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Hot Carrier Impact on Photovoltage Formation in Solar Cells

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Global electricity demands are fueling fast growth in the renewable energy industry, and along with it the technological advances that make these sustainable alternatives more dependable, efficient, and cost effective. Solar cells are among the most promising and environmentally friendly sources of electricity.

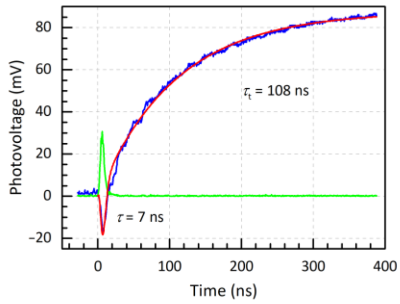

Fig. 1. Temporal shapes of the 0.53 μm laser pulse (green) and photovoltage (blue) across the perovskite solar cell. The excitation laser power density is 0.8 MW/cm^2. The red curve is theoretical calculation.

Here, the results of investigation of photovoltage formation in perovskite and inorganic solar cells under pulsed laser excitation are presented. Transient photovoltage measurements reveal the photoresponse composed of two components with opposite polarities, $U = U_f + U_{ph}$ (see Fig. 1) The fast component follows the laser pulse shape and is attributed to carrier heating, whereas the slow component corresponds to the conventional photovoltage arising from electron-hole pair generation. The latter can be expressed as [1]

$$U_{ph}(t) = U_0[(\exp(-t/\tau_t) - \exp(-t/\tau_{rec})] / (1/\tau_{rec} - 1/\tau_t), \qquad (1)$$

where U_0 represents the initial voltage, τ_t denotes the time constant associated with carrier transport within the absorber layer, and τ_{rec} refers to the time of carrier recombination. The calculated dependence of U_{ph} on time is depicted in Fig. 1. The same figure shows the measured photovoltage. The measured photovoltage as a function of time can be well described by Eq. (1). This enables us to determine the charge carrier transit time through the perovskite layer.

To conclude. the photoresponse of the solar cells under pulsed laser excitation is found to consist of two components: a thermoelectric force generated by hot carriers and a conventional photovoltage arising from light-induced electron–hole pair generation. Carrier heating reduces the conversion efficiency of the solar cells, as the polarity of the hot-carrier thermoelectric force is opposite to that of the conventional photovoltage. The adverse effect of carrier heating on conversion efficiency can be mitigated by employing multi-junction solar cells [2].

REFERENCES

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