Thermalreflectance Imaging: High Resolution Defect Inspection Through Glass

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Abstract

Thermalreflectance Imaging is used for the simultaneous acquisition of thermal, electroluminescent and bright field images of fully packaged solar modules. Thermal images are obtained with the lock-in detection of small changes in reflectivity associated with temperature changes in the PV absorber layer . Reflectivity changes are measured with visible illumination using a conventional high-resolution Si camera. Temperature changes less than 100mK have been imaged with a spatial resolution of <1μm. Images with no illumination are sensitive to electroluminescent emission from of the PV absorber layer and can be combined with the AC thermal images and the steady state bright field images to obtain a combined optical, thermal and EL image of defects in the solar cells and modules

Advantages of Thermal-reflectance Images

1) **Insensitive to thermal emission from glass** with imaging in the visible. Standard IR imaging and lock-in thermography can only image the glass surface.

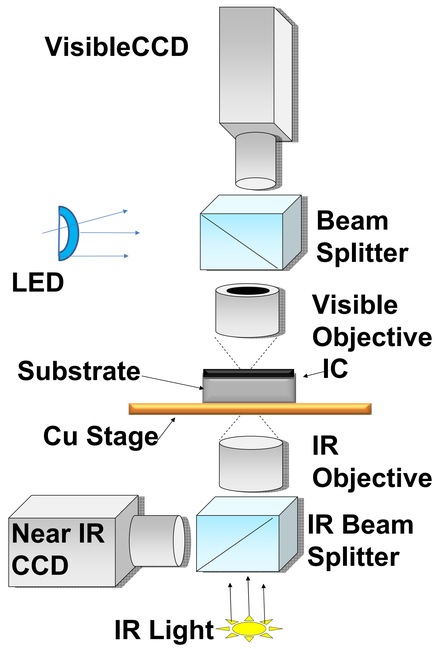
2) **Sub-micron resolution** with monochromatic visible illumination.

3) **Transient response and reduced thermal spreading** with pulsed current and lock-in detection, ns resolution.

4) **Combined EL imaging** for direct correlation of thermal/EL to prebreadown sites.

5) **Combined optical imaging** for direct correlation to visual defects.

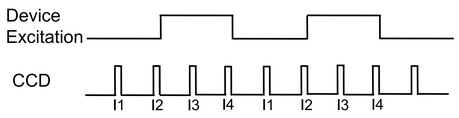
Apparatus



Imaging Technique

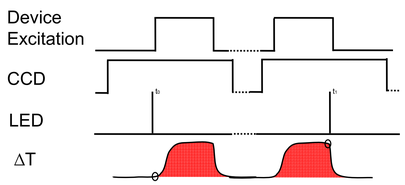
I. Four Bucket

Four images used to extract the phase and magnitude of the signal



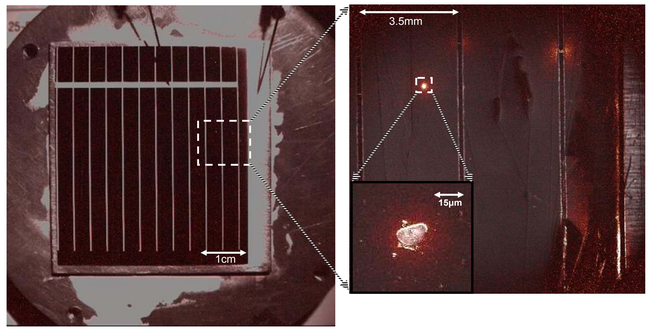
II. Transient Differencing Method

I. Shutter is open the full acquisition period
II. Illumination is pulsed

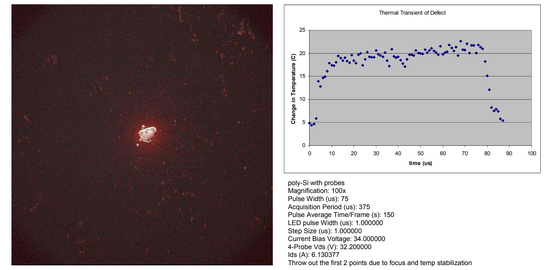


Examples

Combined Thermal/optical Images: Defects in a poly-Si solar cell

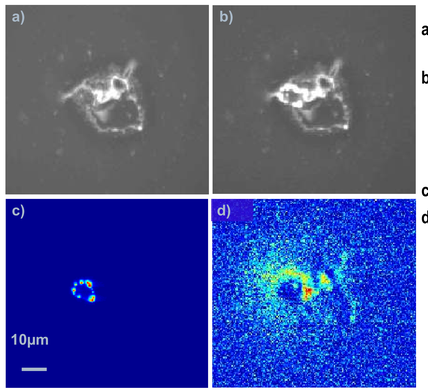


Transient Thermal Response of Defect

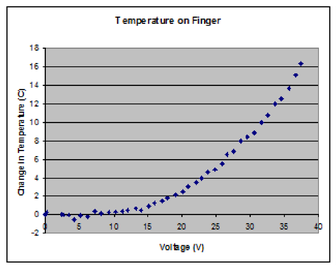


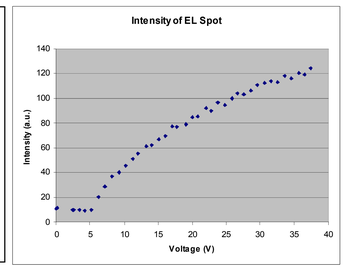
This shows the thermal image 75 us after the rising edge of a voltage pulse in reverse bias. The graph shows the transient response of the silicon around the defect. The defect reaches thermal equilibrium after ~10 us, while the response of the bulk material is on the order of seconds. We can adjust the pulse width and duty cycle to control the maximum temperature of the device.

Electroluminescence and Thermal images

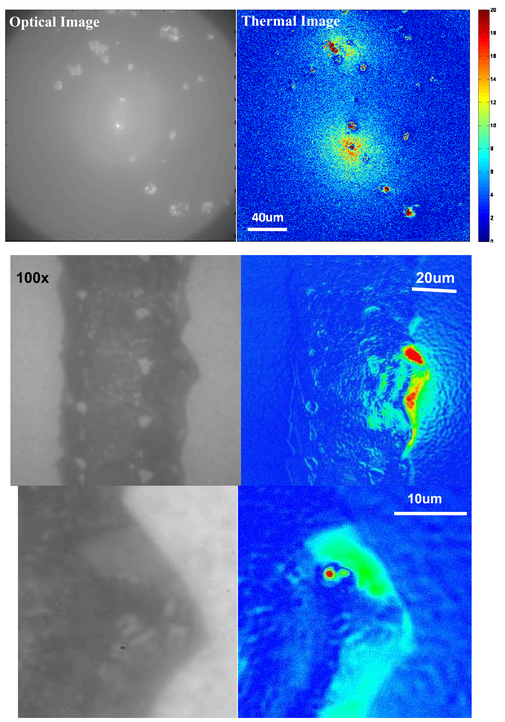


a) Optical image of defect in poly-Si
b) Combined optical and electroluminescence (EL) image to show the location of the EL with respect to the defect
c) EL image
d) Thermal image after 300 s of averaging





High Resolution Thermal images



Conclusions

- Thermal reflectance imaging of defects offers many advantages over conventional lock-in and IR thermography including higher resolution, combined optical / EL / Thermal images and transient response

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