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Thin film THERMONO for cathode temperature gradient of SOFC

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Thin Film THERMONO for Cathode Temperature Gradient of SOFC

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Abstract

High thermal gradient is considered as the main reason for cell degradation and failure. A sizeable number of the available scientific work related to the problem in the literature is focused on using simulation or modelling to predict temperature distribution in the cell. THERMONO, a novel temperature monitoring sensor, has been developed by the authors' group. THERMONO is capable of monitor *{N^2}* temperature reading by using *{2N}* number of external wires, e.g. temperature measurement at 400 multiple points simultaneously can be done only use around 20 wires, whilst commercial thermocouple using 800 wires.

However, there are still difficulties in accurate and real time temperature measurement from a cell stack for practical implementations and desired resolution. Wiring based sensors, which are normally large in size, that are mounted on the cell electrode surface can make significant disturbance to gas flow and operating conditions. In this study, an innovative method is developed to overcome these limitations associated with implementing the large sized wire sensors. Nano-scale thin film THERMONO (FT-THERMONO) will be fabricated on the cell electrode surface to provide enabling technique for in-situ temperature monitoring of the cell with higher spatial and temporal resolution compared to wire sensors.

The novel TF-THERMONO architecture will be directly deposited on a test cell's (50mmx50mm, NextCell-5) electrode surface via sputtering technique. As a result, the test cells' cathode in-situ temperature distribution will be monitored during the normal operation. TF-THERMONO has a great potential for in-situ temperature monitoring by minimizing the unnecessary impact to the cell's operation thus its performance.

Thin film thermocouple array for cathode temperature gradients of SOFC

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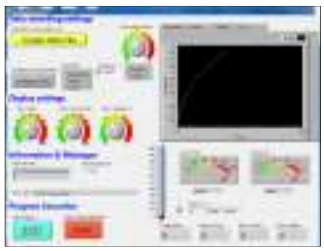
Introduction

- Solid Oxide Fuel Cells (SOFCs) are promising candidates for the production of clean renewable energy [1].
- Premature degradation of cells and stacks is a significant challenge to ensure the longevity of SOFCs and to make them a commercial viable technology to produce cleaner electricity.
- The electrode temperature distribution of an SOFC is an important parameter to monitor in order to get a better insight into the cell performance and its temperature-related degradations [2].
- The present efforts of measuring gas channel temperatures do not accurately reveal the cell surface temperature distribution [3].
- In this work, a thin-film multi-junction thermocouple array (K-type) with 4 sensing points was sputter-deposited on the cathode of a commercial SOFC test cell (NextCell-5), and the temperature of the cell was measured under varying fuel compositions of hydrogen and nitrogen.
- This sensor architecture can independently measure temperature from *{N}* number of sensing points with only *{N+1}* number of thermoelements whereas sets of conventional thermocouples require *{2N}* number of thermoelements for the same *{N}* number of sensing points

Aims and Objectives

- To develop an implementable thin film sensor without disturbing the operating environment and thus monitor the temperature distribution of the SOFC electrode (under open circuit condition)
- To use a magnetron sputter coater to deposit the thin film sensor array and a LABVIEW code/program for data acquisition





Experimental Setup

Material preparation:

- The thin film sensor pattern was deposited by a magnetron sputter coater
  - Four alumel and a chromel thermoelements were formed
  - Four sensing points were created (S1-S4)
  - Two commercial thermocouples were also placed to observe and compare sensor performance

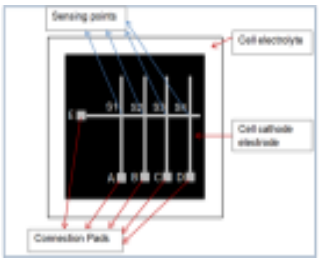




Fig. 1 Thin film sensor patterned cell and wires attachments

Experiments:

- Thin film thermocouple array integrated cell was fixed to the SOFC test rig
- Experimental parameters
  - Reduction Process: T=750 °C , hydrogen flow rate=15 ml/min with 200ml/min nitrogen for 2 hours
  - During experiments ; T=650-800 °C with varying flow rate



Fig. 2 Cell, sensor, thermocouples and test rig arrangement within furnace

Table 1. Volumetric flow rates

Flow Region	Flow Rates(ml/min) : H2/N2	Time (min)
A	100/150	10
B	150/100	10
C	200/50	10
D	250/50	10
E	200/50	10
F	150/100	10
G	100/150	10

Results

- The thin film sensor array was observed to be more sensitive to temperature changes than the commercial thermocouples
- Slightly higher temperature was obtained from the sensor than the thermocouples during cooling due to the higher bulk temperature of the cell and surrounding atmosphere

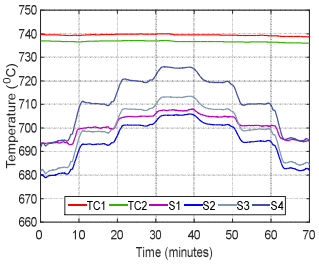


Fig. 3 Temperature response to varying flow rates

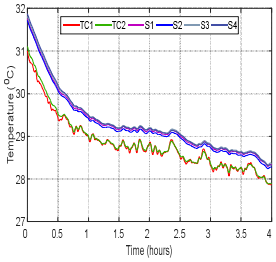


Fig. 4 Temperature monitoring during cooling down phase after experiment

- The OCV-temperature relation was also obtained and confirms the Nernstian inverse relationship between temperature and OCV; the thermocouples and the sensor array follow the same trend but show a marked difference in the temperature values recorded:

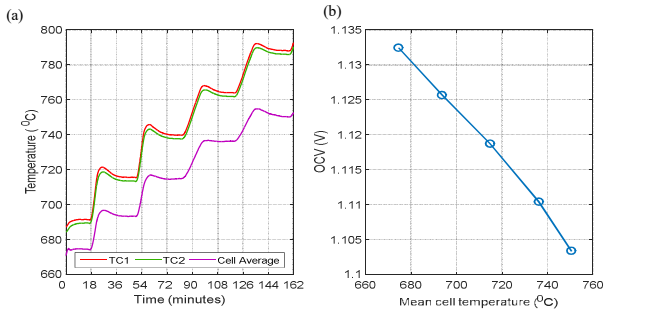


Fig. 5 Cell response to varying temperatures (a) The average cell temperature and the thermocouple temperature (b) the change of OCV with the increase of cell temperature

- OCV values were also obtained with different flow rates to ensure that nominal values for OCV under hydrogen operation were still being achieved, and that in OCV conditions (no current load) the sensor array pattern does not significantly influence the operation of the cell:

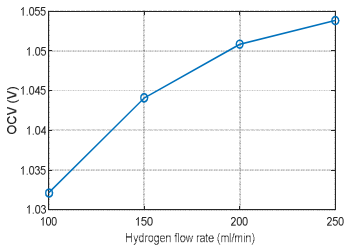


Fig. 6 OCV vs hydrogen flow rate

Conclusions

- Thin film thermocouple array was sputter deposited on the cell cathode surface
- Due to its architecture 4 sensing points were created by using only 5 thermoelements
- Notable temperature gradients were revealed across the cell under different flow rate configuration
- OCV changes under different flow rates and different temperatures was obtained
- Incapability of the thermocouples to detect the temperature changes with different flow rate was examined

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