Int. J. Nanoelectronics and Materials **9** (2016) 85-92

Effects of the ambient temperature and the defect density on the performance the solar cell (HIT)

Bouzaki Mohammed Moustafa[1,*], Benyoucef Boumediene[1], Benouaz Tayeb[1], Benhamou Amina[2], Soufi Aicha[1], Chadel Meriem[1], Maamar Hicham[1]

[1]*URMER, Department of Physics, Faculty of Science, University of Tlemcen, BP. 119, Tlemcen, Algeria*
[2]*Department of Physics, Faculty of Science, University of Boumerdess, Boumerdess, Algeria*

Received 31 Dec. 2014; Revised 4 March 2015; Accepted 2 April 2015

Abstract

The ambient temperature and the defects density in the Hetero-junction with Intrinsic Thin layers solar cells (HIT) strongly influence their performances. In the first part, we presents the band diagram on the front/back simulated solar cell based on a-Si: H / c-Si (p)/a-Si:h. In second part, we modele the following layers structure: ZnO/a-Si:H(n)/a-Si:H(i)/c-Si(p)/a-Si:H(p)/Ag where we study the effect of the ambient temperature and the defects density in the gap of the crystalline silicon layer on the performance of the heterojunction solar cell with intrinsic layer (HIT).

Keywords: Heterojunction solar cell; Solar cell performance; Bands diagram; Ambient temperature; Defect density.

1. Introduction

The heterojunction solar cells (HJ) are obtained by joining two materials with different energy gap (E_g). HJ was first studied in 1974 by Fuhs et al[1] in 1983 the first heterojunction solar cell was fabricated [2-3].

The heterojunction a-Si:H/c-Si is formed by depositing the hydrogenated amorphous silicon on the substrate of the crystalline silicon. The resulting cells can achieve high conversion efficiencies, while using methods for thin film silicon reduces the cost in comparison with the c-Si solar cells [4]. SANYO developed HIT with a very thin layer of intrinsic hydrogenated amorphous silicon (a-Si: H(i)) which is inserted between two layers of a-Si: H(p) and c-Si (n). However, most researchers focus on the use of HIT solar cells with a substrate c-Si(p). This is motivated by the fact that the cost of the c-Si(p) wafer is significantly lower than the cost of c-Si (n) on one hand and that the microelectronic industries widely use p-type wafer for manufacturing devices, on the other hand [5-7].

Today, Sanyo is the market leader in the mass production of HIT modules. They hold, since 2011, the laboratory world record efficiency of 23.7% at 100.4cm, with a V_{OC} of 745mV, J_{SC} of 39.4mA/cm^2 and FF equal to 80.9% [8-9].

[*]) For Correspondence;E-mail: bouzaki_physique1@yahoo.fr

In addition, Sanyo has also achieved very high yields in production: 20% efficiency at the cell level and18.3%at the module level [10-11].

2. Description of the electric model

The Poisson the transport equations for electrons and holes are solved in one dimension.

$$\frac{\varepsilon_0 \varepsilon_r}{q}\frac{\partial^2 \psi(x)}{\partial x^2} = p(x) - n(x) + N_D - N_A + \sum_{defaut} \rho_t(x)$$
$$-\frac{1}{q}\frac{\partial j_n(x)}{\partial x} = G_n(x) - R_n(x) \quad (1)$$
$$\frac{1}{q}\frac{\partial j_p(x)}{\partial x} = G_p(x) - R_p(x)$$

The electron density n, the hole density p, and the electric potential represent the independent variables for which the system of equations is solved. (The meaning of the other variables is such as x denotes the position in the device, q the electron charge, $\varepsilon_0 and\ \varepsilon_r$ the absolute and relative dielectric constants, respectively, R the recombination rate , G the generation rate of electrons and holes, J_p and J_n the current density of the electrons and holes). $N_{D/A}$ are the concentrations of donors/acceptors, that are assumed to be completely ionized.

The current $j_{n,p}$ electron/hole are caused by the gradient of the respective quasi Fermi energy $E_{Fn/p}$. In the portion of a semiconductor, it is equivalent to the sum of the diffusion and drift current with a corresponding mobility $\mu_{n,p}$

$$j_n(x) = q\mu_n n(x)\frac{\partial E_{Fn}(x)}{\partial x} = -\frac{\mu_n kT}{q}\frac{\partial n(x)}{\partial x} + \mu_n n(x)\frac{\partial \varphi(x)}{\partial x} \quad (2)$$
$$j_p(x) = q\mu_p p(x)\frac{\partial E_{Fp}(x)}{\partial x} = -\frac{\mu_p kT}{q}\frac{\partial p(x)}{\partial x} - \mu_p p(x)\frac{\partial \varphi(x)}{\partial x} \quad (3)$$

3. Solar cell's structure

In this section, we utilized the parameters presented by Bouzaki et al [12] to build a heterojunction of silicon solar cell. This allowed us to study the evolution of its performance based on the parameters of the defects density and depending on the ambient temperature. The first structure is constituted of the following layers (Fig.1).

1. A layer of hydrogenated amorphous silicon n-type (a-Si: H (n)) " emitter".
2. An intrinsic layer of hydrogenated amorphous silicon (a- Si: H (i)) .
3. A crystalline layer of p-type silicon (c-Si (p)) "absorber ".
4. A layer of hydrogenated amorphous silicon p-type (a -Si: H (n)) " BSF ".

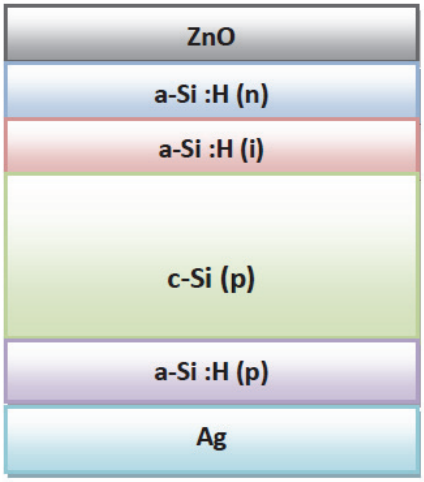

Fig.1: Schematic structure of the simulated solar cell [12]

The crystalline silicon p-type is selected with a doping of 10^{16} cm^{-3} and a thickness of 300 µm. We define a point defect in the middle of the gap so that it is very effective (Fig.2).

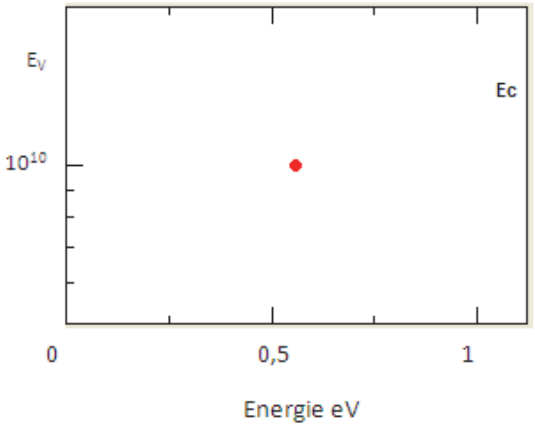

Fig.2: The defect density in the gap of c-Si [12]

We then need to define the parameters for amorphous silicon hydrogenated thin film. The gap of this material may vary between 1.55eV and 2.10eV, but the standard valueis1.74eV at 300K. Electron mobility was taken $20cm^2.V\text{-}^1.s^{-1}$ and that for holes $5cm^2.V\text{-}^1.s\text{-}1$.

Two densities of states of donor type (tail valence band and Gaussian deep states) and two types accept or densities (tail conduction band and Gaussian deep states) are defined. The densities statements edge of conduction band and valence are taken equal to those of crystalline silicon $Nc \approx Nv \approx 10^{21} cm^{-3}$.

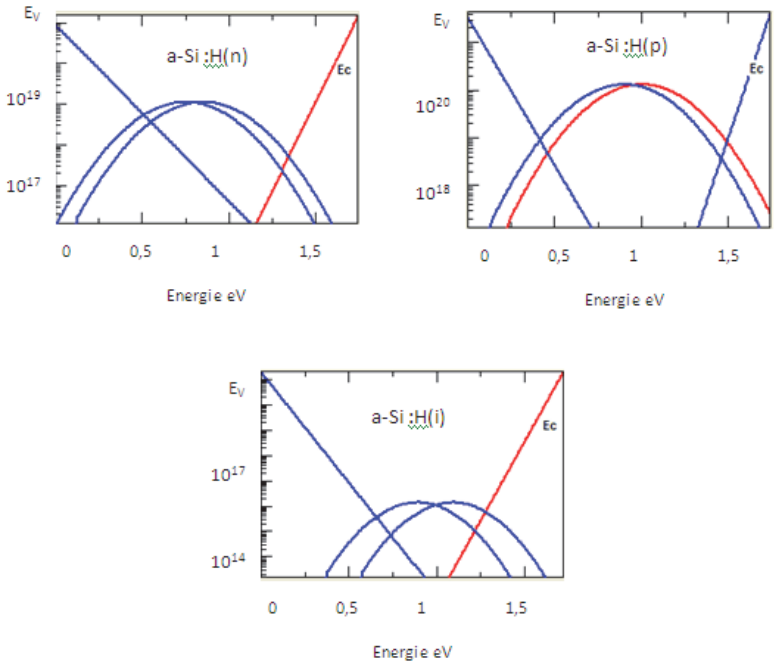

Fig.3: The distribution of the density of defects in the gap of different types of a-Si: H [12]
The parameters for the four layers of the cell are given in [12, 13, 14].

4. Results and discussion

4.1 Bands diagram

The energy gap difference between the c-Si (E_{g1}) and a-Si:H (E_{g2}) causes discontinuities "Band Offsets" in the valence band (ΔE_v) and conduction (ΔEc). These discontinuities affect the potential barriers (V_{bn}) and (V_{bp}) on either side of the junction. They therefore increase the diffusion potential (V_d) of the junction a-Si: H / c-Si compared to a conventional homo-junction. However, they also impose certain limitations on the collection of the carriers according to the discontinuities distribution [15].

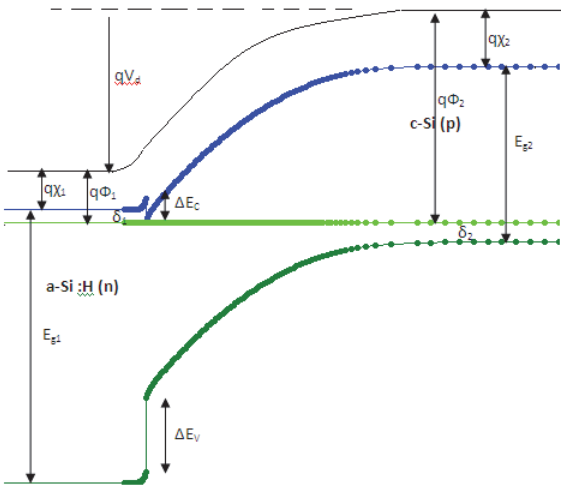

Fig.4: Diagram of the bands on the front face a-Si: H/ a-Si (p).

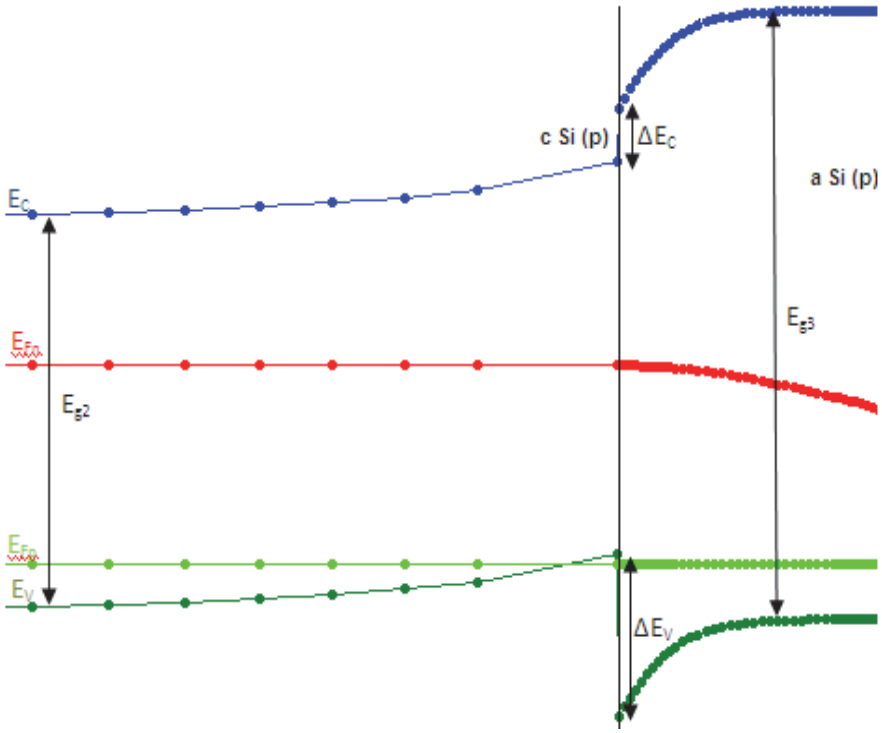

Fig.5: Diagram of the cell bands in rear face c-Si (p) / a-Si: H(p).

4.2 The characteristic J (V)

Fig.6 shows the simulation results for the characteristic current density-voltage under illumination (AM1.5) at 300K. Our cell gives good results: an V_{OC} of 743.1mV, J_{SC} of 38.21mA/cm^2, FF 82.6% and η of 23.45%.

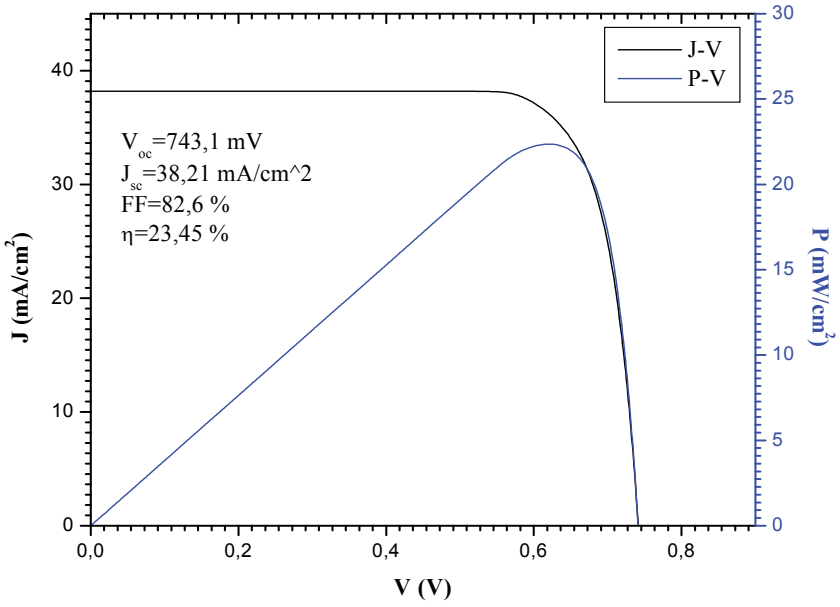

Fig.6: J-V and P-V

4.3 The influence of temperature

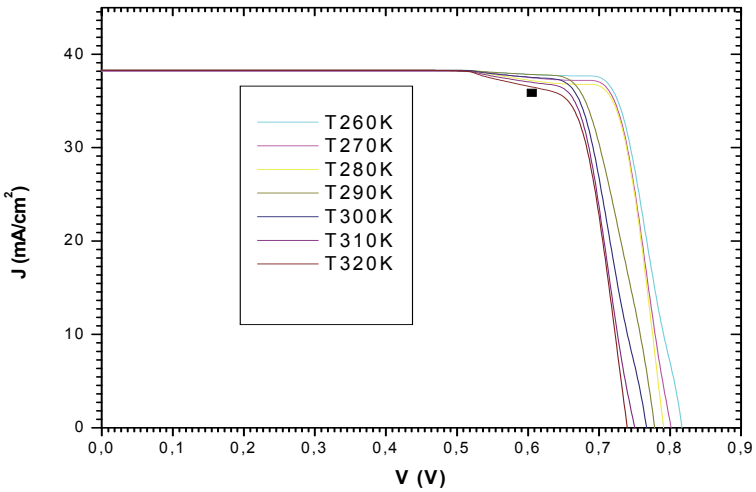

Fig.7: Influence of the ambient temperature on the characteristic J-V

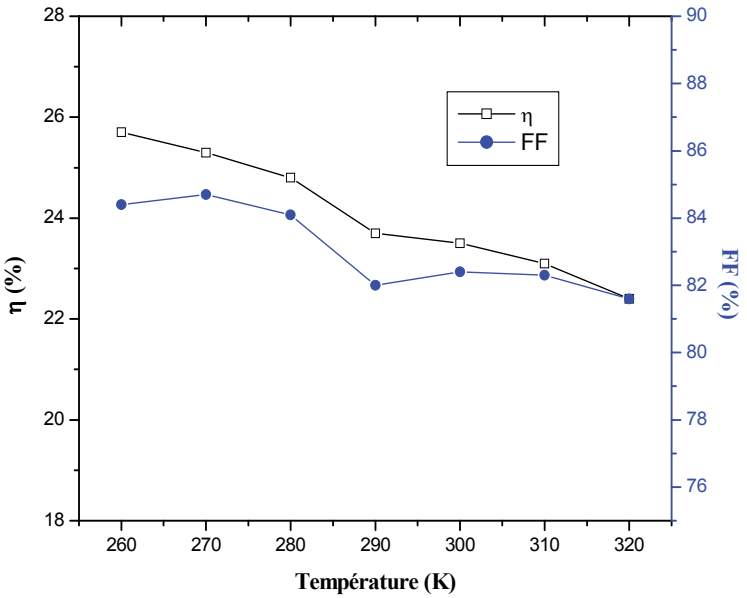

Fig.8: Influence of the ambient temperature on FF and η

From the two figures above, we can see that with the increase of the cell temperature, the open circuit voltage decreases. The same goes for FF and η.

4.4 Effect of the defects density

Fig.9 shows that the cell performance strongly depends on the density of defects in the gap of the absorber. The increase in the density of states for these defects leads to a decrease of Voc, Jsc, FF and η.

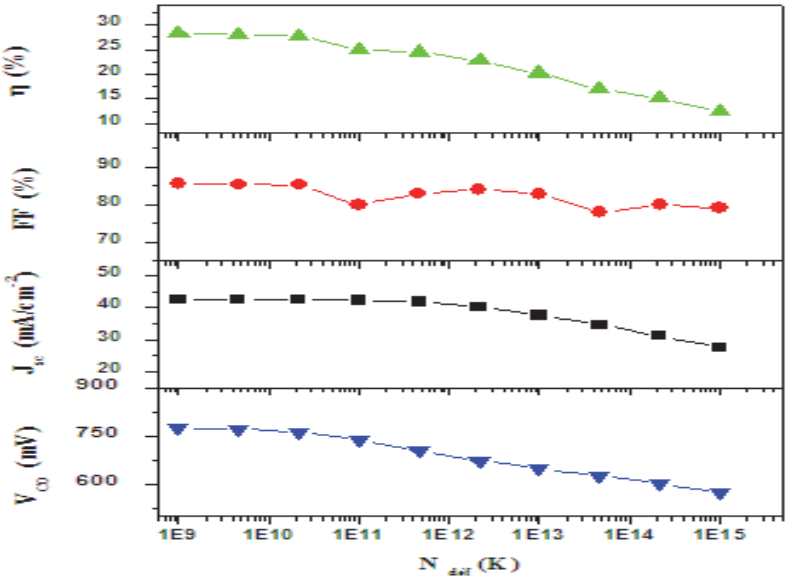

Fig.9: Variation in cell performance as function of the defects density in the gap of c-Si

5. Conclusion

The effects of the ambient temperature and the defects density in the Hetero-junction with Intrinsic Thin layers solar cells (HIT) have been studied. It is shown that, the performances of the solar cell were influenced with variation in ambient temperature and also in defects density. A record efficiency of 25,7% could be obtained. Relevant parameters values are V_{OC} (790mV), J_{SC} (43mA/cm^2) and FF of 85%.

References

[1] W. Fuhs, K. Niemann, et J. Stuke, AIP Conference proceedings, **20** (1974) 345-350.
[2] K. Okuda, H. Okamoto, Y. hamakawa, Japanese Journal of applied Physics Jpn.J.Appl.Phys. **22** (1983) 605-607
[3] Y. Hamakawa, K. Fujimoto, K. Okuda, Applied Physics Letters, **43** (1983) 644-646
[4] J. Coignus, M. Baudrit, J. Singer, R. Lachaume, D. Muñoz, P. Thony, Energy Procedia **8** (2011) 174–179.
[5] L. Zhao, H.L. Li, C.L. Zhou, H.W. Diao, W.J Wang, Solar Energy **83** (2009) 812–816.
[6] L. Zhao, C.L.Li, Solar Energy Materials & Solar Cells **92** (2008) 673-681.
[7] N. Dwivedi, S. Kumar, A. Bist, K. Patel, S. Sudhakar, Solar Energy **88** (2013) 31-41.
[8] SANYO Electric Co. Ltd, Press release, May 2009.
[9] T. Kinoshita, D. Fujishima, A. Yano et al, 26th European Photovoltaic Solar Energy Conference and Exhibition, Hamburg (Germany), (2011) 871-874
[10] N. Nakamura, M.ouchi, K. Ibi, 26th European Photovoltaic solar Energy conference and Exhibition, Hamburg (Germany), (2011) 2194-2197.

[11] HIT photovoltaic module (September 2012). http://panasonic.net/energy/solar/hit/
[12] M. M. Bouzaki, B. Benyoucef, International Journal of Computer Applications **80** (2013) 0975 – 8887
[13] B. G. Rasheed, H. G. Rashid, Y. Z. Dawood, A. T. Hassan, Int. J. Nanoelectronics and Materials, **6** (2013) 97-104
[14] R. A. Swady, Int. J. Namoelectronics and Materials, **4** (2011) 59
[15] Fantoni, Y. Vigranenko, M. Fernandes, R. Schwarz, M. Vieira, Thin Solid Films, **383** (2001) 314-317