Application of Infrared Thermal Imaging to the Study of Solid Oxide Fuel Cells

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Abstract
The application of infrared thermal imaging to the study of solid oxide fuel cells is demonstrated. The temperature increases accompanying polarization of gadolinium doped ceria (CGO) pellet cells is measured and the effect of temperature increase on polarization characteristics is modelled. Temperature increases of the order of 2.5°C were observed for heavily electrically loaded pellet cells. Measurement accuracy of 0.1°C and spatial resolution of 0.5 mm allows temperature distribution heterogeneity to be clearly discerned. A total heat transfer coefficient is derived from experimental results, allowing for the development of a model that predicts the extent of self-heating. For pellet fuel cells, self-heating is not expected to have a large effect on the polarization characteristics; however, for thin electrolytes and high current density the effect becomes appreciable. Infrared thermal imaging is also used to measure temperature distribution across a 4 cm × 4 cm electrolyte supported SOFC when exposed to a cold gas stream and the induced stresses derived.

Model predictions based on temperature increase
A model [2] that describes the performance of CGO electrolyte based SOFCs was used to assess the effect of temperature increase on electrochemical performance for different electrolyte thicknesses. It was found that the temperature increase for thick cells (350 µm) typically used for pellet cell testing are not significantly affected by self-heating; however thin electrolyte cells (30 µm - not used as pellet cells) experience appreciable performance modification (Figure 8).

Experimental

Thermo-mechanical stress analysis
Figure 9 shows the IR image for an electrolyte supported SOFC when exposed to a ‘cold’ air stream at its centre. The solid line shows the interface between active electrolyte and electrolyte area. Taking a cross-section of the temperature distribution, the principle stress field was derived using the finite element tool – Abaqus. A temperature gradient of over 9°C mm⁻¹ was recorded without the electrolyte cracking or electrode delaminating.

Conclusions
Infra-red thermometry has been applied to the study of operational IT-SOFCs to determine the temperature changes and spatial distribution associated with different current densities for electrolyte supported pellet cells. Temperature changes of up to 2.5°C were observed for heavily electrically loaded pellet cells. Evidence of temperature distribution heterogeneity was observed at low cell voltage, although this was not significant for cells operating over typical polarization limits. The effect of cell heating on polarization characteristics was investigated using a model. For a CGO electrolyte supported pellet cell with a thickness of 350 µm, the cell heating effect on the polarization response is not significant. Thinner electrolytes, suitable for technologically relevant SOFCs (but not pellet cells) show an appreciable temperature increase that is beneficial to electrochemical performance but not suitable for the accurate measurement of electrode performance. Collectively, the electrochemical and temperature measurements made suggest that pellet cells are a reasonable means of assessing cell performance and that the assumptions made about their operation are valid for most circumstances. Temperature gradients due to manufacturing or reactant heterogeneity has been shown to be present in SOFCs which were previously assumed to be homogeneous and isothermal. Determining the maximum thermal gradient tolerance of SOFC materials will be the subject of further experiments using the method presented.

REFERENCES

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