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Development of Interdigitated Back Contact Heterojunction Silicon Solar Cells by using One-Dimensional Numerical Simulation

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Abstract—in this paper, we will present the (IBC-SiHJ) solar cells (interdigitated back-contact heterojunction silicon solar cells) that have both the emitter and the complete metallization on the rear side. This eliminates the shading present in conventional solar cells, and the sunward surface and back-side of the solar cell can therefore be independently optimized for optical and electrical performance, respectively. We use "PC1D", which is a simulator from software package. PC1D is extensively used for modeling a lot of devices, and it is well suitable for modeling solar cells. One-dimensional numerical simulations were performed to derive design rules for low-cost, high-efficiency of interdigitated back contact (IBC-SiHJ) solar cells on a low-cost substrate. So we study the influence of the doping and the thickness of the front surface layer (FSF) and rear surface layer on the characteristics of an IBC solar cell, in order to obtain the optimal structure of these cells.

Index Terms—Heterojunction, Solar cell , Amorphous silicon, Crystalline silicon, interdigitated back contacts silicon heterojunction.

1 Introduction

One very promising high-efficiency solar cell concept is the interdigitated back-contact heterojunction silicon solar cell [1], [2]. This type of cell design has already been proven to be compatible both with high efficiency [1] and large-scale production. Placing both negative and positive contacts on the back side of the solar cell has a lot of advantages in a cell performance and applications over the conventional structures. Eliminating the front contact provides not only a potential to improve short circuit current but also the deposited of amorphous silicon (a-Si) layer give a better surface passivation, so a higher open circuit voltage (V_{OC}) [3]. Since the heterojunctions are on the rear side, they can be optimized for electrical performance while the front surface is designed for optimum optical performance. High-quality front surface passivation is needed since most of carriers are generated near the front surface while the collection heterojunctions are on the rear side. A long diffusion length is required since the minority carriers in back contact solar cells have to travel a longer distance than those in the conventional screen printed solar cells before they are collected.

This could simplify the heavy process of IBC-SiHJ cells and make those high efficiency devices cheaper to fabricate. So, the patterning is easier in heterojunctions than the diffuse junctions in conventional a rear junction cells but in the IBC Si-HJ solar cells performances is up to now mainly limited by a trade-off between Fill Factor (FF) and Open Circuit Voltage (V_{OC}) values. The rear emitter of such devices can be fabricated with an a-Si:H buffer layer between the p-type a-Si:H layer and the crystalline substrate. In this work, numerical simulations of IBC-SiHJ devices are presented. A one-dimensional model is established, for the optimization and evaluation of this kind of structure (IBC-SiHJ).

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In this paper, we investigated the effects of physical cell parameters on the cell performance to implement the IBC structure into low-cost substrates here, we focus on the front side and the rear side, or we are going to study and discuss of the influence of physical and geometrical parameters. So we also study the influence of the doping and the thickness of the front surface layer (FSF) and rear surface layer on the characteristics of a solar cell IBC-SiHJ, in order to obtain the optimal structure of these cells.

2 Structure and Physical Models

For our simulation we use "PC1D", which is a simulator from software package, it is for one-dimensional test structures. The schematic diagram of the conventional IBC-SJH cell used for the simulation is shown in Fig.1. The front structures of this structure of cell are textured, diffused with phosphorus, and passivated with SiN, respectively. A gap of 80 µm between a-Si:H(p) (BSF) and a-Si:H(n) (emitter) for the IBC-SHJ cell was assumed in order to eliminate the possibility of shunting. The front surface recombination velocity and the back surface recombination velocity on a-Si:H(n) emitter and a-Si:H(p) (BSF) were fixed to 1000 cm/s for the IBC-SiHJ cell, which is achievable by SiN or SiO2 passivation [4]. The key parameters used for the modelling were the minority carrier lifetime, distance between negative and positive grid fingers (pitch; P), and surface recombination velocity of the gap (Eg). That varied from 10 to 1000 cm/s. The effect of contact opening width on the cell performance was investigated.

A 50 µm p-type polished crystalline silicon wafer is used as the substrate, corresponding to a doping density of $5.10^{16}cm^{-3}$ which is acceptable (the goal being to keep good diffusion length for photogenerated electrons. The front (illuminated face) is a-Si:H(p) and is heavily doped (10^{19} cm^{-3}). The rear face is highly doped a-Si:H(n) ($5.10^{19}cm^{-3}$). As the recombination rate varies between 100-1000-10000 cm / s and lifetimes of minority carriers varies between 22-50. The junction depth of the front face and the heterojunction in rear face are fixed to 0.6µm. The relationship between the diffusion length of the minority carriers and the thickness of the cell must be greater than two for the interdigitated structure, is interesting in terms of conversion efficiency, which means that for a cell to 50 µm we must have diffusion lengths exceeding 100µm [5], [6]. The doping zones a-Si:H(n) and a-Si:H(p) to ensure the contacts are at least equal to $5x10^{19}$ cm^{-3} at the surface [7]. We defined two electrodes at the rear of the wafer a n-type a-Si:H(n) emitter and an p-type amorphous silicon (a-Si:H) back surface field. The 50 µm wide region between the two doped layers (gap region) is modelled with an insulator layer. BSF and emitter are totally covered with aluminium metal. The device parameters used in the modelling were summarized in Table1

TABLE1
PHYSICAL DEVICE PARAMETERS USED IN THE MODELLING

Cell parameters of IBC-SiHJ	
Substrate (Si(p))	W = 50 µm
	d = 80 µm
	L = 200 µm
	N = $5x10^{16} cm^{-3}$
	Uniforme
	S_{FAV} = 1000cm/s
	e_{ARC} = 80nm
	n = 2.05
	L_D = 100 µm
Emitter (a-Si:H(n))	W = 0.6 µm
	N = $5x10^{19}$ cm^{-3}
	Se = Sh = 10^7 cm/s
FSF (p+)	W_{FSF} = 0.6 µm
	X_{FSF} = 200 µm
	N_{FSF} =10^{19} cm^{-3}
	Uniforme
BSF a-Si:H(p)	W = 0.6 µm
	N = 10^{19} cm^{-3}
	Se=Sh=10^7cm/s

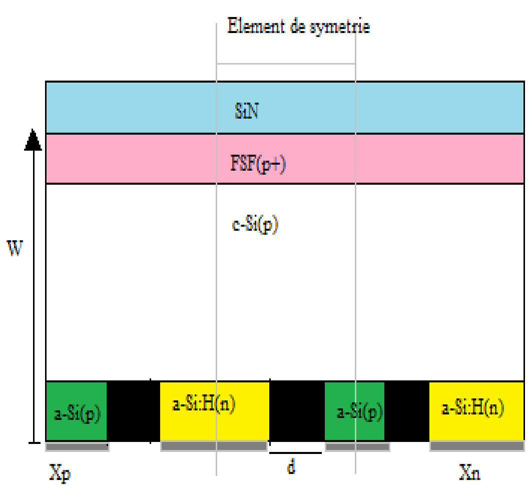

Fig. 1 Structure of interdigitated back contacts silicon heterojunction (IBC-SiHJ) solar cell

3 SIMULATION RESULTS

3.1. Study of I-V characteristics, P-V, and the response spectral of interdigitated back contact crystalline silicon solar cell

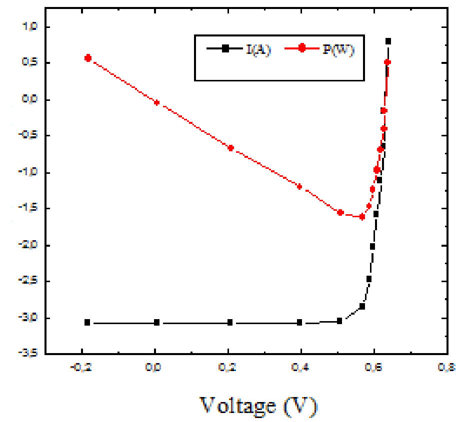

Fig. 2 The I-V and P-V characteristics, of (IBC-SHJ) solar cells

The results are:
Isc = 30.8mA/cm², Voc = 635mV , pmax = 1.62W

$$\eta = \frac{p_m}{p_{in}} = \frac{V_m I_m}{p_{in}} = \frac{FF \times V_{oc} \times J_{sc}}{P_{in}} \qquad (1)$$

$$FF = \frac{P\max}{V_{oc} x I_{sc}} \qquad (2)$$

Or FF = 82.83%

This gives η ≈ 20% of efficiency

3.2 The response spectral

The junction area p + p generates an internal electric field and plays an important role in the functioning interdigitated back contacts crystalline silicon heterojunction solar cells. Indeed, it has four effects on the performance of solar cells (Push the electrons towards the junction and improve the collection efficiency of carriers; Motivate the trapping of minority carriers; Decrease in rear surfaces recombination of minority carriers; Increasing the optical absorption of. part of the incident solar spectrum).

(Fig. 3) represents the internal quantum efficiency

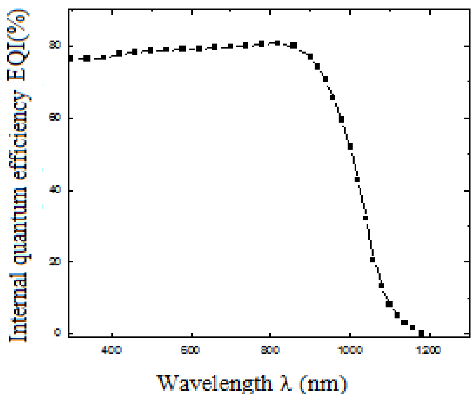

Fig. 3. Variation of the internal quantum efficiency of interdigitated back contacts silicon heterojunction (IBC-SiHJ) solar cell.

3.3 Study of the influence of doping and the thickness of the FSF on the performance of interdigitated back contact crystalline silicon solar cell

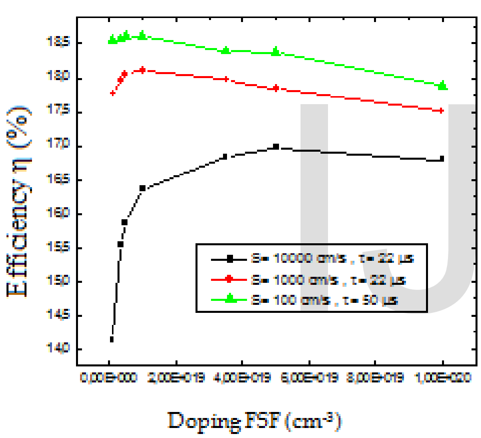

Fig. 4. Influence of doping the front surface layer (FSF) on efficiency of a (IBC-SHJ) solar cells

We note that the surface recombination velocity and doping of the FSF (Front Surface Field) have a significant influence on the efficiency of interdigitated back contact silicon solar cell.

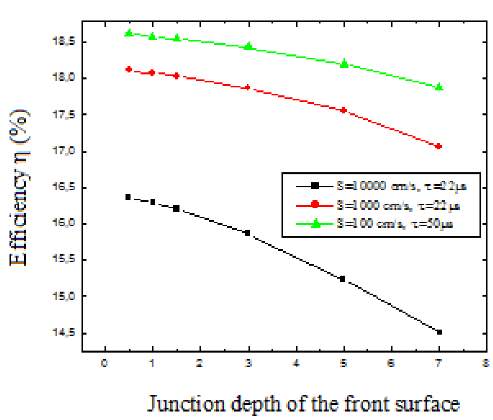

Fig.5. Effect of junction depth of the front surface layer (FSF) on the efficiency the of IBC-SHJ solar cell

We note that increasing the junction depth of front surface layer decreases the efficiency and again the efficiency variations are even more sensitive than the surface recombination velocity is high.

3.4 The influence of doping and the thickness of the rear face on the performance of a solar cell IBC

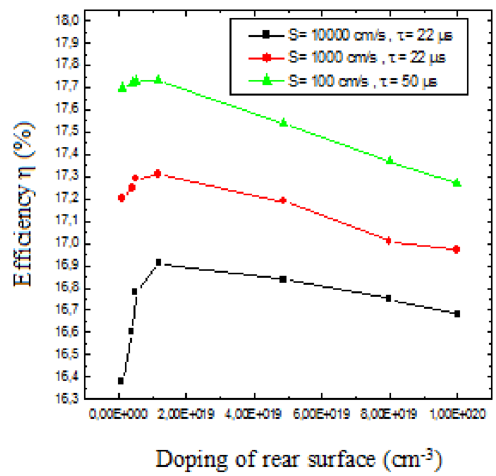

Fig.6. Influence of doping the rear surface layer on the efficiency of a (IBC-SHJ) solar cells

It can be said that this curve clearly shows the influence of the (c-Si(p)/a-Si:H(n)) heterojunction of the solar cell back to the three different values of recombination velocity on the rear face.

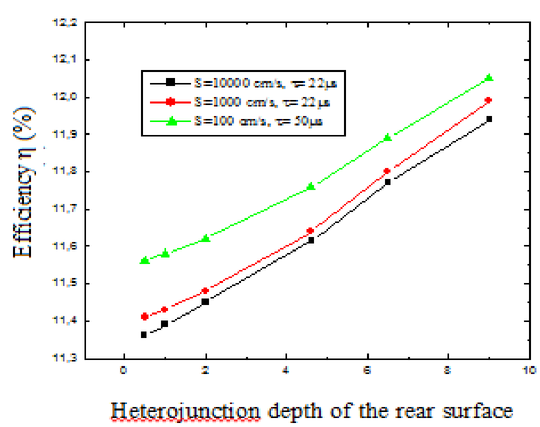

Fig.7. Effect of heterojunction depth of the rear surface layer on the efficiency the of IBC-SHJ solar cell

We note here that an increase in the thickness of the rear junction enhances the efficiency, and here in parallel with the increase in the recombination velocity.

4 Conclusion

In this paper, a one-dimensional simulation of interdigitated back-contact heterojunction silicon solar cell IBC-SHJ solar cells has been established by using PC1D. Optimizations of IBC-SHJ solar cells were then discussed. the efficiency curves observed in experiments were simulated, and three methods to improve efficiency (i) decreased thickness of front surface layer and decrease front surface recombination velocity, (ii) increased doping (conductivity), and (iii) increase thickness of rear surface .Finally, estimation of the potential efficiency of the IBC-SHJ structure is addressed, and an efficiency of 19.75% for IBC-SHJ solar cells is potentially achievable.

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References

[1] P.J. Cousins, D.D. Smith, L. Hsin-Chiao, J .Manning, T.D. Dennis, Waldhauer a et al. Generation 3: Improved performance at lower cost. Conference records of the 35th IEEE Photovoltaic Specialists Conference, Hawai,USA 2010; 275-278

[2] M. Lu, S. Bowden, U.Das, R. Birkmire, "*Interdigitated back contact silicon heterojunction solar cell and the effect of front surface passivation.* ", Appl. Phys. Lett. 2007; 91: 063507-3

[3] U.K. Das, M. Burrows, M. Lu, S. Bowden and R.W.Birkmire, "*Surface passivation and heterojunction cells on Si (100) and (111) wafers using dc and rf plasma deposited Si:H thin films*", Appl. Phys. Lett. 92, 2008 p.063504.

[4] M.J. Kerr, J.S. chmidt, A.Cuevas,"*Study of Tandem-Junction, Front-Surface-Field, and Interdigitated Back Contact Solar Cells* "Appl Phys., 80, no.7, 3821-3826(2001).

[5] J.G.Fossum, A.Neugroschel, F.A.Lindholm, «*A Unifying Study of Tandem-Junction, Front-Surface-Field, and Interdigitated Back Contact Solar Cells*», 1980.

[6] Rapport D'activité du GER-PV Strassbourg, «*Simulation D'une Cellule à Contacts arrière », 1998-1999.*

[7] *A.. Martinez-Gil, R.. Boubadia, « Conception et Technologie des Cellules Solaires Interdigités »,Projet de Fin d'Etudes de l'Institut National des Sciences Appliquées de Lyon* 2000-2001.