DIRECT HOT CARRIER IMPACT ON PHOTOVOLTAGE OF A SOLAR CELL

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ABSTRACT

The Shockley-Queisser limit sets maximum efficiency of a single-junction solar cell. According to the theory, only photons with energy close to a semiconductor forbidden energy gap can be used effectively in the formation of the output signal. Residual extra energy of the high energy photons is accounted only via the process of carrier thermalization, i.e. through the lattice heating and this way negatively influencing solar cell efficiency. Photons having energy lower than the forbidden energy gap are assumed to be not absorbed at all.

Our investigation is based on the belief that high energy and low energy photons should be accounted through the hot carriers participating in the total photoresponse before they dissipate their extra energy.

In this work, we demonstrate the impact of hot carriers on the operation of a single-junction solar cell. The objects of investigation were GaAs and Si p-n-junctions illuminated with ns-long laser pulses of 1.06 μm and 1.34 μm wavelength with varying intensity. Short enough pulse and appropriate wavelength to demonstrate experimentally the presence of hot carrier photoresponse and its impact on the net photovoltage.

In addition, we provide a model describing solar cell’s output signal via three its components by assuming p-n-junction as a first-order linear time-invariant system. The finding helps to reveal conditions determining contribution of each component into the net photovoltage. The proposed model shows good agreement with the experimental results.

As for conclusion, photovoltage across a p-n-junction consists of three simultaneous components resulting due to electron-hole pair generation, hot carrier effect and later semiconductor lattice heating. The model allows to reveal individual input of each component.

As for application, to raise the efficiency of a single-junction solar cell, the hot carrier effect should be minimized. This can be achieved by means of stronger infrared reflection, lower operation temperature, higher potential barrier.

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