Voltage Backtracking Behavior in Intermediate-Band Solar Cell under Intensive Bi/Uni-Color Photoexcitation Examination

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Intermediate-band solar cell (IBSC) is regarded as one of the promising ways to jump out the dilemma of highly limited efficiency from conventional single junction photovoltaic devices[1]. Generally, three critical photon harvesting paths are pronounced in IBSC on account of emerging intermediate band (IB) containing between the valence band (VB) and conduction band (CB), splitting it into two sub-band gaps. The carrier populations can be independently described by the quasi-Fermi levels in each of them, namely E_{FI}, E_{FV} and E_{FC}, setting down the electrochemical potential difference between intrinsic bandgap (E_{CV}) as $E_{\mathrm{CV}} = (E_{\mathrm{FC}} - E_{\mathrm{FI}}) + (E_{\mathrm{FI}} - E_{\mathrm{FV}})$. In a real case, it is, nevertheless, found that a reduction of sub-band transition strength stemming from thermal electron escape of intermediate state can lead to an unwanted voltage loss, though this can be recovered with the help of second-step photon absorption process. Here, a unique backtracking behavior of output voltage under intensive excitation situation is for the first time revealed, confirming the existence of an optimal light irradiation condition for the practical operation.

The device was fabricated by the molecular beam epitaxy technique with a specific quantum dot-in-well structure[2]. To accurately elucidate its output performance, two-step photoexcitation method was applied. Figure 1 shows the open-circuit voltage difference, ΔV_{OC}, of additional intraband light at varied interband irradiation intensity. This can be qualitatively explained by the dynamic movement of E_{FI} along with extent of quasi-Fermi level split. As a result, the light match supporting transitions between subband gaps is visualized and manifests its importance, again highlights the optical design of such devices. The waste-from-excess phenomenon of intraband energy enlightens further research into the voltage response of single irradiation condition, which is elucidated in Figure 2. Albeit the similar backtracking behavior of outputs, different mechanism is taken into account. A small-signal model is utilized to analyze the output response[3], and diodes in the equivalent circuit describe internal non-negligible generation-recombination process between each electronic band. The extent of carrier movement for different excitation therefore are abstracted as the diode response under different bias condition. By subsequently shifting the resistance of D_{VI} and D_{CV}, voltage rise and fall are intuitively balanced.

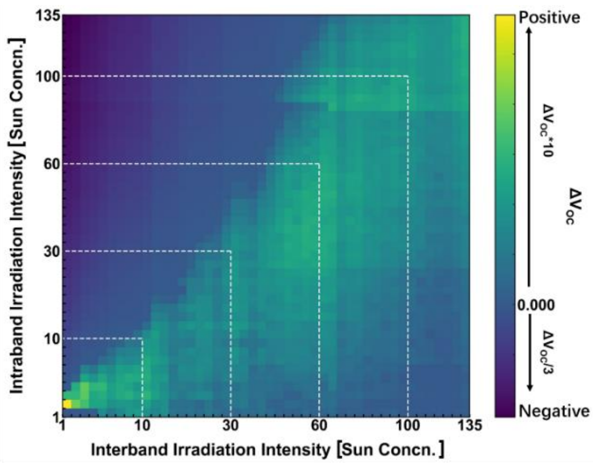

Fig. 1 Irradiation intensity dependence of open-circuit voltage difference w/o intraband excitation (T=298K).

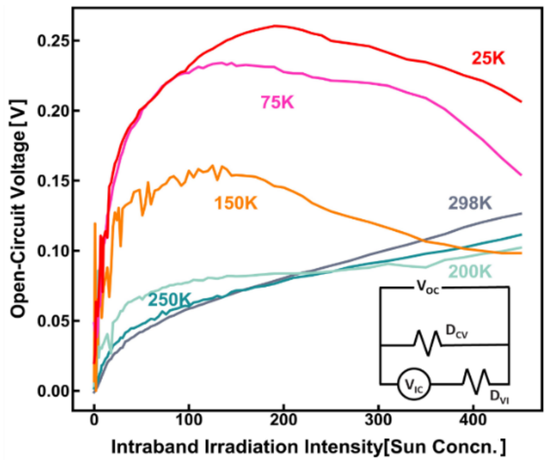

Fig. 2 Voltage response of IBSC within intraband excitation under varied temperature condition. Inset is equivalent circuit for small-signal mode

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