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Subcell carrier collection efficiencies in multijunction solar cells determined by time-resolved photoluminescence

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Multijunction solar cells allow to exceed the Shockley-Queisser limit due to improved conversion of different solar spectral parts in different subcells.[1,2] At present, realized efficiencies are as high as 43.5%.[3] Due to the complexity of the device, the optimization procedure required to realize best possible efficiencies becomes difficult.

The common optimization procedure is to measure current-voltage curves and external quantum efficiency of the device under short circuit condition,[4,5] or in an advanced approach under several different bias conditions.[6] The latter approach accounts for the voltage dependent carrier collection efficiencies in solar cells, a well established method in a-Si solar cell technology.[7] However, since subcells are not directly accessible, highly complex light biasing or measurement on separately grown subcells are required to obtain the necessary data.[8] These introduce uncertainties, possibly shading the actual problem point of the grown tandem structure by an additional unknown parameter.

In this work, we apply a simple time-resolved optical analysis of a high efficient triple junction solar cell device for space applications. Optical excitation and detection of photoluminescence (PL) allow each subcell to be separately excited and probed. We present the time-resolved PL dynamics of top and middle subcells, and explain their behaviors with a rate equation model based on the uniform field approximation. Our new optical characterization technique allows to obtain the required voltage dependent carrier collection efficiency with high accuracy in each subcell, even if it is not physically contactable. The accurate assessment of the voltage dependent carrier dynamics with time-resolved techniques allows to identify the part of the device which requires further optimization.

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