SIDE - LEAD INTERCONNECTION FOR ALLOY - SEPARATOR PLANAR STACKS

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ABSTRACT

A new idea of flexible interconnections between air electrodes and alloy separators in planar stacks is presented. The edge of the air electrode support of a cell is connected with a LaCrO₃ ring which is sandwiched with the edges of adjacent alloy separators. The electric current in the cell flows radially in the LSM support and collected to the LaCrO₃ ring. The LaCrO₃ ring is connected to the alloy separator with a nickel felt in the fuel gas atmosphere. By using the proposed interconnections, we can avoid the difficulties in the junctions between air electrodes and alloy separators in conventional planar stacks.

INTRODUCTION

The durability of planar SOFC stacks against thermal cycles increases by adopting alloy separators with sliding seals and flexible interconnections (1-4). The use of alloy separators in planar stacks brought about the corrosion problems which lowered the quality of the electric connections between the air electrodes and separators. The corrosion proceeds at the interfaces between the LSM cathodes and the surface of the separators. The dissolution of chromium ions from alloy separators into the LSM cathodes is another problem (5). In this study, we present a new idea of interconnections between the air electrodes and alloy separators, which solves these problems caused by the direct contact of the LSM with the alloy separator in the oxidative atmosphere.
INTERCONNECTIONS THROUGH THE EDGES OF PLANAR CELLS

Current collection using the air electrode support

The concept of the air electrode supported (AES) cells, which was developed for tubular cells in Westinghouse, is extended to planar cells. When we design a stack of AES planar cells, the current in the air electrode can be collected through the thick air electrode. Therefore the air electrodes can be connected to the adjacent alloy separators outside of the active areas of the single cells. The electric connections between air electrodes and alloy separators can be placed in the reducing atmosphere of fuel gas. We call this stack "CE (connecting at the edges of the cells) stack" in this paper. Figure 1 shows the current path in a cross flow CE stack. The two sides of a CE stack exposed to the air and fuel gas are illustrated in Fig.2. The figure indicates that the LSM supports (air electrodes) are connected with separators in the reducing fuel gas atmosphere. Figures 3 and 4 show the schematic drawings of the cross section of a CE stack. The fringes of the LSM supports are coated with LSC (La(Sr)CrO3). Figure 3 illustrates the current pass through the nickel felts which connect the LSC layers to the alloy separators. The LSC coating protects the LSM support from the reducing power of fuel gas. Ceramic sheets must be inserted to isolate the air electrodes from adjacent separators in the fuel sides of the cells as shown in Fig.3. It is advisable to adopt sliding seals and flexible interconnections in planar stacks, so as to release the thermal stresses (1-4). The interfaces of the sliding seals and the flexible interconnections using nickel felts are indicated in Fig.3 and 4, respectively.

Estimation of IR potential drops in the CE stack

We estimate the IR potential drops in the CE stack. The calculation was made with a planar disk cell having a LSC ring shown in Figs.5a and 5b. The diameters of the fuel electrode, LSM support and LSC ring are indicated as dA, dM and dc, respectively. The thicknesses and the resistivity of the YSZ electrolyte, the LSM support and LSC ring are assumed to be 4.0x10^-4mm, 3.0mm and 5.0mm, and 10.0Ωcm, 5.0x10^-3Ωcm and 2.5x10^-2Ωcm, respectively. The porosity of the LSM is 33.3%. Figure 5c shows the circuit model used for the calculation. Points A, B, C and D indicate fuel electrode, the edge of the active area of the cell, the edge of the LSM support and the edge of the LSC ring, respectively. Resistors r_p1, r_p2, ..., and r_q1, r_q2, ... represent the resistances of the small segments of electrolyte, and those of LSM support, in the active area of the cell. Resistors r_p and r_q indicate the resistances of LSM and LSC rings, respectively. The results of the calculation for dA = 192mm, dM = 200mm and dc = 220mm are in Table I. The potential drops for the current density of 300mA/cm^2 in the active area are also listed in the table. The calculation of the resistance r_q was made according to a model of a solid LSC ring, therefore a relatively high potential drop of 57.3mV was derived. We can reduce the potential drop by extending the edge of the LSM support into the LSC interconnecting ring, as it is shown in Fig.3. It is assumed that the resistance of the

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junctions between the Ni coated LSC and the alloy separator is much lower than the resistances described above. In the following section, we perform an experiment about the resistance of the junctions between Ni felts and a heat resistant alloy.

**REDUCTION IN THE RESISTANCE OF THE JUNCTIONS BETWEEN HEAT RESISTANT ALLOYS AND NICKEL FELT**

**Reduction in the resistance by Ni coating**

Heat resistant alloys form passive oxide films when they are heated to high temperatures. Typically, these films are Cr$_2$O$_3$ and Al$_2$O$_3$. The Cr and Al atoms are contained in the alloys, and they precipitate on the surface of the material at high temperatures and form impermeable and insulating oxide films. When the atmosphere contains water vapor, the passive films are formed even in the fuel gases at operating temperatures. We have developed a method to control the film formation in fuel gases by coating the surfaces of alloys with thin Ni layers before the alloys are heated. Figure 6 shows the test piece used for the resistance measurement at 900°C. A square sample of 20x20mm with a thickness of 2mm was cut out from an HA214 alloy plate (Mitsubishi metal Co.). The both sides of the sample were polished with a diamond paste, and Ni was evaporated using an electron beam heating device in the vacuum of $6.0 \times 10^3$ Pa. The substrate temperature was 600°C. The deposition rate and the thickness of the Ni layer were $0.5 \mu$m/min and $4 \mu$m, respectively. The sample was sandwiched with Ni felt pieces and pressed with alumina plates. Pt wires are connected to the Ni felts and the sample was inserted in a furnace. The atmosphere was controlled with hydrogen gas containing 3% H$_2$O. The heat treatment was continued for 200h at 900°C. The resistivity change was also measured using a sample which was not coated with Ni.

**Results and discussion**

The resistance changes measured with the Ni coated and uncoated samples are shown in Fig.7. The low resistance of the Ni coated sample demonstrates that the formation of the passive oxide films was suppressed by the Ni coating. When the uncoated alloy surface came into contact with Ni felt and was heated, the formation of the oxide film was suppressed only at the contact points between the alloy surface and the fine fibers of the Ni felt, and consequently, the sintering of the Ni felt onto the surface of the alloy was blocked by the oxide layers. The oxide layer which was developed in the same heat treatment condition, showed a high resistance of 3kΩ at 900°C, therefore, the formation of the oxide layer in the junction must be prevented.
CONCLUSIONS

A new idea of interconnection between air electrodes and alloy separators in planar SOFC stacks is developed. It solves the corrosion problems encountered from the direct contacts between LSM air electrodes and alloy separators at high temperatures in the oxidizing atmosphere. A concrete example of the new interconnection in a planar stack was presented. The calculation of the ohmic losses on the proposed stack proved that the losses in the stack were not substantial. An effective method to make good contacts between alloy separators and Ni felt, which was essential to materialize the new stack, was presented.

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Table I  Resistances calculated for the segments in the model shown in Fig. 5, and the potential drops for the current density of 300mA/cm² in the active area of the cell.

| Resistance (Ω) | IR drop for 300mA/cm² (mV) |
|---------------|-----------------------------|
| r_AB          | 1.38 x 10⁻⁴                 | 12.0 |
| r_DC          | 1.62 x 10⁻⁴                 | 14.1 |
| r_CD          | 6.6 x 10⁻⁴                  | 57.3 |

Fig. 1  Conceptual drawing of a CE stack. The air electrode is connected with the separator edge, in the outside of active area of the cell.
Fig. 2 Schematic drawing of square planar cells which are stacked with the proposed interconnections.
Fig. 3  Schematic diagram of a CE stack showing the current in air electrodes, Ni-felt interconnections and alloy separators.
Fig. 4 Schematic diagram showing sliding seals and Ni-felt flexible interconnections in a CE stack.
Fig. 5 Models of a disk cell with a LSC connecting ring, used for the calculation of the IR losses in the proposed cell stack; (a) side view, (b) top view, (c) equivalent circuit.
Fig. 6 Cross section and top view of the sample used for the measurement of the resistance in the junctions between Ni coated HA214 alloy and Ni felts.

Fig. 7 The resistances of the junctions between the HA214 alloy and Ni felt at 900°C in H₂ (3% H₂O).