Intermediate-band (IB) solar cells have attracted attention as a method of overcoming the efficiency limit of single-junction solar cells [1]. Photons with energies below the bandgap energy of the host semiconductor are absorbed via new states called as IB, which generates additional photo-current in the host solar cells. To demonstrate IB solar cells, we have so far proposed wide-bandgap InGaP-based type-II InP quantum dot (QD) solar cells [2] and demonstrated an extended optical absorption in InP QD solar cells [3].

In this work, we investigate the impact of the device design to the properties of the InGaP-based InP QD solar cells. In an ideal intermediate-band concept, the host semiconductor generates the current by absorbing short-wavelength light. Only long-wavelength light that transmitted through the host materials should be absorbed by the transitions via the intermediate band. Here we focus on the impact of the host absorber thickness at the front side of the cells. We prepared the InGaP-based InP quantum dot solar cells with the front i-InGaP layer [Fig. 1(a)] and compared with the sample without the front i-InGaP layer [Fig. 1(b)].

Figures 1(c) and 1(d) show the spectral response and the current-voltage curve, respectively. In the cell without i-InGaP layer, the quantum efficiency decreases in the visible and ultraviolet region. This indicates that the short-wavelength light is not absorbed by the host InGaP layer without QDs but the QD layers, resulting in the reduced carrier extraction efficiency [3]. In contrast, the cell with the front i-InGaP layer shows a slight increase in EQE in the visible region. This implies that the shorter-wavelength light is absorbed at the InGaP host. As a result, the short-circuit current density increases in the cell with the front i-InGaP layer, compared to the cell without the front InGaP layer [Fig. 1(d)]. This result indicates that the optimization of the host semiconductor thickness is critical for achieving the ideal operation of the intermediate-band concept in the quantum dot solar cells; the QDs should not be placed at the front side but the rear side of the host semiconductors.


Figure 1: (a) Structural schematic of InGaP-based InP quantum dot solar cells with the front i-InGaP layer and (b) without the front i-InGaP layer. (c) External quantum efficiency. (d) Current-voltage curves.