Thin film thermocouple array for temperature gradient and flow distribution of SOFC cathode

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Thin Film Thermocouple Array for Temperature Gradient of SOFC Cathode

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Outline

• Background and research focus
• Sensor development and testing
  – Fabrication
  – Implementation to SOFC cell
• Experimental Results
• Conclusions & Future works
Background & research focus

• Converts the chemical energy of reactants into electricity without combustion

\[
\begin{align*}
\text{Anode} & : 2\text{H}_2 + 2\text{O}^{2-} \rightarrow 2\text{H}_2\text{O} + 4\text{e}^- \\
\text{Cathode} & : \text{O}_2 + 4\text{e}^- \rightarrow 2\text{O}^{2-} \\
\text{Overall} & : \text{H}_2 + 1/2\text{O}_2 \rightarrow \text{H}_2\text{O}_{\text{steam}}
\end{align*}
\]
Research objectives and contributions

- More reliable data for performance modelling
- Management of the thermal stress
- Temperature distribution measurement within a working SOFC cell and stack
- Better understanding of degradation phenomena
- Should be good as a health monitoring tool
Present state of cell temperature identification

Cell temperature identification

Simulation

Experiments
Present state of cell temperature identification

- Mathematical equations to model cell temperature gradient
- Software tools (Comsol)
Present state of cell temperature identification

- Cell temperature has been measured using thermocouples (from gas channel)

Experiments

- Thin film sensor
- Reduce the required number of wires
- Signal processing software

No practical means of measuring cell surface temperature has been developed yet
Thin film Sensor configuration

- Thin film sensor: sputter deposition

N: number of sensing points
N+1: required thermo-element
It requires only $2N$ thermo-elements for $N^2$ measuring points.

Increases the spatial resolution.
Thin-film Sensor Fabrication

- Sputter deposition was used to deposit thin film on the cathode

- A metal mask used to shape the pattern

Sputtering Parameters:
- $I = 150\, \text{mA}$
- $T = <50\, ^\circ\text{C}$
- Deposition rate: $14\, \text{nm/min}$
Test rig with thermocouple array and sensing locations

- Anode chamber
- Fuel supplier
- Commercial thermocouples
- Current collector
- TC1
- TC2
- S1, S2, S3, S4
Anode reduction process: Temperature distribution of the cell

Fuel (H₂) sent

Table 1: Volumetric flow rates

<table>
<thead>
<tr>
<th>Flow Region</th>
<th>Flow rates (ml/min)</th>
<th>Time (min) (Approx.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>100 / 100</td>
<td>10</td>
</tr>
<tr>
<td>B</td>
<td>150 / 100</td>
<td>10</td>
</tr>
<tr>
<td>C</td>
<td>200 / 50</td>
<td>10</td>
</tr>
<tr>
<td>D</td>
<td>250 / 0</td>
<td>10</td>
</tr>
<tr>
<td>E</td>
<td>200 / 50</td>
<td>10</td>
</tr>
<tr>
<td>F</td>
<td>150 / 100</td>
<td>10</td>
</tr>
<tr>
<td>G</td>
<td>100 / 100</td>
<td>10</td>
</tr>
</tbody>
</table>

Temperature (°C)

Time (minutes)

Flow region:
- A
- B
- C
- D
- E
- F
- G

Flow rates:
- H₂
- N₂

Flow rates (ml/min):
- 100
- 150
- 200
- 250
- 100

Time (min) (Approx.):
- 10

Diagram showing temperature distribution and flow regions.
When the furnace temperature manually changed
Conclusions & Future works

- The thin film sensor is capable for SOFC temperature measurement
- Temperature distribution of the cell was obtained
- Gas leakage was by the sensor
- Exploring the potential of thin film sensor
  - Health monitoring tool
  - As energy harvesting tool
Acknowledgement

Modelling Accelerated Ageing and Degradation of Solid Oxide Fuel Cells (EP/I037059/1)

Novel diagnostic tools and techniques for monitoring and control of SOFC stacks - understanding mechanical and structural change (EP/M02346X/1)