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Detailed Study of Defects in Silicon Solar Cells by Cathodoluminescence Spectrum Imaging

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DETAILED STUDY OF DEFECTS IN SILICON SOLAR CELLS BY CATHODOLUMINESCENCE SPECTRUM IMAGING

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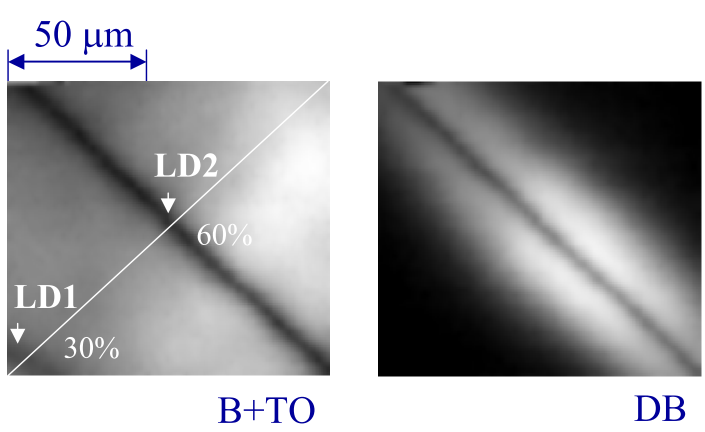
We have recently developed a spectrum imaging system for cathodoluminescence (CLsi) at NREL, which has been successfully applied to different semiconductors. The advanced multi-channel detection required for CLsi consists of an ultrafast spectrum acquisition triggered by the electron beam during scanning. Spectra are acquired either with a Roper Scientific silicon EEV-1340×400 cryogenic CCD or an InGaAs 512×1 cryogenic PDA, depending on the range of spectral emission. Acquisition times by pixel are typically of 10 to 20 ms (180 seconds for a 100×100 pixel image). The output of spectrum imaging measurements is thus represented by a series of emission spectra. CCDIMAG, the software developed for CLsi, processes this spectrum series to reconstruct monochromatic images or extract the spectrum from any area on the image. This system is operated on the JEOL-5800 scanning electron microscope (SEM). CLsi measurements can be performed at temperatures between 15 K and 300 K. A low-vibration ARS Displex DE-202 closed-circuit cryostat provides cryogenic operation. The interface for vibration isolation has been developed to be compatible with SEM observation.

Because of the technological importance of silicon for photovoltaics, a collaboration between NREL and USF has been established to study defects in multi-crystalline silicon solar cells (mc-Si) combining scanning photoluminescence and CLsi. From photoluminescence mappings, defective areas of the solar cells are selected to perform cathodoluminescence measurements with higher resolution.

The figure shows images of a selected area with a strong defect-band emission near 0.8 eV, as confirmed previously by scanning photoluminescence. At low temperatures, band-to-band emission is substituted with the TO phonon replica of the boron-bound exciton at 1.093eV (B+TO). Defect-band recombination is associated with linear defects highly effective as non-radiative recombination centers: DB recombination is observed for a linear defect with a contrast of 60%, but not for linear defects with contrast below 40%.

Based on a detailed analysis of the cathodoluminescence results, a model for these defects will be further discussed.



Cathodoluminescence images of linear defects identified in mc-Si solar cells for the (a) B+TO, and (b) defect-band transitions. The linear defect LD1, with a contrast of 30% does not show DB recombination. E_b = 20 keV, I_b = 2 nA, T = 19.8 K.

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13. ABSTRACT *(Maximum 200 words):* We have recently developed a spectrum imaging system for cathodoluminescence (CLsi) at NREL, which has been successfully applied to different semiconductors. The advanced multi-channel detection required for CLsi consists of an ultrafast spectrum acquisition triggered by the electron beam during scanning. Spectra are acquired either with a Roper Scientific silicon EEV-1340×400 cryogenic CCD or an InGaAs 512×1 cryogenic PDA, depending on the range of spectral emission. Acquisition times by pixel are typically of 10 to 20 ms (180 seconds for a 100×100 pixel image). The output of spectrum imaging measurements is thus represented by a series of emission spectra. CCDIMAG, the software developed for CLsi, processes this spectrum series to reconstruct monochromatic images or extract the spectrum from any area on the image. This system is operated on the JEOL-5800 scanning electron microscope (SEM). CLsi measurements can be performed at temperatures between 15 K and 300 K. A low-vibration ARS Displex DE-202 closed-circuit cryostat provides cryogenic operation. The interface for vibration isolation has been developed to be compatible with SEM observation.

14. SUBJECT TERMS: photovoltaics; spectrum imaging system; cathodoluminescence (CLsi); scanning electron microscope (SEM); closed-circuit cryostat

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