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Enhanced performance of a Graphene/n-GaAs Schottky Barrier Solar Cell by means of an AlGaAs/GaAs thin multi-quantum well layer

Insertion of a multi-quantum well (MQW) AlGaAs/GaAs layer thin film between the graphene layer and the bulk n-GaAs layer is expected to improve cell performance in the following way: solar photons generate photo-excited carriers in all three regions of the cell (a) electrons thermionically escaping from the graphene side to the mqw and bulk side (b) electron-hole pairs photogenerated in individual quantum wells and (c) holes generated in the bulk n-GaAs (1.42eV) and diffusing to the junction. We propose a unified model for total current and open-circuit voltage, for all three transport processes in such a cell. The device is a Schottky Barrier cell with a thin region between graphene and n-semiconductor regions, which provides a wider solar photon window (1.80eV, with 30% Al content). On the other hand, mqw's (lattice-matched AlGaAs and GaAs layers) offer an optical gap of 1.59eV, for further photon absorption with 25Angstrom well-widths. Photogeneration in quantum wells splits electron/holes pairs (EHP) in opposite directions. Under the influence of the local junction electric field, electrons join the majority carriers in the n-GaAs and holes diffuse to the Graphene/AlGaAs junction. GaAs quantum well geometry (well width) is pre-selected to confine only one eigen-energy (the ground state) while the second one is coinciding with the edge of the wide band gap conduction band. This ensures increase of thermionic escape of electrons to the conduction band continuum, before recombination. The existence of quantum wells also ensures separation of electron-hole pairs (reducing recombination). We calculate such thermionic currents from MQW's from first principles. We also calculate thermionic currents from the graphene layer over the Schottky Barrier (G/AlGaAs). In both cases, thermionic currents (TE) are found to vary with T^3/2 due to 2D-dimensionality of the quantum well density of states and of the unique properties of the graphene density of states respectively. Simultaneously, photo-generated holes from the bulk and the mqw region diffuse fast to the junction. Such an existence of an MQW layer in the depletion region of the G/AlGaAs junction offers (a) wider band gap for absorption (b) wider optical gap for further absorption due to MQW's (c) higher device current due to two thermionic emission currents (TE) form the graphene and the quantum wells along with reduce recombination. Insertion of AlGaAs layer at the junction increases the Schottky barrier by 0.247eV, thus increasing open-circuit voltage. Under AM1.5 conditions, we predict 1.113V as open-circuit voltage, short circuit current 18.4mA/cm^2, and fill factor 75% leading to a clear improvement of a 15.35% collection efficiency.