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High spatial resolution monitoring of the temperature distribution from an operating SOFC

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Abstract

In situ monitoring of cell temperature distribution of an operating SOFC is crucial to understand its performance and degradation. The available efforts recorded in literature are incapable of measuring the temperature from electrodes. Instead, they measure the gas channel temperature from a selected few points, mainly, by inserting thermocouples into the stack, which significantly limits the spatial resolution of measurements and introduces disturbance to the SOFC's normal operation. To overcome these weaknesses, the authors developed a new temperature sensor architecture that shares the merits of thermocouple thermometry and measures temperature at $\{N^2\}$ points with only $\{2N\}$ number of thermoelements. This sensor is capable of measuring the electrode temperature distribution with greater spatial resolution than thermocouples. Using this sensor, authors are successful to measure the spatial cathode temperature distribution in high spatial resolution out of an SOFC test cell (50 mm x 50 mm, NextCell-5) under varying fuel flow rates (from 50 ml/ min at A to 250 ml/min at F&G). The temperature measurements were validated with commercial thermocouples. Correlations between cell temperatures, flow rate and, OCV were observed and analysed.

Remark: Paper runs for a publication in EFCF Special Issue Series (www.EFCF.com/LIB, SI EFCF 2015) in Journal 'FUEL CELLS - From Fundamentals to Systems'.

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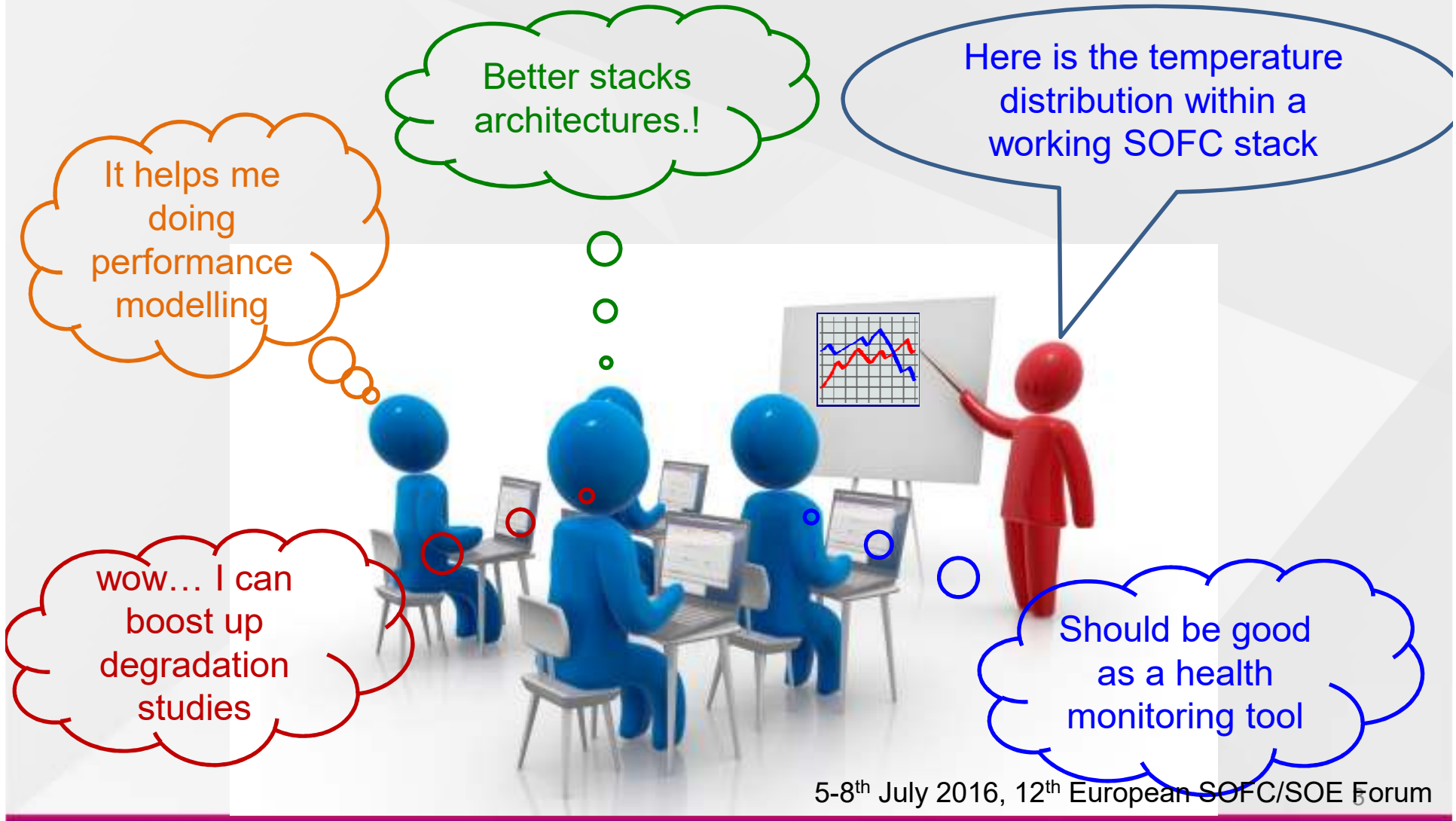
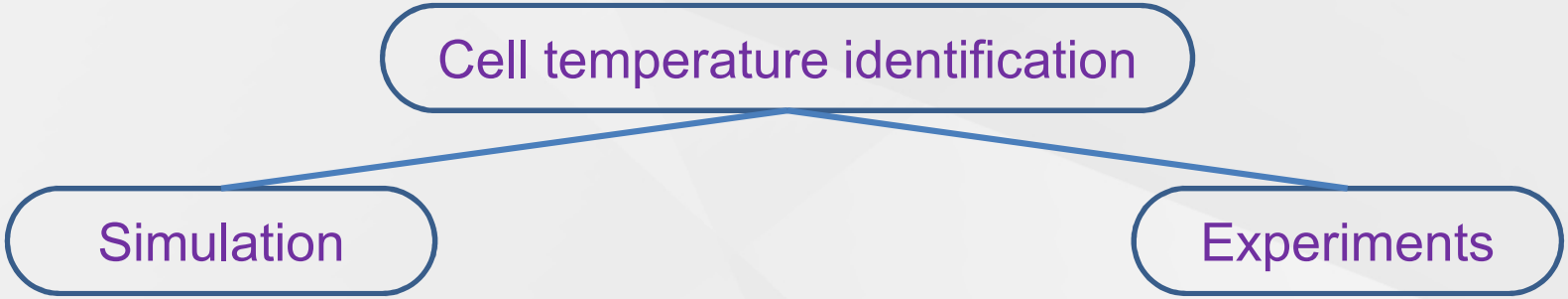
Outline

- Importance & difficulties of temperature monitoring from SOFC
- Sensing method; sensor fabrication and apply
- Real-time temp. monitoring and validation/comparison
- Conclusions & Future works

Introduction and Impact



Present state of cell temperature identification



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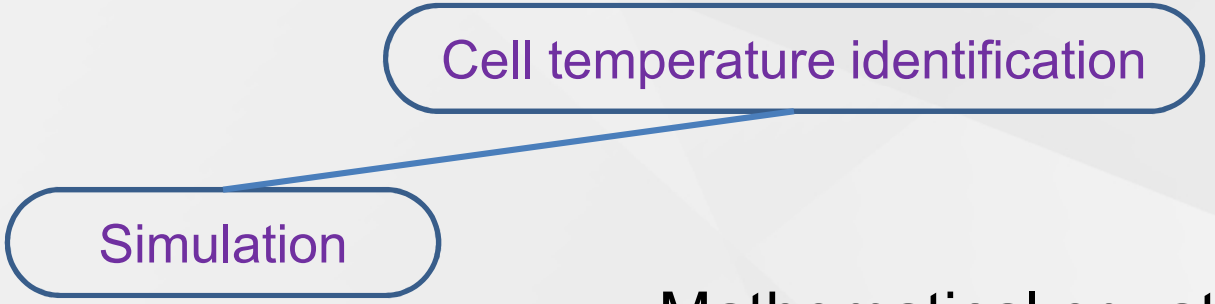


- Mathematical equations to model cell temperature gradient
- CFD modelling
- Software tools

Present state of cell temperature identification

Cell temperature identification

Experiments

- Gas inlet and outlet temperature has been measured using thermocouples

No practical means of measuring cell surface temperature has been developed yet

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

New thermocouple architecture was developed

It requires only *2N* thermo-elements for N^2 measuring points

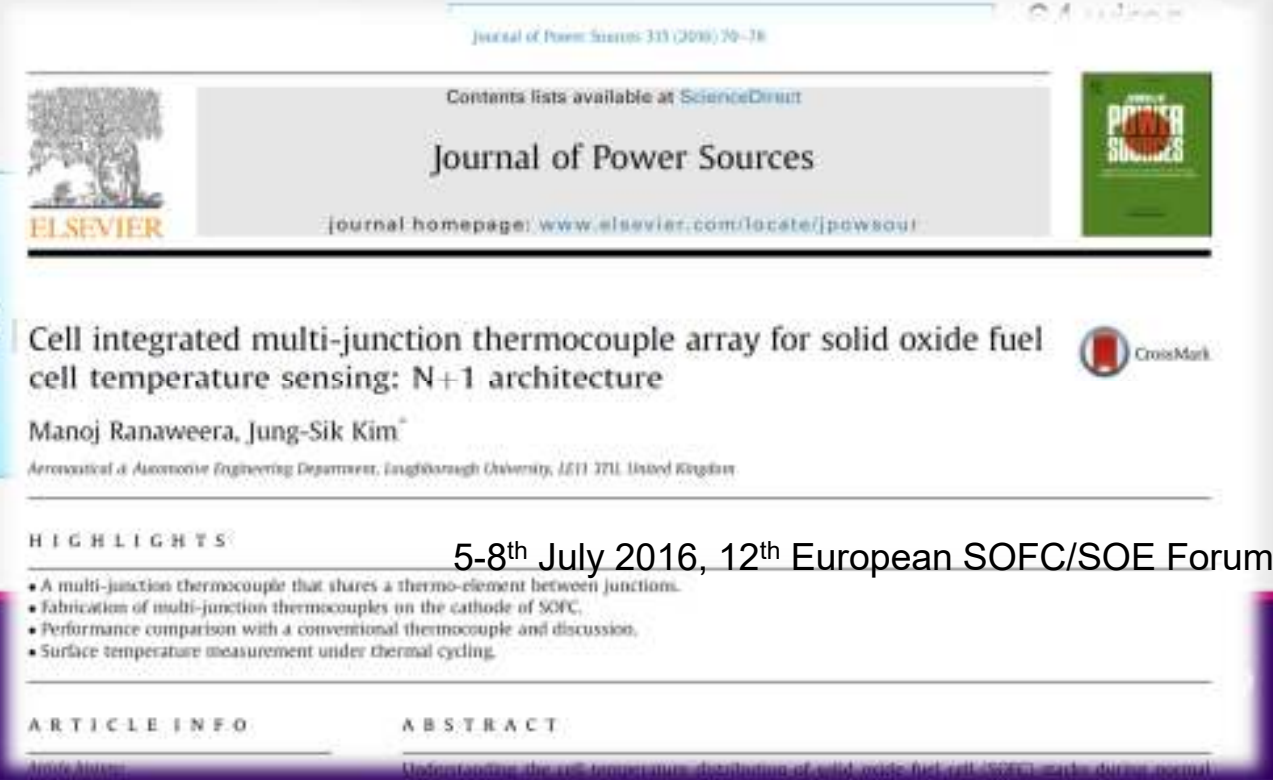
Patent App. No: GB1509690.2

Increases the spatial resolution of measurements

9 points

6 wires

36



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ELSEVIER

Cell integrated multi-junction thermocouple array for solid oxide fuel cell temperature sensing: N+1 architecture

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HIGHLIGHTS

- A multi-junction thermocouple that shares a thermo-element between junctions.
- Fabrication of multi-junction thermocouples on the cathode of SOFC.
- Performance comparison with a conventional thermocouple and discussion.
- Surface temperature measurement under thermal cycling.

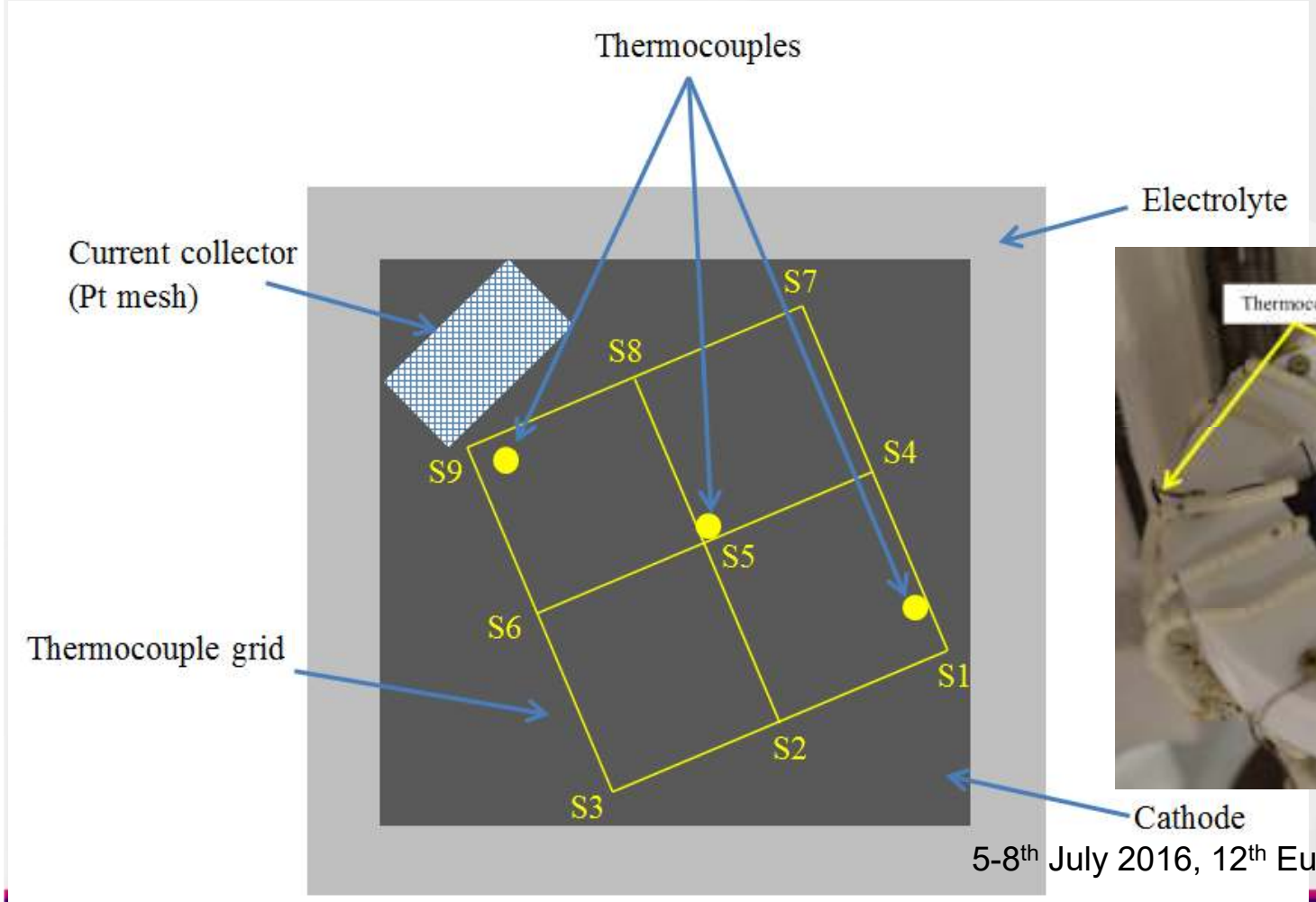
ARTICLE INFO

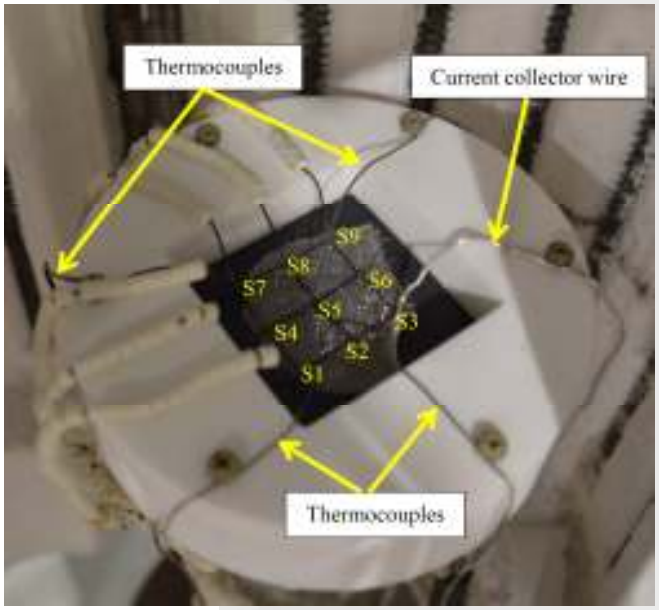
ABSTRACT

5-8th July 2016, 12th European SOFC/SOE Forum

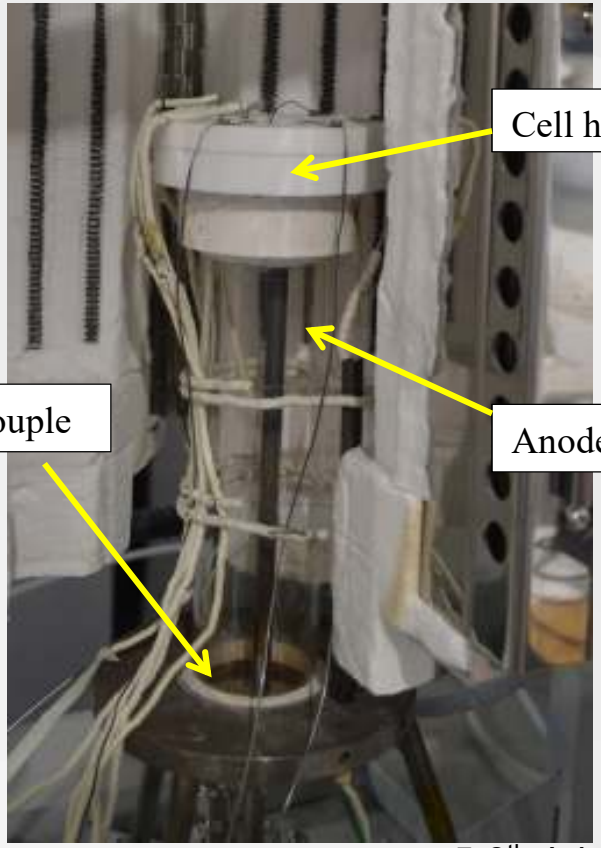
Loughborough University

Sensing locations

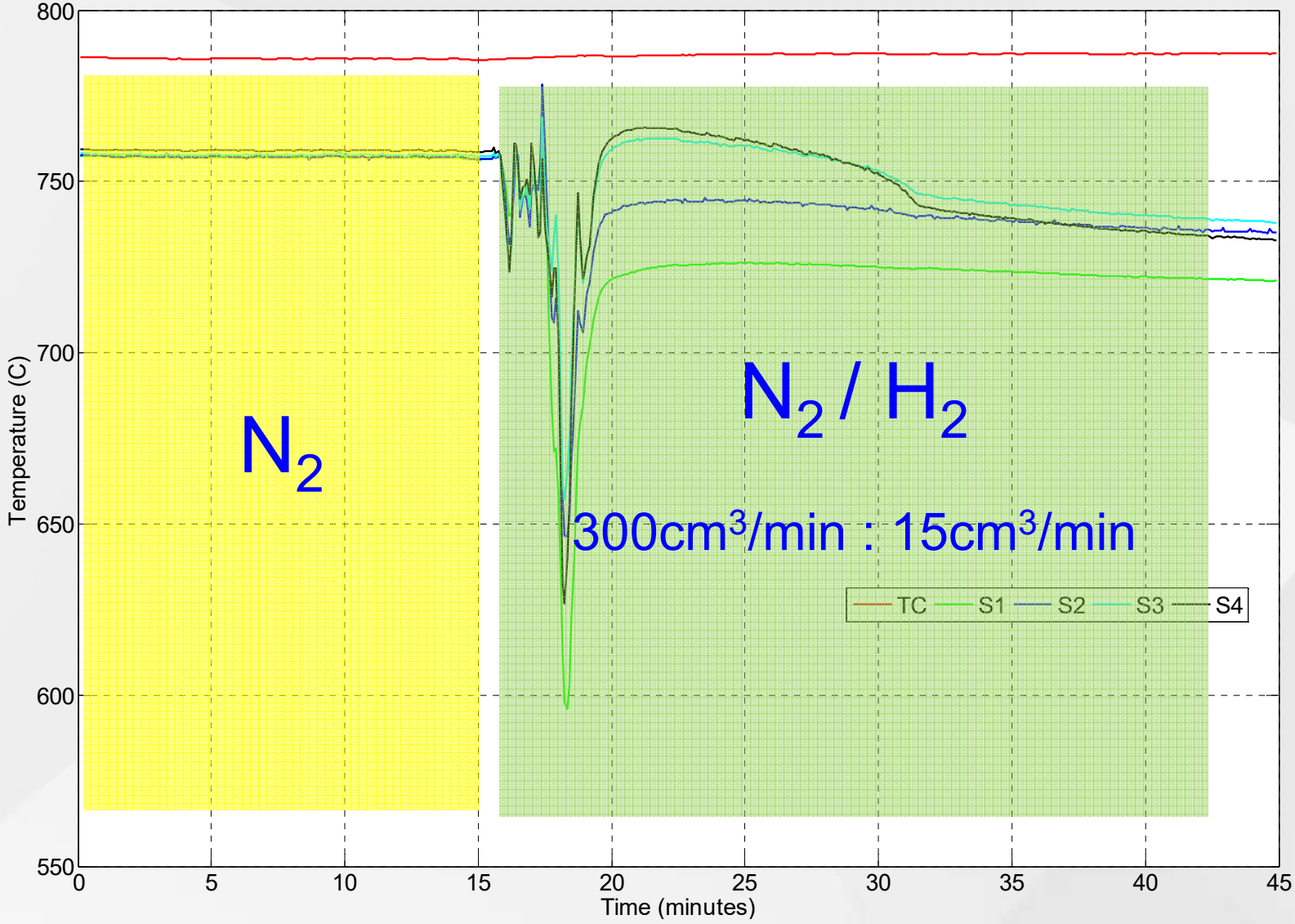




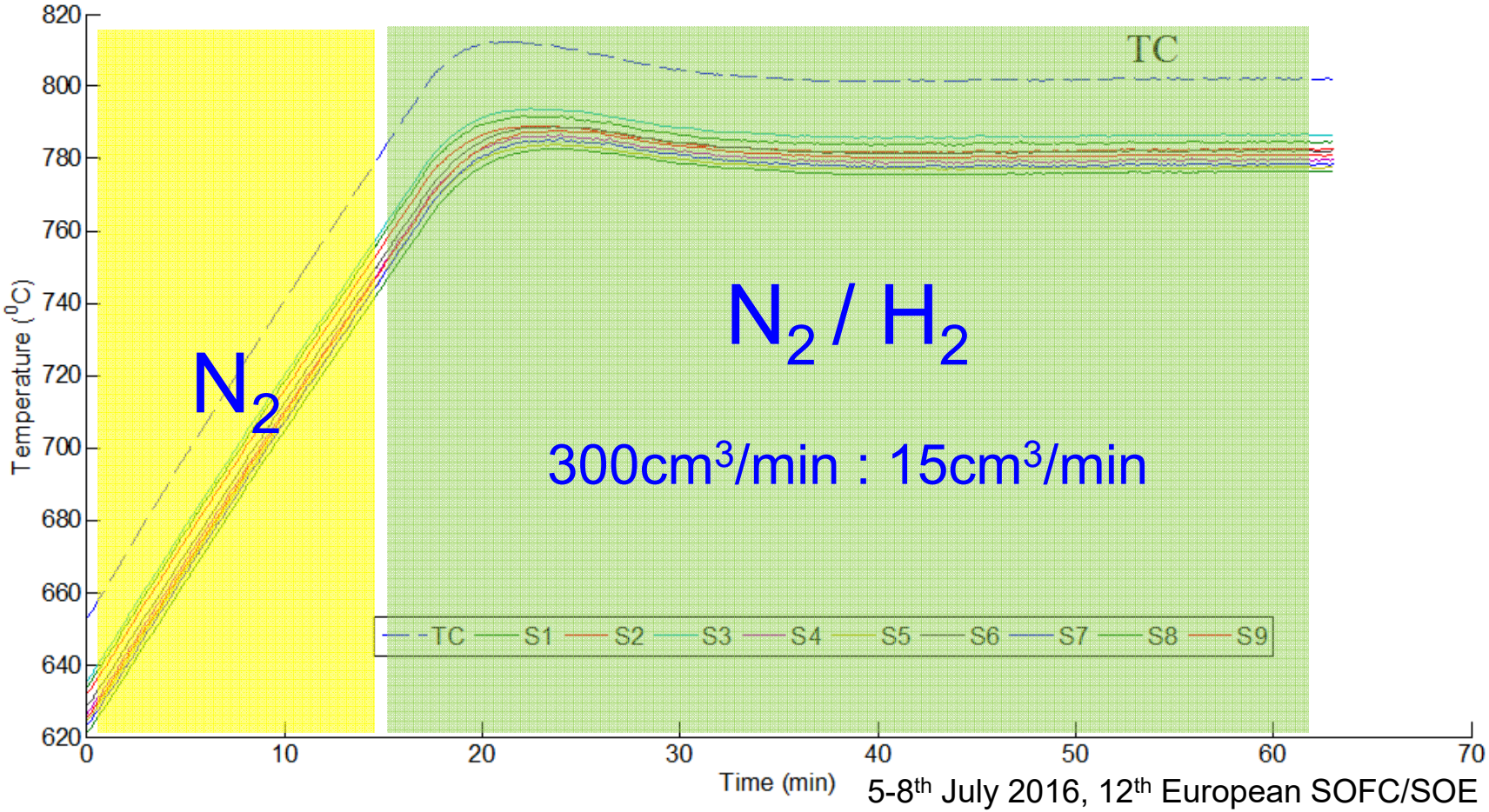
Test Rig



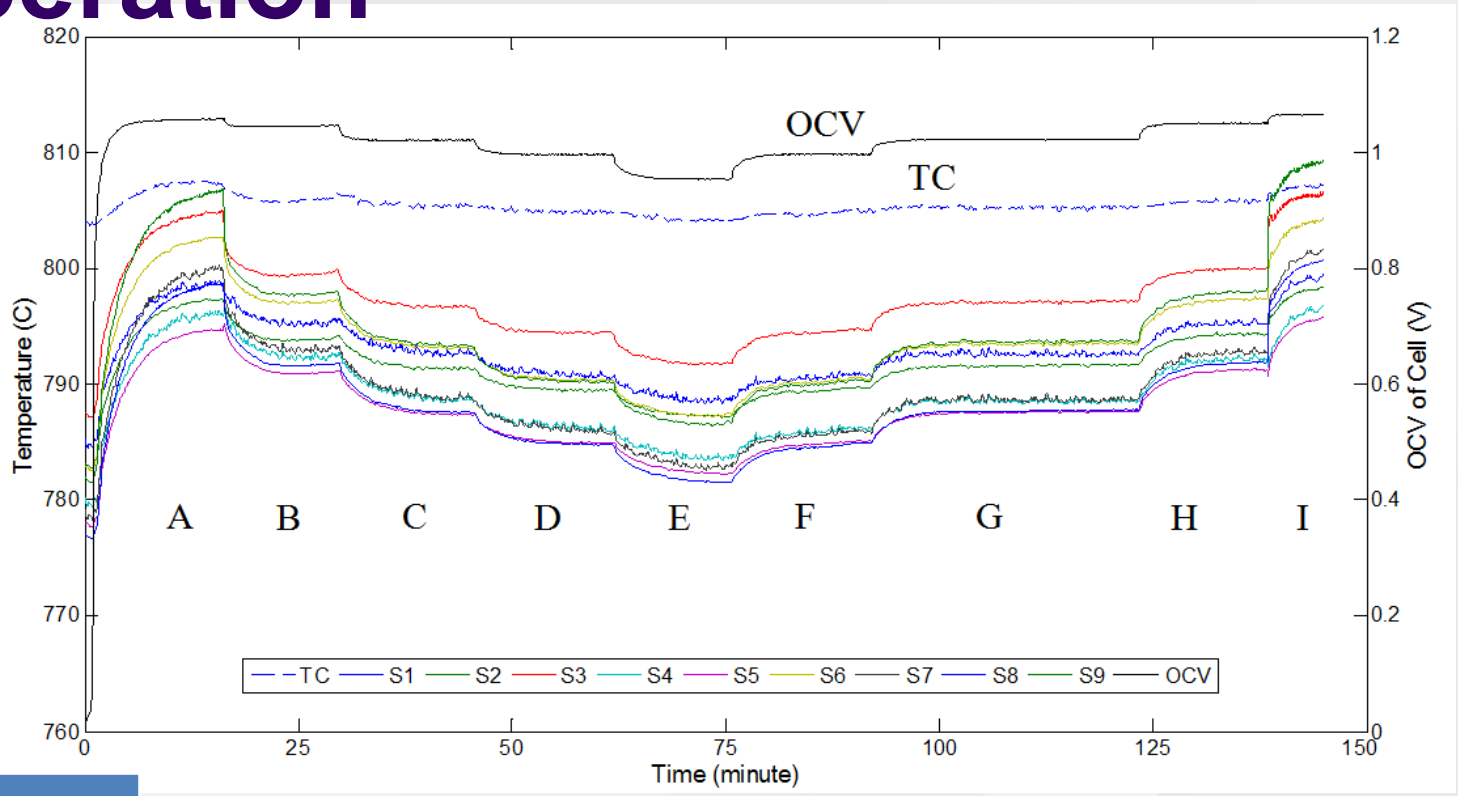
Anode reduction process



Anode Reduction

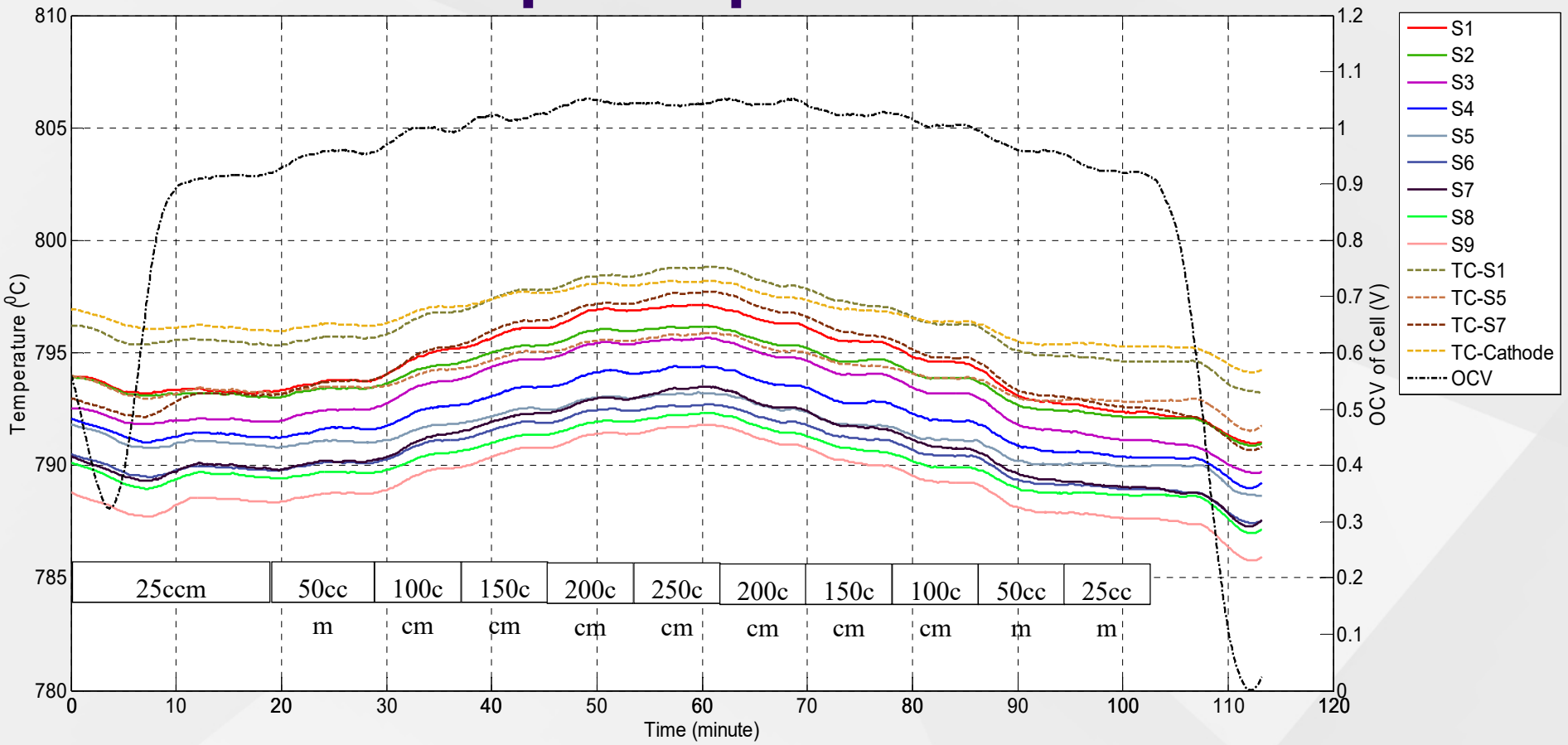


Cell operation



Setting	H_2 flow rate
A/ I	500 cm^3/min
B/H	250 cm^3/min
C/G	150 cm^3/min
D/F	100 cm^3/min
E	50 cm^3/min

OCV and temp comparison



S1 to S9: the 9 sensing points from THERMONO

TC-Si: The commercial thermocouple that touches the Cathode in close proximity to i^{th} sensing point of THERMONO (i = 1,5,7)

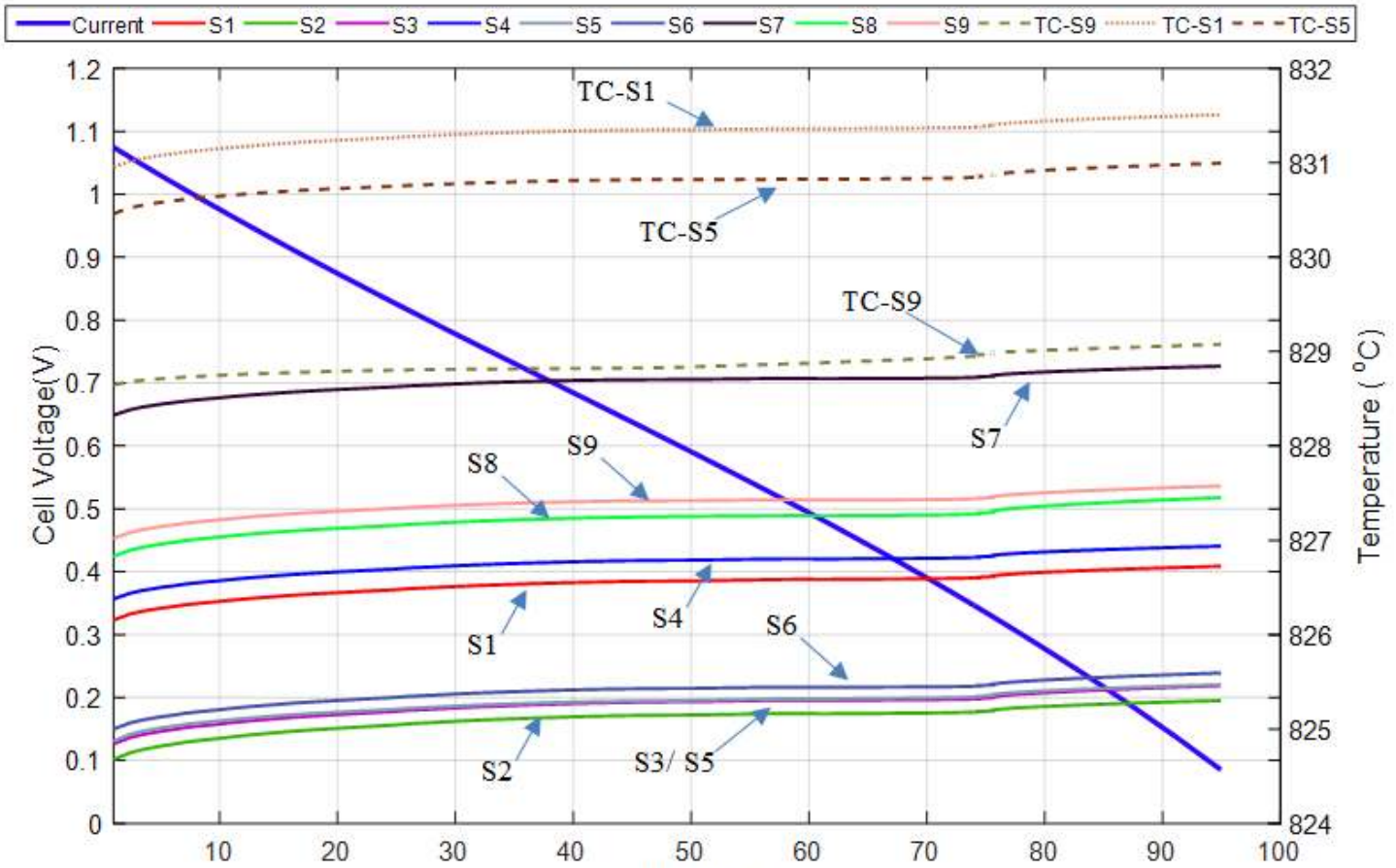
TC-Cathode: The commercial thermocouple kept about 2mm adjacent to cathode right above S5

Cell Temperature vs Voltage

Change of OCV with temperature				
Furnace Temperature (°C)	700	750	800	850
OCV (V)	1.1256	1.1055	1.0963	1.0853
Average cell temperature (°C)	680.67	729.20	779.27	827.61

Change of cell voltage different temperature under 60 mA current				
Furnace Temperature (°C)	700	750	800	850
Cell voltage (@ I = 60 mA)	0.426	0.455	0.463	0.494

Load-Temperature Relationship (850 °C)



Conclusions & Future works

- A new thermal sensor array has been applied to monitor a temp distribution from an operating cell.
- The monitored temp distribution was validated.
- Load driven cell temperature fluctuations has been observed.
- Local cell temperature could be used as a measure to identify normal/abnormal electrochemical behaviour of cells
- Real-time detection of gas reforming, carbon deposition etc.
- Q: what temp. do you run your cells (stacks)? A: @ 750 ˚C

  Wrong Q&A..!!!
- Q: what range of temp. do you run yours? Model A: @ 750 ˚C ± 45 ˚C

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)

5-8th July 2016, 12th European SOFC/SOE Forum