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

In(Ga)As / Al$_{0.2}$GaAs QUANTUM DOT INTERMEDIATE-BAND-ASSISTED HOT-CARRIER SOLAR CELL WITH FABRY-PEROT CAVITY

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In this study, we work on a ∼560 nm-thick Al$_{0.2}$Ga$_{0.8}$As single-junction solar cell with 10 layers of In(Ga)As quantum dots (QDs) designed for intermediate band solar cell (IBSC) purpose. QDs IBSCs have proven to be limited by thermal escape at room temperature. In such case, fundamental improvements are only possible if carrier in the IB are not in equilibrium with the lattice. On the other hand, intermediate-band-assisted hot-carrier solar cell (IB-HCSC) has been proposed in order to help the extraction of HCs from an absorber that has an IB. It provides a high-efficiency limit and enables to work with all relaxation mechanisms (thermalization, carrier-carrier scattering, thermal photons). Following a consistent approach, (i) we investigate the absorber structural and optoelectronic properties, (ii) characterize quantitatively the device operation and (iii) improve the optical design by implementation of a Fabry-Pérot (FP) cavity. For a high irradiation, we evidence the emergence of a HC population in the QDs. Absolute calibrated photoluminescence (PL) spectroscopy indicates that the triggering mechanism happens when the QD ensemble gets half-filled behaving as a metal-like IB. At the same time, sequential two-photon absorption (S-TPA) is demonstrated both optically and electrically. FP cavity implementation improves greatly the S-TPA for both subbandgap transitions. For the valence band (VB) to QD states transition, an EQE enhancement factor of ∼6 is found due to FP resonance. For the QD states to conduction band (CB) transition, +1% gain on the EQE can be attributed to AM1.5 IR photons (ΔEQE/EQE). Two-color excitation PL at high irradiation regime indicates a -25% decrease of PL from QDs and +20% increase for the host material. These experimental results indicate that an IB-HCSC might work at high irradiation regime. In Figure 1 (a), we schematize our findings on the evolution of quasi-Fermi level splitting (QFLS) with increase irradiation. In Figure 1 (b), we illustrate the impact of bandfilling on QDs absorptivity evidencing the advantage of a hot population to maintain subbandgap absorption in a thermally activated IBSC.

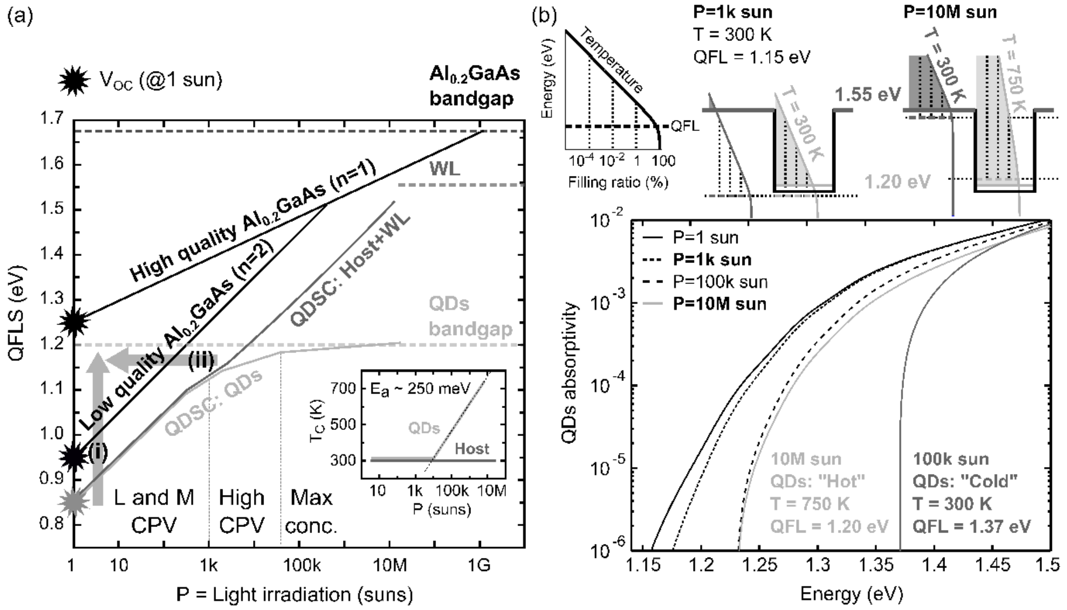

Figure 1: (a) Evolution of QFLS with increase irradiation for our studied QDSC. Comparison (V$_{OC}$@1 sun, ideality n) with low-quality reference solar cell without QDs (our lab, n=2) and high-quality Al$_{0.2}$Ga$_{0.8}$As solar cell (Fraunhofer ISE in 2015, n=1) are shown. Arrows (i) and (ii) show possible improvements e.g. by capping or doping. Insets show the evolution of carrier temperature (T$_C$) following an Arrhenius' equation with activation energy (E$_a$) related to barrier energy of holes (unipolar escape). (b) Impact of bandfilling on QDs absorptivity. Carrier Fermi-Dirac distributions are logarithmically plotted to evidence the change of slope due to temperature. For a "cold" carrier population at 100k sun, we see that subbandgap absorption below 1.37 eV becomes impossible for VB to QD states due to bandfilling.