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A COMPARATIVE STUDY BETWEEN CONVENTIONAL AND BSF SOLAR CELLS TO GAUGE THE EFFICIENCY FACTOR

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ABSTRACT
Solar cell is a device that converts solar energy directly into electrical energy. This paper explains the basic working principle of a solar cell. Its performance is studied analytically through fundamental device equations. The objective of this paper is to explain the operation of a silicon p-n junction solar cell and study its performance analytically with particular reference to the Back Surface Field (BSF) solar cell. The improved performance of a back surface solar cell as compared to a conventional solar cell has been elucidated.

KEYWORDS: fill factor (FF), Back Surface Field (BSF), minority carriers, short circuit current, p-n Junction

INTRODUCTION

Silicon solar cells have been a topic of immense interest and investigation during the past few decades (Reference [1], [2], [3], [4], [6]). The Silicon solar or photovoltaic (PV) industry has consistently maintained healthy growth rates over last 15 years (Reference [7]). Rising oil prices and depleting fossil fuels has led to increase in research and development of non-conventional sources of energy around the world. Solar energy is huge in supply, non-polluting, non-hazardous (unlike nuclear energy) and suitable for rural places not connected by power transmission lines. If the growth rates are maintained, conservative estimates indicate that PV market will reach ~ 100 GWp/year before the year 2020 (solarbuzz website, 2008). The paper explains the operation of a silicon p-n junction solar cell and studies its performance analytically with particular reference to Back Surface Field (BSF) solar cells. Fundamental equations pertaining to solar cell, electric current and electronics have been studied analytically. The theoretical calculations have been done and graphs plotted.

METHODOLOGY

The insertion of a p^+ layer at the back of a conventional solar cell gives a BSF solar cell (Reference [8], [9]). Light falls on the front surface and it is absorbed throughout the cell, as a result of which electron-hole pairs are created in the thin front region of the cell, the wide base region and also in the depletion region region of the cell. At the junction of the solar cell, in the space-charge region, a built-in field exists, which separates the electrons and holes so that move in opposite directions and gives rise to the open-circuit voltage. If the two terminals of the cell are connected by a wire, a current flows through it, which is called the short circuit current of the cell.

If I_m and V_m be the current and voltage respectively at the maximum power Pm and I_{sc} and V_{oc} be the Short circuit current and open circuit voltage the the Fill Factor (FF) is defined as

$$FF = I_m V_m / I_{sc} V_{oc} \quad ....(1)$$

The efficiency of a solar cell in converting light of any arbitrary spectral distribution into useful power is given by:

$$\eta = P_{output} / P_{input} \quad ....(2)$$

Where the input power is:

$$P_{input} = A_t \int [illegible] (\lambda) [illegible] \quad ....(3)$$

Where,
A_t is the total device area
F (λ) is the number of photons per cm2 per second incident on the device at wavelength λ
hc/λ is the energy carried by each photon.

$$P_{out} = V_m I_m = FF V_{oc} I_{sc} \quad ....(4)$$

The generation rate of electron-hole pairs at a distance x from the semiconducrtor surface is given by,

$$G(\lambda, x) = \alpha(\lambda) F(\lambda) [1-R(\lambda)] \exp[-\alpha(\lambda) x] \quad ....(5)$$

Where,
α (λ) is the absorption coefficient
R (λ) is the fraction of photons reflected from the surface.
The one dimensional steady state continuity equations are:
For electrons in p-type semiconductor,

$$Gn- [illegible] + [illegible] = 0 \quad ....(6)$$

For holes in n-type semiconductor,

Gp- - $\frac{\ }{}$ + $\frac{\ }{}$ = 0 ....(7)

The current density equations are:

J_n = qµn n_p E + q D_n — ....(8)

J_p = qµn n_p E + q D_n — ....(9)

For an abrupt p-n junction with constant doping on each side of the junction, there is no electric field in the bulk of the region. Combining these equations, the following differential equations are obtained:

D_p — + α F (1-R) exp (-αx) - - — = 0 ....(10)

D_n — + α F (1-R) exp (-αx) - - — = 0 ....(11)

Where
τ_n and τ_p are the lifetimes and Dn and Dp are the diffusion constants of electrons and holes respectively.

The general solution equations (10) and (11) are:

p_n-p_{no} = C_1 cos h C_2 sin h [— —] exp (-αx) ....(12)

n_p-n_{po} = C_3 cos h C_4 sin h [— —] exp (-αx) ....(13)

where L_p = $\sqrt{\ }$ and Ln = $\sqrt{\ }$ are the diffusion constants

C_1, C_2, C_3, C_4 are constants which can be determined from the boundary conditions at the different surfaces.

The boundary conditions in a BSF cell are calculated as under:

1. At the surface (x = 0)

   D_p — = Sp (p_n- p_{no}) ....(14)

2. At the depletion layer edge (x = ω)

   p_n- p_{no} = 0 ....(15)

   n_p- n_{po} = 0 ....(16)

3. At the back surface (x = 0)

   S_n (n_p- n_{po}) = - D_n — ....(17)

Where S_n is the back surface recombination velocity. Using the boundary conditions, the values of the constants C_1, C_2, C_3, C_4 are obtained.

The photocurrents due to holes and electrons can bre calculated using the following equation at x = w:

J_n = q D_n — ....(18)

J_p = - q D_n — ....(19)

For ordinary doping concentrations, Einstein's relation is valid:

$$\frac{D_p}{\mu_p} = \frac{D_n}{\mu_n} = \frac{kT}{q}$$ ....(20)

RESULTS AND DISCUSSIONS:

The values of Relative Photo current Jn for Spp+ = 0 Spp+ = ∞ have been given in the table 1.

Absorption Coefficienta(l)	10	100	1000	10000	100000
Relative Photo current Jn for Spp+ = 0	0.05	0.35	0.8	0.62	0.3
Relative Photo current Jn for S_{pp}+ = ∞	0.1	0.65	0.98	0.62	0.3

Table 1: The values of Relative Photo current Jn for Spp+ = 0 Spp+ = ∞

Figure 1 shows the relative photocurrent as a function of absorption coefficient for the two extreme values of the back surface recombination velocities S_{pp+} = 0 and S_{pp+} = ∞. It is observed that the two curves coincide for higher values of absorption coefficient. This can be explained by observing the fact that shorter wavelength, which correspond to higher values of α, are observed very near the front surface. As the back surface is far from this surface, the back surface recombination velocity S_{pp+} will have negligible effect on these carriers. At lower values of α there is significant increase in the photocurrent for a cell having S_{pp+} = 0 as compared to S_{pp+} = ∞.

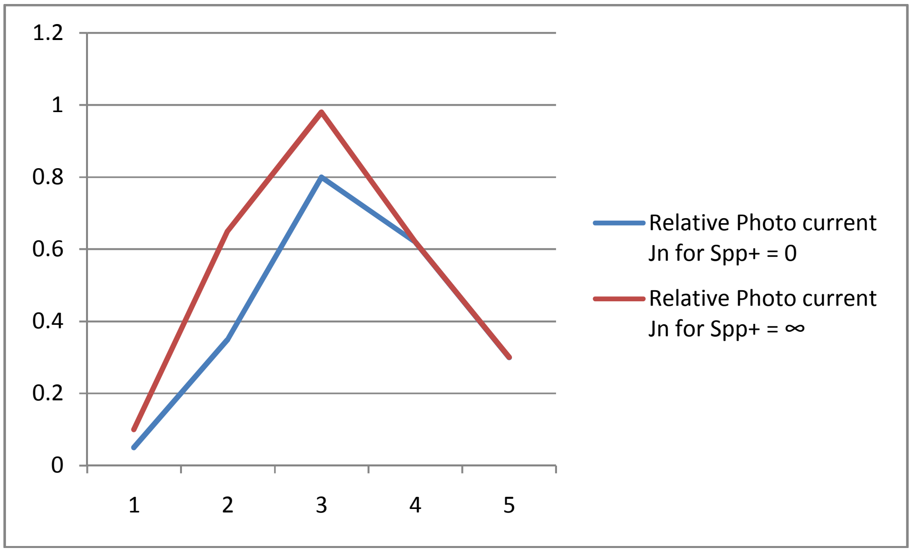

Figure 1: Relative Photo current Jn for two extreme values of Back surface Recombination Velocity.

CONCLUSIONS

The photocurrent in a BSF solar cell is significantly larger as compared to the conventional solar cell, which has been attributed to the presence of low-high junction in a BSF cell. This junction decreases the effective back surface recombination velocity of the minority carriers giving a larger value to photocurrent in a BSF cell.

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