Cell integrated thin-film multi-junction thermocouple array for in-situ temperature monitoring of Solid Oxide Fuel Cells

Manoj Ranaweera, Indae Choi, Jung-Sik Kim*
Department of Aeronautical & Automotive Engineering
Loughborough University
Loughborough, LE11 3TU, United Kingdom
* j.kim@lboro.ac.uk

***Abstract*— A thin-film multi-junction thermocouple array was developed and tested for multi-point simultaneous temperature measurements from an operating SOFC stack. The array requires only *{N+1}* number of wires/ thermo-elements for *N* number of independent temperature measuring points. Hence, it requires less number of lead wires than any available contact-temperature sensor requires for the same number of measurements. Because the multi-junction thermocouple array operates on the same principle of a conventional thermocouple, the Seebeck effect, it shares all the merits of a thermocouple. A thin-film multi-junction thermocouple array was sputter deposited on the cathode of a SOFC test cell and tested and evaluated up to 1050^{0}C from 20^{0}C. Temperature measured from the thermocouple array was compared with that from a commercial thermocouple placed adjacent to it during the test; they were in very good agreement within the entire temperature range that a SOFC stack generally operates.**

Keywords—multi-junction thermocouple; SOFC; thin-film thermocouple

I. INTRODUCTION

Solid Oxide Fuel Cell (SOFC) is promising technology for future clean energy production from hydrogen and hydrocarbons. However, premature degradation of cells and stack is a significant technical challenge to overcome to ensure wide-spread of this technology. Thermal cycling at high temperature (usually, in the range from 600^{0}C to 900^{0}C) and uneven temperature distribution contribute significantly to premature degradation by creating severe mechanical failures such as delamination and cracking of cell components and sealing. A comprehensive knowledge on cell level temperature distribution of an operating SOFC stack is important to understand these phenomena and thereby to successfully mitigate them.

Thermocouple thermometry has been the most successful approach used to measure stack temperature so far [1]- [4]. Although these approaches could yield successful results within their respective scopes, the inability to measure temperature closer to reaction cites on the cell is a significant drawback commonly noticed in these approaches. Therefore, authors devised to use cell integrated thin-film thermocouples (TFT) to get better details on cell level temperature distribution.

TFT finds a number of applications in different application domains. They are generally fast responsive and can measure temperature with as high as 10nS responsiveness[5]. However, unlike most of those applications that already employed TFTs; SOFC requires temperature measurement with greater spatial resolution because of potential significant temperature variations that exist across a cell[6]. Since each sensing point of a thermocouple is formed by intersecting two thermo-elements, integrating a large number of thermocouples onto the cell covers a large area from reaction sites and thus causing a significant disturbance to the normal operation of the cell/stack. In order to overcome this drawback while sharing the merits of TFT, the potential of multi-junction thermocouples that share some thermo-elements to reduce the number of thermo-elements required in multi-point temperature sensing is investigated. This paper discusses the fabrication, testing, and the results of a multi-junction thermocouple fabricated on a SOFC electrode.

II. FABRICATION AND TESTING

A. Material Selection

From among different high temperature thermocouple materials, K-type materials (Alumel - Ni:Al:Mn:Si 95:2:2:1 by wt. and Chromel - Ni:Cr 90:10 by wt.) were chosen for thermo-elements. These materials have standardized performance up to 1372^{0}C and they are more economical to test than other high temperature noble metal thermocouples. External wires to collect the signals were chosen from the same material as thermo-elements to prevent formation of an intermediate junction with a third material, which may otherwise induce an additional electromotive force.

B. Sensor Fabrication

A multi-junction thermocouple array having 4 sensing points was fabricated on the cathode of 52mm diameter commercial test cell (KERAFOL®). It is important to test the thermocouple array's survivability on a porous substrate as both the electrodes are porous in an operating SOFC. The cathode (made of LSM) is always porous and the anode (made of NiO – YSZ) becomes porous only after NiO is reduced to Ni. Therefore, cathode was chose as the substrate to deposit the array.

978-1-4799-8203-5/15/$31.00 ©2015 IEEE