Photoluminescence-imaging-based Evaluation of Non-uniform CdTe Degradation

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Study module degradation mechanisms by understanding the semiconductor device at the microscopic level, such as kinetics of impurities, changes in materials, and damage to device architecture.

Imaging for photovoltaics

- CdTe Module PL imaging
  - scan laser beam for excitation
  - Cepida Silver 660M FLIR SC5600-M
- PL imaging
  - Silicon charge-coupled device (CCD) 16-bit camera with 1024 x 1024 pixels (13um pixel pitch), cooled to ~60°C
  - InSb 14-bit lock-in camera with 840 x 512 pixels (15um pixel pitch), cooled to ~80K
- LIT imaging

Cepida Silver 660M FLIR SC5600-M

PL imaging on cored regions from degraded CdTe mini-module

- PL -- raster pattern, 532 nm laser diode, ~1 mm spot size, ~1-Sun intensity excitation.
- EL --~3 J/cm² current excitation.
- DLIT -- forward bias, ~3 J/cm² current excitation.

Before stress

After stress

Stress (light/heat)

- Cut out samples from regions of interest.
- Avoid shunt areas with any grown-in defects.
- Based on PL image intensity: Least degraded, Mid-degraded, Most degraded

Cu profiles of stressed CdTe cores using Time-of-Flight Secondary Ion Mass Spectrometry (TOF-SIMS)

Reduced PL intensity correlates to more Cu at the front junction.

Kelvin Probe Force Microscopy (KPFM) potential imaging on cross-sections of stressed CdTe cores

Increased shallow acceptors after degradation leads to narrower space charge region.

Ion transport (Cu-ions) to front junction [1] leads to both:
- shallow centers for increased doping, and
- deep defect generation
  - increased carrier recombination
  - reduced cell performance.

In [1], TRPL was inconclusive, but here, PL intensity shows correlation to degradation.

Core selected areas from degraded modules

- Use diamond-based coring bit and liquid-cooled drill to cut through Si cell or thin-film and glass.
- Cut sample for extraction
- On thin-film modules, glue posts to cored glass, or core completely through the module and dissolve encapsulation.
- After the glue is set, use a wrench to shear the sample from the module.
- Cored samples from ~12 to 25 mm diameter
- Soak in acetone to dissolve Super Glue and remove areas. Or, use a short tool that fits in measurement tools and does not need to be removed.

AFM

Increased shallow acceptors after degradation leads to narrower space charge region.

TCO and junction region

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