# Tracking PV Changes: Bridging Between Thin-Film Cells and Modules

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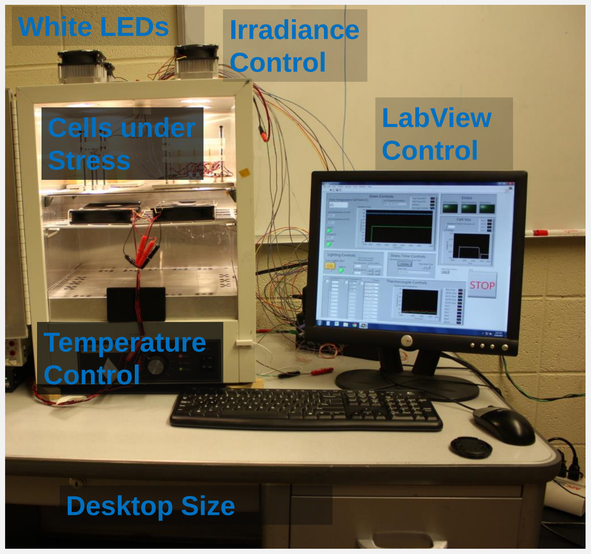
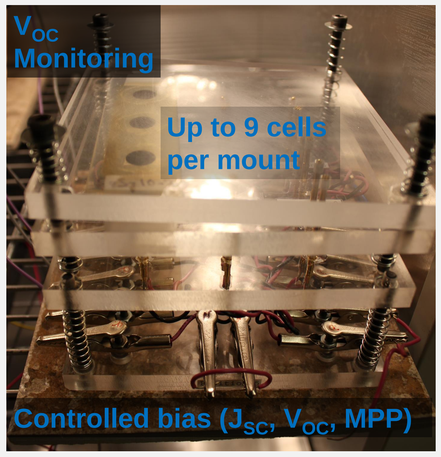
## Abstract

Although field testing of modules is the best indicator of their reliability, detailed tracking of changes in cells exposed to elevated temperatures under simulated solar conditions can make several practical contributions to the understanding and correction of reliability issues. In general, cell studies are cheaper, faster, more flexible, and more comprehensive. An important goal is for a cell to replicate a module as closely as possible, which would include the same cell edges, contacts, and encapsulation as in a module. Types of measurements where cell-level tracking can be more comprehensive include current-voltage and capacitance-voltage as a function of temperature, and spatial-uniformity tracking through electroluminescence and light-beam-induced current.

## Cell Stressing System

- Compact desktop size
- Independent temperature and irradiance control
- White LED illumination with good spectral and irradiance match to sunlight
- Good temperature uniformity and stability (1 °C)
- Controlled voltage bias conditions ($J_{SC}$, $V_{OC}$, MPP, etc.)
- Automated system, stress, and characterization logging
- Suite of external characterization tools
  - Possibility for in-situ tracking



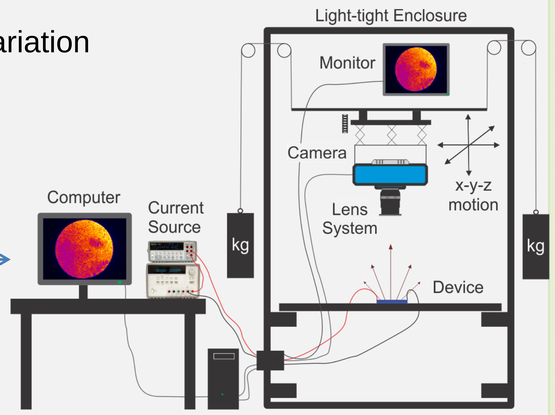




### Reasons for cell measurements

- Understand device physics of degradation mechanisms
- Isolate device degradation from encapsulant and scribe degradation
- Full characterization available for cells
- Easier to work with than modules

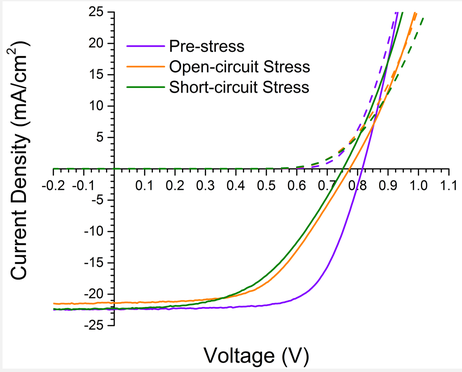
## Characterization Suite

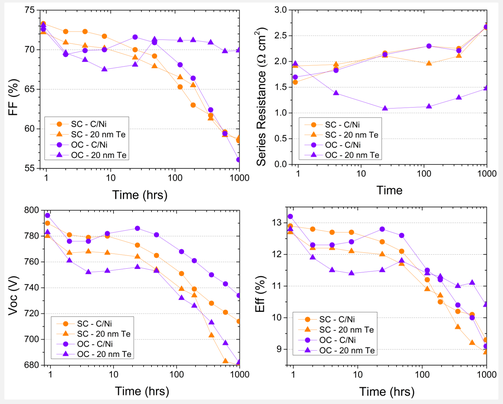
- Current-Voltage (J-V)
  - Temperature, intensity, and spectral variation
  - Cell parameter analysis ($J_0$, A, $R_s$, $r_{sh}$)
- Quantum Efficiency (QE)
- Capacitance
  - Frequency and voltage dependence
  - Admittance Spectroscopy
- Electroluminescence (EL)
  - Tracks well with $V_{OC}$
  - Easily extended from cells to modules
- Light-Beam-Induced Current (LBIC)
  - QE spatial mapping
  - 4 wavelengths, 1-100 um resolution, variable voltage bias



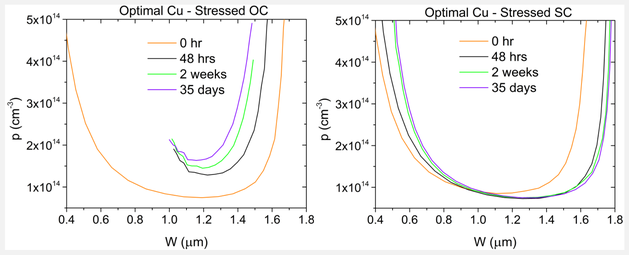

## Preliminary Results

- Cells exhibit degradation under stress
  - Mechanisms depend on stress condition
    - Open-circuit-stressed cells lose more current
    - Short-circuit-stressed cells lose more voltage
    - Both lose significant fill factor (series resistance)
  - Mechanisms depend on processing conditions (eg., back contact)

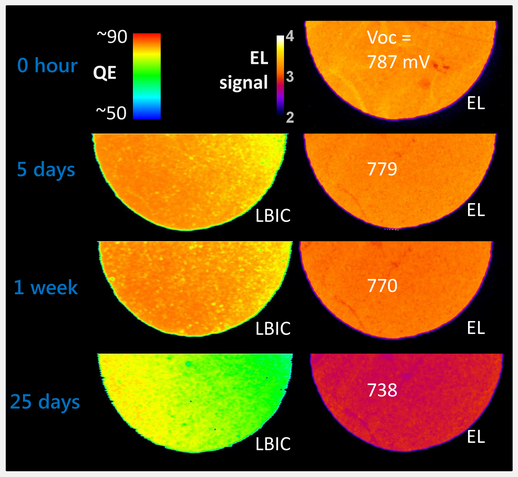


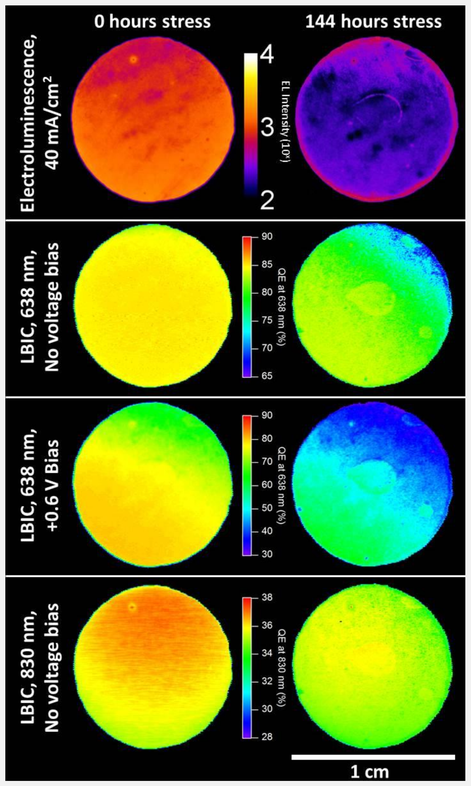




- C-V analysis shows changes in doping profile connected to stress conditions




- Uniformity typically degrades with stress
  - EL can be tracked regularly with stress
  - May show uniform or localized degradation
  - Some features may be predictive of degradation




## Summary

- Compact cell stress system recently constructed
- Allows for comprehensive studies of device physics degradation mechanisms
- Preliminary work shows degradation in cell performance and uniformity

## Acknowledgements

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