Optimization of All-Back-Contact GaAs Solar Cells

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***Abstract*—The optimized condition of all-back-contact solar cells is studied to eliminate the problem of light blocking by the front contacts in conventional solar cells. The influences of layer thickness and pitch distance are studied. The optimized structure is obtained with a 2 μm thick base layer and a 631 μm contact pitch, and the efficiency can reach to 26.15%.**

***Keywords*—GaAs, AlInP, GaInP, back contact, solar cell**

I. Introduction

For single-junction solar cells, GaAs has been a good candidate due to the better energy conversion efficiency compared with other materials [1]. Since GaAs has excellent material properties, the optimization of structure design becomes more critical to boost the performance. Therefore, we try optimize the design of all-back-contact GaAs solar cells in this paper. The all-back-contact solar cell can reduce the shadow loss caused by the front contacts, resulting in an increment in short-circuit current density (J_{sc}) and open-circuit voltage (V_{oc}) respectively. Consequently, a higher efficiency could be achieved.

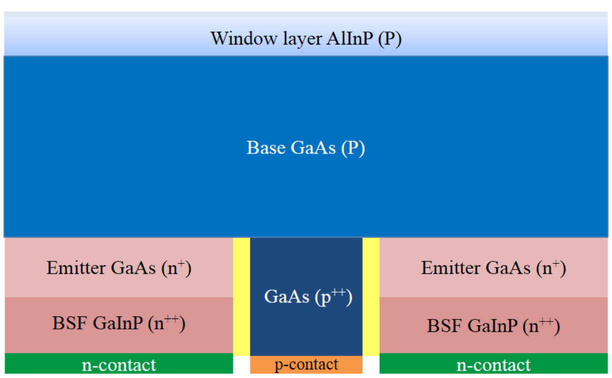


Fig. 1: Simulation model of all-back-contact GaAs solar cells

II. Simulation Model, Parameters and Methodology

The simulation model of all-back-contact GaAs solar cells and the structural dimensions are shown in Fig. 1. The setting of parameters is listed in table I. In this model, AlInP is used as the window layer and it can be served as a passivation layer so that the drawback of high surface recombination velocity of GaAs can be minimised. The heavily doped GaInP is used as the back surface field (BSF) layer to create a barrier, which can prevent minority carriers from recombination at the rear surface. Then, the model with different thickness of GaAs-based layer (h) is simulated from 2 μm to 4 μm. The width of p-contact is fixed to 30 μm, while the width of n-contact (S) is simulated from 400 μm to 800 μm to find out the optimal contact pitch.

In this paper, we used our in-house developed program — two-dimensional finite element Poisson and drift-diffusion [2] solver to numerically simulate the performance of all-back-contact solar cells with different structures. The spectral irradiance of AM1.5G is used as the reference incident sunlight [3]. The generation rate in the device is calculated by using the Lambert-Beer absorption formula (1) as shown below

$$I = I_0 e^{-\alpha x}, \tag{1}$$

where I_0 is the initial incident light, α is the absorption coefficient of the material, x is the penetration depth.

III. Results And Discussion

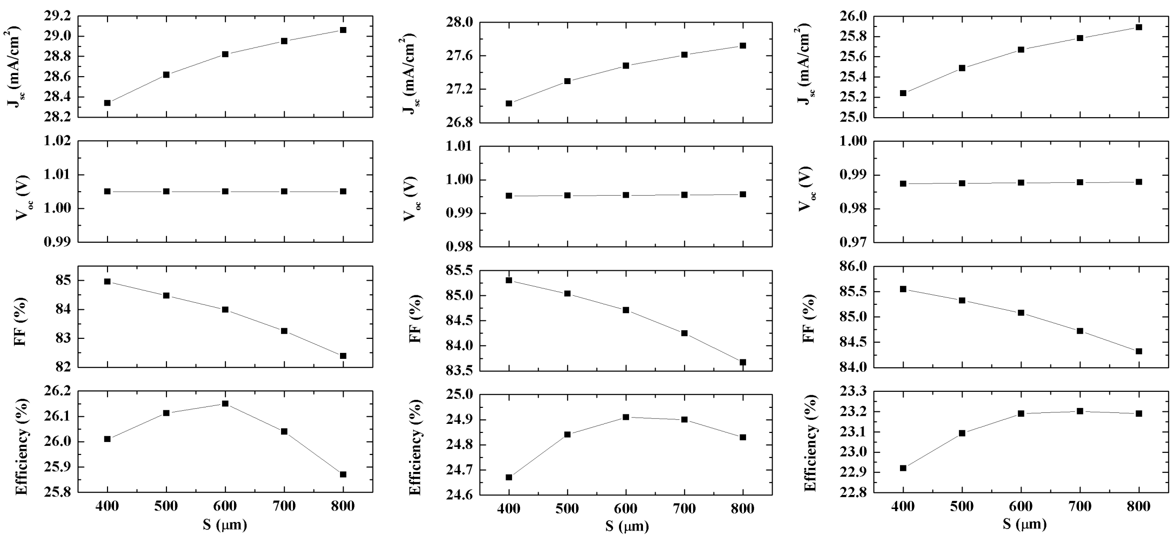
The simulation results are shown in Fig. 2, and they're arranged into three categories based on the different thickness of base layers. The best efficiency of each category is obtained when S = 600 μm for h = 2 μm and 3 μm, and S = 700 μm for the case of h = 4 μm. And it's found that the case with h = 2 μm has the best efficiency among these cases (see table II).

Comparing the characteristic parameters of different h, J_{sc}, V_{oc} and Efficiency, all have a descending trend as h increases from 2 μm to 4 μm, while the fill factor (FF) becomes larger with the increasing h. We further analyze the reason why J_{sc} would be larger for the smaller h. The recombination current is calculated as shown in table III. We divide the device into three divisions: the window layer, the bulk layer, and the p-n junction depletion layer. It's found that the bulk recombination is dominant than all the other regions. Therefore, a thicker base layer means a higher recombination current in the bulk layer. Hence, for h = 2 μm, a larger J_{sc} is obtained.

Now we analyze the performance of various pitch size, S with fixed h. It can be seen that except of V_{oc}, other characteristics all have an obvious change with different S. The power conversion efficiency first increases and then decreases after

TABLE I: Simulation parameters settings for all-back-contact GaAs solar cells

Layer	Interface	Window	Base	Emitter	BSF	p−contact
Material	$Al_{0.5}In_{0.5}P$	$Al_{0.5}In_{0.5}P$	GaAs	GaAs	$Ga_{0.5}In_{0.5}P$	GaAs
Thickness (nm)	5	35	2/3/4	100	100	200
Type	p	p	p	n^+	n^+	p^{++}
Doping Concentration (cm^{-3})	5×10^{17}	5×10^{17}	1×10^{17}	2×10^{18}	2×10^{18}	1×10^{19}
Bandgap (eV)	2.368	2.368	1.42	1.42	1.968	1.42
μ_e/μ_h ($cm^2V^{-1}s^{-1}$)	100/10	100/10	3000/150	2000/150	400/80	1000/100
τ_n, τ_p (s)	1×10^{-11}	5×10^{-9}	1×10^{-8}	1×10^{9}	1×10^{-9}	1×10^{-9}
Radiative Recombination (cm^3s^{-1})	1.1×10^{-10}	1.1×10^{-10}	7.0×10^{-10}	7.0×10^{-10}	6.0×10^{-11}	7.0×10^{-10}



(a) h = 2 μm (b) h = 3 μm (c) h = 4 μm

Fig. 2: Characteristics of all-back-contact GaAs solar cells

S comes to a certain value. The optimized power conversion peak is fallen at S = 600 μm.

TABLE II: Optimized performance of all-back-contact GaAs solar cells with different base layer thickness.

h (μm)	S (μm)	J_{sc} (mA/cm^2)	V_{oc} (V)	FF (%)	Efficiency (%)
2	600	28.82	1.005	83.99	26.15
3	600	27.48	0.995	84.71	24.91
4	700	25.78	0.988	84.72	23.20

TABLE III: The recombination current density (mA/cm^2) in each region with various h

Region	h (μm)		
	2	3	4
Window	0.019	0.018	0.018
Bulk	2.742	4.181	6.041
Junction	0.019	0.014	0.012

IV. Conclusion

To summarize, the ideal base layer thickness and the contact pitch for all-back-contact GaAs solar cells is investigated by the numerical analysis. The efficiency reaches 26.15% with device structure of h = 2 μm and S = 600 μm. According to the simulation result, the bulk recombination is dominant in the device, where a further optimization is needed in this region. The further optimization including doping profile adjustment will be discussed in the talk.

V. Acknowledgments

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