Bias-voltage dependence of time-resolved photoluminescence decays in solar cells

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Triple-junction solar cells can ideally achieve conversion efficiencies of 52% for unconcentrated light. This is significantly larger than the Shockley-Queisser limit of about 30%, owing to the spectral splitting using different subcells.[1–3] The total device performance critically depends on the subcell performances. To improve the present devices, detailed characterization of the subcells is important.

Electrical measurement techniques such as current-voltage and external quantum efficiency (EQE) are the standard techniques for characterization.[4–6] Electroluminescence techniques combined with EQE data have been used to determine the subcell performances electrically.[7] A complementary optical technique based on time-resolved photoluminescence (PL) has been proposed recently.[8] Time resolved PL is useful to directly characterize the subcell carrier dynamics. So far, the PL decays of the subcells were measured only at open circuit conditions, *i.e.*, no applied bias. The dominant fast and slow PL decay time constants at low and high excitation powers have been used to determine the subcell performance at short-circuit condition. The performance at high voltages was estimated with the uniform-field approximation.[9] This provides the upper limit of the charge collection efficiencies of subcells. To characterize the subcells electrical performance more precisely, we need to analyze the bias-voltage dependence of the time constants.

In this work, we measure PL decays from a GaAs subcell of a triple-junction solar cell for varied bias voltages. Additionally, results from a GaAs solar cell are used to quantitatively discuss the voltage dependence. We explain how the time constants are related to the electrical properties of the subcell.

The fast PL decay at low excitation power densities has been assigned to the charge separation by the large electric field at short circuit.[8] The time constant depends on the voltage and mobility of the material. The slow PL decay obtained for high excitation power densities and open circuit condition, has been attributed to almost flat band structures under high voltages. By setting the bias voltage to zero, a fast PL decay is observed again. In such a way, the bias-voltage dependence of the time constants can be used to discuss the carrier transport and recombination. We consider that the PL decay time constants are suited to analyze the subcell performances at low and high voltages.

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