FUEL CELL FABRICATION AND CHARACTERIZATION OF SINGLE CELL OF PROTON CONDUCTING SOFC

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Abstract

BaCe$_{0.8}$Y$_{0.2}$O$_{3-\delta}$ (BCY) is well known electrolyte material for proton conducting solid oxide fuel cells (SOFCs). In this work, we have synthesized BCY by sol-gel route and also selected corresponding cathode and anode materials to prepare single cell. Hence, an attempt was made to fabricate anode supported single cell with Ba$_{0.5}$Sr$_{0.5}$Co$_{0.2}$Fe$_{0.8}$O$_{3-\delta}$ (BSCF) as cathode and BCY-Ni cermet as anode materials. Current-voltage characteristics of this single cell were measured at different temperatures.

Introduction

Fuel cells which is an alternative energy technology, have received growing attention in recent years since they have been a most promising energy production systems to reduce pollutant emissions. They are electrochemical devices that directly convert the chemical energy into electrical energy. Among the different types of fuel cells, the Solid Oxide Fuel Cell (SOFC) emerges as one of the most promising devices with regard to its fuel flexibility, high efficient power generation and also provides significant environmental benefits. Conventional SOFCs are based on oxygen ion-conducting electrolyte (SOFC-O), state of art the electrolyte, in which yttria-stabilized zirconia (YSZ) is used. However, their high temperature operation (800-1000 °C), creates problems associated with the lack of stability and compatibility with other cell components. SOFCs using ceramic proton conductors as a solid electrolyte (SOFC-H) have attracted more interests as compared to traditional oxide ion conductors due to their capability for low temperature operation [1-2]. In early 1980s, Iwahara et al found several perovskite-type oxides exhibiting high proton conductivity at elevated temperatures, above 450 °C [1].

Among different proton conducting materials, perovskite based rare earth doped BaCeO$_3$ shows excellent proton conductivity at lower temperature [3,4]. Hence, BaCe$_{0.8}$Y$_{0.2}$O$_{3-\delta}$ (BCY) is selected as electrolyte material for cell fabrication. Suitable cathode and anode materials for BCY electrolyte are also synthesized in our laboratory, Ba$_{0.5}$Sr$_{0.5}$Co$_{0.2}$Fe$_{0.8}$O$_{3-\delta}$ (BSCF) is well known mixed conducting cathode material with low polarization resistance used in IT-SOFC [5,6]. Whereas, Ni-cermet is used as anode material in composite form with NiO and BCY. In present work, anode supported single cell is fabricated from above selected materials and their current-voltage characteristics are investigated.

Experimental

In this work, anode supported single cell for proton conducting SOFC, comprising of BSCF (Ba$_{0.5}$Sr$_{0.5}$Co$_{0.2}$Fe$_{0.8}$O$_{3-\delta}$ cathode) | BCY (BaCe$_{0.8}$Y$_{0.2}$O$_{3-\delta}$, anode)
electrolyte) \( \text{NiO-BCY (anode)} \) has been fabricated. BCY powder synthesized in our laboratory by sol-gel route heated at 1200 °C was used for cell fabrication. Anode powder was prepared by mixing BCY and commercially available NiO powder in 50:50 wt% respectively and 10% starch was added as a pore former. BSCF cathode material was synthesized by glycine-nitrate gel-combustion route. X-ray diffraction (XRD) patterns of all materials were recorded prior to use them for cell fabrication. Also, chemical as well as mechanical compatibility of all three cell components was previously checked. To begin with, half cell of BCY \( \text{NiO-BCY} \) was prepared by co-pressing and co-firing at 1400 °C for about 4 h. Over the electrolyte layer BSCF cathode layer was brush painted in the form of slurry with terpineol binder which was then sintered at 900 °C. The diameter of anode supported cell is \(-12 \, \text{mm}\) where electrolyte, cathode and anode thickness are \(-0.5 \, \text{mm}, \ -0.2 \, \text{mm} \) and \(-0.12 \, \text{mm} \) respectively. This single cell was tested using ProboStat (NorECs, Norway) set up. Anode chamber was exposed to humidified hydrogen \(-3\% \, \text{H}_2\text{O}\) and the cathode was exposed to atmospheric air. Current-voltage \((I-V)\) characteristics were recorded at 500 °C and 600 °C. Microscopic features of the cross section of single cell were examined after cell testing using scanning electron microscope, SEM (Seron Technology, Korea).

Results and discussion

XRD pattern recorded for BCY, BSCF and BCY-Ni showed that all three components are phase pure and also it was found that selected materials are well compatible with each other in working temperature range making them suitable for the fabrication of proton conducting single cells. Fig. 1 shows the SEM micrograph of cross section of anode supported single cell made up of above three components. The electrolyte layer was found to be quite dense and sandwiched by porous cathode and anode layer.

The current-voltage \((I-V)\) characteristics were measured with the help of laboratory made testing system with humidified hydrogen \((-3\% \, \text{H}_2\text{O})\) as a fuel and oxygen as oxidant at 500 °C and 600 °C. Electrical performance of the single cell at 500 °C and 600 °C are shown in Fig. 2. An open circuit voltage \((\text{OCV})\) of about 0.833 V was achieved at 500 °C, and 0.809 V at 600 °C, respectively. This suggests that proton conducting single cell was successfully fabricated where output of cell can be further improved by optimizing the thickness of electrolyte.

Fig. 1: SEM micrograph of cross section of anode supported single cell

Fig. 2: Cell voltage and power density as a function of current density for the single cell
Conclusions

Proton conducting anode supported single cell was successfully fabricated by co-sintering and co-firing technique. The cell fabricated generated an OCV of 0.833 V at 500 °C. All cell components are well compatible with each other. Higher current could not be drawn because of shortfall in sealing, poor current collection and high lead wire resistance. Performance can be improved by addressing these as well as by minimizing electrode polarization resistance through refining and optimizing the ceramic processing parameters. Overall, the present study establishes that co-sintering and co-firing approach can be a viable technique for fabrication of anode supported planer SOFC.

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References