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Effect of cell-to-cell distance in segmented-in-series solid oxide fuel cells

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ABSTRACT

Segmented-in-series solid oxide fuel cell (SIS–SOFC) is prepared by laminating cell components on all sides of partially stabilized zirconia supports using decalcomania method. Since such support is conductive, it generates shunting current and hence voltage loss occurs. Such loss compromises the benefit achieved by segmenting solid oxide fuel cell in series. Therefore there would be greater merits to study the effect of cell-to-cell distance on the voltage loss. Output characteristics according to the cell distance is reported in this study.

Open circuit voltage and maximum output density show higher value in the order of cell distance of 2, 3 and 1 mm. While the shunting current decreases with increasing cell distance, the ohmic resistance, however, increases with increasing cell distance as the interconnector length increases. The impedance analysis shows that the polarization resistance decreases substantially as the cell distance decreases. This study demonstrates that care should be taken for the SIS–SOFC as the cell-to-cell distance influences the output characteristics.

Introduction

Solid oxide fuel cells (SOFCs) that operate at high temperatures have attracted much attention for the advantages they offer, such as high power density, system efficiency, fuel flexibility, low cost and scalability [1–6].

For SOFC, the potential difference can be achieved from a single cell is 1.1 V. To achieve higher voltage, it is necessary to stack several cells in series. As the number of cells in a stack increases, however, the volume increases and the interconnection of cells becomes complex. To solve such problems, Rolls-Royce developed SIS–SOFC, in which several cells in series were stacked on a support in order to achieve higher

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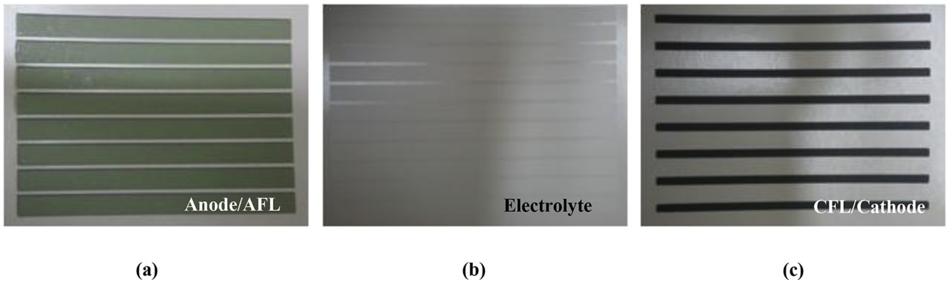

Fig. 1 – The picture of decalcomania paper (a) Anode/AFL, (b) electrolyte and (c) CFL/Cathode.

voltage with minimum possible volume for a compact system [7]. There has been much research effort on SIS–SOFC since [8–12].

The disadvantages of SIS–SOFC are, however; 1) it cannot use cell components as a support because it has to place several cells on a single support, and 2) the support should be a porous insulator with high mechanical strength. To satisfy such characteristics of SIS–SOFC, partially-stabilized zirconia (PSZ) is being used as PSZ is porous and chemically stable. The thermal expansion coefficient of PSZ is also compatible with cell component materials. One limiting factor for wide use of PSZ is that it has small ion conductivity. Therefore, there occurs shunting current between two anodes, which results in loss of voltage and subsequent diminished functionality of the SIS–SOFC [13,14].

Oh et. al. [13] added Al_2O_3 to the PSZ support to reduce the shunting current in SIS–SOFC. They reported that the more Al_2O_3 is introduced to the SIS–SOFC support, the less the support becomes porous, while they were able to improve the cell output characteristics as the shunting current decreased.

Lai et. al. [14] calculated equipotential line of SIS–SOFC using numerical analysis method. They showed that shunting current increased when cell-to-cell distance decreased. They attributed the result to higher localized current density between the cells as equipotential lines became narrower with smaller cell-to-cell distance.

Most of studies, however, have investigated on cell stacked on a single side of porous PSZ using wet slurry. There has been no report on the effects of cell distance stacked on all sides of a porous PSZ support.

The objective of this study is to investigate the effect of the cell distance on shunting current, voltage loss and output power when components of SIS–SOFC are stacked on all sides of a porous PSZ support using decalcomania method.

Experimental

Flat-tubular supports are extruded using 8 mol% Y_2O_3 doped ZrO_2 (Daejung, Korea) plastic mass through a specially prepared die. A dry mixture for the support is made with yttria stabilized zirconia (YSZ) powder, activated carbon as pore former and organic binder (YB131-D, YUKEN Industry, Japan). The dry mixture is then mixed with water to prepare a dough and aged at room temperature overnight. The aged dough is extruded to form the flat-tubular support. The extruded supports are dried at 80 °C for 24 h and pre-sintered at 1100 °C for 2 h in air. The sintered PSZ support has porosity of 41% and mechanical strength of 154 MPa.

NiO (Sumitomo Chem. Co. Japan), 8YSZ (TZ8Y, Tosoh Co, Japan) and $La_{0.8}Sr_{0.2}MnO_3$ (LSM, Fuel Cell Materials, USA) powders are used for starting materials. Each cell component is then printed on decalcomania paper as shown in Fig. 1. The mixing ratio of component and decalcomania oil is 1: 0.5–0.7 by weight. The thickness of the cell component is controlled by the number of printing.

Fig. 2 is a schematic diagram of SIS–SOFCs, which depicts the cell-to-cell distance and photographs of the flat tubular SOFC stack. Upon completion of all the firing process,

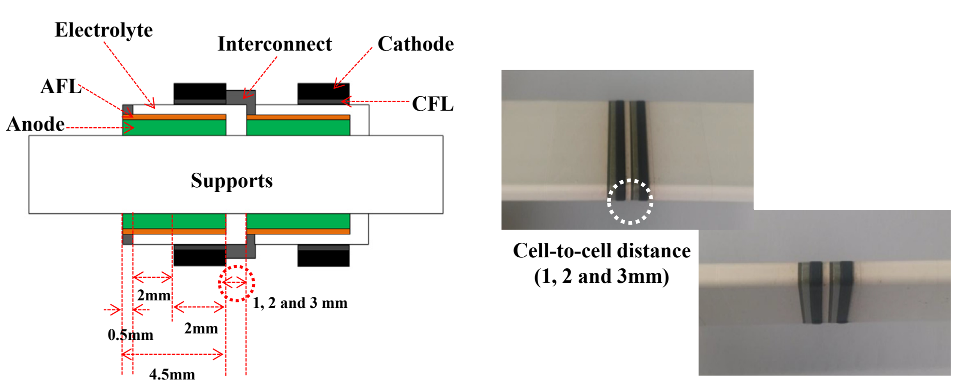

Fig. 2 – Schematic diagram of SIS–SOFCs, which depicts the cell-to-cell distance. The cell-to-cell distances investigated in this study are; (a) 1 mm, (b) 2 mm and (c) 3 mm.