C and 800°C.](image)

**SUMMARY**

EPD is a feasible manufacturing technique and can be used for fabrication of complex shapes and microstructures. Single cell SOFCs are fabricated using EPD with an electrolyte thickness <10 μm. Theoretical open circuit voltage indicates the electrolyte layer does not have pinholes. Cell power output is comparable to any standard tubular SOFC. EPD can simplify the SOFC forming process and reduce the production cost, which is one of the major barriers for fuel cells commercialization.

**REFERENCES**

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