Area: 6 Advanced Concepts and New Emerging Materials for Future PV.

INFRARED ABSORPTION CHARACTERISTICS IN TWO-STEP PHOTON UP-CONVERSION SOLAR CELLS

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Reducing the transmission loss for low-energy photons is a straightforward approach to break through the conversion efficiency limit for single-junction solar cells (SCs). The intermediate-band solar cell (IBSC) can reduce the transmission loss by utilizing the two-step photon up-conversion (TPU) and has been studied as a candidate for the next-generation SC[1]. Our proposing two-step photon up-conversion solar cell (TPU-SC) is another concept which also reduces the transmission loss and dramatically increases photocurrent[2]. The TPU-SC is a single junction SC with a hetero-interface consisted of wide gap semiconductor (WGS) and narrow gap semiconductor (NGS). The below-gap photons for WGS excite NGS and accumulate electrons at the WGS / NGS hetero-interface. The accumulated electrons are pumped upwards to the WGS barrier by the second excitation light, resulting in the efficient TPU. We observe not only a dramatic increase in the additional photocurrent but also an increase in the photovoltage[2]. In this study, we investigated the detailed optical response of the TPU as a function of the wavelength of the second excitation light to elucidate the TPU mechanisms occurring at the hetero-interface.

We fabricated a TPU-SC comprising $Al_{0.3}Ga_{0.7}As$ and GaAs layers on a *p*-type GaAs (001) substrate by using a solid-source molecular beam epitaxy. Here, WGS and NGS are $Al_{0.3}Ga_{0.7}As$ and GaAs, respectively. The $Al_{0.3}Ga_{0.7}As$ / GaAs hetero-interface is formed in the intrinsic layer, where a single InAs quantum dots (QDs) layer was inserted beneath the interface. Figure 1 shows a ΔEQE spectrum of the TPU-SC as a function of the photon energy of the second excitation light. In this measurement, we used a laser diode (LD) with the wavelength of 784 nm for the first interband-excitation in GaAs. The second intraband light source was a supercontinuum white laser passed through a 270-mm single monochromator, which pumps electrons accumulated at the hetero-interface into the $Al_{0.3}Ga_{0.7}As$ barrier. Here, ΔEQE is defined as the difference between the short-circuit current obtained from the current signals with and without the second excitation light illumination, which is normalized by the incident photon flux of the second excitation light at each wavelength. Several absorption peaks were observed in the ΔEQE spectrum. Besides, we measured ΔEQE at different excitation powers of the first excitation. The inset of Fig. 1 shows a photoluminescence (PL) spectrum for the TPU-SC at room temperature. The PL peak at 1.04 eV and the small sideband signal at 1.11 eV are attributed to the fundamental state (FS) and excited state (ES) transition of InAs QDs, respectively. The energy difference between the FS and ES was 0.07 eV, which is comparable to the peak-energy difference at 0.84 and 0.77 eV of the ΔEQE spectrum. This suggests that ΔEQE peaks at 0.84 and 0.77 eV are due to the intraband transition from the FS and ES to the same final bound state formed at the hetero-interface[3]. On the other hand, the absorption peak at 0.69 eV of the ΔEQE spectrum slightly shifts to the higher energy with increasing the excitation power. This suggests that free carrier absorption[4] of the dense electron gas at the hetero-interface causes the absorption peak. This demonstrates that the optically-induced electron gas formed at the hetero-interface play an important role in the efficient TPU.

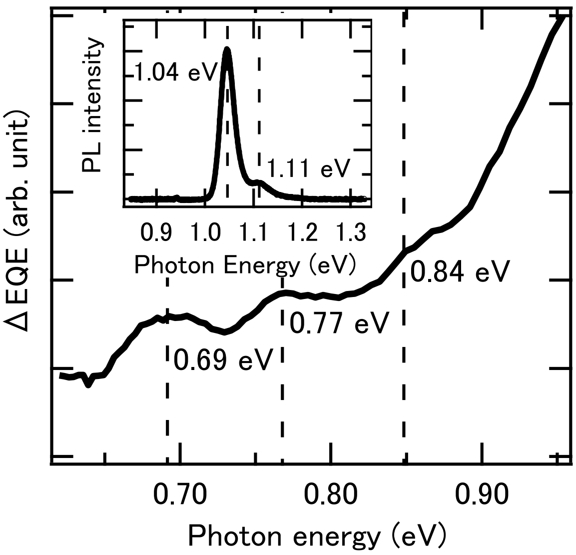

Figure 1: ΔEQE spectrum of the TPU-SC as a function of the photon energy of second excitation light at room temperature. The first excitation light from the 784-nm LD was 300 mW/cm^2. Inset: Photoluminescence (PL) spectrum for the TPU-SC at room temperature. The excitation wavelength and power were 659 nm and 0.8 W/cm^2, respectively.

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