Hotspot Detection for Cell Production Lines

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Abstract

Since the 1970's manufacturers of both thin-film and conventional c-Si modules have known of the reliability problems associated with hotspot defects. The recent multi-GW ramp of PV manufacturing has occurred without industry-standardized inline hotspot tests, and some fraction of today's field failures may be attributed to this class of defect. We describe several of the root causes and outline a measurement technique that has been developed and deployed for use in both R&D labs and manufacturing lines.

Background

Hotspots are, in general, most noticeable when a cell is placed in reverse bias. As an example, consider the c-Si module shown below.

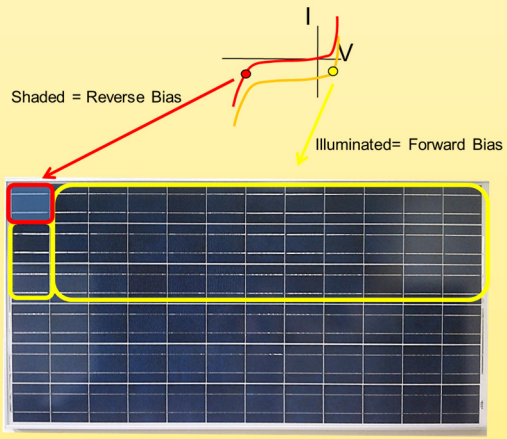
Assume that one cell (outlined in red) is shaded while all other cells are fully illuminated.

Causes of shading might include:

- Bird or Leaf
- Building Shadow… etc.

A shaded cell with minor defects will readily withstand the high reverse bias (~10-12Volts, typical) that persists until the shadow is removed, but a cell with significant shunts will leak reverse current and exhibit extremely localized heating at each defect.

The temperature rise near a defect can vary from mild (1-80C) to extreme (>200C), but equilibrium is reached within 10's of seconds.



Hotspots: Common Causes

x-Si

- Incomplete edge isolation
- Crystalline defects intersecting junction
- Metal-decorated cracks
- Overfiring: pn junction "punchthrough"

Modules

- High resistance or "cold" solder points

Thin Film

- Scribeline shunts- incomplete removal or redeposition

Back Contact & Emitter Wrap-through

- Metal particles & bridges on backside
- Print alignment errors

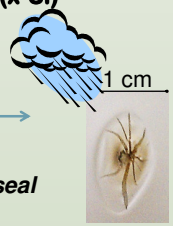
Typical Damage (x-Si)

Mild (<80C rise)

- Low damage probability

Moderate (~80-200C rise)

- Backsheet bubbles
- Coverglass cracking
- ***loss of quasi-hermetic seal***



Extreme (>200C rise)

- Cell damage

Long term effect

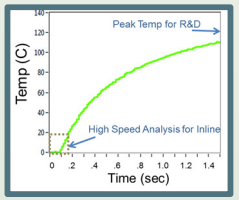
Moisture Intrusion
→ Corrosion & Power Loss
→ Warranty failure.

Manufacturing Requirement

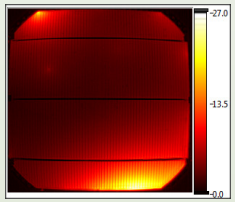
- Reduce Warranty Exposure by removing hotspot cells prior to lamination with high speed (~100-400ms), high reliability (>99.9% accurate) inspection.

Measurement Method

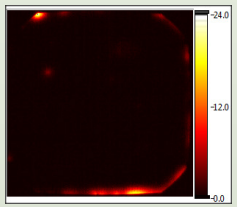
Method: Time-resolved Thermography[Patents Pending]
Camera: LWIR (8-12 micron)
Speed: a) Inline: 30-400ms / cell
b) R&D: 30ms- 5 min.
Simultaneous capture of time-resolved I-V
a) breakdown events
b) busted shunts



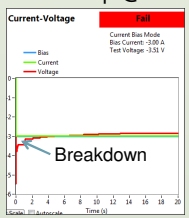
Individual pixel Analysis



Peak Temp @ 20s



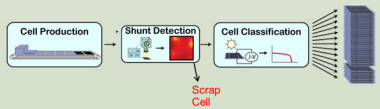
Severity @ 400ms



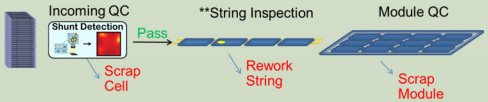
Time-resolved I-V

Inline Inspection Points

Cell Line- Hotspot Detection



Module Line- Hotspot Detection



Summary

Field failures caused by hotspots may be addressed with modern cell or module-level hotspot inspection machines capable of >3000 WPH.

Tau Science
Process Control for PV