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Influence of the use temperature on the Capacitance-Voltage measures and the external quantum efficiency of a Cu(In, Ga)Se_2 thin film solar cell

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ABSTRACT

In this work we are interested by the use parameters of the cell. The studied parameter is the temperature. We study its influence on the Capacitance-Voltage measures and the external quantum efficiency of the solar cell. The range of temperatures considered is about 270K to 320K with a step of 10K. Our study is based on three stages aiming at confirming the veracity of our results. The first stage of our work concerns the handling of the equations which govern the physical parameters which intervene in the heart of the solar cell. The second of our work concerns a simulation using the Solar Cell Capacitance Simulator (SCAPS).The third stage of our work concerns obtaining characteristics using Matlab. The study of the effect of the use temperature on the variation of the capacitance according to the tension shows that more the use temperature is significant more the cell capacitance is important. This capacitance is significant for tensions higher than 0.3eV. The analysis of the Mott-Schottky curves for temperatures of 270K to 320K enables us to note that the effect of the temperature on the Mott-Schottky curves is weakly noted and it appears slightly for the voltages of 0.6V to 0.7V by variations on the characteristics. As let us note, as using the study of the variation of the conductance according to the voltage, we see that for an optimal and maximal applied voltage of 0.8V one notes a conductance equal to 1.77×10^{1} *S.cm* $^{-2}$ *for an use temperature of 270K and* 9.78×10^{1} *S.cm* $^{-2}$ *for an use temperature of 320K. The use temperature has a very weak effect on external quantum efficiency of the cell. For all the range of temperature considered we have a maximum efficiency of 95% for an incidental wavelength of 460nm and a broad beach of absorption.*

Keywords: Cu(In,Ga)Se_2, use temperature, capacitance, Voltage, quantum efficiency.

INTRODUCTION

The use of solar energy is carried out starting from its thermal and photovoltaic sections. The field is extrapolated by our research team is that of solar photovoltaic. The heart of the solar photovoltaic use is the solar cell. One notes several types of solar cells, but our research is concentrated on the $CuInSe_2$ thin film solar cells, the Cu(In,Ga)Se_2 thin film solar cells and their derivatives. Several publications were made in the direction to improve the performances of these types of solar cells. [1]- [3]

In this work we are interested by the use parameters of the cell. The solar is exposed to the environmental bad weather during its use. One notes the influence of several external factors on the performances of the cell such as moisture, the shade, the slope compared to the incidence of the solar radii, etc… the factor studied here is the temperature. We study his influence on the capacitance-voltage measures of the cell and the external quantum efficiency of the solar cell. The range of temperatures considered is of 270K to 320K with a step of 10K. The knowledge of its influence on the Capacitance and Voltage measures would enable us to envisage the use conditions for optimal performances of the cell. In fact the capacitance is defined as being the impedance which a capacitor opposes to the crossing of a given AC current and the voltage as being the difference voltage delivered or applied to the cell. In addition external quantum efficiency is defined as being the relationship between the number of carriers collected and the number of incidental photons.

MATERIALS AND METHODS

The study is carried out under spectrum AM1.5 with an incidental power of sunning 1000W.m^{-2}. We take into account the totality of the wavelengths of the solar radiation which reach the window layer. We study the behavior of the characteristics deduced from the Capacitance-Voltage measures according to the use temperature of the cells. The use temperature takes successively the following values 270K, 280K, 290K, 300K, 310K and 320K.The configuration of the studied cell is given by fig. 1.

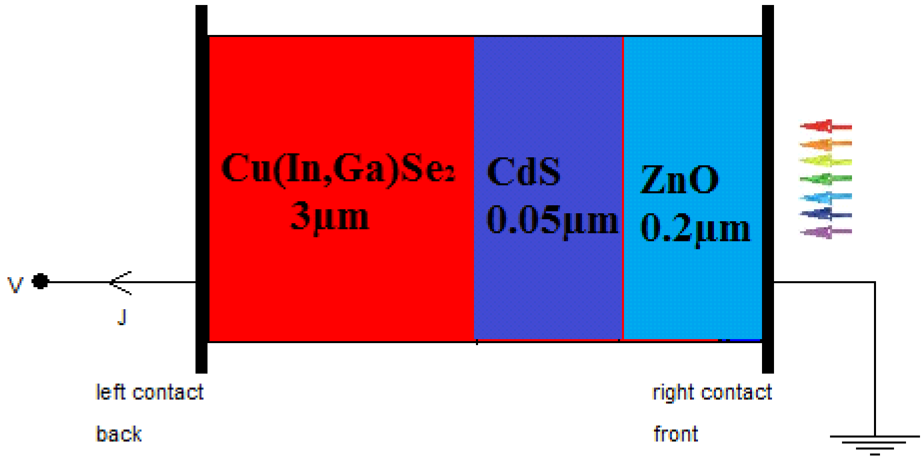

Fig. 1: The Cu(In,Ga)Se$_2$ thin film solar cell configuration

Our study is not based on captured measures taken in a photovoltaic field but it is based on three stages aiming at confirming the veracity of our results.

The first stage of our work concerns the handling of the equations which govern the physical parameters which intervene in the heart of the solar cell. These equations are the Poisson's equation, the equations of continuity and the transport equations. We had to develop these equations before.[4]

The second stage of our work concerns a simulation using the SCAPS. This last is software of digital simulation one-dimensional, developed at the laboratory ELIS of the University of Gent (Belgium) by Marc Burgelman and al… [5]-[6]

To carry out this simulation we use proven film parameters of which certain are indicated by table 1.

Table 1: Some physical parameters of the layers which constitute the studied cells

Physical parameters	Window layer ZnO	Buffer Layer CdS	absorber layer Cu(In, Ga)Se$_2$
Thickness (µm)	0.2	0.05	3
Bandgap (eV)	3.3	2.4	1.1
Electron affinity (eV)	4.45	4.2	4.5
Dielectric permittivity	9	10	13.6
Thermal electron velocity (cm.s^{-1})	10^7	10^7	10^7
Thermal Hole velocity (cm.s^{-1})	10^7	10^7	10^7
Shallow uniform donor density N_D (cm^{-3})	10^{18}	10^{17}	10
Shallow uniform acceptor density N_A (cm^{-3})	10	10	2×10^{16}

Each layer which constitutes the cell was studied in our preceding work already published. [2]

The third stage of our work concerns obtaining characteristics using Matlab. It is a mathematical tool which enables us to obtain the curves of variations studied according to the temperature.[7]

RESULTS AND DISCUSSION

•Influence of the temperature on the variations of the capacitance-voltage plots

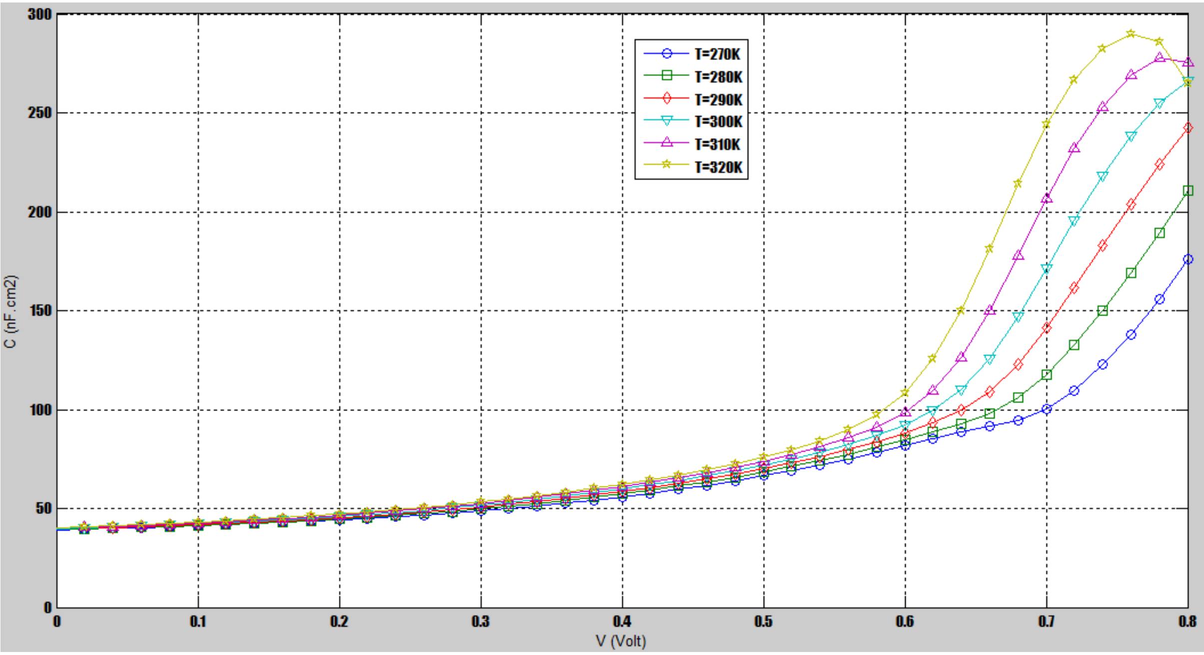

Figure 2: Variation of the capacitance according to the voltage for various use temperatures of the Cu(In,Ga)Se$_2$ thin film solar cell

The Fig. 2 shows us the variation of the capacitance according to the voltage for various use temperatures. For an applied voltage going until 0.3V, the capacitance of the cell varies shortly according to the temperature. Beyond 0.3V we note characteristics which always evolve in the same direction but according to different proportions. Indeed the capacitance increases significantly and we note that more the use temperature is significant more the capacitance of the cell is significant.

The differential capacity of the hetero-junction has as the expression:

$$C(V) = \left|\frac{dQ}{dV}\right| = \left(\frac{q}{2} \cdot \frac{\varepsilon_1 N_{d1} \cdot \varepsilon_2 N_{a2}}{\varepsilon_1 N_{d1} + \varepsilon_2 N_{a2}}\right)^{\frac{1}{2}} (V_d - V)^{-\frac{1}{2}} \qquad (1)$$

This relation explains the growth of the capacitance according to the voltage. However the temperature increasing the impedance of the hetero-junction base-transmitter with the passage of the current explains the fact that the capacitance is more significant for the cell used under a temperature of 320K. We reach with this value a maximum of capacitance of 2.90×10^2nF.cm^2 for a voltage of 0.76V, whereas it is of 1.76×10^2nF.cm^2 for a use temperature of 270K.

•Influence of the use temperature on the Mott-Schotky curves

We approach now the study of the Mott-Schottky curves for various use temperatures. The Mott-Schottky characterization of the junction is carried out by plotting the curve of variation of the reverse of the square of the parallel capacitance according to the applied voltage.[8]

Its expression is given by: $$\frac{1}{C_p^2} = \frac{2(V_{bi} - V)}{A^2 q \varepsilon \varepsilon_0 N} \qquad (2)$$

While posing $$X = \frac{2}{A^2 q \varepsilon \varepsilon_0 N} \qquad (3) \qquad \Rightarrow \qquad \frac{1}{C_p^2} = (V_{bi} - V)X \qquad (4)$$

$$\Rightarrow \frac{1}{C_p^2} = -X.V + X.V_{bi} \qquad (5)$$

By plotting the curve $\left(1/C^2\right) = f(V)$ we obtain an affine transformation (on a range of value of the voltage) whose intercept makes it possible to calculate the intrinsic bias voltage *Vbi* and whose slope allows to deduce the density of carriers *N*.

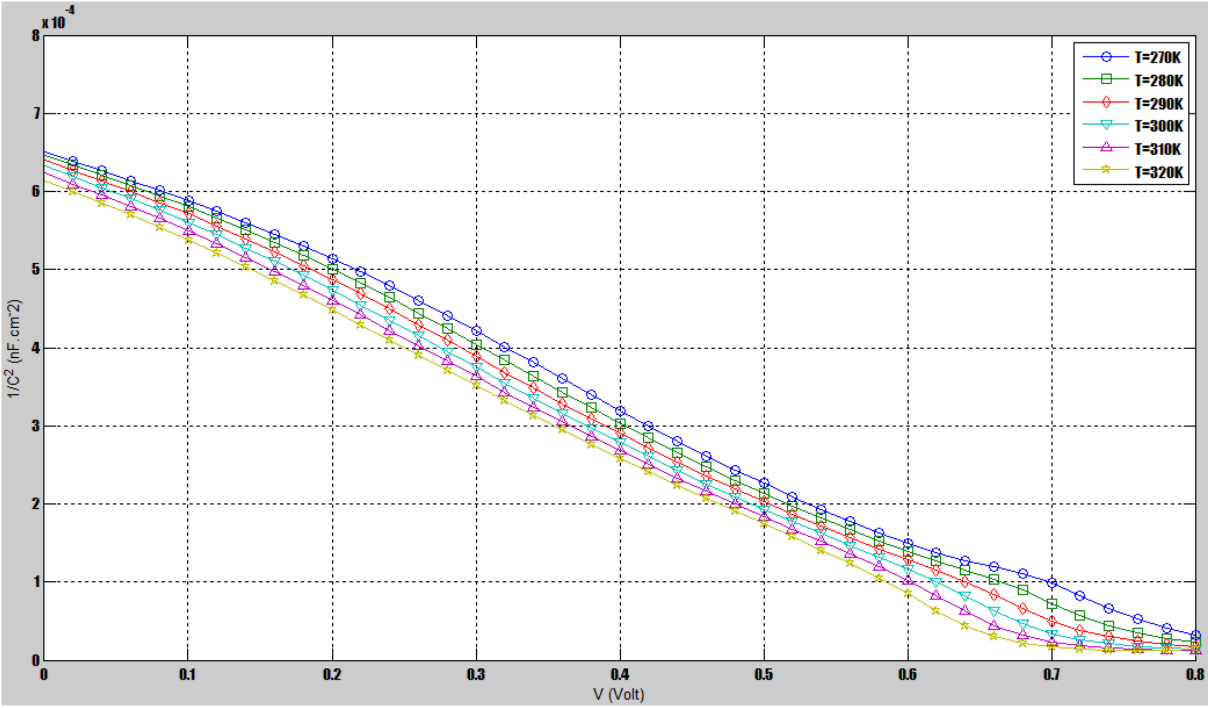

Fig. 3: Variation of the reverse of the square of the capacitance according to the voltage for various use temperatures of the Cu(In, Ga)Se_2 thin film solar cell

The fig. 3 shows us the decrease of the reverse of the square of the capacitance according to the voltage for the various use temperatures studied. This decrease is in agreement with the preceding characteristics where we note the decrease of the capacitance according to the voltage. However the effect of the temperature on the Mott-Schottky curves is slightly noted and it appears for the tensions from 0.6V to 0.7V by variations on the characteristics.

•Effect of the use temperature on the curves of variation conductance-voltage

The study of the variation of the conductance according to the voltage confirms the capacitance-voltage characterization. [9]

Indeed the conductance is the reverse of the resistance which is related to the temperature, from where the influence of the temperature on the conductance. The Fig. 4 gives us the profiles of the conductance of the carriers according to the applied voltage.

We notice that voltages higher than 0.6V increase the conductance which is measured starting from the right-hand side of the cell presented by fig. 1.This conductance is also supported by the increase of the use temperature. The choice of shunt resistances infinite in relation to the series resistances explains the behavior of the conductance. We mention that the reference voltage standard is measured on the right-hand side where the conductance is evaluated, whereas the applied voltage is carried out on the left. For an applied voltage optimal and maximum of 0.8V we note a conductance equal to 1.77×10^1 $S.cm^{-2}$ for a use temperature of 270K and 9.78×10^1 $S.cm^{-2}$ for a use temperature of 320K. The resistance decreasing with the increase in temperature, we note a more significant conductance for the highest use temperature.

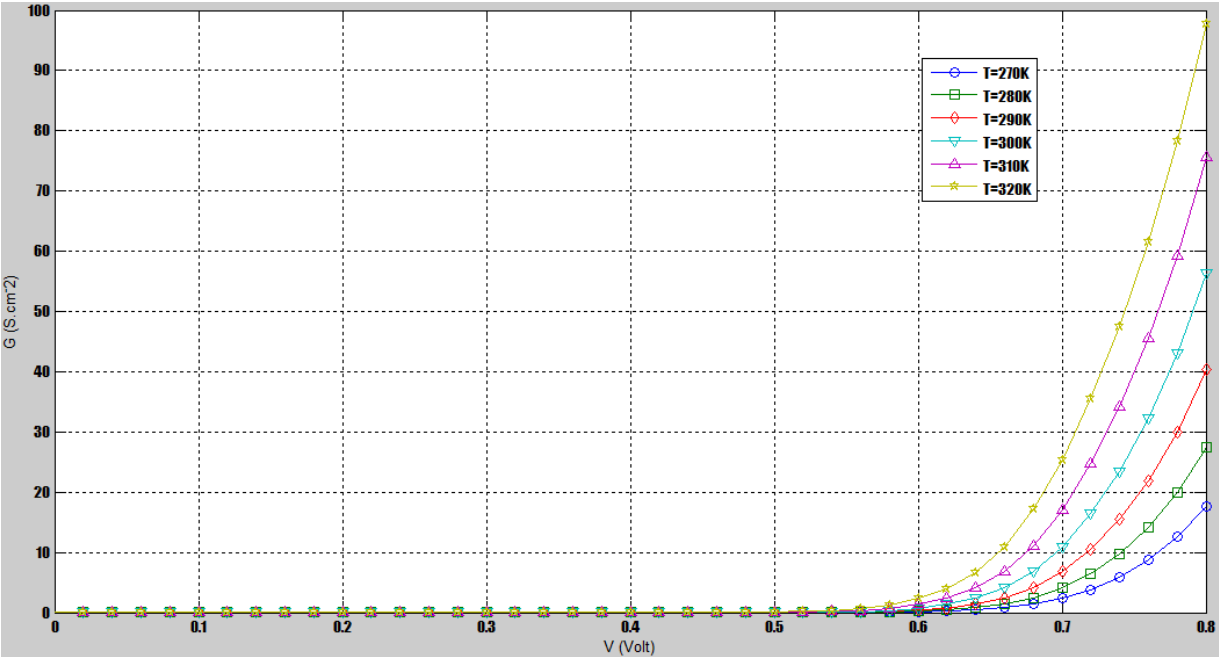

Fig. 4: Variation of the generation of the minority carriers according to the tension for various temperatures of use

•Effect of the use temperature on the variations of the external quantum efficiency of the cell

The external quantum efficiency EQE is the ratio of the number of collected carriers on the number of incidental photons. The characterization of the cell by its quantum efficiency makes it possible to do without the studies of transmittance and reflectance. It is a significant parameter for the characterization which was already used in our former works [10].

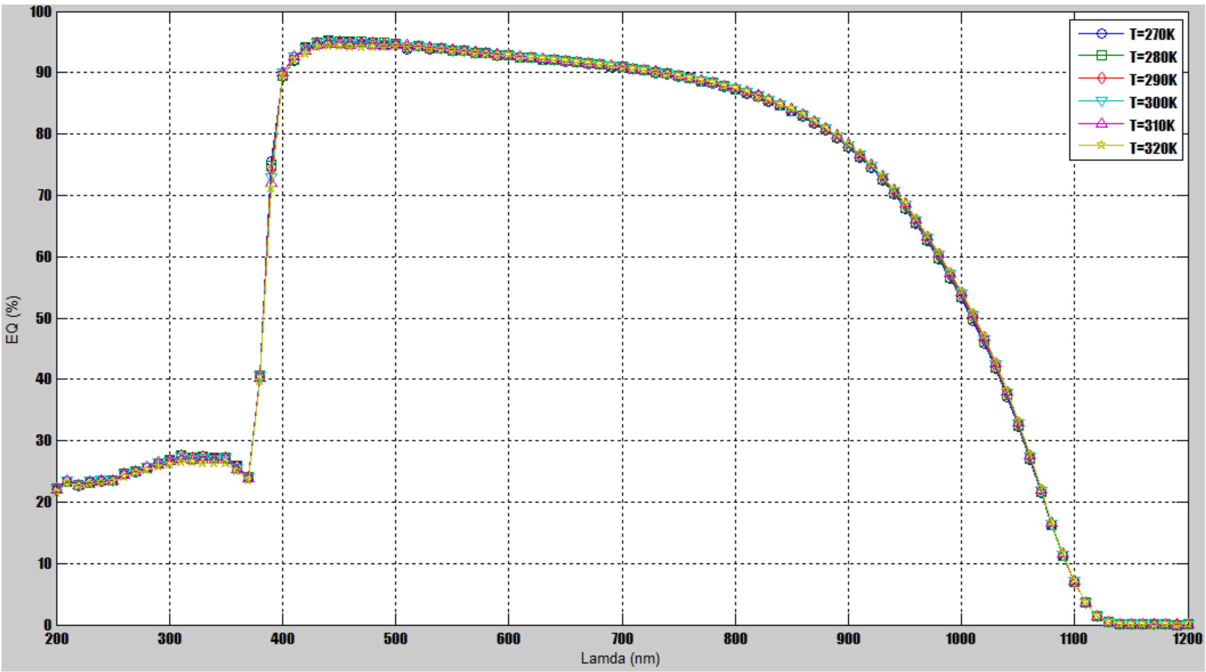

Fig. 5: Variation of external quantum efficiency according to the wavelength for various use temperatures of the $Cu(In,Ga)Se_2$ thin film solar cell

The Fig. 5 gives the quantum efficiency of the solar cell for various use temperatures. The quantum efficiency of the cell has a broad characteristic for all the use temperatures. The low wavelengths going from 200nm to 370nm correspond to incidental photons with significant energy. These photons take part more in the overheating of the cell than to the creation of carriers likely to be collected. They give weak quantum efficiency because the number of carriers is still weak. From 370nm the quantum efficiency becomes significant. It reaches maximum of 95% for an incidental wavelength of 460nm. This wavelength corresponds to energy of 1.7eV. The number of collected carriers is maximum and the density of short circuit current is maximum. Until 830nm the level of injection of incidental wavelengths gives significant quantum efficiency. From this value it drops quickly to be cancelled with λ=1180nm. The incidental energy 1.0eV is insufficient for the creation of carriers considering the gap of the base in Cu(In, Ga)Se_2 which is equal to 1.1eV.

Nevertheless we notice that quantum efficiency is not affected by the temperature variations. For use temperatures going from 270K to 320K one obtains the same profiles.

CONCLUSION

At the end of this work we determine the effect of the temperature on the capacitance-voltage characterizations. The study of the influence of the use temperature on the variation of the capacitance according to the voltage shows that the more the use temperature is significant the more the capacitance of the cell is important. This capacitance is significant for voltages higher than 0.3eV. The analysis of the Mott-Schottky curves for temperatures from 270K to 320K enables us to note that the effect of the temperature on the Mott-Schottky curves is slightly noted and it appears weakly for the voltages from 0.6V to 0.7V by variations on the characteristics. As let us note, as using the study of the variation of the conductance according to the voltage, we see that for an optimal and maximal applied voltage of 0.8V one notes a conductance equal to 1.77×10^{1} $S.cm^{-2}$ for an use temperature of 270K and 9.78×10^{1} $S.cm^{-2}$ for an use temperature of 320K. The use temperature has a very weak effect on external quantum efficiency of the cell. For all the range of temperature considered we have a maximum efficiency of 95% for an incidental wavelength of 460nm and a broad beach of absorption.

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