CERTAIN PARAMETERS FOR DESIGNING A SOLAR CELL

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ABSTRACT

The solar spectrum contains all wavelengths in the range starting from 25 0nm to 2500nm. The study of the solar spectrum was done using spectral response meter. For different wavelengths, current and power were measured. The graph of quantum efficiency vs. wavelength was plotted. The value of quantum efficiency obtained was in the range of 40% to 99%. Overall reduction of Quantum efficiency (QE) is due to recombination, transmission and low diffusion length.

Keywords -- Band gap, diffusion length, quantum efficiency, Solar Spectrum, Spectral Response

I. INTRODUCTION

For designing and developing a solar cell from new materials, for improving its performance by improving its efficiency, its key measurement is "spectral response" of a solar cell. Spectral response is basically sensitivity of cell to light of different wavelengths. It can be defined as measure of short circuit current per unit light power (A/W) [1, 2].

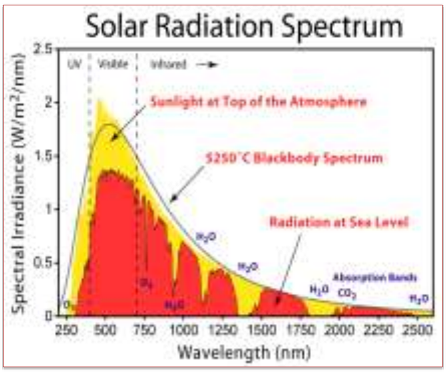


Fig. 1: Solar Radiation Spectrum

Solar radiation is the radiant energy emitted by the Sun. Fig 1 shows the solar radiation spectrum. The relevant radiation for the applications in solar power industries lies within ultra violet (200 to 390 nm), visible range (390 to 780 nm), near-infrared (780 to 4000 nm) and infrared (4000 to 100000 nm) [3].The electromagnetic radiation emitted by the sun covers a very large range of wave-length from radio waves through the infrared, visible and ultraviolet to X-rays and gamma rays. However, 99 percent of the energy of solar radiation is contained in the wavelength band from 0.15 to 4μm, comprising the near ultraviolet, visible and near infrared regions of the solar spectrum, with a maximum at about 0.5μm.

The variations actually observed in association with solar phenomena like sunspots, prominences and solar flares are mainly confined to the extreme ultraviolet end of the solar spectrum and to the radio waves. The contribution of these variations to the total energy emitted is extremely small and can be neglected.

Different methods were detected by Patker et.al [4] for florescence emission and excitation spectra and correction curves were presented. Solar cells based on a new conjugated donor polymer with C_{60} and C_{70} PCBM acceptors afford high quantum efficiencies over a broad spectral range into the near- infrared. The cells provide power conversion efficiencies of up to 4% under simulated AM1.5 G solar light conditions [5]. Martiin et. al [5, 6] tested the spectral response for efficient methanol. Neufeld et.al [7] got external quantum efficiency as high as 63% for III – nitride photovoltaic cells which were grown by metal- organic chemical vapor deposition on (0001) sapphire.

In this research work authors have used the spectral response meter to measure the short circuit current of the solar cell at selected wavelength over a broad range of wavelengths. For crystalline silicon cell, the wavelength is 350nm to 1100nm.To carry out the results, the standard equipment uses a broadband or filters to produce nearly monochromatic light and a device to record short circuit current gives spectral response of the cell. The parameter which highly affects the efficiency of the solar cell are open circuit voltage and short circuit current. High efficient solar cell can be used for utilization of solar energy even at night or in inadequate solar radiation conditions. For this purpose, the power generated by solar cells can be stored in battery backup and can be utilized for cooking, drying or for desalination of water. By using the sun tracker the efficiency can further be increased [8-11].

II. EXPERIMENTAL METHOD

Fig. 2: Spectral Response Meter

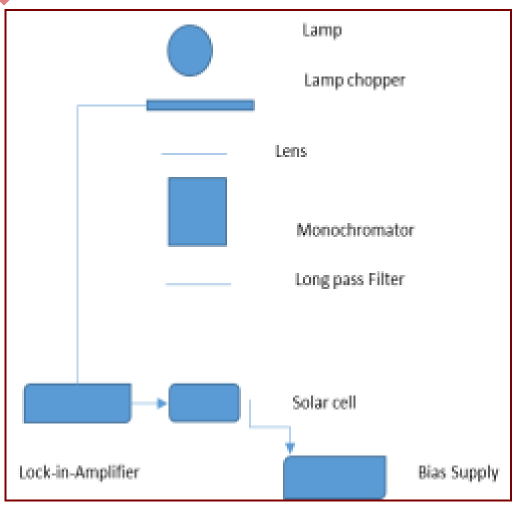


Fig. 3: Standard Arrangement of Spectral Response Meter

Figure 3 shows the standard arrangement for spectral response meter. At the top there is a broadband source which can be either halogen lamp or Xenon lamp followed by monochromator to select light of desired wavelength. In meter, a synthetic light source made up of 20 LEDs covering wavelength range from 360nm to 1060nm is required for measuring the spectral response of crystalline Silicon solar cell.

III. EQUATIONS

Equations (1) and (2) can be used to calculate Spectral Response (SR) and External Quantum Efficiency (η)

$$\text{Spectral Response (SR)} = I_{SC}(\lambda) / P(\lambda) \ \text{(A/W)} \quad (1)$$

$$\text{External Quantum Efficiency } (\eta) = \{ I_{SC}(\lambda) / e \} / \{ P(\lambda) / \hbar\omega \} \quad (2)$$

Specral Responce (SR) can be converted to EQE by equation (3)

$$EQE(\lambda) = 1.238\ [SR(\lambda) / \lambda] \quad \text{where } \lambda \text{ is in micron unit} \quad (3)$$

Similarly, EQE can be converted to SR by equation (4)

$$SR(\lambda) = 0.808\ \lambda\ [EQE(\lambda)] \quad (4)$$

Multiplying EQE (λ) with the solar flux at each λ, over interval λ to λ+Δ λ, and summing over the wavelength range of excitation of electrons in semiconductor, and from this we can find short circuit current density. From spectral responce one additional characteristics of solar cell can be derived i.e. internal quantum efficiency (IQE) provided the losses of light incedent on solar cell by reflection R(λ) and transmission T(λ) are determined. Equation (5) gives the relation between IQE and EQE.

$$IQE = EQE / [1-R(\lambda) - T(\lambda)] \quad (5)$$

The current is normalized with respect to light power versus wavelength spectral response of the cell. In this spectral response meter, the combination of broad band light source and monochromator is replaced by a synthetic source composed of light emitted diodes (LED) which covers the wavelength range from 360nm to 1060 nm. There are 20 LEDs mounted on the top of the spectral response meter on a holder which also accommodates the solar cell. Each LED emits light over a wavelength range about 20- 30 nm .Emission peak wavelengths of different LEDs are separated by about 40-60 nm. An LED of required wavelength can be selected by pushbuttons and the wavelength can be varied by doing so. A 20 mA constant current source was used to excite the light output from the selected LED. Power emitted by LED was measured by using a calibrated reference cell. By exciting the corresponding diode, the photo current was measured. A 10 ohm resistor was connected across the cell was used to develop voltage which was then amplified and digitalized by using an analog to digital converter and stored.

VI. RESULTS AND DISCUSSIONS

TABLE 1: Equipments required for performance of experiment

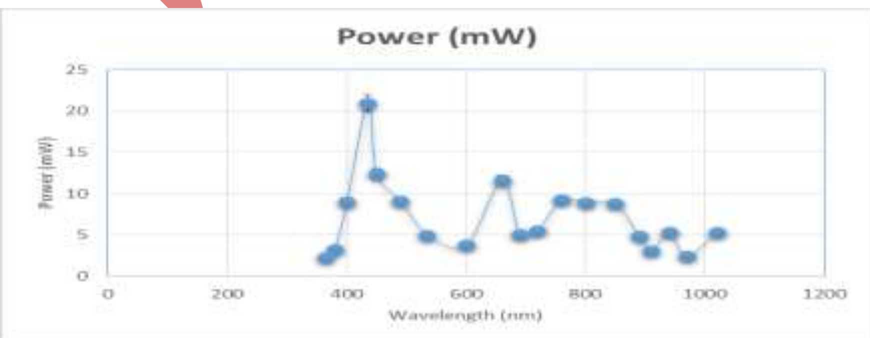
Sr.No	Unit	Description
1	Solar cell	4 x 4 cm^2 C- Si cell
2	Light source(20 LEDs)	360 nm to 1060 nm
3	constant current source	20 mA current flow through selected LED
4	Measurement of power emitted from each LED	Power emitted by each LED at 20 mA
5	Controller for selecting LED and recording short circuit current	LED wavelength, power and response current display

Table 1 shows the equipment required for performing the experiment for studying the spectral response of a solar cell along with their description. One standard crystalline solar cell was illuminated by Light emitting diodes which emitted power at 20 mA. Controller for selecting LED was used which also record short circuit current generated by solar cell.

TABLE 2: The quantum efficiency at different wavelength.

Wavelength (nm)	Power (mW)	Current (mA)	Energy of photon = $1.24/\lambda_g$ (* 10-17)	Quantum efficiency (%)
365	2.28	0.272	0.054	40.57
380	3.26	0.596	0.052	59.78
400	9.01	2.14	0.049	73.71
435	20.94	6.06	0.045	82.60
450	12.40	3.75	0.044	83.48
490	9.13	3.19	0.040	88.71
535	4.99	1.93	0.037	89.81
600	3.78	1.81	0.033	99.05
660	11.60	5.64	0.030	91.43
690	5.03	2.6	0.028	92.95
720	5.51	2.97	0.027	92.87
760	9.25	5.00	0.026	88.36
800	8.91	5.07	0.024	88.37
850	8.796	5.05	0.023	83.89
890	4.89	2.77	0.022	78.95
910	3.04	1.81	0.021	81.11
940	5.28	3.03	0.021	75.79
970	2.39	1.21	0.020	64.90
1020	5.29	2.15	0.019	49.46

Table 2 shows the quantum efficiency at different wavelength. Current and power were measured by spectral response meter and using these values of wavelengths their band gap energy and quantum efficiency were calculated. Figure 4 shows power vs. wavelength plot. The minimum power was 2.28 mW at 365 nm wavelength while the maximum power was 20.94 mW for 435 nm wavelength.



Fig, 4 : power vs. wavelength

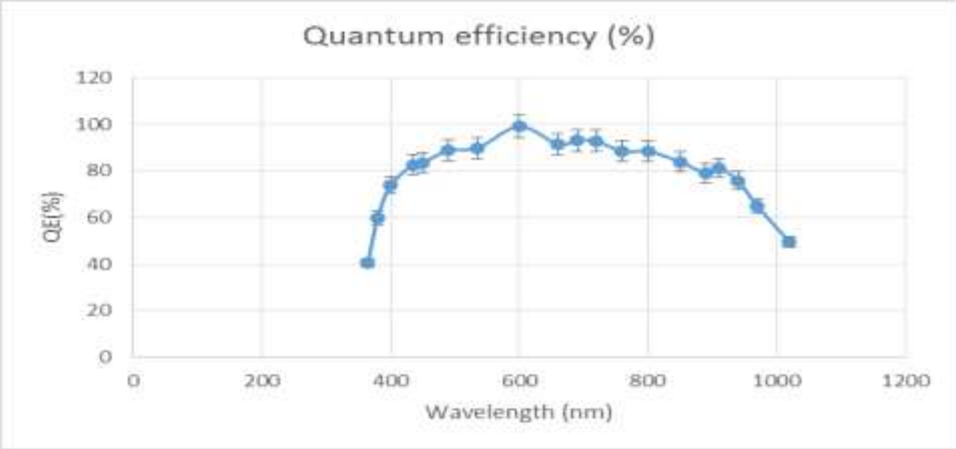


Fig. 5 : quantum efficiency vs. wavelength

Figure 5 shows quantum efficiency vs. wavelength. The crystalline Si starts to respond at about 1100 nm(band gap) and continuous to about 400 nm where it declines sharply. It is evident from figure 5 that the spectral response is directly related to the quantum efficiency. It is seen that EQE rises from nearly zero at 1100 nm, then it remains nearly constant and then falls below 400 nm.

V. CONCLUSION

Quantum efficiency (QE) reduces at short wavelengths due to surface recombination. Quantum efficiency also reduces at long wavelengths due to rear surface recombination, reduced absorption and low diffusion length. Overall reduction of Quantum efficiency (QE) is due to recombination, transmission and low diffusion length. Quantum efficiency (QE) is zero for wavelength longer than band gap. The value of quantum efficiency obtained was in the range of 40% to 99%. If the cell responds poorly at some wavelength, there may be either structural design or material property or fabrication process related problems. The performance of solar cell can be improved by studying its spectral response characteristics and quantum efficiency of solar cell. These highly efficient solar cells can be used for generating power which can be utilized for the applications like cooking, drying, desalination and so on.

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