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Influence of the use temperature on the Capacitance-Frequency measures of a Cu(In, Ga)Se_2 thin film solar cell

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ABSTRACT

In this article, our work concerns a Cu(In, Ga)Se_2 thin film solar cell. We study the influence of the use temperature on the capacitance-frequency measures. This study is done on the scale of the use of the solar cells at ambient environment. This temperature being able to vary according to the environment, we use for our study the temperatures of 270K, 280K, 290K, 300K, 310K and 320K. The first stage of our work concerns a simulation using the SCAPS. The second concerns the utilization of the equations which govern the physical parameters which intervene in the heart even of the solar cell. The third phase concerns the work carried out with Matlab. The study of the variation of the capacitance according to the frequency showed us that the characteristics of the capacitive effects obtained according to the frequency are more affected for the highest use temperatures. Indeed for a temperature of 270K we obtain C_{min} = 38.2nF.cm^{-2} and C_{max} = 39.2nF.cm^{-2} whereas for a temperature of 320K we have C_{min} = 35.5nF.cm^{-2} and C_{max} = 40.4nF.cm^{-2}. Then the exploitation of the variation of the phase of the impedance according to the logarithm of the impulse attested a capacitive behavior of the cell. These capacitive effects are optimal for the maximum values of log(ω). Then the profiles obtained with Nyquist plots once more showed the improvement of the electric parameters of the cell with the increase in the temperature. To finish the study of the variation of the impedance module according to the logarithm of the impulse allows us to notice that the impedance is affected by the temperature only for the lower impulses.

Keywords: Thin film, use temperature, capacitance, frequency, Nyquist plots.

INTRODUCTION

The study of the solar cells is a branch of the scientific research which turns to new ways to be elucidated. This is due to the variety of technologies and materials used in the photovoltaic solar cells. Many work treat thin layer elaboration techniques for obtaining these solar cells.[1]-[2]

Others carried out investigations on the experimental conditions aiming at optimizing the performances of the solar cells.[3]-[4]

Our work concerns the characteristics, properties and electric parameters of the thin film solar cells. In this article our work concerns a Cu(In, Ga)Se_2 thin film solar cell. We study the influence of the use temperature on the capacitance-frequency measures. This study is done on the scale of the use of the solar cells at ambient environment. This temperature being able to vary according to the environment we use for our study of the temperatures of 270K, 280K, 290K, 300K, 310K and 320K. This broad range of temperature includes the bad weather going from the zones having a low annual temperature at the zones having a high annual temperature.

The capacitance-frequency measures would enable us to see the temperature which would give the most powerful results by elucidating capacitive or inductive effects of the cell. The capacitance is indeed defined as being the impedance which a condenser opposes in the passing of a AC current and the frequency as being the number of vibrations of the AC current per unit of time. This frequency is proportional to the pulsation of the AC current of the device.

MATERIALS AND METHODS

The study of the behavior of the characteristics deduced from capacitance-frequency measures according to the temperature is founded on three phases. The first stage of our work concerns a simulation using the SCAPS. This last is software of digital simulation unidimensional, developed at the laboratory ELIS of the University of Gent (Belgium) by Marc Burgelman et al. [5] - [6]

The table 1 shows some properties of the electric parameters used to carry out simulation.

Table1: Some physical parameters of the layers which constitute the exposed solar cell to the incidental solar rays for various temperatures

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
Effective CB density of states (cm^{-3})	2.2×10^{18}	2.2×10^{18}	2.2×10^{18}
Effective VB density of states (cm^{-3})	1.8×10^{19}	1.8×10^{19}	1.8×10^{19}
Electron mobility ($cm^2. V^{-1}. s^{-1}$)	100	100	100
Hole mobility ($cm^2.V^{-1}.s^{-1}$)	25	25	225
Shallow uniform donor density ND (cm^{-3})	10^{18}	10^{17}	10
Shallow uniform acceptor density NA (cm^{-3})	10	10	2×10^{16}

The second stage of our work concerns the equations which rule the physical parameters which intervene in the heart even of the solar cell. The equations used are the Poisson's equation, the equations of continuity and the transport equations. We had to develop these equations before.[7]

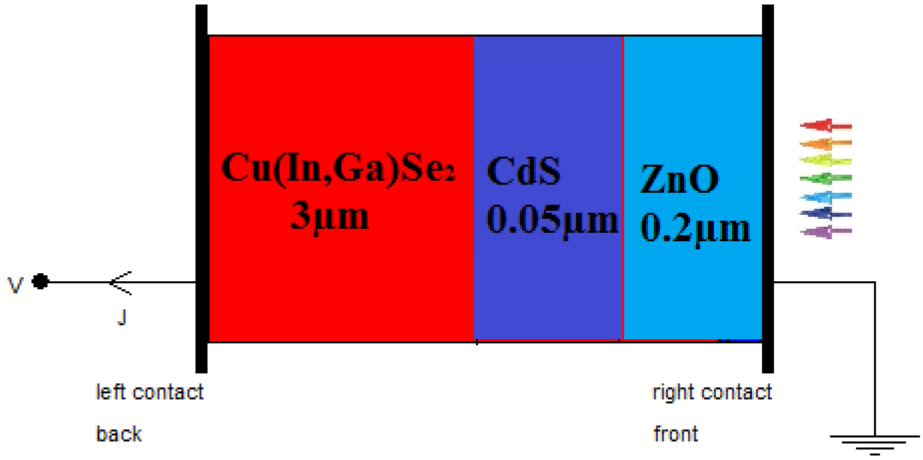

Fig. 1: The configuration of the $Cu(In, Ga)Se_2$ thin film solar cell studied

This stage enables us to check the convergence of the results obtained with the first stage of our work. For these calculations we limited ourselves to a simple configuration cell that is presented by fig. 1.

The third stage of our work concerns the utilization of Matlab. It is a mathematical tool which enables us to obtain the curves of variations studied according to the temperature. [8]

RESULTS AND DISCUSSION

- **The effect of the use temperature of the solar cell on the variation of the curves capacitance-frequency**

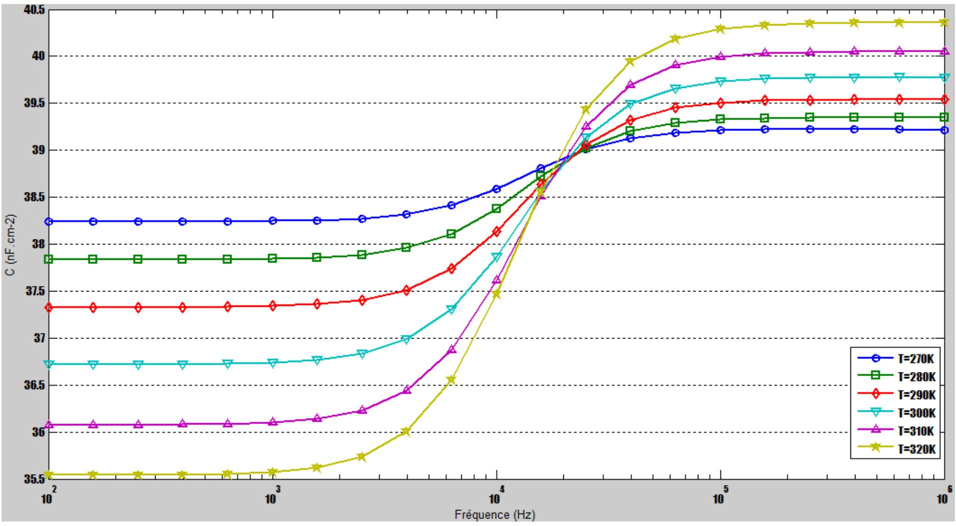

Fig. 2: The variations of the capacitance according to the frequency for various use temperatures of the Cu(In,Ga)Se_2 thin film solar cell

The variation capacitance-frequency enables us to take note of the evolution of the capacitive effects according to the number of vibrations of the AC current per unit of time. The Fig. 2 gives us the variation capacitance-frequency of the Cu(In,Ga)Se_2 thin film solar cell for various use temperatures.

The study is interested in a frequency band going from 10^2Hz to 10^6Hz. From 10^2Hz to 2.51×10^3Hz the capacitive effects remain constant, we note however that they are more significant for a use temperature of 270K. These effects decrease when we increase the use temperature. From 2.51×10^3Hz the capacitance of the cell increases in significant proportions when we rise the use temperature. We notice an intersection and an inversion which intervenes on the characteristics of the cells for a frequency of approximately 2.51×10^4Hz. For values higher than the latter, we note less intense capacitive effects for the lower use temperatures.

This enables us to deduce that the capacitive effects according to the frequency are more affected for the highest use temperatures. It improves the characteristics of the solar cell.

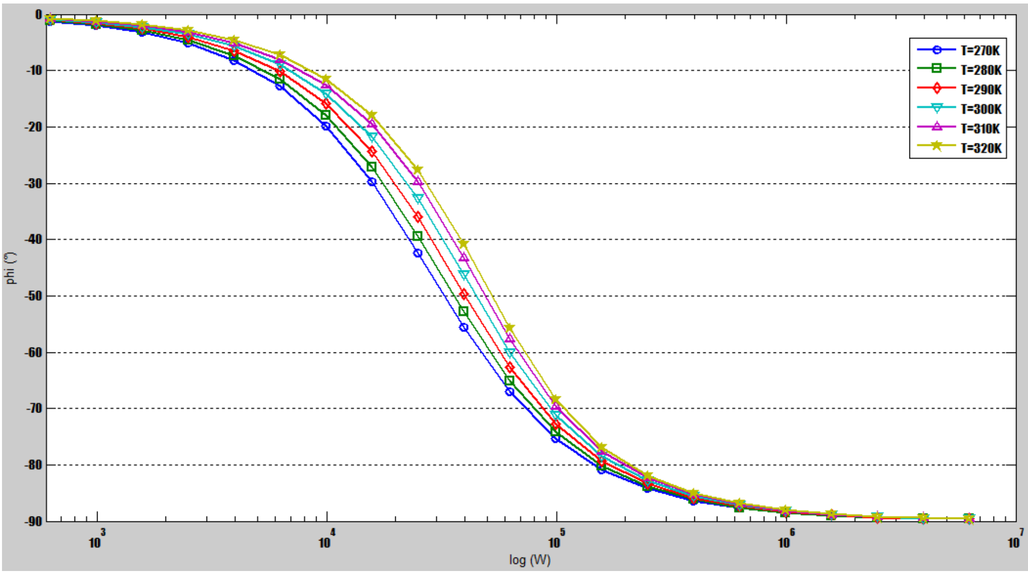

Fig. 3: The variation of the phase Φ of the impedance according to the logarithm of the impulse for various use temperatures of the Cu(In, Ga)Se_2 thin film solar cell

- **Effect of the use temperature of the solar cell on the variation of the phase of the impedance according to the logarithm of the impulse.**

The study of the variation of the phase of the impedance according to the logarithm of the impulse makes it possible to attest a capacitive or inductive behavior of the solar cell. The fig. 3 shows us the characteristics obtained with this study.

The phase Φ of the impedance decreases with the pulsation. It varies from 0 to -90 when log(ω) increases. It shows that the phase remains negative in the frequency band of the study. We consider a capacitive behavior of the cell. These effects are optimal for the maximum values of log (ω). The equivalent circuit which gives this impedance can be represented by fig. 4.

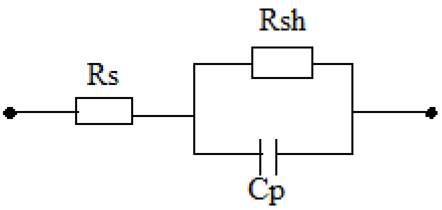

Fig. 4: The equivalent circuit of the capacitive effects of the studied solar cell

Taking into account the effect of the temperature we notice that the characteristics are slightly affected by this factor. We obtain with some differences the same profiles. We conclude from it that the cell preserves its capacitive effects.

- **Effect of the use temperature of the solar cell on the Nyquist plots.**

The characterization of the cell by the method of Nyquist makes it possible to confirm the inductive or capacitive effects of the cell and to deduce other electric parameters such as series and shunt resistances of the solar cell. The Fig. 5 gives us the Nyquist plots of the solar cell for various use temperatures going from 270K to 320K.

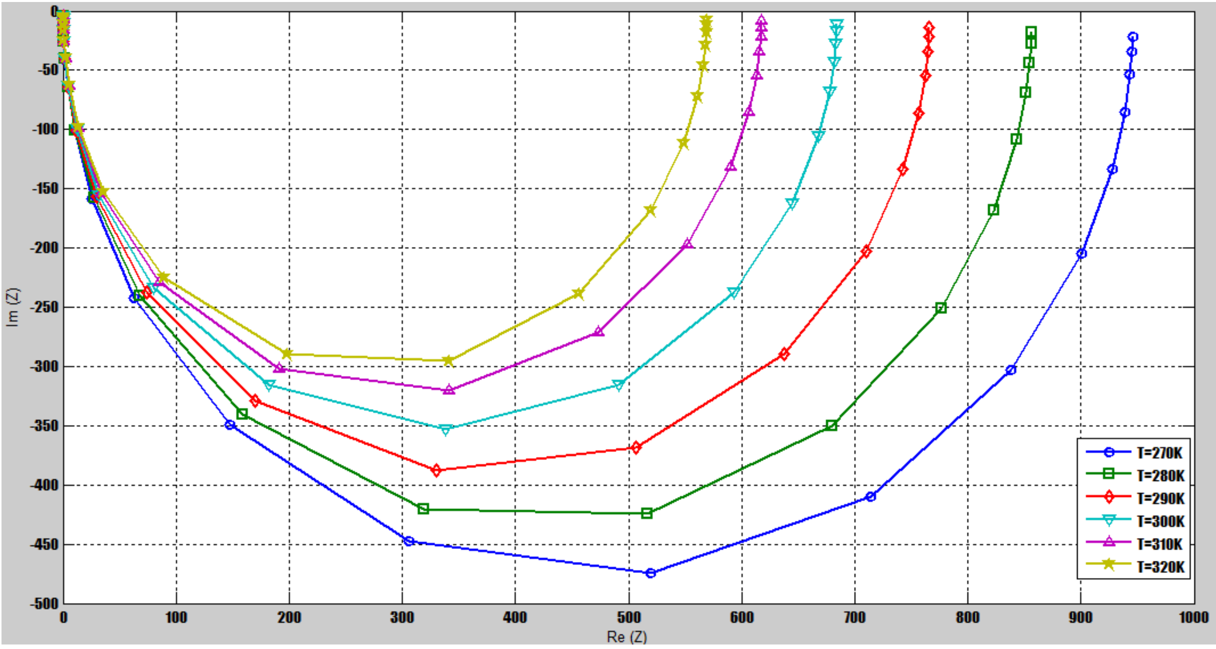

Fig. 5: The Nyquist plots of the $Cu(In,Ga)Se_2$ thin film solar cell for various use temperatures

We plot the imaginary part of the impedance according to his real part while varying the frequency *F*. Indeed the expression of the impedance is:

$$z = R_s + \frac{R_{sh}}{1 + jR_{sh}C_p} \Rightarrow \begin{cases} Z_{\mathrm{Re}} = R_s + \dfrac{R_{sh}}{1 + \omega^2 R_{sh}^2 C_p} \\ Z_{\mathrm{Im}} = \dfrac{R_{sh}^2 C_p \omega}{1 + \omega^2 R_{sh}^2 C_p} \end{cases} \quad (1)$$

We note that the imaginary part of the impedance remains negative. This is due to the capacitive behavior of the solar cell. When the real part of the impedance increases, we note semicircular curves whose curvature radii vary. The more the use temperature is significant, the more the curvature radius is small.

Starting from Nyquist plots, we can find the values of series and shunt resistances used in simulation. Indeed resistance series are obtained while making:

$$f = 0 \Rightarrow \omega = 2\pi f = 0 \Rightarrow Z_{\mathrm{Re}} = R_s + R_{sh} \quad (2)$$

$$f = \infty \Rightarrow \omega = 2\pi f = \infty \Rightarrow Z_{\mathrm{Re}} = R_s \quad (3)$$

Also Z_{max} corresponds to $\frac{R_{sh}}{2}$.

This would give us an infinite resistance shunt compared to resistance series. The study of the Nyquist plots attests once more the improvement of the electric parameters of the cell with the increase in the temperature.

- **Effect of the use temperature of the solar cell on the variation of the module of the impedance according to the logarithm of the pulse.**

The study of the variation of the module of the impedance according to log(ω) enables custom to note the effect of the temperature on the two very significant characteristics of the characterization with the frequencies used. The Figure 6 gives the profiles of the module of the impedance for use temperatures from 270K to 320K. We note that the impedance is affected by the temperature only for the lower impulses. Its module is more significant for use temperature of 270K and decreases with the increase in the temperature. When the log (ω) increases until approximately 10^5 we note an inhibition of the effect of the temperature. The characteristics remain overcome decreasing to be cancelled at log (ω) =10^7.

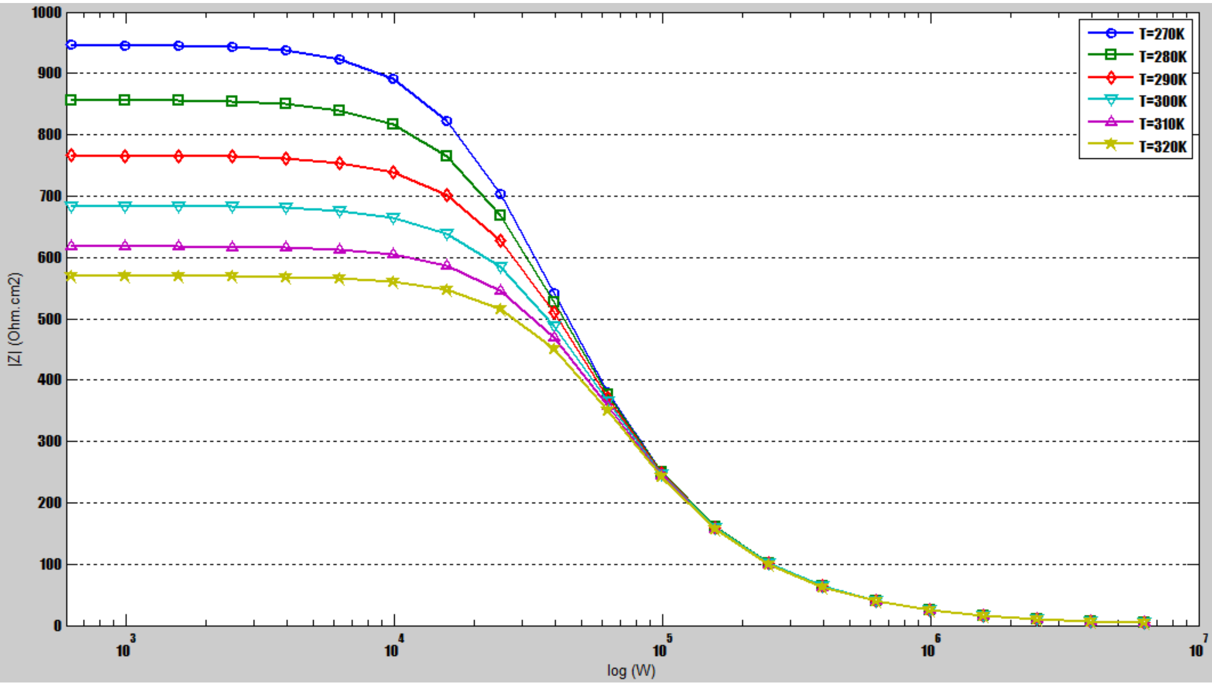

Fig. 6: The variation of the module of the impedance according to the logarithm of the pulse for various use temperatures of the Cu(In, Ga)Se2 thin film solar cell

CONCLUSION

At the end of our study, we now take note of the effect of the temperature on the electric parameters and particularly the variations capacitance-frequency. Our study is initially based on the variation of the capacitance according to the frequency. It shows us that the characteristics of the capacitive effects obtained according to the frequency are more affected by the higher use temperatures. Indeed for a temperature of 270K we obtain C_{min}= 38.2nF.cm^{-2} and C_{max}= 39.2nF.cm^{-2} whereas for a use temperature of 320K we have C_{min} = 35.5nF.cm^{-2} and C_{max}= 40.4nF.cm^{-2}. Then the exploitation of the variation of the phase of the impedance according to the logarithm of the impulse attests a capacitive behavior of the cell. These capacitive effects are optimal for the maximum values of log (ω). Then the profiles obtained of the Nyquist plots attest once more the improvement of the electric parameters of the cell with the increase in the temperature. To finish, the study of the variation of the module of the impedance according to the logarithm of the impulse allows us to notice that the impedance is affected by the temperature only for the lower impulses.

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