

# THERMONO: Cell integrated thin-film sensor array for in-situ monitoring of SOFC temperature

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In-situ temperature monitoring from a working SOFC stack indicates the overall health of the system. It also helps detecting variety of cell problems<sup>[1]</sup> while providing information to understand degradation and to develop better stack designs. Current efforts on simulating temperature distributions involve a great deal of assumptions<sup>[2]-[8]</sup>, which may not present in a working stack. Existing temperature sensing technology does not qualify for in-situ temperature monitoring of a SOFC stack as it causes a significant disturbance to normal stack operation when inserted into a stack<sup>[9]</sup>. Therefore, Novel temperature sensor architecture was developed to in-situ monitor SOFC running temperature while causing only a minimum disturbance to the normal stack operation. This architecture, named as THERMONO, enables to reduce the number of external wires required: only  $\{N+1\}$  number of external wires for  $N$  number of independent temperature sensing points. A thin-film THERMONO having 4 independent sensing points was fabricated on the cathode of a cell ( $\Phi 52\text{mm}$ , Kerafol Ltd, KeraCell II). Standard K-type thermocouple materials, Alumel (Ni 95%, Mn 2%, Al 2%, Si 1%) and Chromel (Ni 90%, Cr 10%) of 99.99% purity were chosen as the THERMONO materials. THERMONO was successfully tested in a furnace up to  $1050^{\circ}\text{C}$ . A commercial K-type thermocouple was placed adjacent to THERMONO as a reference. Transient response of THERMONO was in very good agreement with the thermocouple validating the sensor concept and proving its robustness on commercial cells. THERMONO is being tested in a specially designed fuel cell test rig to sense the temperature from a working SOFC. Integration of THERMONO into commercial fuel cells and short stacks is also covered in this study and the results will be useful to understand various degradation mechanisms and for advancement of SOFC stack operation conditions.

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- [8] Kakac, S., Pramuanjaroenkij, A. & Zhou, X.Y., 2007. A review of numerical modeling of solid oxide fuel cells. *International Journal of Hydrogen Energy*, 32(7), pp.761-786.
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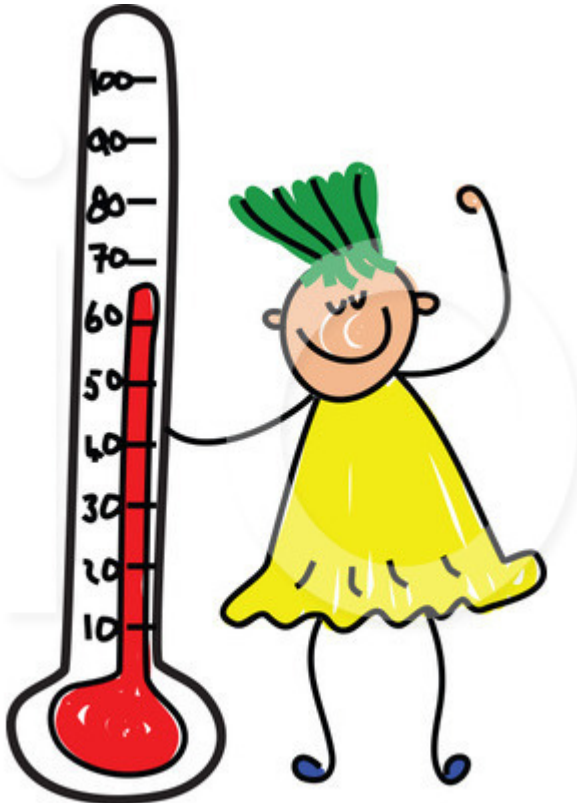


# Outline

- Introduction
- Constraints
- Methodology
- Results & discussion
- Conclusion & future works

# Introduction :

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Good knowledge of temperature distribution will....

- help boost performance modelling
- help boost degradation studies
- help develop new stack architectures
- indicate the overall health of a working stack\*

\*Virkar, A.V., 2007. A model for solid oxide fuel cell (SOFC) stack degradation. *Journal of Power Sources*, 172(2), pp.713-724.

# Introduction :

## Stack temperature distribution

### Simulation



### Experiments



## Constraints:

- Disturbance to the normal cell operation should be maintained at a minimum
- Temperature measuring mechanism should survive in extremely harsh operating environment inside SOFC

## Thermometry

~~Non-Contact thermometry~~

Contact thermometry

Resistance Temperature Detectors (RTD)

Thermocouples (TC)





# Methodology



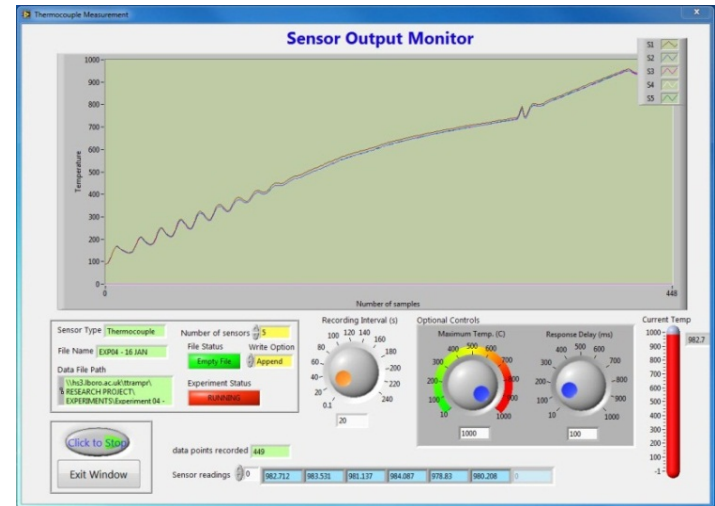
## THERMONO

Novel sensor architecture, that can independently measure temperature at different points with minimum number of external wires

Theoretically proven  
Computationally simulated

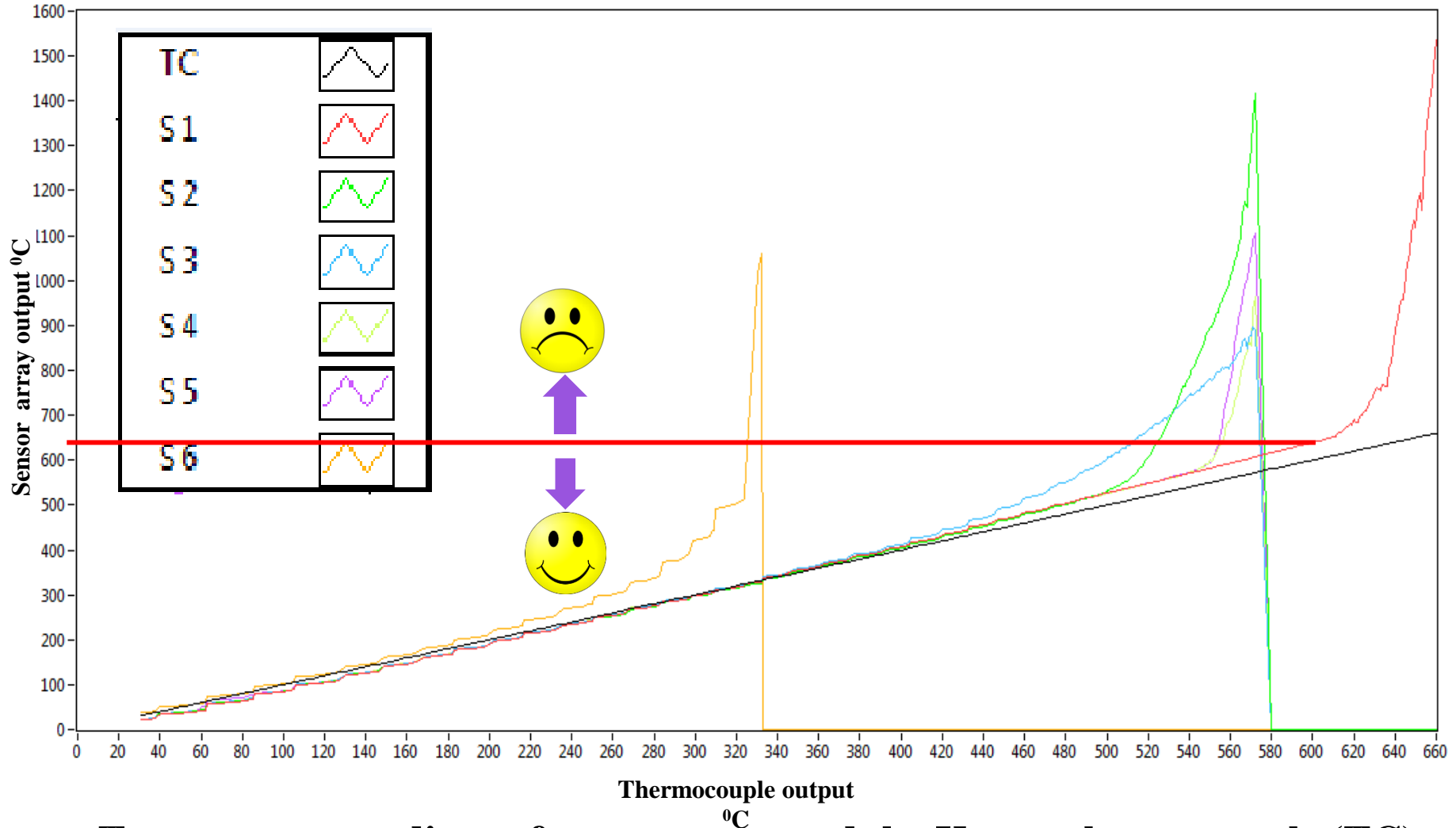
# Methodology

- Data acquisition system was developed using LabVIEW



- Alumel (Ni 95%, Mn 2%, Al 2%, Si 1%) and Chromel (Ni 90%, Cr 10%) of 99.99% purity were chosen as THERMONO materials
- 50-60 nm (approx.) thick sensors were fabricated on a SOFC substrate

# Results & Discussion (1)

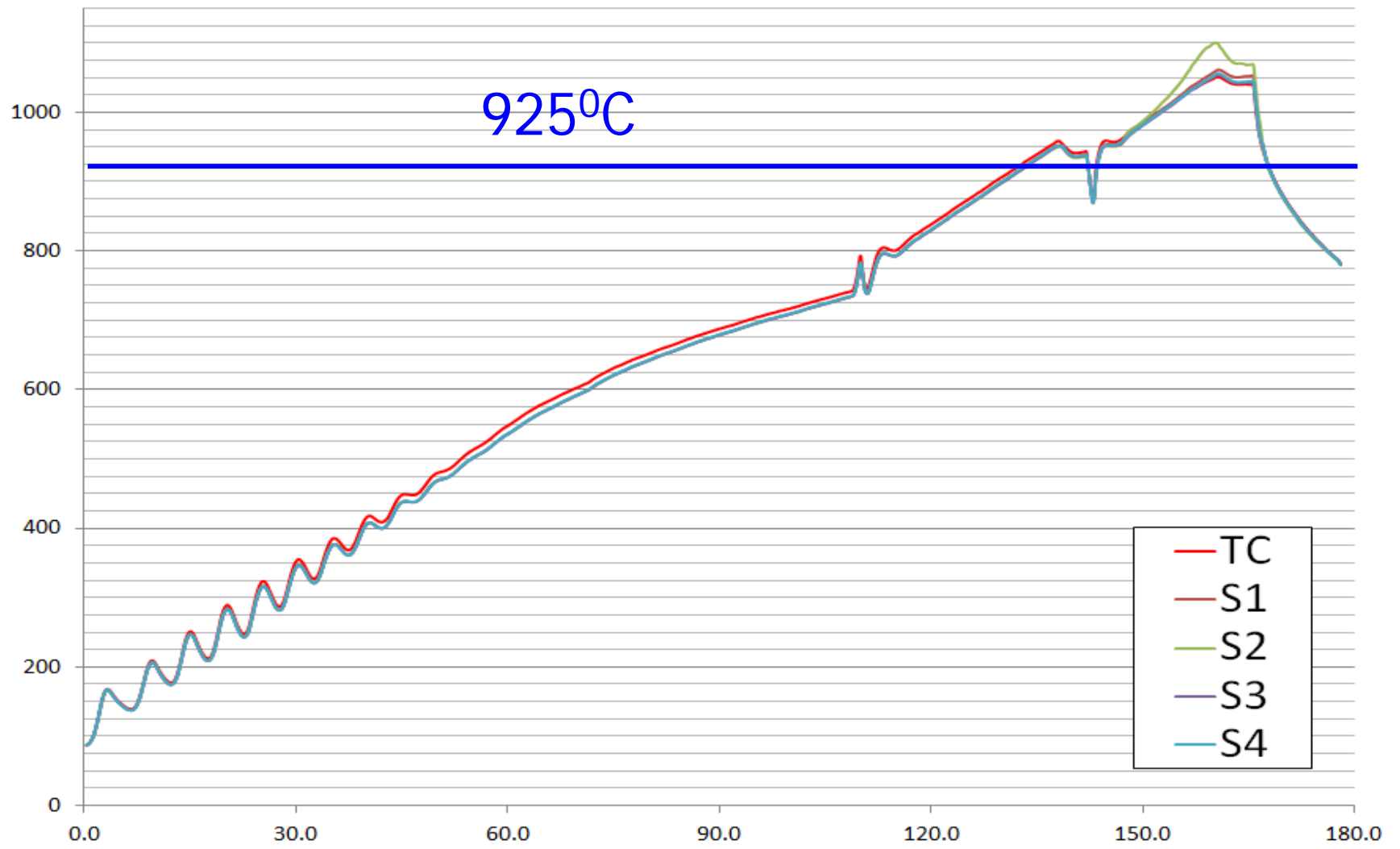


Temperature readings of sensor array and the K-type thermocouple (TC)

## Methodology

- 150 nm (approx) thick sensors were fabricated on the cathode. ( $\Phi$ 52mm, Kerafol Ltd, KeraCell II)
- Sensor patten was protected from oxidation by encasing it with alumina
- Placed a commercial K-type thermocouple next to the sensor array
- Tested in a furnace up to 1050<sup>0</sup>C

# Results & Discussion (2)



## Results & Discussion (2)

	S1	S2	S3	S4
rms deviation (°C) *	8.13	8.15	8.23	7.79
rms deviation as a percentage of full scale output **	0.88%	0.88%	0.89%	0.84%

\* rms deviation – the rms of “TC output – Sensor output” up to 925 °C

\*\* Full scale output – 925°C (in the real application, the sensor is not expected to operate beyond this)

# Conclusion & Future works

- THERMONO was theoretically proven, computationally simulated, and practically validated
- Measuring the temperature of a working fuel cell
- Calibration





**Thank You!**

