ELECTRICAL CHARACTERIZATION OF Cl-DOPED ZnTeO-BASED INTERMEDIATE BAND SOLAR CELLS

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Highly mismatched ZnTe\(_{1-x}\)O\(_x\) (ZnTeO) alloy is one of the potential candidates for an absorber material in a bulk intermediate band solar cell (IBSC) because a narrow, O-derived intermediate band (IB \((E_i)\)) is formed well below the conduction band (CB \((E_c)\)) edge of the ZnTe [1]. The energies of the three possible optical absorption edges between the valence, \(E_v\), and \(E_c\) bands of ZnTeO fit quite well into a large portion of the solar spectrum providing a material envisioned for the multi-band, single junction, high efficiency photovoltaic (PV) devices. Although we demonstrated the generation of photocurrent by two-step photon absorption (TSPA) through \(E_i\) band in ZnTeO-based IBSC with \(n\)-ZnO window at room temperature (RT) [2], the ZnTeO IBSC with \(n\)-ZnS window, which has two-fold higher open circuit voltage \((V_{OC})\) than the device with \(n\)-ZnO, showed the photocurrent by TSPA only at low temperature (<75K) [3]. In order to enhance the TSPA, the IB is required to be half-filled with electrons according to the theoretical calculation. However, there is no report on the electron doping in ZnTeO so far. As a donor impurity, Cl is one of the most promising elements because the successful \(n\)-type doping in ZnTe was reported by Cl doping. In this study, we have fabricated Cl-doped ZnTeO IBSC with \(n\)-ZnS window and the electrical properties of the solar cells have been characterized.

The IBSC structure of \(n\)-ZnSl\(_i\)-ZnTe/Cl-doped ZnTeO/i-ZnTe/p-ZnTe was fabricated on a \(p\)-ZnTe substrate by molecular beam epitaxy (MBE). ZnCl\(_2\) was used as a Cl source. The IBSC using undoped ZnTeO was also fabricated for comparison. As the electrical characterization, the temperature dependence of the external quantum efficiency (EQE), the temperature dependence of the \(V_{OC}\), and the concentration dependence of short circuit current \((J_{SC})\) and \(V_{OC}\) were measured.

Fig. 1 shows the temperature dependence of the EQE of the Cl-doped ZnTeO IBSC. With increasing temperature, the EQE increased gradually and the low energy cutoff at around 2.2 eV shifted to lower energy side due to the decrease of the band gap of ZnTe. In order to characterize the generation of photocurrent induced by TSPA, the EQE was measured with an additional IR irradiation which can excite electrons from the \(E_v\) to \(E_c\) bands, and the increase of EQE, \(\Delta EQE = EQE_{IR, ON} - EQE_{IR, OFF}\), was recorded. Fig. 2 shows the temperature dependence of \(\Delta EQE\) spectra. Positive \(\Delta EQE\) was obtained above 1.65 eV where the electron excitation from the VB to the \(E_i\) takes place, indicating the generation of photocurrent by TSPA. While the \(\Delta EQE\) decreases at low temperature from 50 to 150 K, it increases at the higher temperature above 150 K. This may be related to the generation of carrier in the intermediate band by Cl doping.


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Fig. 1. Temperature dependence of EQE spectra for \(n\)-ZnSl\(_i\)-ZnTe/Cl-doped ZnTeO/i-ZnTe/p-ZnTe IBSC.

Fig. 2. \(\Delta EQE\) spectra for \(n\)-ZnSl\(_i\)-ZnTe/Cl-doped ZnTeO/i-ZnTe/p-ZnTe IBSC.