The Role of Mirror Dichroic in Tandem Solar Cell GaAs/Si

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Abstract
The good choice of the mirror dichroic between two solar cells was key to the development of the first two-terminal monolithic, multi-junction solar cell. In this paper describes a simulation for mirror dichroic between the first cell (GaAs) and second cell (Si). In the simulation, Spectrum of the mirror Issued to first cell is changed the 0.3 **µm** to0.6 **µm** and the rest of the spectrum turns to the second cell. the By varying the mirror dichroic was demonstrate in the form of current-voltage(I-V) characteristics and quantum efficiency (QE).
Keywords: multi-junction, mirror dichroic, quantum efficiency.

1. Introduction

Single-junction photovoltaic devices have limitations in the ability to utilize efficiently the photons of the broad solar spectrum ranging from 300 nm to 2500 nm. For instance, in the case of Si solar cells, they cannot absorb photons with wavelengths longer than 1100 nm, which represents more than 20% of the standard terrestrial normal radiation at AM1.5 [1]. Short wavelengths in the ultraviolet region also are not converted efficiently by Si solar cells because of thermalization effects.

Because solar cells only convert photons with specific wavelengths efficiently, stacking solar cells made of different materials (i.e. different energy band gaps) together proved to be a good approach to increase the efficiency of photovoltaic devices, and many devices made of a stack of single-junction cells have been proposed by many research groups [2].

Indeed, efficiencies as high as 41.3% and 32.6% have been reported for triple-junction and double-junction devices under 343 and 1026 suns, respectively, using the AM1.5 spectrum [3].

For multi-junction solar cells dichroic mode is a photovoltaic device of two cells or three cells, a dichroic mirror divides the spectrum between solar cells. By the definition of its slope and its cutoff wavelength, the mirror allows a better adaptation of the system spectrum of cells used.

In this paper, we propose a two-junction solar cell device having GaAs (1.42 eV) as a first cell and Si (1.12 eV) as a second cell. The two cells are connected electric coupling and separated by mirror dichroic

In the next section, we present the modeling mirror dichroic lead to the best multi-junction solar cell GaAs / Si device

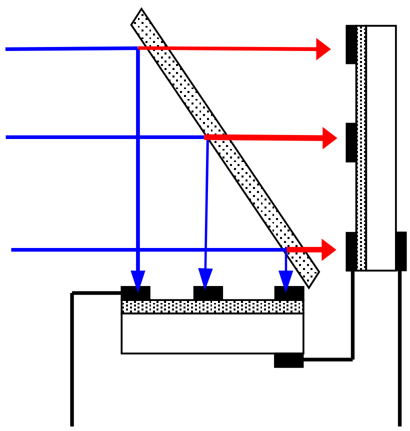

Fig. 1: Schematic of electrical coupling of two cells in series

2 MODEL DESCRIPTION

In this work, calculations were all performed under 1-sun AM1.5 illumination and a temperature of 300 K using the one diode ideal model, and for convenience, several simplifying assumptions were made, including no series resistance losses, no reflection losses and contact shadowing.

2.1. Analytical model

*The total The photo current density from single cells under illumination is given by:

$$j_{ph} = j_n + j_p + j_w$$

Where:

j_n The photo current density in the base region is expressed by:

$$J_n = -eD_n \left.\frac{d\Delta n}{dx}\right|_{x=w_e+w}$$

j_n The photo current density in the emitter region is expressed by

$$J_p = -eD_p \left.\frac{d\Delta p}{dx}\right|_{x=w_{e1}}$$

J_w The photo current density in space charge layer pn is expressed by

$$j_w = I_o \exp(-\alpha(\lambda)w_e)[1-\exp(\alpha(\lambda)w)]$$

GaAs absorption coefficient can be approximated as [5]:

$$\alpha(\lambda) = 0 \quad \text{for } \lambda \succ 0.88\mu m,$$

$$\alpha(\lambda) \approx 10^{-37.5\lambda+34.0}\,cm^{-1} \quad \text{for } 0.8 \le \lambda \le 0.88\mu m,$$

$$\alpha(\lambda) \approx 10^{-3.3\lambda+6.64}\,cm^{-1} \quad \text{for } \lambda \le 0.8\mu m,$$

Si absorption coefficient can be approximated as [5]:

$$\alpha(\lambda) = 0 \quad \text{for } \lambda \succ 1.1\mu m,$$

$$\alpha(\lambda) \approx 10^{-6.7\lambda+8.4}\,cm^{-1} \quad \text{for } 0.8 \le \lambda \le 1.1\mu m,$$

$$\alpha(\lambda) \approx 10^{-3.3\lambda+5.6}\,cm^{-1} \quad \text{for } 0.5 \le \lambda \le 0.8\mu m,$$

$$\alpha(\lambda) \approx 10^{-6.7\lambda+5.6}\,cm^{-1} \quad \text{for } \lambda \le 0.5\mu m,$$

The open circuit voltage is given by

$$V_{CO} = \frac{kT}{q} \times Log \left\{1 + \frac{I_{ph}}{I_0}\right\}$$

*PV characteristic:

The power supplied to the external circuit by the solar cell under illumination depends on the load resistor (external resistor placed across the cell). This power is maximum (rated P_{max}) for an operating point (P_m (I_m , V_m) of the current-voltage curve. To this point we can write:

after approximations

$$V_{mp} = V_{CO} - \frac{K.T}{q}.\log\left(1 + \frac{q.V_{mp}}{K.T}\right)$$

$$I_{mp} = \left[I_{ph} + j_0\left(e^{\frac{qV_{mp}}{KT}} - 1\right)\right]$$

The cell conversion efficiency is usually taken to be:

$$\eta_{mk} = \frac{P_{\max k}}{P_{in}} = \frac{I_{mk}.V_{mk}}{P_{in}}$$

P_{in} is the total incident solar power.

For maximum efficiency, each cell should be operated at its optimal J-V parameters, which are not necessarily equal for each cell. If they are different, the total current through the solar cell is the lowest of the tow. By approximation, it results in the same relationship for the short-circuit current of the multi-junction mode dichroic solar cell: $I = \min\left(I_{mk}\right)$.

An operating voltage V_{mk} and power output will be obtained $P_k = V_{mk}.\min\left(I_{mk}\right)$

The total conversion efficiency to be

$$\eta = \frac{\sum_{k=1}^{n} P_k}{P_{in}}$$

RESULTS AND DISCUSSION

The work was carried out simulations designed to compare different types of cell structure made by changing the threshold wavelength of the spectrum of the dichroic mirror toward the first cell and thereby changing the spectrum-oriented second cell to determine the best structure to increase efficiency more stable solar cells.

1 Influence of the mirror dichroic

The device models are coupled to optical design tools. Figures 2,3,4 shows the effect of the changes in a dichroic mirror design upon the short circuit current, open-circuit voltage and the device total efficiency respectively of a combination of a GaAs cell and a silicon cell where the dichroic mirror splits the spectrum in the vicinity of the GaAs band gap.

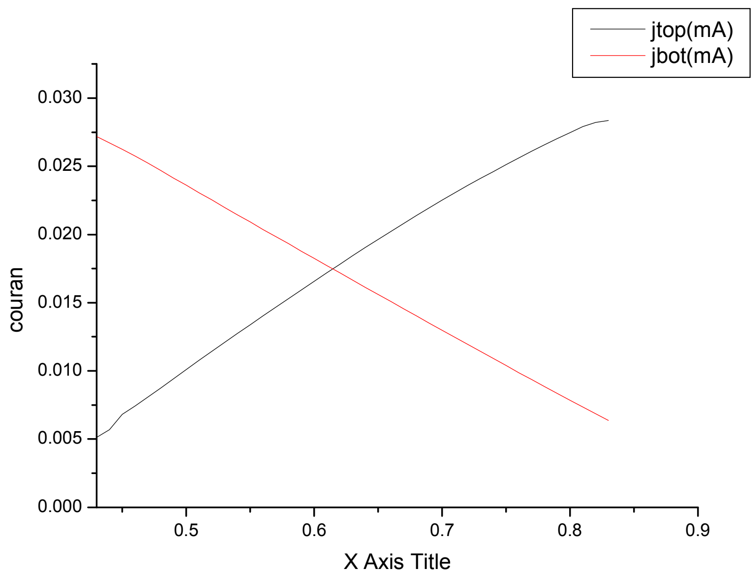

Figure 2: Change in current relative to the Spectrum of the mirror dichroic

The result from Figure 2 that when the wavelength of the threshold of the mirror to the top cell is equal to 0.62, the short-circuit current in the cell Upper and Lower cell are equal.

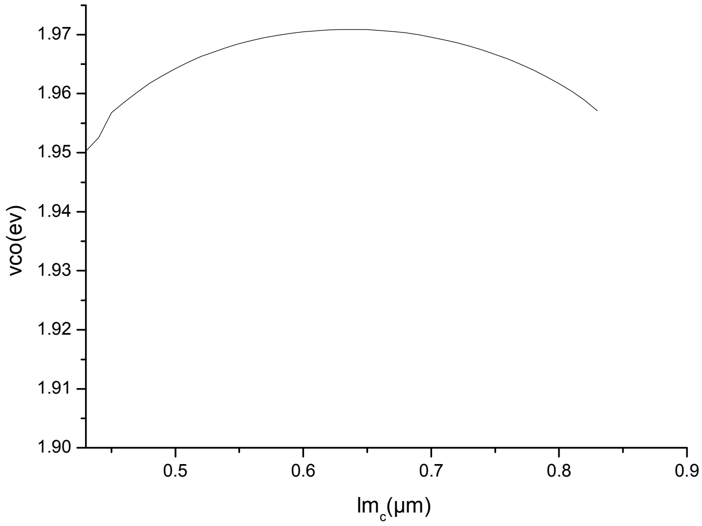

Figure 3: Change in open-circuit voltage relative to the Spectrum of the mirror dichroic

The result from Figure 3 that when the wavelength of the threshold of the mirror to the top cell is equal to 0.62, the open-circuit voltage of the device models is the maximum value V_{oc}=1.97

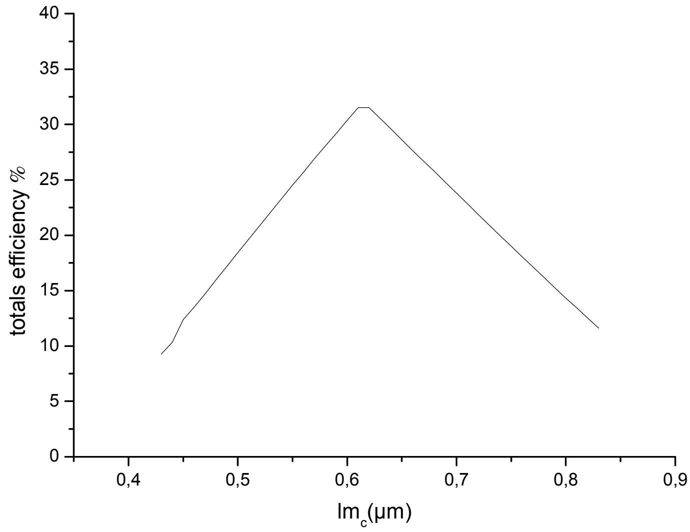

Figure 4: Change in the device total efficiency relative to the Spectrum of the mirror dichroic.

The result from Figure 3 that when the wavelength of the threshold of the mirror to the top cell is equal to 0.62, the device totals efficiency (the sum of the efficiency of top and bottom cells) is the maximum value τ_c=31.05%

2. I (V) characteristics simulation

The current-voltage and power-voltage characteristics generated by multi-junction solar cell the GaAs /Si mode dichroic optimized device under the AM1.5G spectrum and one sun are displayed in figure 5. The corresponding PV parameters (open-circuit voltage Voc, short-circuit current Isc, fill-factor FF and efficiency (η) are all summarized in Table 2.

Table 1.The Parameters PV of the optimized multi-junction mode dichroic GaAs /Si

Photovoltaic parameters	V_{oc}(V)	J_{sc}(A)	FF	τ(%)
	1.97	17.12	0.89	31.05

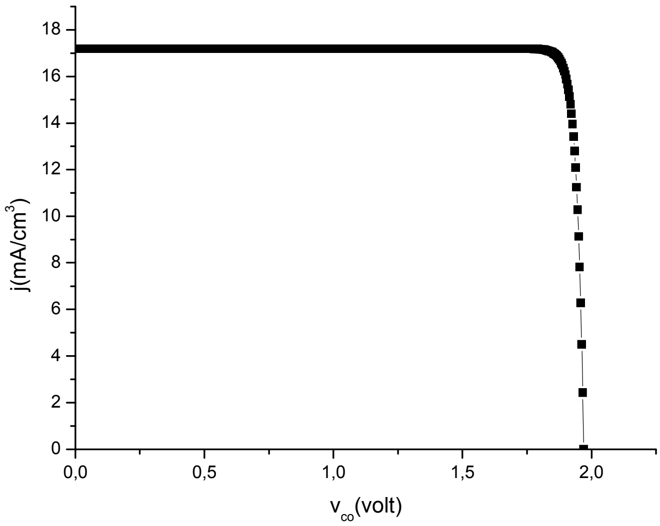

Fig 5: Current density-voltage characteristics

Conclusion

In this investigation, we have shown that the mirror dichroic can achieve high power output significantly. The long-spectral coverage because of the careful selection of the threshold wavelength toward the top cell to enhance the total energy output of device multijunction mode dichroic GaAs / Si. Under the standard solar spectrum and the sun once, and device efficiency is 31.05%, which is much higher than the efficiency of gallium - the perfect one-stop device is under the same lighting conditions

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