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# High resolution real-time inspection of SOFC materials using visible light and infrared imaging

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## Motivation

Local **non-uniformities** in material composition and device properties are often encountered in SOFCs.

Some of the non-uniformities may become **critical defects** that reduce energy output or shorten lifetime, while others may remain benign, without any significant effect on the performance of the SOFC system.

**The detection and evaluation** of the effect of material/property **non-uniformities** remain as a key focus for R&D teams trying to improve overall cost and performance of SOFCs.

## Objectives

1) Develop inspection techniques specifically suited to detect material/property non-uniformities encountered in SOFC materials.
2) Propose methods that have a potential to become valuable real-time inspection tools for detecting critical defects in cells before they are incorporated into systems.
3) The techniques investigated are based on imaging using high resolution visible light and infrared detectors with a SOFC specimen is subjected to various types of excitation sources.

## Type of defect vs. nondestructive techniques

| Non-uniformity / defect type | Recommended nondestructive detection technique |
|---|---|
| surface flaws and anomalies | Visible light high resolution reflectance imaging |
| cracks, surface/subsurface non-homogeneities, delamination | Infra-red imaging with thermal activation |
| electrical shorts in electrolyte, structural defects in electrodes | Infra-red imaging with voltage excitation |
| cracks, separation, delamination | Infra-red imaging with ultrasound excitation |
| electrolyte leaks | Infra-red imaging with CO2 pressurization |

## Visible light reflectance scanning

Sensor: line camera with 12k pixels; Activation: LED light source

Advantage: produces high resolution image of specimen surface

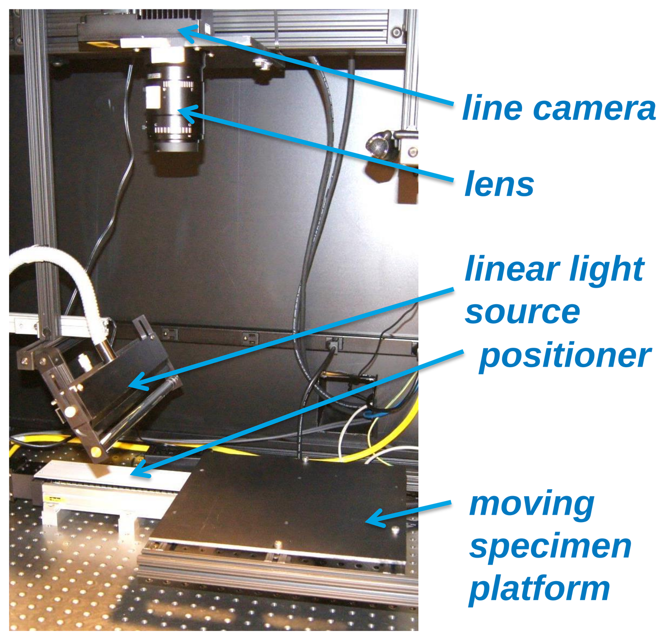


Figure 1. Experimental setup for imaging planar specimens in motion

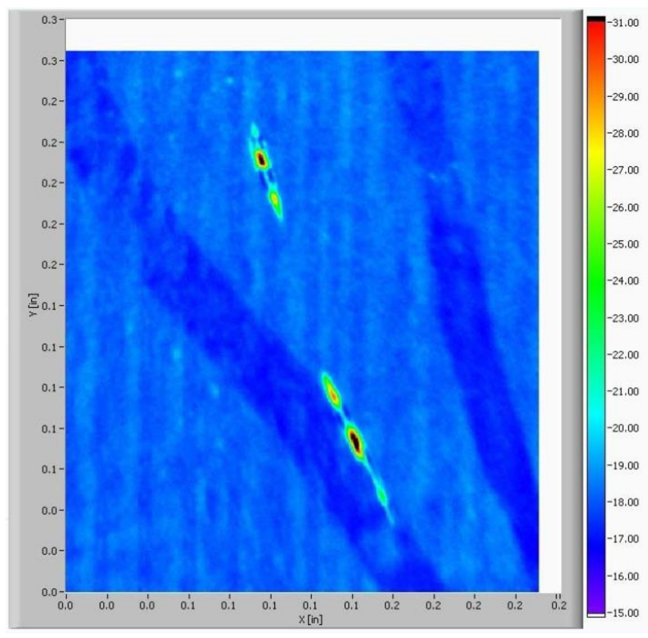

Figure 2. Imaging of surface crack on planar SOFC electrolyte

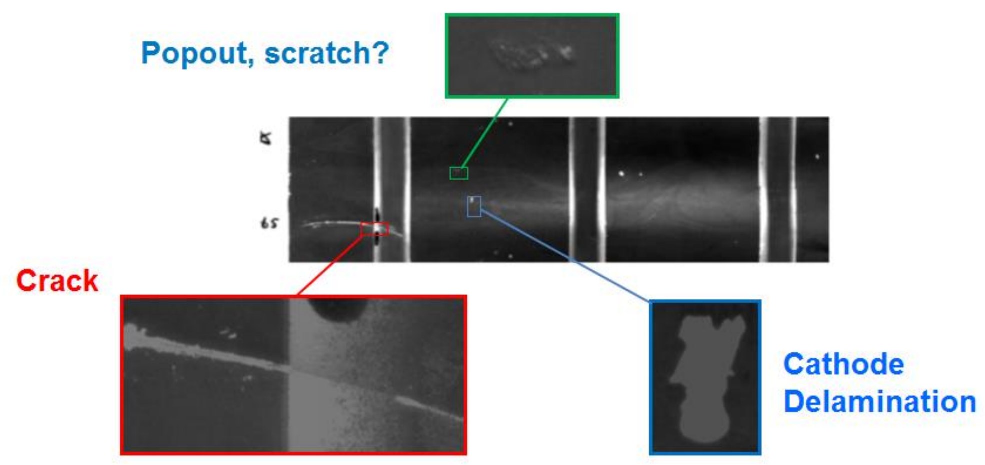


Figure 3. Example of surface map shown at low (center) and high (top and bottom) magnifications acquired for tubular SOFC

## Thermal Scanning with through-plane heat flow

Sensor: IR camera

Activation: rod heater inside SOFC tube

Advantage: potential to detect sub-surface flaws and delamination which are not visible on surface

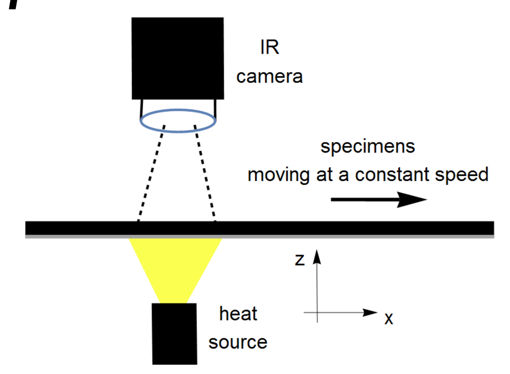


Figure 4. Experimental setup

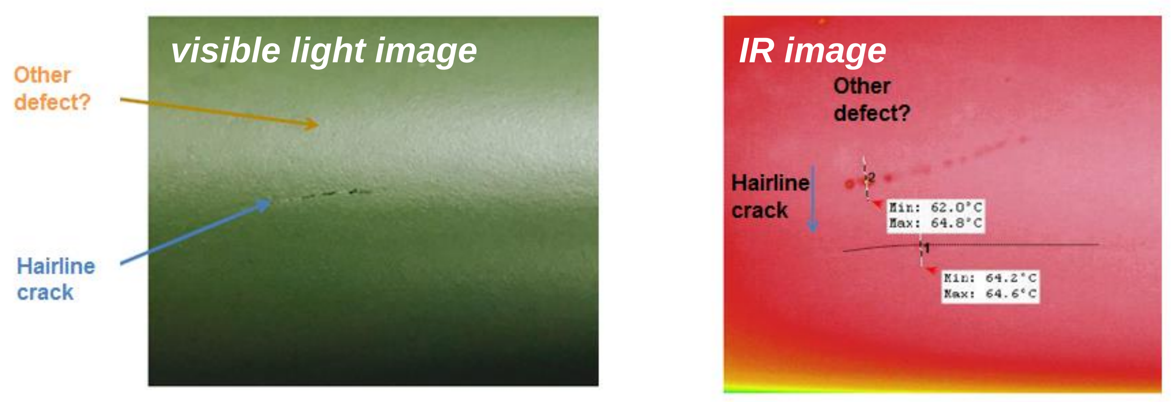


Figure 5. Visible light (left) and infra-red (right) images of the same SOFC tube section that includes a hairline crack and a sub-surface anomaly

## Thermal Scanning with in-plane heat flow

Sensor: IR camera; Activation: thermal line heater

Advantage: especially suited to detect longitudinal crack; also works when the cracks are buried underneath an intact surface layer

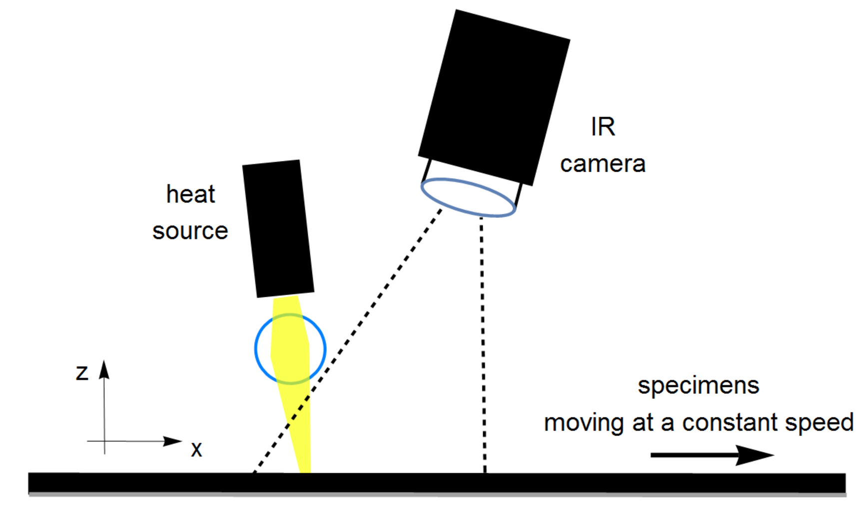


Figure 6. Experimental setup for thermal scanning with external heat source

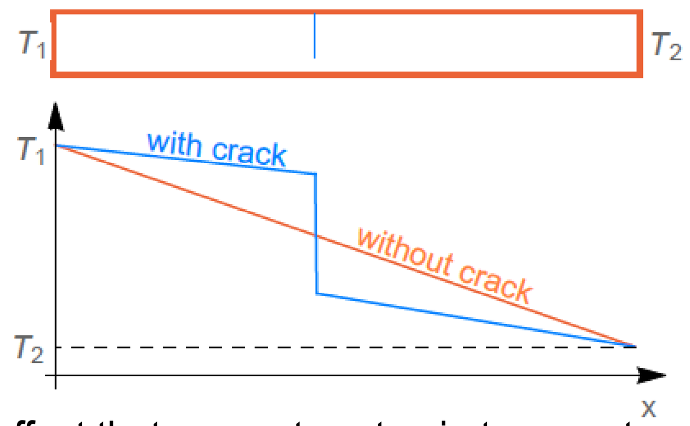


Figure 7. Thermal effect that generates step in temperature delineating cracks

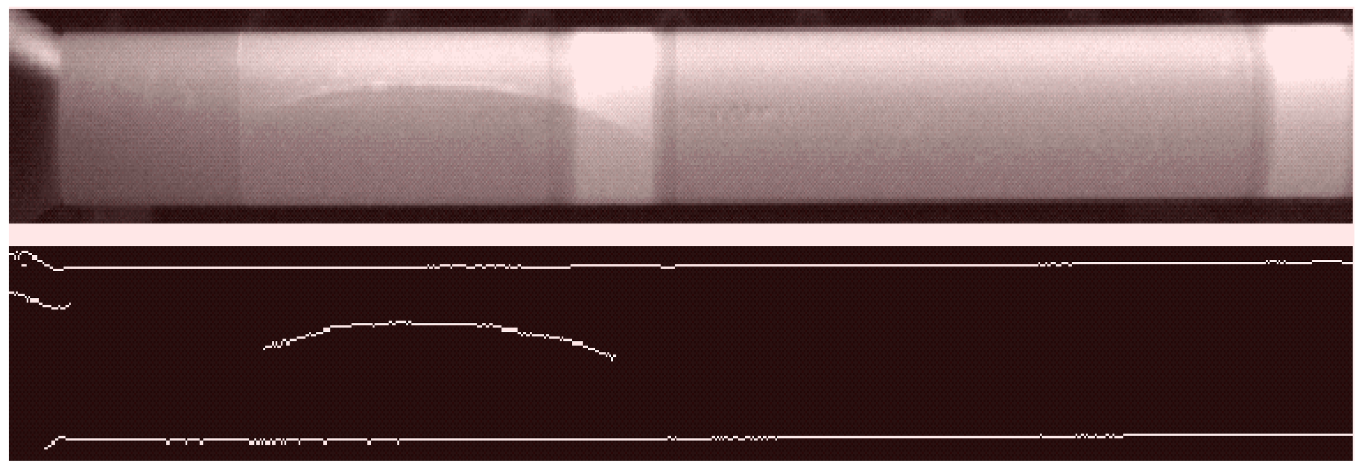

Figure 8. Top - thermal image acquired during thermal scanning of a cracked tubular SOFC. Bottom – automatic crack detection using machine vision

## Infrared imaging with $CO_2$ pressurization

Sensor: IR camera

Activation: SOFC tube is pressurized with $CO_2$ gas and imaged against a constant temperature background

Advantage: reveals location of electrolyte leakage

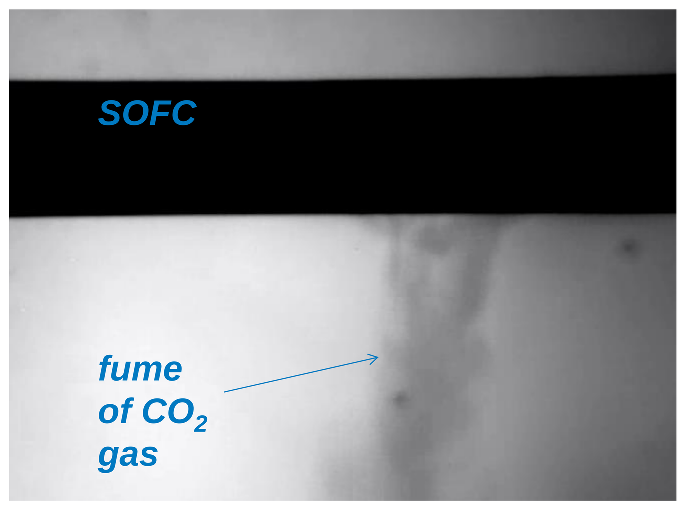


Figure 9. Example IR image

## Ultrasound (US) Excited Thermography

Sensor: IR camera; Activation: ultrasonic source coupled to SOFC material

Advantage: detects cracks that due to vibration become active heat sources

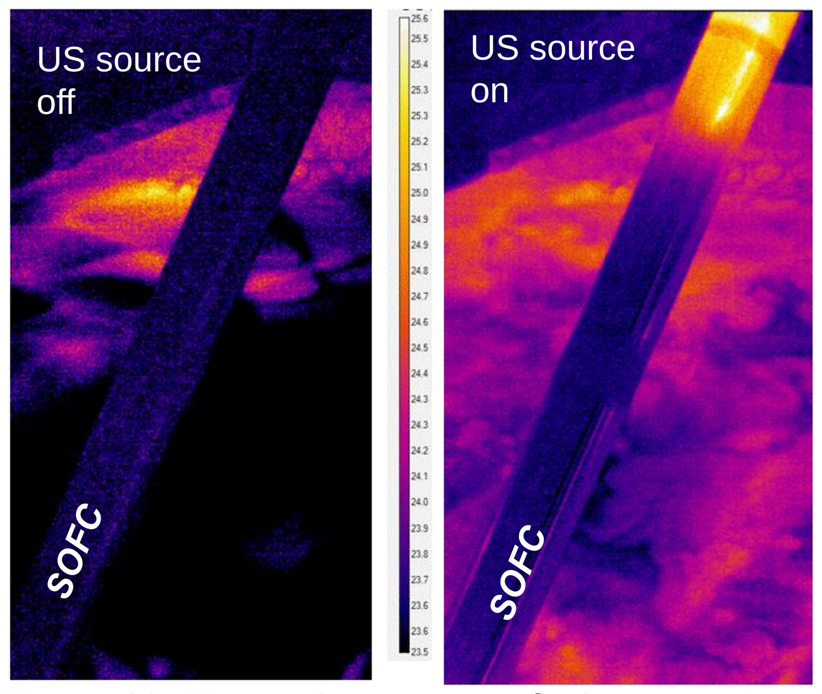


Figure 10. Thermal response of a long crack to US excitation

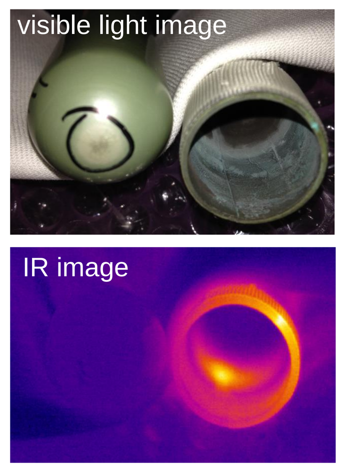


Figure 11. Example of defects that do not respond strongly to US excitation

## Thermal Imaging with Electrical Excitation

Sensor: IR camera; Activation: voltage applied between cathode and anode or between two points within a single cathode or anode

### A) Through-plane DC excitation

Advantage: reveals location of electrolyte shorts

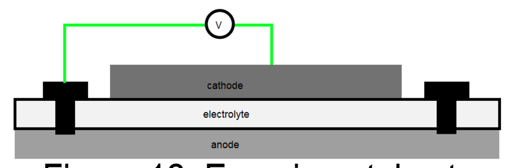

Figure 12. Experimental setup

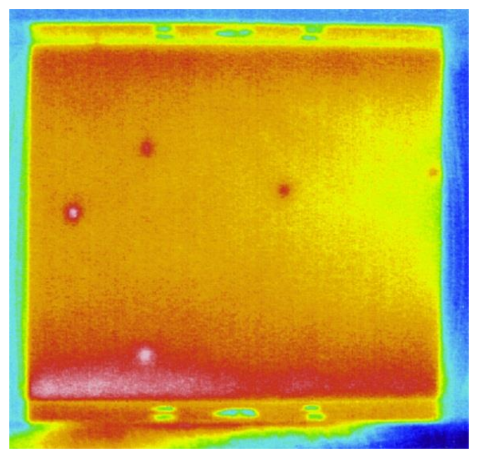

Figure 13. IR image of PEM cell subjected to through-plane DC current

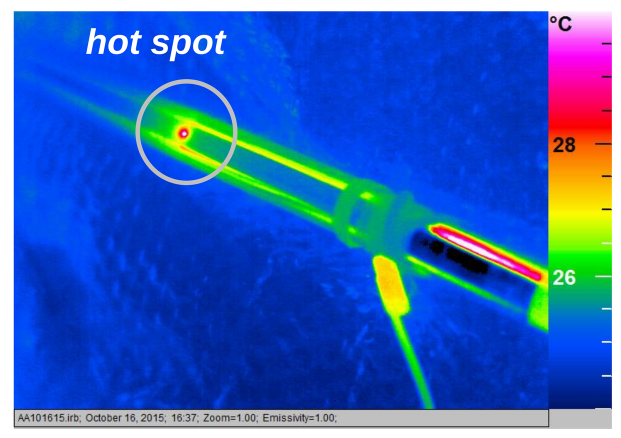


Figure 14. Electrical short identified as hot spot in tubular SOFC

### B) In-plane DC excitation for cathode and anode

Advantage: tests electro-thermal homogeneity of single cathode or anode

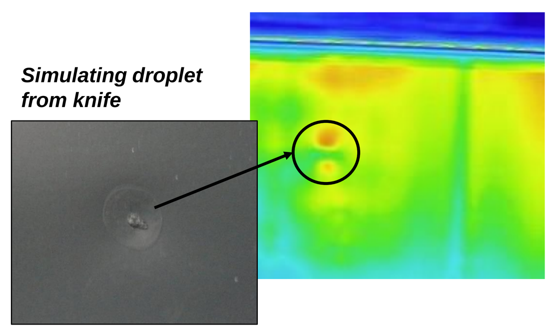


Figure 15. PEM electrode with coating non-uniformity

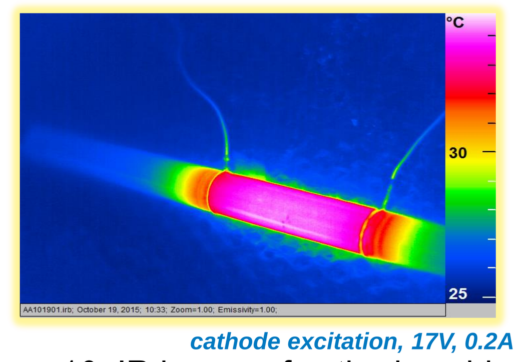


Figure 16. IR image of cathode subjected to DC. Uniform T response was observed.

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