Hysteresis in perovskite-absorber solar cells

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Solar cells using organo-metal-halides as absorber materials have undergone an unprecendented increase in reported device efficiencies during the past two years. However, only recently the research community has become aware and self-critical of reported device efficiency values as severe hysteretic effects in the current-voltage measurements.[1–4] The conditions prior to the current-voltage (IV)-measurements have a huge impact on the device performance suggesting that photo-induced polarization effects due to the inherent ferroelectricity, ion-migration phenomena and charge carrier accumulation affect the IV-measurement. Furthermore, the IV-scan rate, or rather the delay time after a voltage step before current sampling, heavily affects the device performance metrics derived from IV-measurements.

Transiently, a significantly higher photocurrent compared to the steady-state photocurrent can be extracted from the solar cell devices (Figure 1). Consequently, measurements carried out under non-equilibrium conditions, such as IV-measurements at short delay times, give contradicting results to measurements carried out at steady-state conditions, such as EQE-measurements.

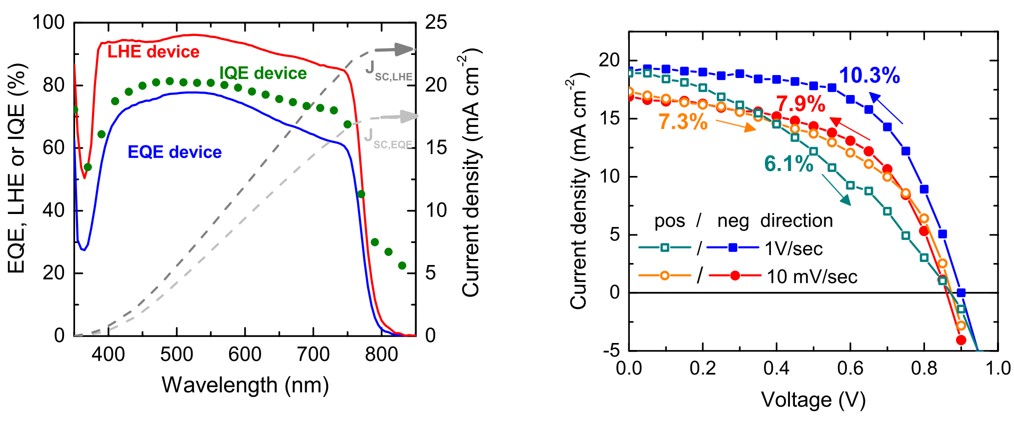

***Figure 1**: (left) External quantum efficiency (EQE), light harvesting efficiency (LHE) and internal quantum efficiency (LHE) of thin film perovskite-absorber solar cell device. (right) Corresponding IV-measurements of this device at different delay times (0.1 ms and 5 s equivalent to scan rates of 1V/s and 10 mV/s).*

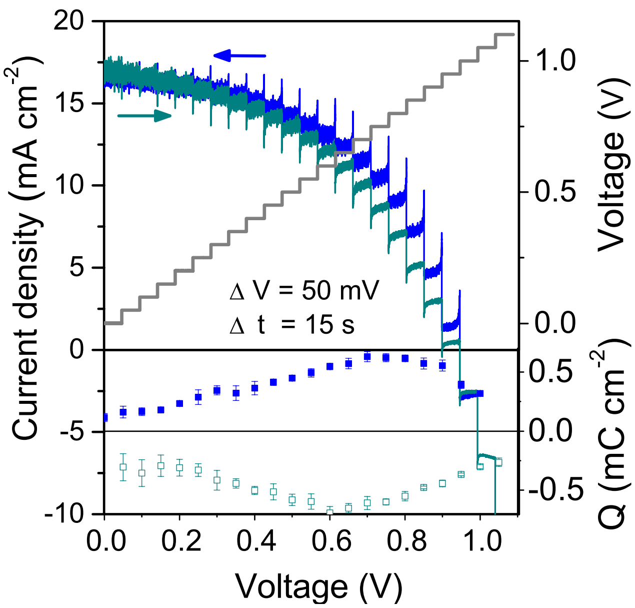

Figure 2: *Staircase voltammetry measurements to evaluate transient capacitive effects and visualize effect of delay time in current-voltage measurements of perovskite-absorber solar cells.*

To illustrate the effect of the delay time after a potential step before the current is being sampled in IV-measurements, we performed staircase voltammetry measurements (Figure 2). Additionally, integration of transient current profiles in each voltage step allows the estimation of the magnitude of the capacitive charging and discharging phenomena during the IV-measurements. For the example of the thin film devices shown in Figure 2, a distinct difference in the extracted profiles of charge carrier density (Q) as a function of applied potential was observed. This is indicative of differences of charge carrier distributions depending on the precondition and scan-direction. We reason that this is caused by photo-induced ion migration.[5] Staircase voltammetry is a valuable tool to compare capacitive effects in perovskite-absorber devices of different architecture and study changes in devices during degradation.

Hysteretic phenomena have been observed in solar cells other than perovskite-absorber solar cells. We will highlight that globally accepted standards on how solar cell device performance metrics are established are of crucial importance to ensure comparability between different research laboratories but also different device technologies.

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