Abnormal temperature behavior of band-to-band electroluminescence on Si solar cells

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Application Note

Introduction

Photovoltaics require quick characterization methods for solar silicon in both the research and manufacturing of solar cells. Non-destructive techniques for in-line quality control like electroluminescence (EL) and photoluminescence (PL) are in great demand.

One of the quality criteria for silicon is the temperature dependence of the band-to-band transition (BB). In previous publications, this temperature dependence had often been examined in PL experiments. The so-called normal temperature behavior was monitored on perfect single-crystal silicon: with rising temperature the luminescence intensity decreased. In contrast to that, poor-quality silicon with a high concentration of crystal defects showed an increase of the luminescence intensity with rising temperature. Since completely finished solar cells are very well-suited for EL experiments, we have examined the temperature behavior of solar cell samples from multi-crystal Si (mc-Si) with different amounts of crystal defects and different luminescence intensities.

Experiment

The samples were placed in a cryostat (10K – 300K). For EL, excess charge carriers were injected in forward direction over a stabilizing power supply. The PL was excited with red light (800nm). The luminescent light was collected with two parabolic mirrors and focused and spectrally dispersed in a spectrograph (Shamrock SR-303i-A). The signal was detected with an InGaAs photodiode array (iDus DU492A-2.2). A major advantage of this system is the fast read-out time of the detector (only milliseconds in the "high-sensitivity" mode of the output amplifier). The easy-to-use software-controlled operation and display of the spectra in combination with the fast readout time allow measurements that show changes in the spectral luminescence distribution in almost real-time. As the InGaAs detector does not require liquid nitrogen cooling, a good signal-to-noise ratio can be achieved even at relatively high temperatures of about -60 °C (air cooling) and about -70 °C (water cooling). The water cooling is realized by a simple external processor cooler that keeps the temperature and thus the signal-to-noise ratio constant for several hours. You can see below an example of examinations of the Si band-to-band line in the spectral area of 1.1µm. We were also able to measure spectra of the dislocation D lines in Si (up to approx. 1.6µm) at phenomenal speed.

Results

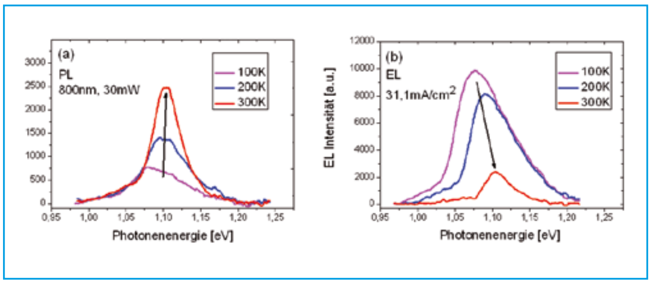

Fig. 1: Temperature behavior of the intensity of the BB luminescence in opposite direction using the example of a mc-Si solar cell sample, measured with PL (a) and EL (b).

Figure 1 shows luminescence spectra that were measured with the spectrometer in approx. 1s each. When using a conventional Ge detector system, the measuring time was between 200s and 300s. Surprisingly, the EL and PL data we acquired from the mc-Si samples we examined show that the temperature behavior is the opposite of what we expected: In PL, the intensity of the BB line increases with the temperature, in EL it decreases. For the thin samples (180µm) examined here, this seeming contradiction can be explained by the dependency of the emission type. Details are to be published: A. Klossek, T. Arguirov, T. Mchedlidze, M. Kittler, "Anomalous temperature behaviour of band to band electroluminescence in silicon solar cells", Physica Status Solidi (accepted).

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