Recombination rates and voltage losses of perovskite solar cells under steady state conditions

Carsten Deibel+, Constantin Bach+, Yitian Du#, Yana Vaynzof#

+ Institut für Physik, Technische Universität Chemnitz, Chemnitz 09126, Germany
# Leibniz Institute for Solid State and Materials Research Dresden (IFW), Helmholtzstraße 20, 01069 Dresden, Germany and Chair for Emerging Electronic Technologies, Technical University of Dresden, Nöthnitzer Str. 61, 01187 Dresden, Germany

The charge carrier lifetime is one of the defining absorber properties for the efficiency of a solar cell. While many methods exist to determine the charge carrier lifetime in perovskite thin-films and solar cells, their application is usually not straightforward: The commonly applied time-resolved photoluminescence can be conducted on thin films but requires additional efforts to relate the determined decay times to steady-state device performance. Voltage-based techniques such as intensity modulated photovoltage spectroscopy (IMVS) or transient photovoltage are often carried out under operating conditions but need electrical contacts and capacitive effects may hide the actual charge carrier lifetime.

We therefore use intensity modulated photoluminescence spectroscopy (IMPLS) [1], also called modulated photoluminescence [2] or quasi-steady-state photoluminescence [3] to determine the charge carrier lifetime in a perovskite thin film. It is determined from the frequency-dependent phase shift and amplitude with respect to a sinusoidally modulated excitation. We also apply this technique to various layer stacks, where we observe two time-constants as previously predicted by mathematical modelling and numerical simulations [2,4]. We also compare IMPLS-measurements on a complete solar cell to IMVS and discuss the relationship of the results with regards to charge carrier lifetime and capacitive effects.

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