Analysis of Crystalline Solar cell using Drift diffusion Model & P-V Analyzer

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ABSTRACT

Solar cell efficiency is defined as the portion of energy in the form of sunlight that can be converted via photovoltaic into electricity. The efficiency of the solar cells used in a photovoltaic system, in combination with latitude and climate, determines the annual energy output of the system. This paper involves the performance analysis of 1 –dimensional crystalline solar cell using drift diffusion model. In this we have simulated the graph of power spectral density versus wavelength through which the efficiency has been determined. Along with this we have also analyzed the current density & doping density of solar cell for different bias voltage for single & multi junction solar cells

Keywords:Drift Diffusion model, Solar efficiency, PV Analyzer, Nano hub

I. INTRODUCTION

Photovoltaic solar cells convert the suns radiant light directly into electricity. With increasing demand for a clean energy source and the sun's potential as a free energy source, has made solar energy conversion as part of a mixture of renewable energy sources increasingly important. As a result, the demand for efficient solar cells, which convert sunlight directly into electricity, is growing faster than ever before. Solar cell constructed by crystalline silicon also known as solar grade silicon made from wafers for 160-240 micrometer thick. Silicon based devices are inexpensive due to compatible existing fabrication technology and availability of silicon in earth crust. The study of a photovoltaic system requires a precise knowledge of the IV and PV characteristic curves, the learning of the curves permits IV and PV characteristic curves allow knowing the function of the cell [1] used

II. Solar cell I-V characteristics

With the solar cell open-circuited that is not connected to any load the current will be at its minimum (zero) and the voltage across the cell is at its maximum, known as the solar cells open circuit voltage, or Voc. At the other extreme, when the solar cell is short circuited, that is the positive and negative leads connected together, the voltage across the cell is at its minimum (zero) but the current flowing out of the cell reaches its maximum, known as the solar cells short circuit current, or Isc.

The point at which the cell generates maximum electrical power and this is shown at the.top right area of the green rectangle. This is the"maximum power point" or MPP in Fig.1.

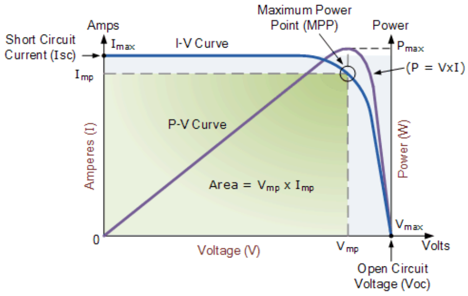

Fig.1 Solar Cell I-V Characteristics

[2] The biggest disadvantage of the solar cell is that the solar cells don't absorb all the light which is incident on them. It captures only the UV portion of the sunlight i.e. only 4-10% of the solar light incident. Therefore, to increase the solar energy conversion efficiency the absorption should be extended to visible and IR region also. This is done with the help of depositing nano particles (nano metals) on the silicon surface. Silicon itself is less efficient because its band gap is less so to improve the capture range nano metals are deposited on the silicon substrate by using hot carrier cells and multiple junction solar cell.

III. Drift diffusion model of solar cell

The drift diffusion model involves the self-consistent solution Poisson & continuity equation. The semiconductor devices and their characteristics can be described in a better way using a simple model called as a Drift diffusion model. This model assumes certain conditions and some basic variables related to the semiconductors and analyze its behavior using certain equations as mentioned below. The assumptions of drift diffusion model are: Full ionization: all dopants are assumed to be ionized, Non-degenerate: The Fermi energy is assumed to be at least 3 kT below/above the conduction/valence band edge, Steady state: All variables are independent of time, Constant temperature: The temperature is constant throughout the device. The ten variables taken in to consideration are ρ the charge density,

n the electron density, p the hole density, E the electric field, ϕ the potential, E_i, the intrinsic energy, F_n the electron quasi-Fermi energy,F_p the hole quasi-Fermi energy, J_n the electron current density , J_p the hole current density.

Charge density equation

$$\rho = q(p - n + N_d^+ - N_a^-)$$

Electric field and potential equations

$$\frac{d\mathcal{E}}{dx} = \frac{\rho}{\varepsilon}\,\frac{d\phi}{dx} = -\mathcal{E}\,\frac{dE_i}{dx} = q\mathcal{E}$$

Carrier density equations

$$n = n_i e^{(F_n - E_i)/kT} \quad p = n_i e^{(E_i - F_p)/kT}$$

Drift and diffusion current equations

$$J_n = qn\mu_n\mathcal{E} + qD_n\frac{dn}{dx}\; J_p = qp\mu_p\mathcal{E} - qD_p\frac{dp}{dx}$$

A. Solar Spectra

AM (Air Mass) is the optical thickness of Earth's atmosphere. In the top of the Earth's atmosphere, sunlight penetrates zero atmospheric thickness. Here the solar spectrum is AM0. Spectrum that is absorbed and scattered after sunlight vertical penetrates atmospheric (1 unit atmospheric thickness) is AM1. The ground application's solar cell optical design usually takes AM1.5 standards, space application taking AM0 as standard. In this work the values of Jsc, Voc, Eff, Jopt and Vopt are obtained for single and multijunction crystalline solar cells for the structure with thickness of n layer & p layer is 0.1 µm & 10 µm respectively and bias voltage =0.65 V & 08.Vin

Fig. 2.

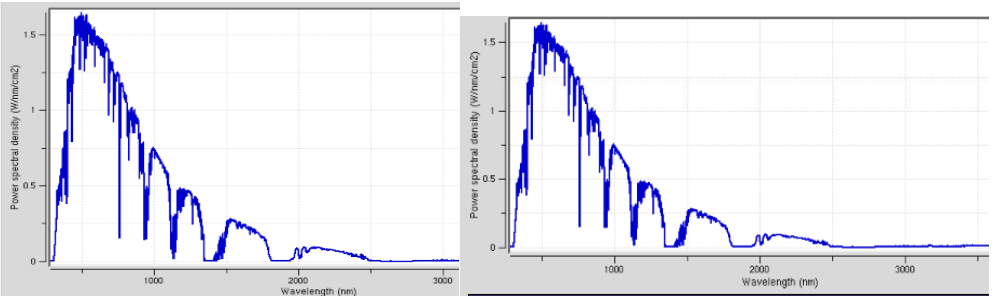

Fig 2 : Power spectral density for bias voltage 0.65 & 8 volt

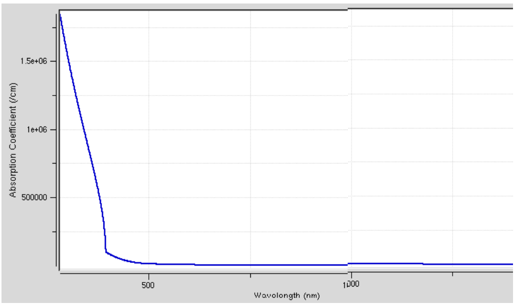

Fig 3 Silicon Absorption coefficient versus wavelength

Silicon absorption coefficient also decreases with increases in wavelength at room temperature as shown in figure 3 For the bias voltage of 0.65 V applied to junction of crystalline solar cell, the variation in the power spectral density with the wavelength is as shown in the Table 1. It can be observed from the graph that the power spectral density decreases with the increase in wavelength & finally it becomes zero.

Table 1: - Power spectral density versus wavelength (bias voltage 0.65)

Power Spectral Density Watt/nm/cm^2	Wavelength Nm
1.6173	481
1.6485	495
0.91546	867
0.73227	990
0.55573	1094

Table 2. Current density & power density for different bias voltages

Bias Voltage=0.8 V			Bias Voltage=0.9 V			Bias Voltage=1 V		
Voltage(V)	Power Density(W/cm2)	Current density	Voltage(V)	Power Density (W/cm2)	Current density	Voltage(V)	Power Density(W/cm2)	Current
0.2	-0.00925	-0.05	0.2	-0.009	-0	0.2	-0.008	0.046
0.4	-0.01825	-0.05	0.4	-0.017	-0	0.4	-0.018	0.046
0.6	0.103	0.17	0.6	0.013	0.1	0.6	0.0103	0.172
0.7	0.103	0.17	0.7	7.25	10	0.7	7.256	10.37
0.8	0.103	0.17	0.8	307.3	384	0.8	307	384.2
0.85	0.103	0.17	0.85	570	696	0.85	994.2	4013

Table 2 is obtained by simulation of crystalline solar cell. We obtained the values of power density & current density for various bias voltage from power density versus voltage & current density versus voltage characteristics. For bias voltage power density & current density is constant after 0.6 v but as we increase the bias voltage power density increases by increasing voltage

V. Thermodynamic Efficiency limit of solar cell

Thermodynamic efficiency limit is the absolute maximum theoretically possible conversion of sunlight to electricity.

Light does not enter through all the regions of the structure as metal contacts exist to tap the current from the solar cell and these contacts prevent the light from entering through them. Shadowing effect of the metal contact has been used which plays an important role in the calculation of the efficiency of solar cell as it is one of the factors that determines the number of effective photons contributing to the generation of electron hole pairs in the device. This effect tends to reduce the efficiency as some of the carriers are lost even before entering the structure [3] There are several factors which affects the efficiency of solar cell such as cell temperature, band gap energy, recombination lifetime, light intensity, doping intensity & profile, sheet resistance, metal grid & optical reflection, energy conversion efficiency, solar irradiance [4]. In order to achieve high energy efficiency, it is desirable to increase Isc or high collection efficiency, high Voc or low dark current & high fill factor or a sharp corner in I-V curve.

$$\eta = \frac{P_m}{P_{in}} = \frac{V_{oc} \times I_{sc} \times FF}{\text{incident solar power}}$$

Table 3 Density versus voltage for single & multi junction solar cell

Single Junction		Multi Junction	
Voltage	Jopt	voltage	Jopt
0.613	35.82	0.613	35.82
0.5	35.82	0.5	35.82
0.75	35.819	0.75	35.89
1	34.4	1	34.61

Table 4 Various parameters for single & multi junction solar cell

Single Junction		Multi Junction	
Jsc	35.82 mA/cm2	Jsc	16.7934
Voc	1.0240 V	Voc	3.3473
EFF	32.45%	EFF	50.2607
Jopt	34.86 mA/cm2	Jopt	16.38 mA/cm2
Vopt	0.9310 V	Vopt	3.0601

By using PV thermodynamic calculator we obtained the solar spectrum AM 1.5 G at sun temperature of 5778 K & device temperature of 300 k& We also obtained various parameters of single &multijunction solar cell which also affects the efficiency of solar cell as given in table 3 & 4

VI. PV Analyzer

PV analyzer extract compact model parameters from given data PV Analyzer is a tool for rapid data analysis and parameter extraction from solar cell measurements. Current version analyzes the dark current-voltage (IV) characteristics of solar cells to extract the diode and shunt current parameters. Large area solar cells have a significant parasitic conduction due to parallel shunt paths. In thin film cells in particular these shunt currents are non-ohmic and symmetric with voltage. The shunt and diode current components are also separated by this PV analyzer and then uses separate equations to fit the two current components. This separation and fitting method yields parameter values which are free from fluctuations due to parasitic and can be related to physical processes in the device. Multiple IV data can also have analyzed by this tool at once, and all the data as well as fit parameters can be downloaded as text files for further analysis.

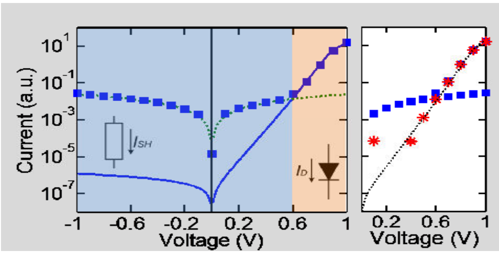

Fig 4: Typical dark IV characteristics of thin solar cell showing diode (solid line) & shunt (dotted line current) dominated regimes .Using the symmetry of shunt current the forward diode current can be obtained (stars)

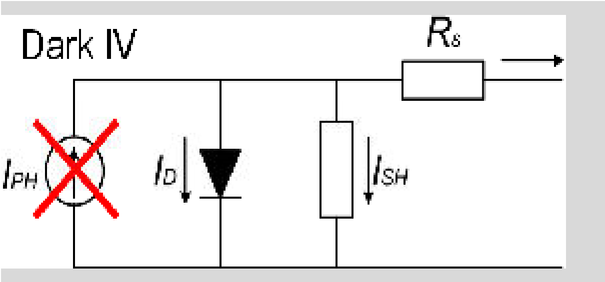

Fig. Equivalent diagram of dark current showing diode current I_D& non-ohmic shunt current I_{SH}

$$I_D \approx I_0 e^{(V - I_D R_S) / n(k_B T/q)}$$

$$I_{SH} \approx G_{SH} V + I_{0SH} V^{n_{SH}}$$

The various parametes such as short current ,voltage ,fill factor,maximum power point depends upon type of PV modules we used[5]

VI. RESULT & CONCLUSION

The efficiency of the crystalline solar cell is calculated using thermodynamic calculator of nanohub software for various values of the parameter.

Table 5 Solar efficiency versus doping mobility

Electron doping mobility minimum (cm^2/Vs)	Electron doping mobility maximum (cm^2/Vs)	Solar efficiency
80	1600	25.40%
80	1400	25.60%
80	1200	25.70%
80	1000	26%
80	500	26.50%

The parameter which waas taken in to consideration is range of electron doping mobility and its effect on efficiency is as shown in Table . The maximum efficiency of 26.50% was achieved for the range of electron doping mobility from 80 to 500 cm^2/Vs.Solar illumination obtained for single &multijunction solar cell is given by table 6.From the table it is clear solar illumination is better in multijunction solar cell than in single junction solar cell.

Junction	Solar illumination
Single junction solar cell	$Io=1000.6031W/m^2$
Multi junction solar cell	$Io=1000.3553W/m^2$

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