한국에너지공학회 (2007년)
추계학술발표회 논문집

500W 급 연료극 지지체 평관형 고체산화물연료전지 스택의 운전 특성

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Operating Characteristics of Advanced 500W class Anode-supported Flat Tubular SOFC stack in KIER

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초 록

KIER has been developing the anode supported flat tubular SOFC stack for the intermediate temperature (700~800℃) operation. For this purpose, we have first fabricated anode supported flat tubular cells by the optimization between the current collecting method and the induction brazing process. After that we designed the compact fuel & air manifold by adopting the simulation technique to uniformly supply fuel & air gas and the unique seal & insulation method to make the more compact stack. For making stack, the prepared anode-supported flat tubular cells with effective electrode area of 90 ㎠ connected in series with 12 modules, in which one module consists of two cells connected in parallel. The performance of stack in 3 % humidified H_2 and air at 800℃ shows maximum power of 507 W. Through these experiments, we obtained basic & advanced technology of the anode-supported flat tubular cell and established the proprietary concept of the anode-supported flat tubular SOFC stack in KIER.

Keyword: solid oxide fuel cell, stack, induction brazing method, gas manifold

1. Introduction

The SOFC has two type structures of the tubular and planar designs. The tubular designhas been applied from small to large-scale power generation system. The planar design has also been studied for long time and was developed for the small power system. For the commercialization of SOFC technology, there are strong needs for establishing key technologies such as cell components and fabrication technology, high performance cell, and stacking technology, etc. In order to increase the durability and to allow cost reduction by less expensive materials such as metallic interconnect, many researchers are currently concentrating on development of SOFC operating at reduced temperatures below 800°C.

We developed first an anode-supported tubular SOFC [1-3] with high thermal cycle resistance for the intermediate temperature SOFC. After our development,many research groups including Acumentrics started the development of the anode-supported tubular

SOFC [4-7]. In this work, we reported an anode-supported flat tubularSOFC stack to improve the power density of the cylindrical tube cell and make the compact stack system. The advanced 500W class anode-supported flat tubular SOFC stack was fabricated by the optimized fabrication method and its performance was evaluated.

2. Experimental

The extruded flat tubular anode support was served as fuel electrode and other cell components were fabricated in thin layers onto it. The 40 vol. % Ni - 8YSZ(8 mol. % Y_2O_3-stabilized ZrO_2) anode powder was prepared by mixing 8YSZ (TZ-8Y, Tosoh co.) and nickel oxide powders (J.T. Bakers co.). Anode powder and activated carbon as pore former were weighed and mixed in ethanol by ball milling for 14 days and then dried. Organic binder and 25 wt. % distilled water were added to the dried powder, and then the well dispersed paste was extruded in the form of flat tube. The extruded flat tubes were dried and in the drying oven at 120 °C for 12h. It was pre-sintered at 1100 °C. The YSZ electrolyte layer was coated on the presintered anode tube by vacuum slurry dip coating to form a dense layer and cofired at 1400 °C. Cathode material, LSM($(La_{0.85}Sr_{0.15})_{0.9}MnO_3$) and LSCF($La_{0.6}Sr_{0.4}Co_{0.2}Fe_{0.8}O_3$) were prepared by solid state powder reaction method by weighing in a selected proportion and mixed in ethanol by ball milling for 10 days. The synthesized powder was calcined at 1000 °C for 5h. Themulti-layered cathode composed of LSM/8YSZ composite, LSM, and LSCF were coated onto the co-sintered flat tube by slurry dip process and sintered at 1200 °C.

The flat tubularcell has four ribs inside the tube, which is considered to increase the mechanical strength and the electrical conductivity of the anode tube. The flat tubularcell was brazed with a metal cap by induction brazing process as shown in figure 1. The metal cap plays roles of the fuel flow path and the anode current collector. Two brazed flat-tube cells are connected in parallel, which is defined as an bundle. In one bundle, two brazed anode-supported flat tubular cell was connected in parallel. Figure 2 shows 2 cell-unit bundle. The anode-supported flat tubular SOFC was connected in-parallel with 2 cells and in-series again. The two-cell unit bundle was placed in air chamber. 3% humidified hydrogen as fuel was supplied through the chamber connected with brazing cap. The air was supplied through the air distributor. In the case of the fabrication for compact unit bundle, we designed the compact fuel & air manifold by adopting the simulation technique to uniformly supply fuel & air gas and the unique seal & insulation method to make the more compact unit bundle. The equipment of performance test was composed of a gas control system, a heating unit, a preheating system, humidified chambers, an electronic load, and a data acquisition system. The stack performance was evaluated by adjusting the electronic load. Using the same concept as that of 2 cell-unit bundle, the 500W class stack was designed and fabricated. The stack has the 12 bundles connected in series, that is, number of cells is 24 cells. The elective area of the flat tube cell is 90 cm^2. The stack performance was evaluated using hydrogen with 3 % water and air.

3. Results and discussion

An electron current path of the cylindrical tubular type SOFC structure is geometrically determined by half circle of the cell, so the power per mass or per volume is much lower than the planar type. Onthe other hand, the flat-tube structure is possible to increase the power density per unit volume by giving the electron current path through the ribs as shown in figure 1. Its mechanical strength is higher as compared to the conventional planar type.

The thickness of the anode-supported flat-tube was 1.9 mm, and each of electrolyte and cathode layers had thickness of 10, 25 μm, respectively. The electrolyte showed a dense microstructure without any detrimental defects. Gas Permeability tests were conducted to estimate the gas-tightness of electrolyte. The gas permeability for cells as a function of differential pressure by using He gas was measured. It has shown the value below 6 x 10^{-8} $Lcm^{-2}sec^{-1}$ to the pressure difference of 3 atm (Figure 2). The prepared anode-supported flat tubular cells were brazed by using induction brazing process, in which the metal cap was bonded to the end of the flat tubular cell without cathode layer. The cathode current-collection was made by the wiring of silver wires. The induction brazed anode and metal cap play a role of current-collecting of anode.

Figure 3 shows the result of 2 cell-unit bundle performance at operating temperature of 800°C. The stack performance was the maximum power of 73 W in 3 % humidified hydrogen and air condition at 800°C.

The advanced 500W class stack was manufactured on the basis of the experimental date of 2cell-unit bundle. The stack has the preheater in air and fuel inlets and during the stack operation the temperature of the preheated gases was set at 550°C. Figure 4 shows a performance of the advanced 500W stack. The stack performances of 507W in air were obtained. The stack furnace was set at 800°C but the measured stack temperatures were in the range of 790 to 810°C.

4. Conclusions

We havedeveloped successfully the advanced anode-supported flat tubularSOFC stack. The end of the flat tube cell was connected with the metal cap by an induction brazing process. The brazed parts had efficient gas tightness. The metal cap played two roles of the anode current collection and the fuel supply path. The anode-supported flat tubular cell stack with 2 cells shows the maximum power of 73 W at operating temperature of 800°C. The 500W class flat tube stack with 24 cells (2x12) was designed and fabricated, which showed performances of 507 W in air at 800°C. The improvement of the stack is in progress.

5. References

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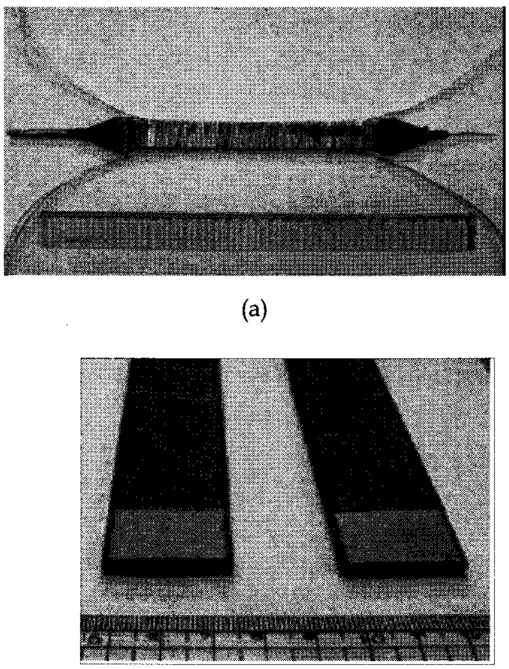

(a)

(b)

Figure 1. Brazed anode-supported flat tubular cell with metallic cap (a) and cross section of cell (b)

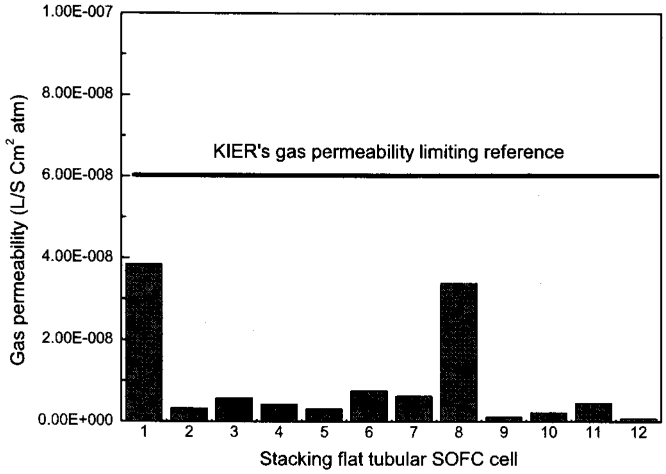

Figure 2. Gas permeability of flat tubular SOFC cell

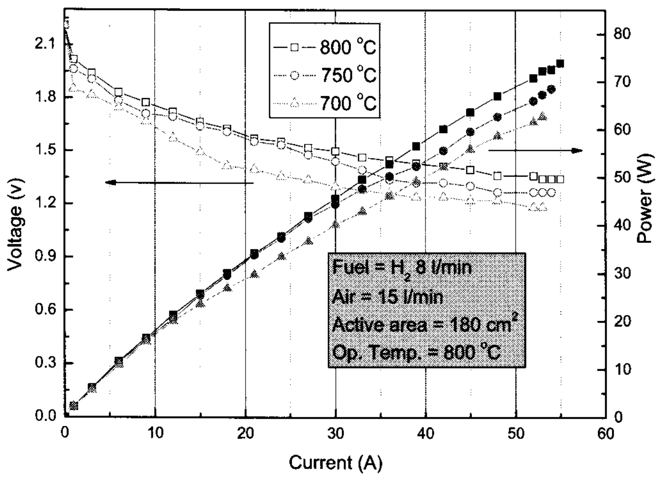

Figure 3. Performance of the anode-supported flat tubular unit bundle with 2 cells

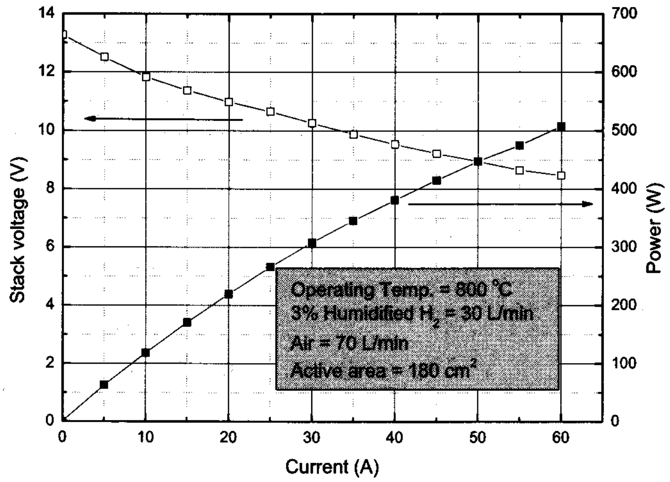

Figure 4. Performance characteristic of the advanced 500W class anode-supported flat tubular stack