LBIC (Light-Beam-Induced Current) Analysis of Thin-Film Polycrystalline Solar Cells

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Thanks to Markus Gloeckler and Alan Davies for their work on LBIC projects.

Special thanks to Dr. Jason Hiltner, who built much of the LBIC facility currently in use.
Outline

(1) Description of LBIC apparatus.

(2) How is the best way to present the data? And how reliable and reproducible is it?

(3) Types of LBIC features seen.

(4) LBIC as a tool to track elevated-temperature stress.

(5) Additional information from wavelength and bias dependence.

(6) Conclusions.
Can measure photocurrent from 1-micron spot at 1-sun intensity.

Laser wavelengths are 638, 685, 788, and tunable 825-860 nm.
Lens is 40X, N.A. = 0.55, 9 mm working distance, correction collar.
Translation stage repeatability better than 1 micron.

Hiltner and Sites, EPVSEC 16, 630 (2000)
Photograph of LBIC Apparatus

Objective: 40X / N.A. = 0.55 w/ correction collar
working distance = 8.8 mm
Translation Stages: +/- 1 micron repeatability

Fiber Positioner
Lens: f=20 mm
Single Mode Fiber In: N.A. = 0.12
Wavelengths: 635, 685, 780, 830 nm
Data Presentation Formats

CdTe Quantum Efficiency Map

Note: “Normal” regions will generally appear in **GREEN**

Histogram (same data as above)

CIGS z-axis projection (showing grids)
Three LBIC Resolutions Commonly Used

NREL CIGS Cell

Low Resolution  Mid-Resolution  High Resolution

5 x 5 mm field  500 x 500 micron field  50 x 50 micron field
100 micron spot  10 micron spot  1 micron spot

Notes:
(1) LBIC QE very consistent with standard QE
(2) Standard conditions: zero bias, 1 sun, and 638 nm
Measurement Reproducibility

Two-Student Comparison

Student A

Student T
One Week Later.
Sample remounted and recalibrated.

x-y convention reversed
Absolute calibration better than 1%

Low Resolution

Mid-Resolution

QE

84%
83%
82%
81%
80%
79%
78%
77%
Measurement Reproducibility

Two-Measurement Comparison

Electroluminescence map (Scott Feldman, Colorado School of Mines)

LBIC map of same CdTe cell (Colorado State University)
QE Reduction Due to Reflection

Quantum-Efficiency Map at High Resolution [10% Decrease]

Reflection Map of Same Area [10% Increase]

20-micron Feature Emphasized

Astropower Silicon Cell
Blemish on SS-Foil CIGS Cell

Low Resolution

High Resolution

Mid-Resolution
High-Efficiency Single-X Cells

Single Junction
(note some defects)

Triple Junction
(photons absorbed equally in top two layers)
Shunt in Three-Junction Cell

Shunt is located very near grid line.

Shunt affects large area: field is 1 cm²
**Much More Dramatic Shunt**

CIGS cell with grid finger edge short. Very low QE.

QE fully restored

- Cut gridline at least partially folded over to back contact
- Gridline extends to edge
- Gridline (and shunt path) dissolved with acetone
Processing Variations: CdTe:Cl

Variations in no-CdCl\(_2\) map due to local areas of higher resistance
Note: average QE has dropped from 80% to 60%.

Areas shown are 50×10 \(\mu\)m.
High-resolution 1-\(\mu\)m spot size
Intensity about 1sun

Hiltner and Sites, Proc. MRS 668, H9.8 (2001)
Elevated-Temperature Stress

CdTe cell subjected to 100°C under illumination at short-circuit. (Low-resolution LBIC)

No Stress  8 Hours  8 days

Average QE decreases by 2%

Much greater decrease for isolated spots.
Stress-Altered QE for Two Cells

Two CdTe cells were processed differently before the back contact was applied.

QE of left cell changed very little with stress. QE of right one both dropped and showed greater spread.
Stress-Induced Shunt Seen by LBIC

Shunt in corner appeared after stress. J-V curve also showed characteristic shunting behavior.

Before Stress         5 Days Stress
(Left map also shows reductions where mechanical probes had been applied; they are masked in right map)
LBIC Variations with Wavelength

High-resolution maps of CdTe cell with increasing wavelength
10x50 micron field, 1 micron spot

Explaination of variations near the band gap:
CdS intermixing not uniform on scale of grains.
[Hiltner and Sites, Spring 2001 MRS]
Two CIGS cells with different Ga-content (mid-resolution).

Left LBIC (“standard” curve) has isolated spots, but changes little with bias.

Right LBIC (“distorted” curve) changes significantly with bias.
Conclusions

(1) LBIC is a reliable tool for investigating a wide variety of solar-cell non-uniformities.

(2) LBIC has become much more practical with improvements in translation stages, laser diodes, and data-handling techniques.

(3) LBIC is particularly valuable to explain differences due to processing variations or changes induced by elevated-temperature stress.

(4) LBIC can be reliably combined with other investigation techniques to study the same cell area at different labs.

(5) Poorer performing cells almost always show larger LBIC variations indicative of poorer uniformity.