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Irradiance and temperature impact on thin film materials I-V curves

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Abstract:

The thin-film solar cells are becoming increasingly used in various applications; this is mainly due to the continued high cost of mono or polycrystalline silicon. In addition, the thin film technology offers the most diverse applications including uses low solar irradiance. The main fields of thin film solar cells are: the chain of amorphous silicon (a-Si), the chain of cadmium telluride (CdTe) and chalcopyrite sector (CIS and CIGS material). In this paper, a study on the influence of light and temperature on the characteristics I (V) of different thin film photovoltaic cells (a-Si:H single, a-Si:H tandem a-Si:H tripple, CdTe and CIS) is detailed. Under standard conditions (illumination of 1000W/m² and cell temperature 25° C), we see that the CdTe is the closest that the monocrystalline silicon which has a maximum value of short circuit current material (3,26A).

Keywords: *Thin films, Efficiency, Electricity, irradiance, temperature.*

I. Introduction

Thin films are the second generation of photovoltaic technology, they have many applications in various areas such as optics, electronics, sensors in the photovoltaics technology. In this generation, there are three main channels:

A. die amorphous silicon (a-Si)

These cells are comprised of a glass substrate or plastic on which is deposited a thin layer of silicon [1], a process requiring very little energy. Although the performance of such cells is lower than crystalline cells (5-9%), which is due to the low mobility of charge carriers in these materials.

B. The die telluride of cadmium (CdTe)

It is a highly promising technology, allowing yields perfectly adequate (16.5%) in the laboratory. Share a bandgap of 1.5 eV perfectly adapted to the solar spectrum [2] and a very high absorption coefficient, only a layer of 2 µm is necessary to obtain a very opaque material and absorbing a large part of the solar spectrum.

C. Chain chalcopyrite (CIS and CIGS material)

Selenium copper and indium (CIS) is a ternary material having a chalcopyrite structure. It has a coefficient of absorption between 100 and 1000 times greater than that of amorphous silicon. Cells based on chalcopyrite quaternary material such as CIGS (Cu for (Ga, In) (Se, S)$_2$) also has very interesting performance.

Production of such cells (thin film) is less expensive than the first generation (crystalline silicon) since it consumes less semiconductor material and does not require going through the step of converting the silicon "wafers". The problem of second-generation cells is lower efficiency of this cell type (6-7% and 14% in the lab for the amorphous silicon) and the toxicity of certain elements (cadmium) for their manufacture. However, this generation has many advantages for niche applications such as flexible modules, with low lights or high temperatures. Selenium and copper indium (CIS), which is at the stage of industrial production and offers a yield of 10 to 12% for its commercial modules does not present problems of toxicity of cadmium [3,4].

II. Modeling of thin film photovoltaic cell

The functioning of a photovoltaic cell is described by the "standard" model based on a single-diode (Figure 1), established by Shockley for a single PV cell and generalized for PV module by considering it as a set of identical cells connected in series / parallel [5, 6].

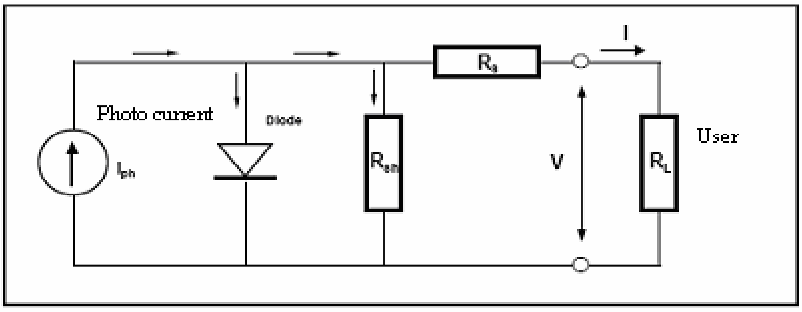

Figure 1: Equivalent circuit of a PV cell.

The current delivered by the panel is given by the following relationship [5]:

$$I = I_{ph} - I_0\left[\exp\left(q.(V + I.R_S)/(N_{CS}.\gamma.k.T_C)\right) - 1\right] - (V + I.R_S)/R_{Sh} \quad (1)$$

With:
V: Voltage across the panel [V].
I_{ph}: Photo current [A], proportional to the irradiance, corrected by T_C.
I_D: Current in diode means teme I_0 [exp (...) -1].
I_0: Diode reverse saturation current, temperature dependent [A].
R_s: serial resistance [Ω].
R_{sh}: shunt resistance (or parallel) [Ω].
Q: Electron charge = $1.602.10^{-19}$ Coulomb.
k: Boltzmann's constant = $1.381.10^{-23}$ J / K.
γ: Quality factor of the diode, typically between 1 and 2.
N_{CS}: Number of cells in series.
T_C: Effective temperature of cells [Kelvin].
The photocurrent I_{ph} varies with irradiance and temperature, we will determine relative to data values at reference conditions [5]:

$$I_{ph} = (\Phi/\Phi_{ref}).\left[I_{phref} + \mu_{ISC}.(T_C - T_{Cref})\right]$$
(2)

Where:
Φ and Φ_{ref} : Effective and reference irradiance [W/m^2].
T_{Cref} and T_C: Temperature cell, reference and effective [°K].
μ_{ISC} : Temperature Coefficient of photo current (or short circuit) [A/°K].
The reverse saturation current of the diode is assumed I_0 vary with temperature according to the expression [5]:

$$I_0 = I_{0ref}(T_C/T_{Cref})^3.\exp\left[(q.\varepsilon_G/\gamma.k).(1/T_{Cref} - 1/T_C)\right] \quad (3)$$

Where ε_G: energy gap of the cell material (crystalline Si: 1,12 eV; amorphous silicon 1,7 eV CIS: 1,03 eV CdTe = 1,5 eV).

Reference conditions Φ_{ref} and T_{Cref} external conditions that are specified for the data used for model establishment. These are either the manufacturer's specifications, data always at STC ("Standard Test Conditions" 1000W/m^2, 25°C, AM1.5 spectrum) or values from in situ measurement module.
The model thus involves the following six unknown parameters: I_{phref}, I_{0ref}, γ, R_s, R_{sh} and μ_{ISC}). The temperature coefficient of the photocurrent μ_{ISC} is often given by the manufacturer and it is generally positive with a very low value (value/degree).
The value of the shunt resistance R_{sh}, represents the inverse of the slope of the plateau I (V) to V low. It can be easily determined from the measured data.
So we have four parameters (I_{phref}, I_{0ref}, γ, R_s) from the measurement of the characteristic I/V for a given pair (Φ_{ref}, T_{cRef}) reference conditions.

III. Simulation

In the previous section, we presented the basis of mathematical modeling of thin film PV modules. This model was developed under the matlab environment, then we simulated the characteristics I(V) for a wide range of variation of the illumination received by the photovoltaic panel (between 200 and 1000W/m^2) for a constant temperature (25°C) of the cell, and for a wide range of variation of cell temperature (from 25°C to 70°C) for a fixed light (1000W/m^2). We applied the standard model to the different diode thin film photovoltaic modules (a-Si:H single, a-Si:H tripple, a-Si:H tandem, CdTe and CIS).

IV. Results and Discussions

The study of the influence of light on the characteristics I(V) for various photovoltaic modules (Figure 2) for a fixed cell temperature (25°C) shows that increasing the illumination (from 200 to 1000W/m^2) results in a displacement of the characteristic I=f(V) along the axis of the currents. The increase in the short circuit current is much greater than the open circuit voltage, since the short-circuit current is a linear function of illumination, whereas the open circuit voltage is logarithmic [7].

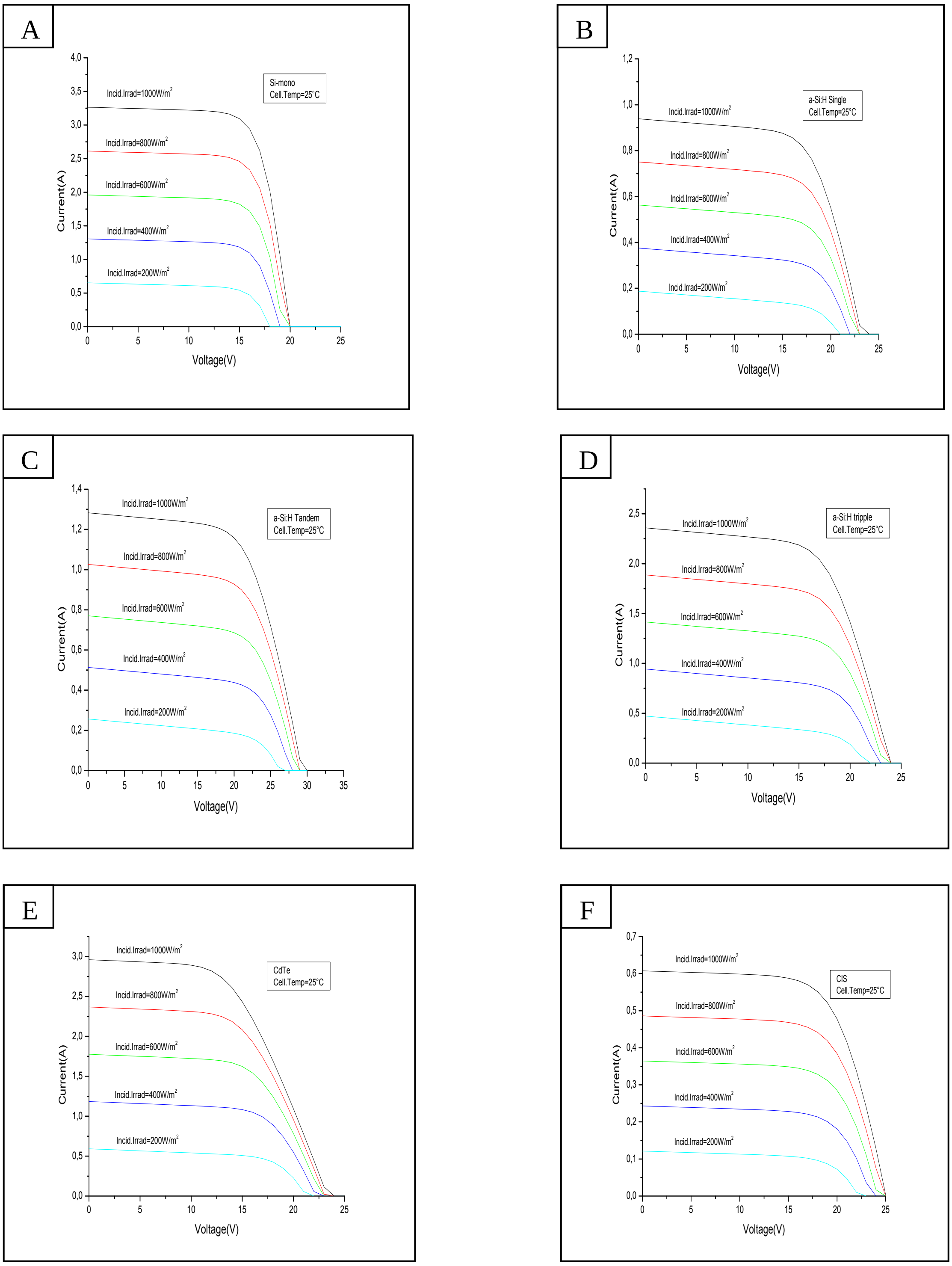

Figure 2: Changes characteristics I (V) as a function of the illumination for different modules:
(A) : Monocrystalline silicon module.
(B) :Module of a-Si:H single.
(C): Module of a-Si:H tandem.
(D): Module of a-Si:H tripple.
(E): Module of CdTe.
(F): Module of CIS.

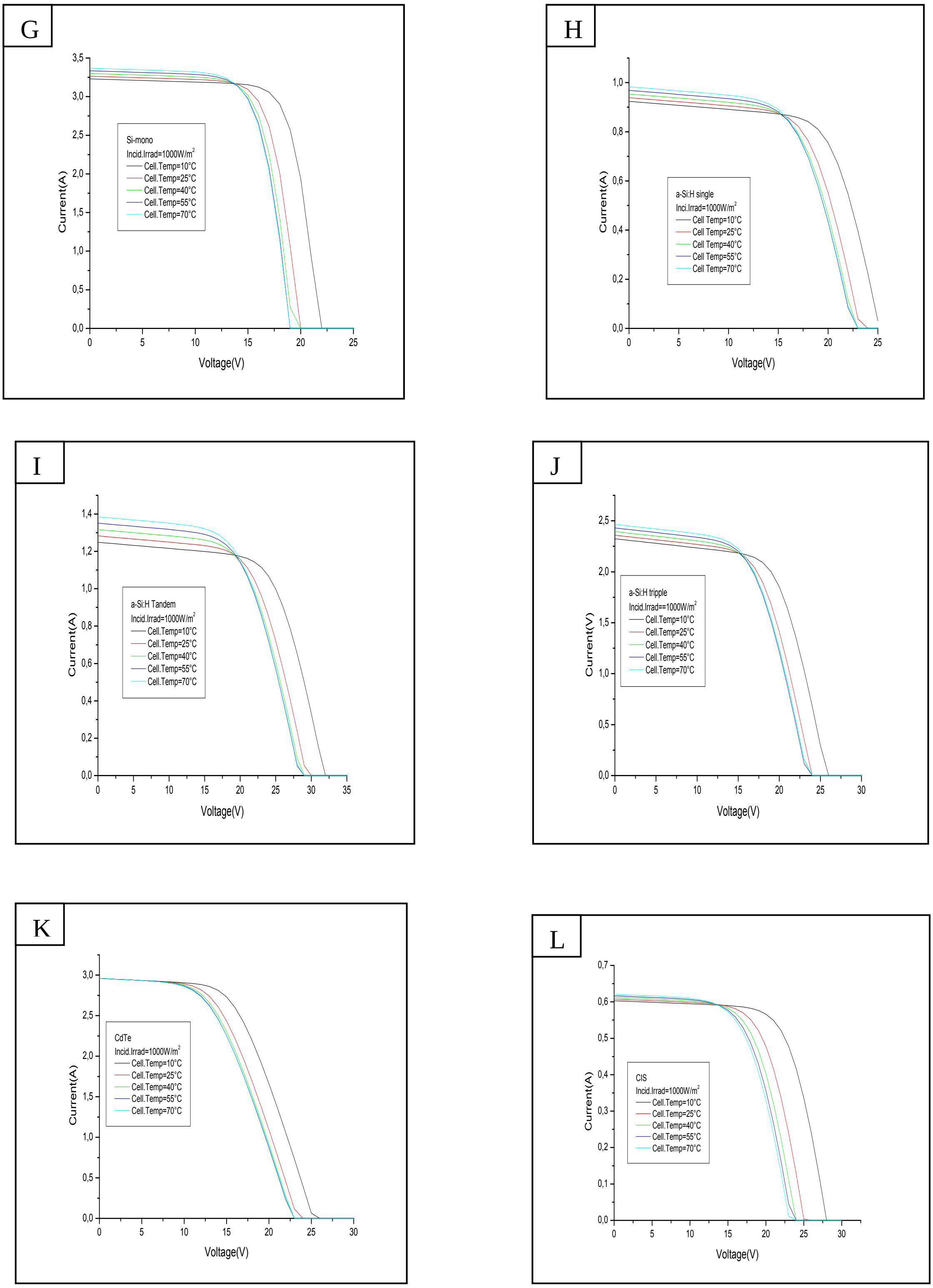

Figure 3: Changes characteristics I (V) as a function of temperature cell for different modules:
(G): Monocrystalline silicon module.
(H): Module of a-Si:H single.
(I): Module of a-Si:H tandem.
(J): Module of a-Si:H tripple.
(K): Module of CdTe.
(L): Module of CIS.

The study of the influence of the cell temperature on the characteristics I(V) for various photovoltaic modules (Figure 3) for a fixed illumination (1000W/m^2) shows that increasing the cell temperature and also module temperature (from 10°C to 70°C), the Photo current I_{ph} also increases, this is due mainly to the decrease in the width of the band gap of the material. The forward current of the junction, but also increases and much faster resulting in a decrease of the open circuit voltage.

The results obtained (Figures 2, 3) show that in standard conditions (illumination of 1000W/m^2 and a cell temperature of 25°C) the short circuit current reaches its maximum value (2.96 A) for the CdTe (Fig. 2E) and (2.36 A) for (a-Si:H tripple) (Fig. 2D), by against, it reaches minimum values for the a-Si:H single (0.94 A) (Fig. 2B) and CIS (0.61 A) (fig. 2F) and the a-Si:H tandem (1.28 A)(Fig. 2C). By comparison, one sees that the CdTe is the closest material that the monocrystalline silicon which has a maximum value of short circuit current (3.26 A) (Fig. 2A).

V. Conclusion

In this work, we introduced the electric model with a diode modules for various thin film (a-Si:H single, a-Si:H tandem a-Si:H tripple, CdTe and CIS) at different conditions sunshine and cell temperature.

The study of the effect of illumination on the characteristics I (V) for different modules for a fixed cell temperature (25°C) shows that increasing the illumination leads to an increase in short-circuit current, while the increase in cell temperature for a fixed illumination 1000 W/m^2 leads to an increase in short circuit current and a reduction in the open circuit voltage.

Under standard conditions (illumination of 1000 W/m^2 and cell temperature 25°C), we see that the CdTe is the closest that the monocrystalline silicon which has a maximum value of short circuit current material (3.26 A).

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