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## The Copper Indium Selenium ( $\text{CuInSe}_2$ ) thin films solar cells for Hybrid Photovoltaic Thermal Collectors (PVT)

H. Haloui<sup>#1</sup>, K. Touafek<sup>1</sup>, M. Zaabat<sup>2</sup>, H. Ben cheikh el hocine<sup>1</sup>, A. Khelifa<sup>1</sup>

<sup>1</sup>Unité de Recherche Appliquée en Energies Renouvelables, URAER, Centre de Développement des Energies Renouvelables, CDER, 47133, Ghardaïa, Algeria

<sup>2</sup>Laboratoire des composants actifs et matériaux, université d'Oum El Bouaghi, Algérie

<sup>#</sup>haloui\_h@uraer.dz

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### Abstract

Ternary chalcopyrite compounds which may act as an absorber in thin films solar cells are mainly  $\text{CuGaSe}_2$ , the  $\text{CuInS}_2$ ,  $\text{CuInSe}_2$  and the  $\text{CuAlSe}_2$ . Because of their large optical absorption coefficient, a thickness of 1.5-2 microns is sufficient to absorb the useful portion of the solar spectrum. The most promising appears to be the  $\text{CuInSe}_2$  material, a 18.8% efficiency is obtained by the solar cells based on this material. However, its low band gap (1,04eV) limits the open circuit voltage and thus the efficiency of the solar cell.

In this work we present the application of this material in hybrid photovoltaic thermal collectors (PVT). For the determination of its electrical and thermal performance through the development of a heat balance that involves heat exchange between the different components of the collector. The results obtained show that we can have a thermal efficiency equal to (85.68%) and an electrical efficiency of the order of (19.22%) for our PVT collector based on CIS are better than the values obtained by PVT collector based on monocrystallin silicon.

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## 1. Introduction

Photovoltaic (PV) cells can absorb up to 80% of incident solar radiation available in the solar spectrum, however, only small part of the absorbed incident energy is converted into electricity depending on the conversion efficiency of the PV cell technology used [1]. The remainder energy is dissipated as heat and the PV module can reach temperatures as high as 40°C above ambient. This due the fact that PV cells convert a certain wavelength of the incoming irradiation that contributes to the direct conversion of light into electricity, while the rest is dissipated as heat [2].

Increasing the temperature of solar cells is regarded as one of the most critical problems that affect their performance [3], causing a serious deterioration and shorten the life time of cells. Therefore the cooling of photovoltaic modules during operation is essential and must be an integral part of individual PV systems in sunny areas [4]. There was also using to exploit this phenomenon by the combination of photovoltaic systems with a thermal system to form the PVT hybrid collector, which will generate the same time electricity and heat [5].

The materials used in photovoltaic applications can be produced in a wide variety of crystalline and polycrystalline forms, although crystalline materials showed very high conversion efficiencies, but their production costs are still relatively high. Several polycrystalline materials have recently gained more and more attention because of their performance (Figure 1) [6], stability and low production cost.

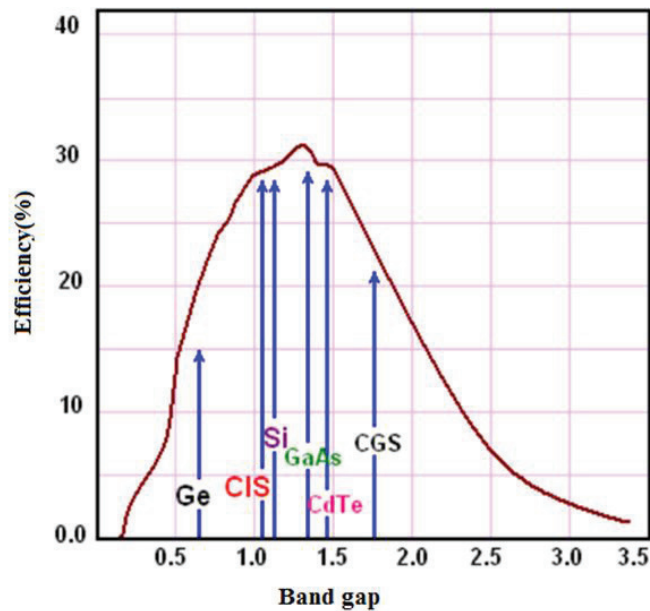


Fig. 1. Evolution of the absorption peak performance for the usual semiconductors in mono-junction as a function of the band gap in the AM 1.5 illumination conditions.

A few years ago, silicon photovoltaic panels had yields of 10 to 18%, which made them interesting because is not profitable enough (too expensive to too low energy conversion yield). But recently, thin film technology appears to increase the efficiency and reduce the cost. For application in hybrid collectors, various types of solar photovoltaic hybrid collectors (PVT) based on new materials for solar cells have been developed [7] such that the binary semiconductor, ternary and quaternary materials and organic [8]. Among the ternary materials Copper

Indium Selenium (CuInSe<sub>2</sub>) based thin-film photovoltaic (PV) technology is recognized as a second-generation thin film PV technology and its module efficiency has currently reached a level comparable to that of the market-dominant wafer-based polycrystalline-Si PV technology, so that the CIS is considered one of the most appropriate choices given the good optical properties it presents[9].

Despite the higher efficiencies achieved in photovoltaic conversion (> 19%) the cells based on CuInSe<sub>2</sub> are still improving and their electrical properties are not fully understood and are the subject of many research subjects in order to increase their performance.

## 2. Modeling

In this work we made a model of a hybrid collector Photovoltaic Thermal based on thin film CIS cell (Figure 2), it consists of three essential elements, namely:

- The photovoltaic module, whose role is the conversion of sunlight into electrical energy and consists of three layers: the first is a layer of glass, the front face is exposed to radiation, the second layer containing photovoltaic cells based CIS and the third layer is copper which has been used as rear contact metal.
- A copper pipe as a radiator or coil, where a coolant circulates whose role is to remove the heat.
- Finally, to minimize heat loss in the system, insulate the walls by one or more layers of insulation.

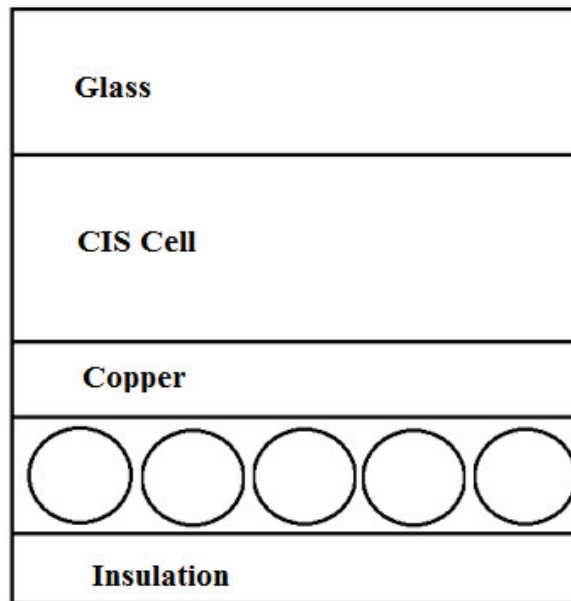


Fig. 2. Structure of PVT collector based on CIS.

The thermal efficiency of the hybrid collector is determined by the following expression [10,13]:

$$\eta_{th} = \frac{Q_{th}}{A_c G} \quad (1)$$

G: Total direct radiation absorbed by the solar cell, W/m<sup>2</sup>.

A<sub>c</sub>: Surface of the PVT collector, m<sup>2</sup>

$Q_{th}$ : It is the heat energy supplied by the hybrid collector is given by the following relationship [11]:

$$Q_{th} = A_c F_R [\pi \alpha^* G - U_{p-a} (T_s - T_a)] \quad (2)$$

F<sub>R</sub>: Extraction factor of the heat collector.

U<sub>p-a</sub>: Coefficient of heat loss.

Where  $\alpha^*$  is the factor absorbcency [12] expressed as:

$$\alpha^* = \alpha - \eta_{PV} \quad (3)$$

$\alpha$ : Absorptivity coefficient of the solar cell based on CIS.

The electrical efficiency of the hybrid collector is determined by the following expression [10,13]:

$$\eta_{ele} = \frac{Q_{ele}}{A_c G} \quad (4)$$

$Q_{ele}$ : This is the electrical energy delivered by the cell is given by the following relationship [14]:

$$Q_{ele} = \frac{Q_{sun}}{\alpha_{cel}} \eta_{ref} \exp(\beta(T_{cel} - T_{ref})) \quad (5)$$

$\eta_{ref}$ : is the reference yield is measured on a reference temperature  $T_{ref}$  taken equal to 25 ° C.

$\beta$ : The temperature coefficient that represents the relationship between the efficiency of the solar cell and the temperature (about 0.0048 / ° C for the CIS) [4].

### 3. Simulation

In this work we made a modeling of a hybrid collector Photovoltaic Thermal cell-based thin-film CIS and compare with Photovoltaic Thermal collector based on Si performed by A.Khelifa et al [15], which is makes the determination of the output temperature of the coolant of the PVT collectors solving the equations developed by a heat balance system in matlab by the method of Range Kutta.

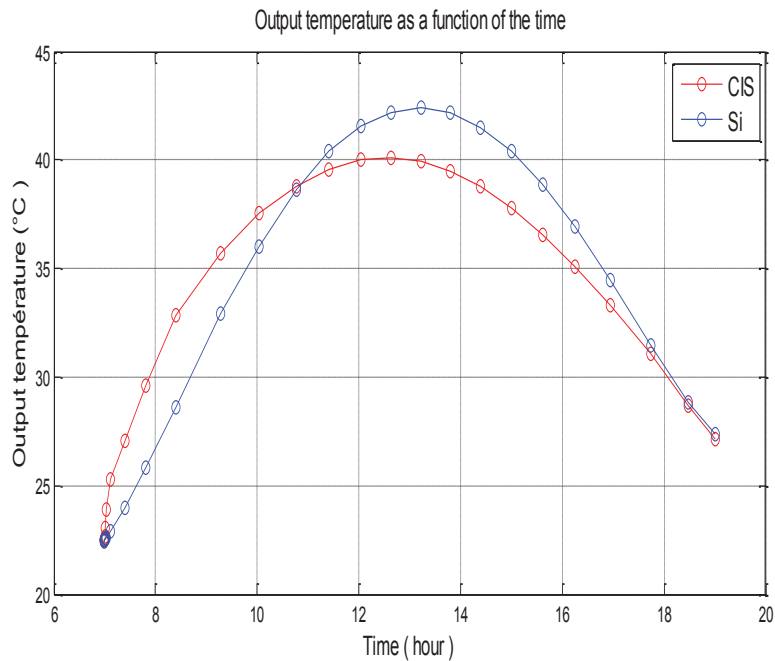


Fig. 3. Variation of the output temperature of the coolant in the PVT collectors based on CIS and Si.

**Figure 3** shows the variation of the output temperature of the coolant in the collectors PVT based on CIS and Si as a function of the time, it is observed that the temperature increases from an initial value at  $t = 7^h$  almost parabolically to its maximum values between  $12^h$  and  $14^h$ .

It also means that the output temperature of the coolant is more important for the PVT collector based on **CIS** compared to PVT collector based on **Si** in the morning (between  $7^h$  and  $11^h$ ) and the opposite way in the evening (between  $11^h$  and  $19^h$ ).

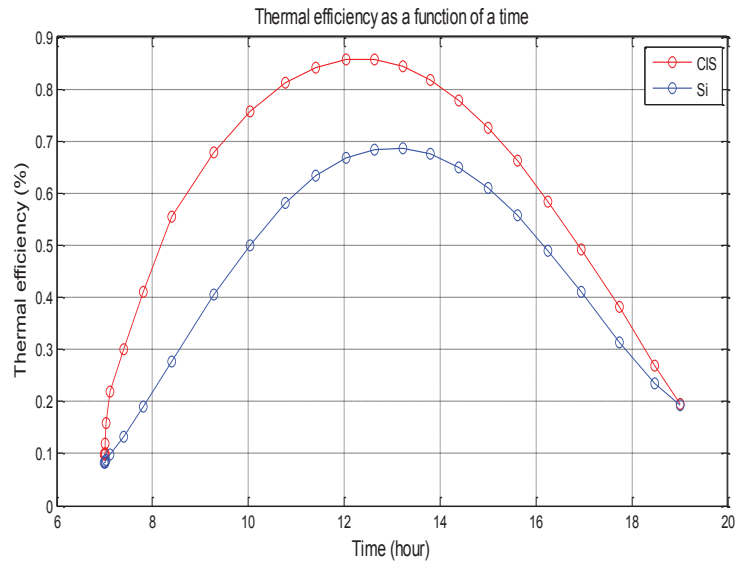


Fig. 4. Variations in the thermal efficiency of the PVT collector based on CIS and Si.

**Figure 4** shows the variation of the thermal efficiency with time of the PVT collector based on CIS and Si, respectively, whose shape is parabolic with maximum values between **12<sup>h</sup>** and **14<sup>h</sup>**, which it reaches a maximum around noon and declines following to a minimum value to **19<sup>h</sup>**. This means that we can use the thermal energy produced by our hybrid collector throughout the day.

We see that the thermal efficiency for the CIS reaches a maximum of about **85.67%** tandisque the thermal efficiency for Si reaches a maximum value of **68.72%**.

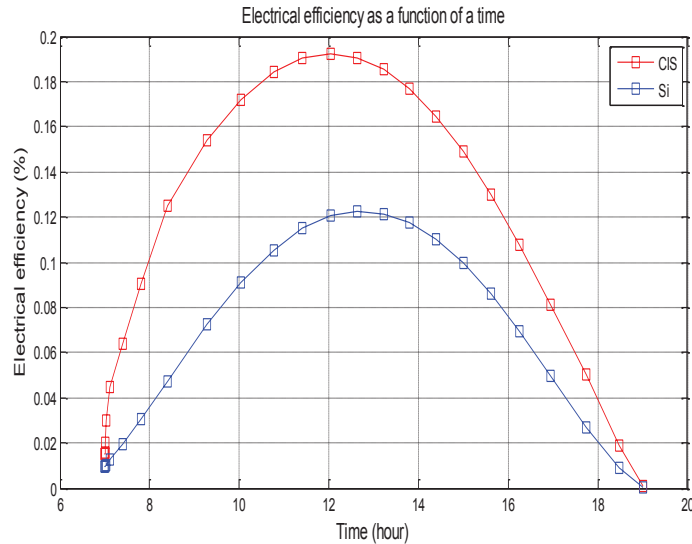


Fig. 5. Variations in the electrical efficiency of the PVT collector based on CIS and Si.

**Figure 5** shows the variation of the electrical efficiency over time of PVT collector based on CIS and Si, respectively, whose shape is parabolic with maximum values between **12<sup>h</sup>** and **14<sup>h</sup>**.

We see that the maximum value of electrical efficiency for the CIS (**19.22%**) is higher compared to that of Si (**12.27%**), since the CIS has a direct gap and Si has an indirect gap.

#### 4. Conclusion

In this work we have done the modeling of a thermal photovoltaic collector based on CIS and compare it with the thermal photovoltaic collector based on Si.

The output temperature of the coolant is more important for the PVT collector based on CIS compared to PVT collector based on Si in the morning and the opposite way in the evening.

We got a thermal efficiency equal to (**85.68%**) of our PVT collector based on CIS is larger than PVT collector based on Si (**68.72%**).

In the same way one way that our PVT collector based on CIS gives an electrical efficiency of the order of (**19.22%**) is close to the theoretical value (**18.8%**) of the basic cell of our PVT collector is better than the value for the electrical efficiency obtained by the PVT collector based on Si (**12.27%**).

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