

Performance Study On An Intermediate Temperature Solid Oxide Fuel Cell (IT-SOFT) Fabricated By Dry Pressing Method

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Abstract: An intermediate temperature solid oxide fuel cell (IT-SOFC) has been developed by using the dry pressing method. Widely studied materials were used for anode and cathode and SDC based electrolyte was used in this study. The cells were fabricated by dry-pressed at different pressures using a die without any binding material, a known amount of three electrode materials in powder form were pressed together and a nickel mesh was used as current collector. The test area of the fabricated cells was 0.785 cm². The experiments were conducted using H₂ as fuel and compressed air as oxidant. The cells were tested under different operating temperatures with varying fabrication parameters. The fabricated cells recorded an open cell voltage (OCV) of 765mV while operating at 560°C. The maximum current density obtained was 726mA/cm² and with a power density of 193mW/cm²

Keywords: Current Density, Power Density, SDC, Cell operating temperature

INTRODUCTION

Research focus has been to solid oxide fuel cells recently due to the increase in the petroleum fuel price and also because of the call for environmental pollutions. Solid Oxide Fuel Cells (SOFC) are a part of the research due to its advantages in accepting wider range of gases as fuel and also for that nature that it's all solid based. Different research has been going on in the area of optimization and fabrication. The main drawback of the SOFCs is its high temperature operation in the range of 1000°C, resulting in material constraints for both electrode and cell construction. Recent focus is on reducing the operating temperature as it will give several advantages mainly giving a wider choice of low-cost and high performance materials with a higher stability which will reduce the degradation, increased freedom for structural design etc. [1-4]. Interestingly the trend of research has been following the renewable and sustainable energy means with lower if not null impact on the environment.

Researchers are studying SOFC using gas derived from gasification using wood or coal [5-7]. Sylvia et al studied the impact of wood derived gasification gases, which consists of H₂, N₂, CO, CO₂ and CH₄ on an IT-SOFC [7]. Zhu discusses the

advantages of IT-SOFC for tractionary applications. The ceria-based composite material, which was used shows a super ionic conductivity at 400-600°C operated between 300-1500mA/cm² with a power density of 200-700mW/cm² [8]. An SOFC using ceria-carbonate composite electrolyte have demonstrated 0.15-0.25 W/cm² at a very low temperature in the range of 320-400°C and ceria-lanthanum oxide composites show a better performance of 0.35-0.66W/cm² while operating at a temperature of 500-600°C [9]. Different fabrication techniques have been carried out by researchers to get better performances in SOFC. Hatae et al studied the i-V and i-P characteristics for three separate single cell samples with multi-layered anode, recording the maximum power density at 0.32 W/cm² which operated at 800°C with 10 layers of anode [10]. Kim et al in his research fabricated an anode-supported electrolyte thin film SOFC for intermediate temperature showing a performance of 550mW/cm² at 850°C [11].

Different fabrication techniques have been followed in order to get the most cost-effective method by different researchers [12-15]. The potential of screen-printing technology to manufacture planar SOFC devices were investigated by Rotureau et al [14], who showed a power density of 1.2mW/cm² without

optimizing the performance of the cell at 800°C and Xia et al [15] fabricated SOFC by a simple and cost effective dry-pressing process which was tested between 400-650°C obtaining a maximum of 145mW/cm² and 400mW/cm² at 500 and 600°C respectively [15]. In this paper studies on an IT-SOFC, which was fabricated by dry-pressing method has been conducted. Results are presented by operating the cells fabricated with varying compaction pressure.

MATERIALS AND METHODS

The electrolyte material used for the preparation of the electrode was based on Samaria-doped-ceria (SDC), synthesized using cerium nitrate hexahydrate and samarium nitrate hexahydrate [16] in 1M solutions. The solutions were mixed in the desired stoichiometric amounts such as 20-mol% Sm in Ce. The anode is usually nickel, but a new type of alloy material based on Ni-Cu-Fe (70-20-10 mol %) was prepared to characterize the activity of each anode. The cathode was either composed of lithiated nickel oxide or was based on barium-strontium-cobalt-iron oxide (BSCF) prepared according to the report by Shao et al [17]. The electrolyte was mixed in 1:1 volume ratio with respective anode and cathode materials.

Cells were fabricated by dry pressing method using a hardened metal mold to press the electrode parts (anode, electrolyte and cathode) one above the other, where the electrolyte is sandwiched between the anode and cathode. The pressed electrode measures 1.2 cm in diameter and thicknesses were varied both by changing the compaction pressure and the weight of the ingoing electrode materials to the mold. Each electrode material was pressed separately at a lower pressure to compact it before the other part (electrode powder) was added to the mold, preventing the uniform layers from each part. The compaction pressures were varied to get the effect of cell formulation and adhesiveness. Following compaction, the cells were placed in a temperature-controlled oven for 1 hour at various temperatures. This technique, which has been widely used in laboratories and industries to make parts thicker than 0.5mm is simple, very cost-effective and reproducible [15].

Before test performances, SOFCs' constituents were characterized using conventional techniques using X-ray diffraction, SEM and EDX. Polarization measurements were recorded by a data logger (SR630 by Stamford Research Systems) after loading the cells using a variable resistor.

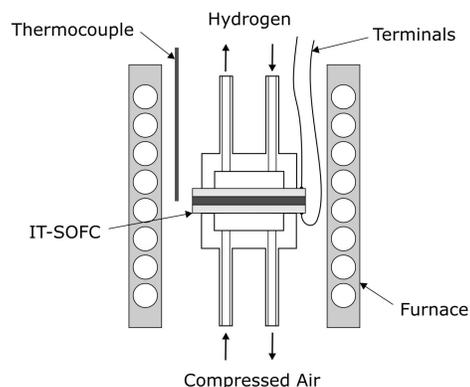


Fig. 1. Schematic of experimental setup

A test bench consisting of two gas chambers was developed using stainless steel (SS304) as shown in Fig. 1. The flow rate of hydrogen and compressed air supplied to the cell chambers were controlled using flowmeters (A-03267-09 for air and A-03267-02 for hydrogen, Cole-Palmer). The contact of cell with the holder was made using silver conductive paint (186-3593 by RS Components). A temperature controlled furnace is used to maintain the cell temperature with a maximum working temperature of 1200°C.

RESULTS AND DISCUSSION

Material characterization

Fig. 2 shows the cross-sectional SEM micrographs of cell components. Thicknesses of the electrodes were about 440µm, 400µm and 440µm for anode, electrolyte and cathode respectively. The particle size varies from 0.5 to 3 µm for the anode and 1 to 3 µm for the electrolyte. Some small voids were observed under the SEM investigation but no pinholes or cracks were observed on the electrodes.

Cell performance

Fig. 3 shows the *I-V* curves and the corresponding power densities at different cell operating temperatures as fabricated at different compaction pressures of 100, 150 and 200kg/cm² for (a), (b) and (c) respectively. As seen from the figures it is observed that the best cell performance was for the cells fabricated with the compaction pressure of 150kg/cm² (Fig. 3b). This indicates that this compaction pressure is apposite for hydrogen permeation and reaction through the anode compartment as well as the optimum conditions for the cell performance. The cell provided the maximum voltage of 840mV while operating at 560°C whereas the highest power density for this cell was recorded when it was operating at 680°C with an OCV of 675mV and a power density 195mW/cm² at a current density of 700mA/cm².

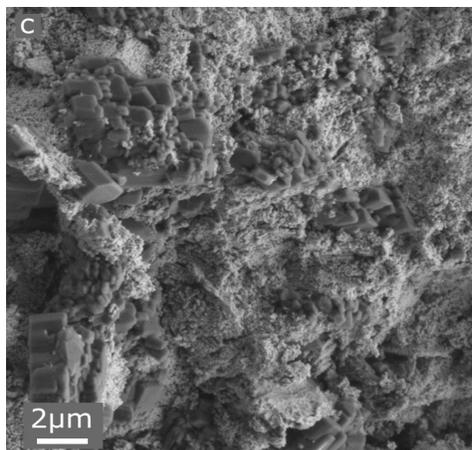
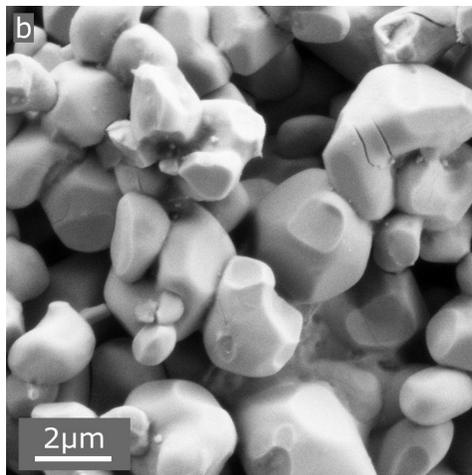
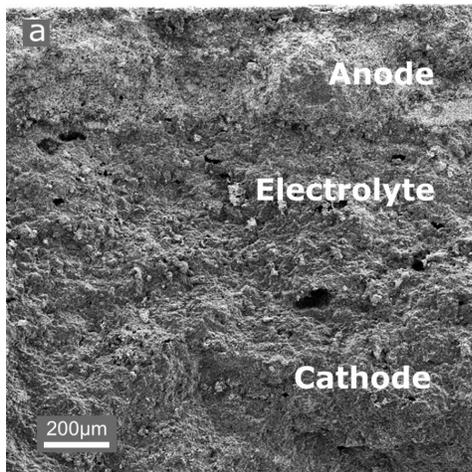


Fig. 2: Cross-sectional SEM micrographs of (a) a single cell, (b) porous Ni anode and (c) dense SDC electrolyte

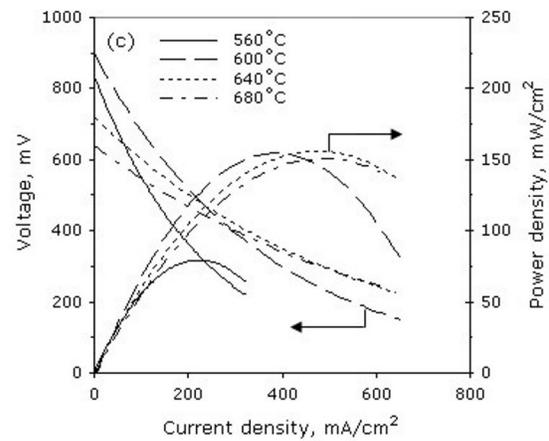
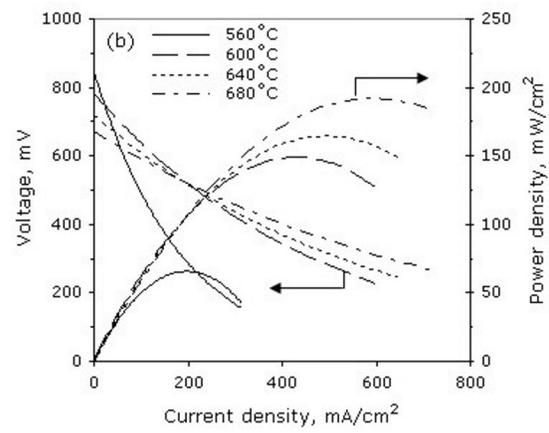
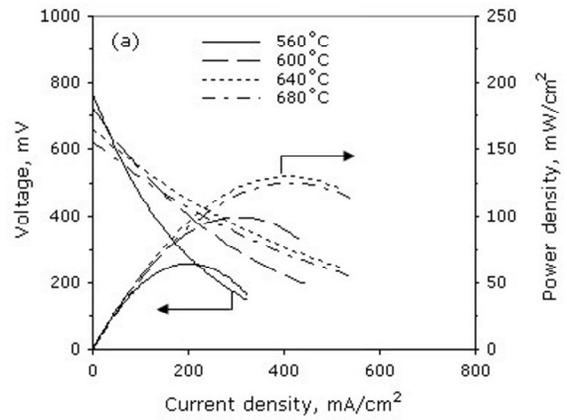


Fig. 3. I-V curves and corresponding power densities at different cell operating temperatures fabricated with (a) 100kg/cm², (b) 150kg/cm² and (c) 200kg/cm² compaction pressures

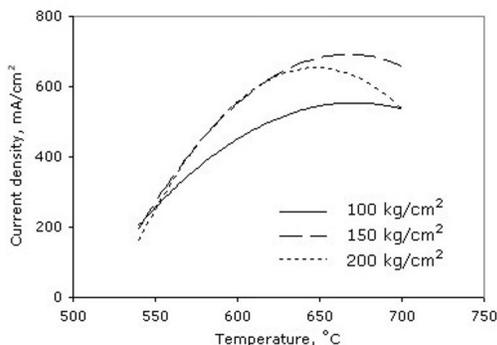


Fig. 4: Maximum current densities for different compaction pressure at varying cell operating temperatures.

The maximum power density was achieved by the cell fabricated with 150kg/cm² compaction pressure operating at 675°C followed by the cell fabricated with 200kg/cm² compaction pressure as shown from the comparative studies of the curves in Fig. 4.

At lower temperatures the cells were

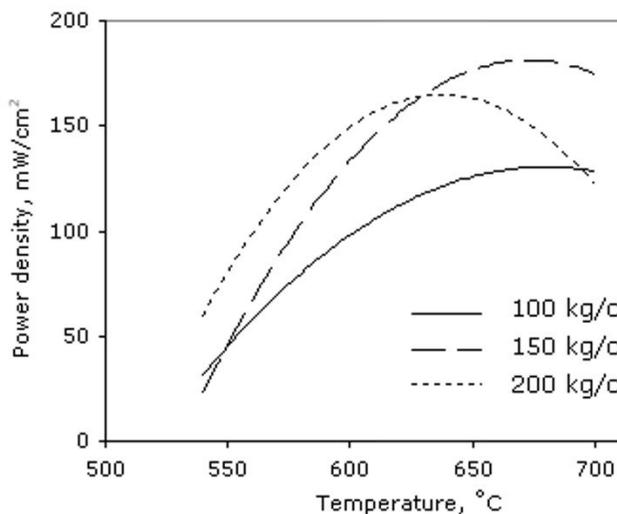


Fig. 5. Maximum power densities for different compaction pressure at varying cell operating temperatures.

CONCLUSION

The cells fabricated by dry-pressing method have performed well compared with the work done by other researchers in terms of power output. The method being cost effective and simple, the cells reached a maximum power density of 195mW/cm², while operating at a temperature of 680°C. The open circuit voltages were reasonably low due to the conductivities

of the materials and were observed to vary with the operating temperature in the range of 650 to 900mV for temperatures ranging from 560 to 680°C. The cells recorded the best performances at 650°C making it as intermediate temperature operations.

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