Performance Degradation of Quantum Dot-in-well Intermediate Band Solar Cell under Intense Bi-color Barrier and Intraband Photoexcitations

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The universal application of photovoltaic devices has been greatly inhibited because of the unfavorable cost efficiency, by which an improved power conversion rate is of importance for systematical optimization. Typically, a maximum achievable efficiency of 33% is predicted for single junction solar cell based on Shockley-Queisser thermodynamic detailed balance model. To break such kind of limit, intermediate band solar cell (IBSC) was proposed and on the concept toward a reduction of transmission losses for common devices. With incorporating intermediate levels into bulk material bandgap, multi-step absorption process for below-gap photons can occur in addition to fundamental excitations, providing a larger photogenerated current profile with voltage preservation. In recent reports, we have investigated the electrical performance of an $Al_{0.3}Ga_{0.7}As$ p-i-n solar cell containing InAs/GaAs quantum dot-in-well (DWELL) structures. A remarkably long-lived electron behavior is confirmed in quantum dots even at room temperature, which is beneficial for adiabatic two-step photoexcitations[1]. Special negative voltage recovery phenomenon is observed under strong asymmetric sub-bandgap irradiations, as a result from the rearrangement of quasi-Fermi levels[2]. Here, we investigated the device outputs with excitations in barrier region. It is found that a voltage degradation can be as well detected by applying extra intraband incident light.

The device was fabricated through molecular beam epitaxy technique. Bi-color photoexcitation method was applied to stimulate transitions simultaneously. Figure (a) shows the voltage outputs at different temperatures. A monotonous decrease on voltage is obtained when increasing intraband irradiation. Corresponding current delivery is also given in Figure (b). The current shows almost same tendency as that for voltage. However, with lowering the temperature, a current boost is obtained under faint intraband excitation intensities. This could be attributed to the extraction of carriers from trapped states in DWELL structures by means of absorbing below-gap photons, which will otherwise possibly thermal escape in high temperature regime. The origin of performance degradation can be qualitatively explained with the help of photoluminescence spectrals, as shown in Figure (c). At specific temperature, the radiative recombination of carriers in QDs decreases with intensified intraband excitation, reflecting an increasing non-radiative recombination takes place when taking current reduction into account. The red shift of peak around 1150 nm can partly stem from the heat effect during this process, while the quantum confined stark effect should also be highlighted regarding the ~10 nm position difference. It is reasonable to conclude that all of these factors are attributable to voltage reduction, but details should be further examined.

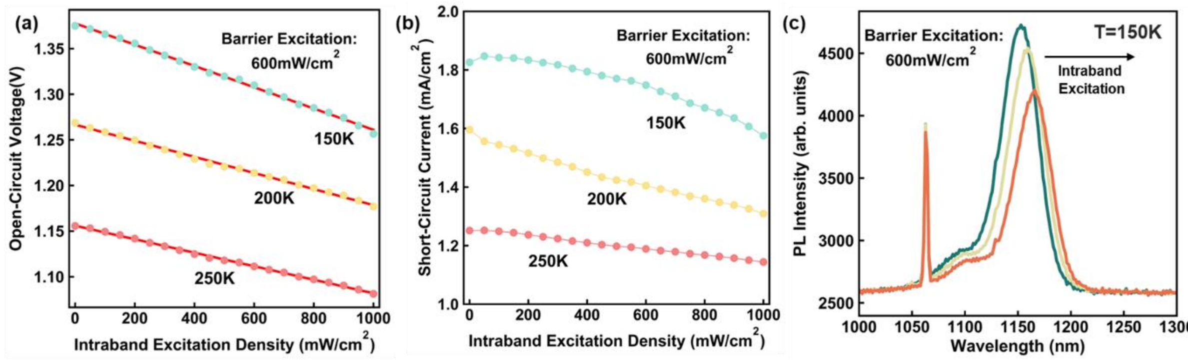

Figure (a) Voltage outputs and (b) current deliveries of DWELL IBSC under bi-color photoexcitation at varied temperatures. (c) Photoluminescence spectrum measured at varied intraband excitations.

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References

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