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

FULL SPECTRUM QUANTUM EFFICIENCY MAPPING ON TYPE-II QUANTUM NANOSTRUCTURE SOLAR CELLS

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Intermediate band solar cells (IBSCs) have been proposed to overcome the limiting efficiency of single-junction solar cells [1]. In IBSCs, an additional sub-bandgap level, that is the IB, in the host single-junction solar cell can reduce transmission losses. In addition to the interband transitions, two-step photon absorption via the IB can convert low energy infrared (IR) photons to photocurrent. We have explored III-V semiconductor nanostructures as promising candidates to implement the IB [2]. In this study, hole-confinement type-II GaSb/GaAs quantum nanostructures were fabricated in the *i*-region of *p*-*i*-*n* single-junction solar cells on *n*-GaAs substrates by molecular beam epitaxy (MBE) [3].

Here, we have investigated two-step photon absorption processes by using 2D photocurrent excitation spectroscopy. Monochromatic visible to near-IR light and a mid-IR light source equipped with a Fourier transform infrared (FTIR) spectrometer simultaneously illuminated on the solar cell in an optical cryostat. The photon flux spectra from the FTIR spectrometer and the monochromator were measured by wavelength insensitive pyroelectric detectors, and divided the 2D photocurrent spectral maps to obtain the relative photocurrent response for the same photon flux excitation. Moreover, absolute photocurrent intensity was calibrated by the near-IR external quantum efficiency (EQE) of the solar cells under study at room temperature. As the result of above measurement and data analysis, 2D-ΔEQE maps for both the first step and the second step transitions on two-step photon absorption have been evaluated in detail.

2D-ΔEQE maps on GaSb/GaAs quantum ring solar cells at (a) 9 K, (b) 70 K, and (c) 120 K are summarized as shown in Figure 1. The horizontal and vertical axes, respectively, indicate the first step and the second step photon absorption energy. The gray scales indicate logarithmic ΔEQE with three orders of magnitude at respective temperatures. The ΔEQE was determined by the number of collected photo-carriers as a function of irradiated mid-IR photons (vertical axis) under with and without monochromatic bias light. As shown in Figure 1, the intensity of the 2D-ΔEQE maps decreased as increasing temperature, indicating thermionic emission of photo-carriers out of quantum rings at higher operation temperature. Furthermore, the maximum value for 2D-ΔEQE maps were obtained at short wavelength excitation for the first step interband transitions, where photo-carriers were re-excited that captured by quantum rings from the conduction band. This phenomenon should be minimized to get further efficiency gain. On the other hand, 2D-ΔEQE maps were systematically blue-shifted as increasing the temperature, which suggested the larger band offset for the hole-confinement in GaSb/GaAs quantum ring solar cells. It could be considered as the desirable property for photocurrent generation processes via two-step photon absorption as IBSCs.

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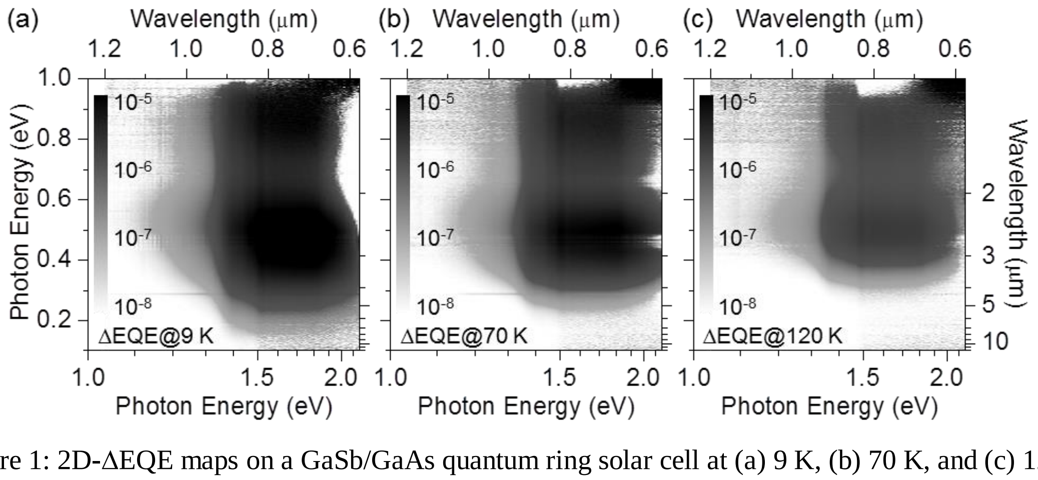

Figure 1: 2D-ΔEQE maps on a GaSb/GaAs quantum ring solar cell at (a) 9 K, (b) 70 K, and (c) 120 K.

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