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Enhancement of External Quantum Efficiency of GaSb/GaAs solar cell Based on Graphene

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***Abstract*— The main limitations of the typical solar conversion device is that low energy photons cannot excite charge carriers to the conduction band, therefore do not contribute to the device's current, and high energy photons are not efficiently used due to a poor match to the energy gap. Currently, Graphen based Solar Cells GBSC are one of the most active research fields in the third generation solar cells which can resolve this problem. In the present work, we are interested in modeling and simulating of both standard GaAs p-i-n solar cell and GaSb/GaAs Graphene Solar Cell. When comparing 40-layers GaSb/GaAs Graphene solar cell with standard GaAs solar cell, the conversion efficiency in simulation results increased from 16.48 % to 22.46 %, which is relatively 36.3% increase. Also, the absorption range edge of photons with low energies extended from 900 to 1200 nm. The results reveal that the GaSb/GaAs Graphene solar cell manifests much larger power conversion efficiency than that of p-i-n junction solar cells.**

Keywords— ***Solar Cell, Graphene, Grating***

I. INTRODUCTION

One of the most widely used in the branch to enhancement the photovoltaic conversion efficiency of a solar cell technology is the use of the Graphene solar cell. Currently, graphen based Solar Cells are one of the most active researches branch in the third generation solar cell. Comparing with quantum well, Graphene has more quantum confinement effects, which is in 3-dimension. Graphene has its unique state density function. This technology is created by embedding multiple layers of Graphene inside i-region typical solar cell n / p by several methods of growth (Chemical Beam Epitaxial: CBE, Stranski-Krastinow, Metal Organic-Chemical Vapor Deposition: MOCVD………) [1], which results in the quantization of energy levels due to quantum confinement effect in 3D. Thus, the tightly arrangement of quantum dots makes the potential barriers narrow, which leads to electrons co-movement. And then a subband is formed between conduction band and valence band in the band gap, which can be seen and named as the intermediate band. Due to this intermediate band, electrons can jump from valence band to intermediate band temporarily, and then jump from intermediate band to conduction band with the help of another photon [2]. Hence, even the photons with lower energy than band gap can contribute to photocurrent. In this work, we are interested in modeling and simulation of two kinds of solar cells, including standard p-i-n GaAs and GaSb/GaAs Graphene solar cell respectively, in goal to see the effect of QDs on the solar cells characteristics parameters.

Nomenclature	
InAs	Indium Arsenide
GaSb	Gallium Antimonite
GaAs	Gallium Arsenide
InGaP	Indium Gallium Phosphor
p	Holes concentration in p-type semiconductor
n	Electrons concentration in n-type semiconductor
i	Intrinsic region
GBSC	Quantum Dots Solar Cell
QDs	Quantum Dots
J_{sc}	Short circuit current
V_{oc}	Open circuit current
FF	Fill Factor
η	Efficiency
μ_{n0}	Electrons mobility
μ_{p0}	Holes mobility
R_{SRH}	Taux de recombinaison SRH
m_e^*	Effective mass of electrons
m_h^*	Effective mass holes
n_i	intrinsic concentration

Ψ_i	Wavefucntion
τ_n	Electron lifetime
τ_p	Hole lifetime
TMUN	Lattice temperature coefficient for the temperature dependence of electron mobility
TMUP	Lattice temperature coefficient for temperature dependence of hole mobility
MUN	Electrons mobility
MUP	Holes mobility
ETRAP	Difference between the trap energy level and the intrinsic Fermi level
$P_{c.n}$, $C_{r.p}$, $C_{s.n}$, $P_{c.p}$, $C_{r.p}$, $C_{s.p}$	Reference levels of doping
α.n, α.p, β.n, β.p	Exposant coefficients
$\mu_{max.n}$, $\mu_{max.p}$	Mobility's of majority carriers
$\mu_{min.n}$, $\mu_{min.p}$	Mobility's of minority carriers
e	Regions thickness

II. Structure of Standard P-I-N Solar Cell

The model used in this simulation is a p-i-n solar cell, which has five layers in total as shown in the Fig.1. Two red layers are made of InGaP, which are called window layer and back surface branch layer respectively; they are used to reduce the surface recombination at the top and bottom of the solar cell [3]. The other three layers are made of GaAs, which are emitter region p-type, intrinsic region, and n-type base region respectively.

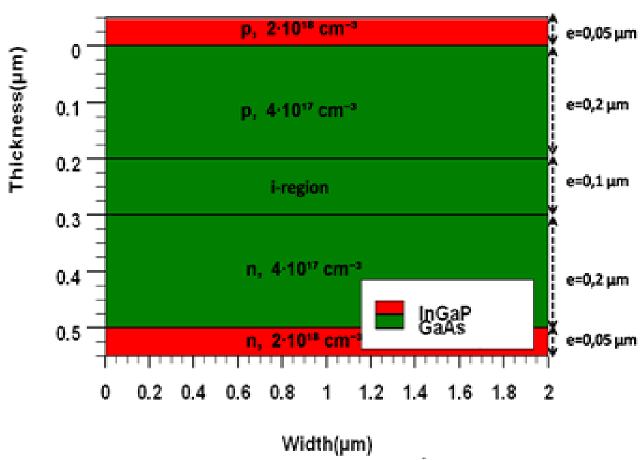

Fig.1. Structure of standard p-i-n solar cell.

III. Modeling of P-I-N Quantum Dots QDs Solar Cell

The previous p-i-n structure is used as the structure of Graphene Solar Cell (GBSC) in this simulation. The Quantum Dots (QDs) are inserted inside the intrinsic layer which is between the p-type region and n-type region. We studied GaSb/GaAs QDs solar cell structure to show the impact of the insertion of the QDs on the solar cell characteristics parameters. The QDs inserted introduce a several confined electrons and holes state inside the intrinsic region and they will enhance the drifting action of the carriers by making use of the built-in electric branch of the p/n junction. The GaSb/GaAs model of the GBSC is shown in the Fig.2. All the physical models used in the simulation are described in appendix A, while the used materials parameters are listed in table2 of appendix B.

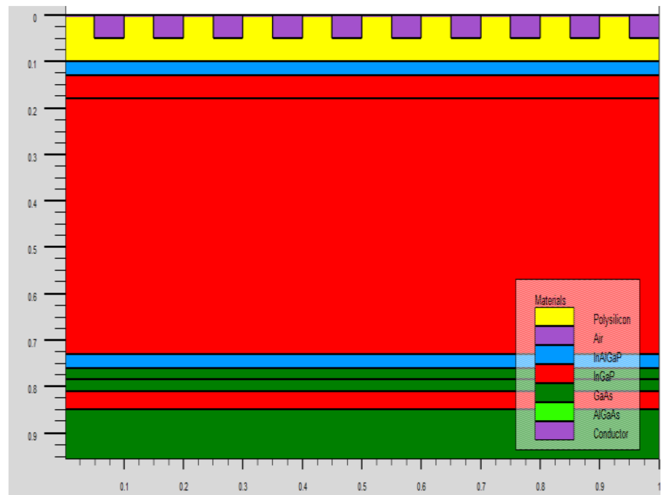

Fig.2. GaSb/GaAs GBSC with 13-layers QDs embedded in intrinsic region

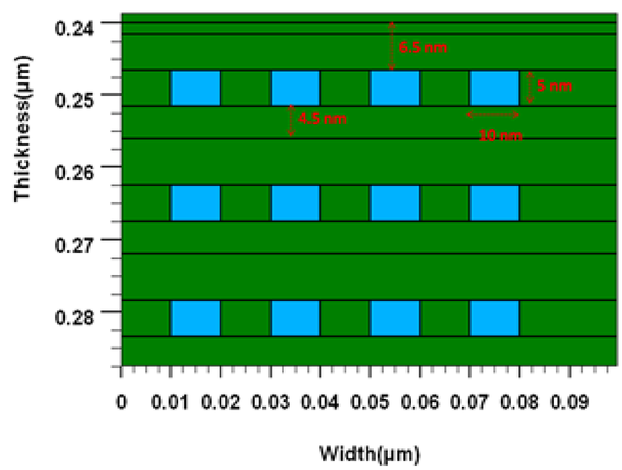

Fig.3. Zoomed-in view of quantum dots inserted in intrinsic region.

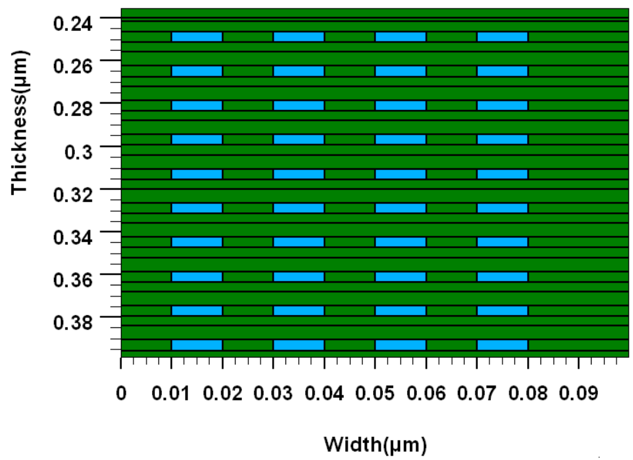

Fig.4. Sizes of quantum dots and barriers in one layer QDs.

IV. THE STRUCTURE OF MDM WAVEGUIDE

Results and discussion

Along this work, we choose one-sun AM_0 illumination condition for simulating. First, we start the simulation results of the standard p-i-n solar cell presented in the Fig.1, after we pass to the simulation results of GaSb/GaAs Graphene solar cell structure with different numbers of QDs layers (10, 20 and 40) respectively. For each simulation, the J(V) characteristic, P(V) characteristic, the External Quantum Efficiency EQE, and the important parameters of the solar cells are shown and discussed.

a. J(V) results

Fig.5 and Fig.6 show the J(V), P(V) characteristics of the standard p-i-n solar cell (baseline). As can we see, the GaAs p-i-n solar cell provide short-circuit current density of 21.65 mA/cm^2, open voltage of 1 V approximately and an electrical power of 16.48 mW/cm^2. That match with the results of others works studied previously [5].

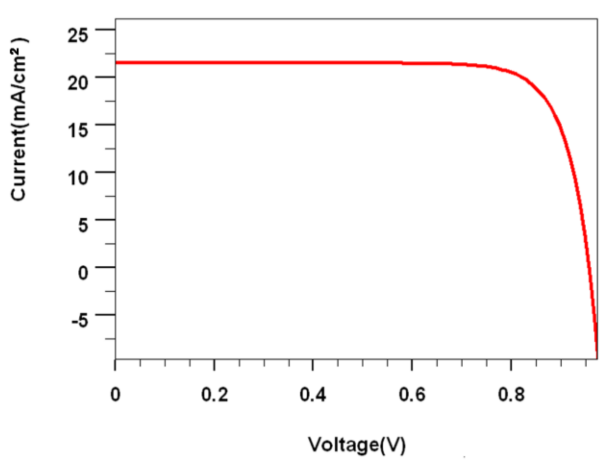

Fig.5. J(V) variation of current density as a function of the voltage of a solar cell.

Fig.7 shows the J(V), of GaSb/GaAs Graphene solar cell for 0, 10, 20 and 40 QDs layers respectively. It's clear that the short-circuit current is increasing with the number of QDs layers embedded inside the i-region of the p-i-n solar cell due to the additional pairs electrons-holes photo-generated. The open-voltage stays approximately constant when the number of QDs layers increases. A relative augmentation about 1.8 % of short-circuit is obtained when comparing 40-layers GaSb/GaAs Graphene solar cell with standard solar cell.

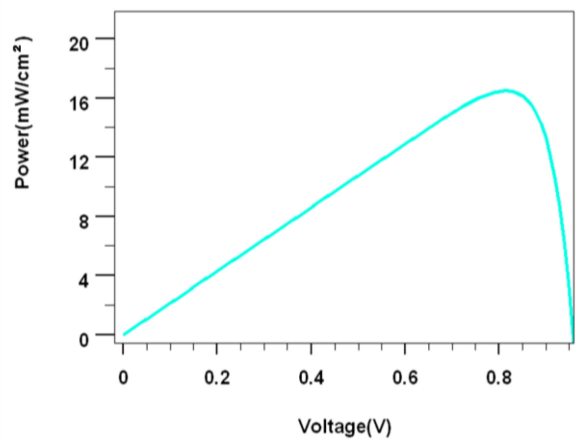

Fig.6. P(V) variation of the power according to the voltage of a solar cell.

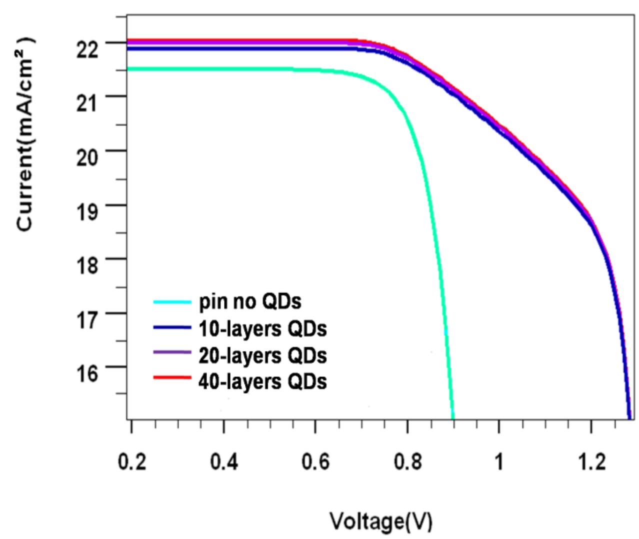

Fig.7. J(V) of GaSb/GaAs Graphene solar cell (QDs layers= 0, 10, 20, 40).

Table 1 shows the simulation results of four different solar cells. One is the standard p-i-n solar cell without quantum dots. The other three are all GaSb/GaAs graphen based Solar Cells with different number of Graphene layers, which are 10-layers, 20-layers and 40-layers, respectively.

Table 1. The important parameters of standard solar cell and GaSb/GaAs Graphene solar cell with different number of QD layers.

Number of QDs	Jsc (mA/cm^2)	Voc (V)	FF (%)	η (%)
0	21.65	0.98	79.76	16.48
10	21.89	1.33	76.64	22.33
20	22	1.33	76.57	22.42
40	22.04	1.33	76.54	22.46

From table I, the short-circuit current increases when more quantum dots are inserted and open circuit voltage almost stays the same. As a result, the conversion efficiency increases relatively about 36.3 % when comparing 40-layers GaSb/GaAs Graphene solar cell with standard solar cell.

External Quantum Efficiency(EQE) results

According to the discussion in introduction, the most important impact of quantum dots is to help solar cells absorb those photons with lower energy, which also means long wavelength. The maximum photons that can be absorbed by a typical standard GaAs solar cell is around 875 nm [4]. After inserting the quantum dots (GaSb), photons with wavelength 900 to 1200nm are also able to be absorbed. Fig.8 shows the External Quantum Efficiency EQE, of GaSb/GaAs graphen based Solar Cells for 0, 10, 20 and 40 QDs layers respectively.

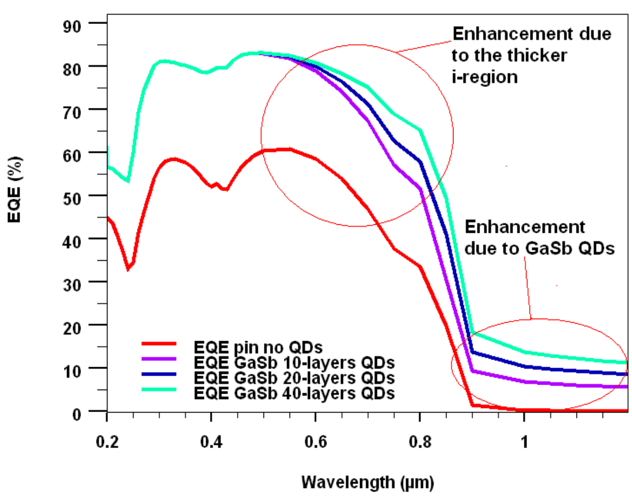

Fig.8. External Quantum Efficiency of standard solar cell and GaSb/GaAs Graphene solar cell with different number of QD layers.

It is clear in the Fig.7, that the EQE of a standard p-i-n solar cell indeed to turns to zero around the wavelength 900nm. The EQE from 900-1200 nm of GaSb/GaAs Graphene solar cell with 10-layers, 20 layers and 40 layers varied from 6% to 12%, which means the photons in this wavelength range are effectively absorbed and contribute to photocurrent creation. In addition we can see another increase happening at the range of 550 to 900nm. This is due to the larger thickness of intrinsic region by the increasing of the quantum dots layers number. A thicker intrinsic regions means more photons can be absorbed in this region.

V. Conclusion

In this work, we studied the influence of insertion GaSb quantum dots material inside the intrinsic region of a GaAs p-i-n standard solar cell on the characteristic parameters enhancementment. After programming and building complete data library of material parameters, models with different parameters are built and simulated. We achieved a several results as shown below. First, the insertion of 40-layers of GaSb/GaAs QDs inside i-region of p-i-n GaAs enhances relatively the conversion efficiency by 36, 3%. Second, insertion of 40-layers of GaSb/GaAs QDs inside the i-region of p-i-n GaAs extends the absorption range edge of photons with low energies from 900 to 1200nm.

References

[1] Pablo Garcia-Linares Fontes, "Research on Intermediate Bands Solar Cells and development of experimental techniques for their characterization under concentrated illumination", Thesis Doctoral, Universidad Politécnica de Madrid, 2012.

[2] A.Luque, A. Marti, A.Nozik, "Solar cells based on quantum dots," MRS bulletin, 2007, 32:236-241.

[3] C.Bailey, "Optical and mechanical characterization of InAs/GaAs Graphene solar cells," a dissertation for the degree of Doctor of Philosophy, Rochester Institute of Technology, January, 2012.

[4] C.Bailey, S.Polly, R.Raffaelle, et al, "Open-circuit voltage enhancementment of InAs/GaAs graphen based Solar Cells using reduced InAs coverage," IEEE Journal of Photovoltaic, Vol.2, No.3, July 2012, 269-275.

[5] P. Michalopoulos, "A novel approach for the development and optimization of state-of-the-art photovoltaic devices using Silvaco," M.S. Thesis, Naval Postgraduate School, Monterey, California, March 2002.

[6] D.J. Roulston, N.D. Arora, and S.G. Chamberlain, "Modeling and Measurement of Minority-Carrier Lifetime versus Doping in Diffused Layers of n ±p Silicon Diodes", IEEE Trans. on Electron Devices, ED-29, Feb. 1982, p. 284-291.

[7] Boujdaria K, Ridene S and Fishman G 2001 Luttinger-like parameter calculation *Phys. Rev.* B 63 235302.

[8] Vurgaftman I and Meyer J R 2001 Band parameters for III–V compound semiconductors and their alloys *J. Appl. Phys.* 89 5815–62.

[9] MASETTI G., M.SEVERI, AND S.SOLMI, "Modeling of Carrier Mobility Against Carrier Concentration in Arsenic, Phosphorous and Boron doped Silicon", IEEE Trans. Elec. Dev. ED-30, (1983): 764-769.

