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# Photovoltaic and Thermal Hybrid Collectors (PVT) based on Binary Materials

H. Haloui [#1], K.Touafek [1], M. Zaabat [2], H. Ben cheikh el hocine[1], A.Khelifa[1]
[1] *Unité de Recherche Appliquée en Energies Renouvelables, URAER, Centre de Développement des Energies Renouvelables, CDER, 47133, Ghardaïa, Algeria*
[2] *Laboratoire des composants actifs et matériaux, université d'Oum El Bouaghi, Algéria*
[#] haloui_h@uraer.dz

***Abstract*-- The photovoltaic collectors have proved great efficiency in the solar energy power conversion; however, different PV and hybrid thermal collectors are being attracting many researchers. Throughout this attempt, a PVT based on thin-film cell binary materials (GaAs and CdTe) has been put in reliability study. Based on the solar radiation and the temperature data, recorded from the heat balance of each layer, the electrical and thermal energy rates have been estimated, through a Matlab simulation. The obtained efficiency of the actual system has been compared to the efficiency provided by the mono-crystal silicon PV and thermal hybrid collector, previously tested. It has been averred that the obtained electrical and thermal efficiency of the actual PVT is more important than once provided by the previous system. Accordingly, the proposed design has proved its efficacy in our arid and semi-arid region, furthermore, this kind of application may be extended for other areas of different specific climate conditions.**

***Index Terms*-- Solar collector, Photovoltaic, Thermal, thin films, GaAs, CdTe, efficiency.**

## I. INTRODUCTION

A wide variety of materials is used to produce thin films. These include metals, alloys (possibility of several alloys: binary, ternary, quaternary), refractory compounds (oxides, nitrides, carbides), intermetallic compounds and polymers [1]. For ten years, considerable efforts have been made in the field of new materials synthesized at low cost to be integrated into solar cells based on CIS absorber layers: CuIn (S, Se)$_2$, and GICS: Cu (In, Ga) (Se, S) [2].

Due to their high performance and large area module production, thin film solar cells of cadmium telluride (CdTe) have currently held the second largest market after crystalline silicon solar cells [8].

Of all the possible binary compounds, not all have the same potential interest. The study of their properties, and in particular the band structure shows that the lighter elements give compounds with which the band gap is wide and indirect, and in which the effective mass of electrons is high [3], which there are the III-V and II-VI semiconductors are essential for the development of microwave components, optoelectronic, logic circuits, and gas collectors [4]. These semiconductors have a direct gap as better absorb light such as GaAs for the III-V semiconductor and the CdTe for III-VI semiconductors.

During the last years, solar cells based on gallium arsenide (GaAs) have been widely used, particularly for space applications, and because of their high efficiency and their low degradation in the face of irradiation in the space [5]. The efficiency of this cell exceeded 20% in the late 70s when Woodall and Hovel fabricated heterostructures cells with a efficiency of 22% [6]. Today these solar cells have achieved efficiencies of the order of 20-25% [7].

Because of their high performance and production in the modules of large area, thin film solar cells of cadmium telluride (CdTe) have now held the second largest market share after the solar crystalline silicon cells [8].

Therefore, CdTe is an ideal candidate for PV energy conversion with a high absorption coefficient (~$10^5$ $cm^{-1}$) and a direct optical band gap (1.45 eV) optimally matched to the solar spectrum, and its theoretical efficiency is expected to be about 29% [9]. In recent years, the technologies of preparation of solar cells based on CdTe have achieved rapid development [10–11], and various CdTe solar cells with high efficiency of (>10%) have been successfully fabricated by several techniques, including close spaced sublimation [12], vapor transport deposition [13], magnetron sputtering [14] and screen printing [15]. To date, First Solar Inc. has reported the best efficiency of 20.4% (0.4778 $cm^2$) for a small area of CdTe solar cell and a module efficiency of 17.5% (7021 $cm^2$) by high temperature fabrication process [16].
For these reasons, we choose the application of these two materials in the collectors (PVT).

## II. MODELING

In this work we made a modeling of a Photovoltaic Thermal hybrid collector (PVT) based on thin film solar cells of GaAs and CdTe (Fig. 1), 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 of GaAs and CdTe and the third layer is the 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.


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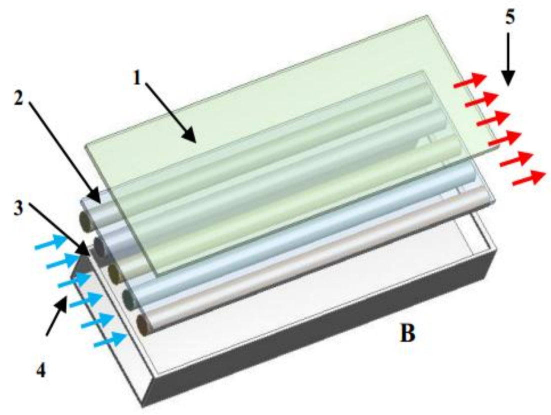


Fig. 1. Structure of a PVT collector.
1- Photovoltaic module.
2- Copper.
3- Insulation.
4- Fluid Enter.
5- Output fluid.

The thermal efficiency of the hybrid collector is determined by the following expression [17, 20]:

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

G: Total direct radiation absorbed by the solar cell, W/m$^2$.
$A_c$: Surface of the PVT collector, m$^2$

$Q_{th}$: It is the heat energy supplied by the hybrid collector is given by the following relationship [18]:

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

$F_R$: Extraction factor of the heat collector.
$U_{p-a}$: Coefficient of heat loss.

Where $\alpha^*$ is the factor absorbency [19] expressed as:

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

α: Absorptivity coefficient of the solar cell.

The heat energy can be calculated by the following relationship [19]:

$$Q_{th} = \dot{m} c_p \left(T_{fs} - T_{fi}\right) \quad (4)$$

$\dot{m}$: Mass flow, kg/s.
$c_p$: Specific heat, 1/kg.°K.
$T_o$: The output temperature of the coolant.
$T_i$: The inlet temperature of the coolant.

The electrical efficiency of the hybrid collector is determined by the following expression [17, 20]:

$$\eta_{ele} = \frac{Q_{ele}}{A_c G} \quad (5)$$

$Q_{ele}$: This is the electrical energy delivered by the cell is given by the following relationship [21]:

$$Q_{ele} = \frac{Q_{sun}}{\alpha_{cel}} \eta_{ref} exp\left(\beta\left(T_{cel} - T_{ref}\right)\right) \quad (6)$$

$\eta_{ref}$: is the reference efficiency 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.

## III. RESULTS AND INTERPRETATIONS

In this work we made a modeling of a photovoltaic thermal hybrid collector (PVT) based on binary materials: CdTe and GaAs for a thickness of about 5 µm of the active layer of the solar cell of the two materials and compare them with the collector monocrystalline silicon performed by A.Khelifa et al [22], which is made determining the output temperature of the coolant of the PVT collector by the solving of the equations developed by a heat balance system in matlab by the method of Range Kutta.

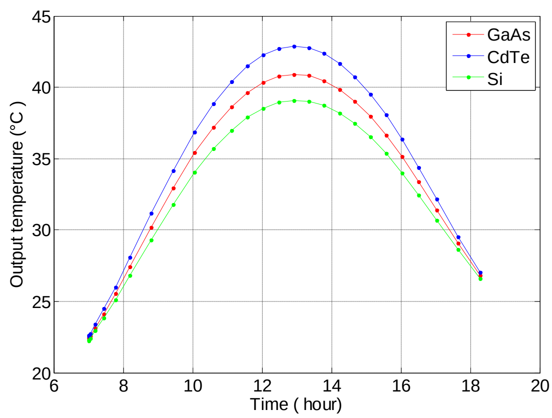


Fig. 2. Variation of the output temperature of the coolant in the PVT collectors based on GaAs, CdTe and monocrystalline silicon.

Fig. 2 shows the variation of the output temperature of the coolant in the PVT collector based on GaAs, CdTe and monocrystalline silicon as a function of a time, it is observed that the temperature rises from an initial value at t = 7$^h$ almost parabolic to its maximum values between 12$^h$ and 14$^h$.

We also see that the output temperature of the coolant is higher for the PVT collector CdTe (**43°C**) and GaAs (**41°C**) with respect to PVT collector based on


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monocrystalline silicon (**39°C**.), for an inlet temperature fixed at **20°C** of the coolant.

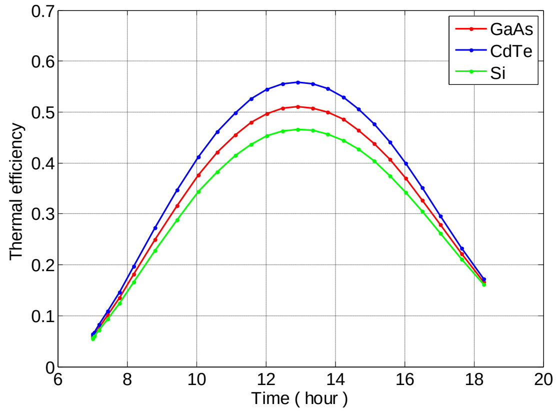


Fig. 3. Variations in the thermal efficiency of the PVT collectors based on GaAs, CdTe and monocrystalline silicon.

Fig. 3 shows the variation of the thermal efficiency with the time of the PVT collector based on GaAs, CdTe and monocrystalline silicon, respectively, whose shape is parabolic with maximum values between $12^h$ and $14^h$, which it reaches a maximum around noon and decreases subsequently to a minimum value to $19^h$. This means that we can use the thermal energy produced by our hybrid collector throughout the day.

It is found that the thermal efficiency reaches a maximum value of the order of **56%** for the CdTe and **51%** for the GaAs, which is greater than the value obtained by the PVT collector based on Si (**47%**).

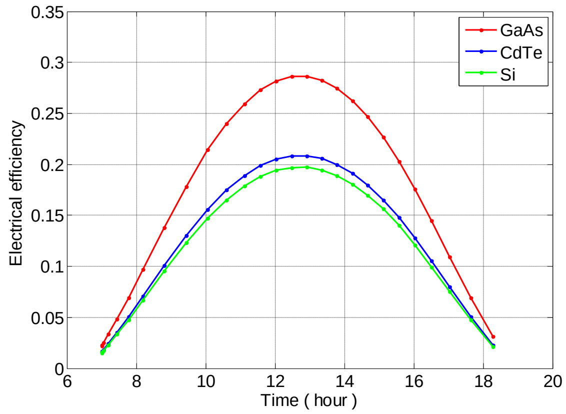


Fig. 4. Variations in the electrical efficiency of the PVT collectors based on GaAs, CdTe and monocrystalline silicon.

Fig. 4 shows the variation in the electrical efficiency with time of the PVT collector based on GaAs, CdTe and Si respectively, whose shape is parabolic with the maximum values between $12^h$ and $14^h$.

The maximum value of the electrical efficiency for GaAs (**28.62%**) is found to be greater than that of CdTe (**20.85%**) and Si (**19.71%**), since GaAs and CdTe have A direct gap and the Si has an indirect gap.

## IV. CONCLUSIONS

In this work we have a modeling of the thermal photovoltaic collector (PVT) based on binary materials: GaAs and CdTe to a thickness of 5 µm of the active layer of the thin solar cell of the two materials and compare them with the monocrystalline silicon collector.

It is found that the thermal efficiency reaches a maximum value of the order of **56%** for the CdTe and **51%** for the GaAs, which is greater than the value obtained by the PVT collector based on Si (**47%**).

The maximum electrical efficiency value for GaAs (**28.62%**) is found to be higher than that of CdTe (**20.85%**) and Si (**19.71**).

For application in PVT collectors, the CdTe will be selected because of their low cost and it gives a maximum value of the output temperature.

## REFERENCES


[1] Sana Hariech, Elaboration and characterization of thin films of cadmium sulfide (CdS) prepared by chemical bath (CBD), Magister Thesis, University Mentouri - Constantine in 2009.

[2] M. Adnane, Elaboration and Characterization of $Ag_2S$ and binary $Cu_xS$ materials developed by the SILAR technique for solar cell buffer layer based on CIS absorber layer, Renewable Energy Review Vol. 13 No. 4 (2010) 625-632.

[3] Benatmane Khaled Study of lasers based on III-V semiconductors, Magister Memory, University of Batna, 2011.

[4] Mouet Toufik, study and characterization of InP MIS structures and nanostructures based on ZnO, PhD Thesis, University of Constantine, 2011.

[5] S. Belghachi and A. Khelifi, The Role of the Layer Window in the performance of a solar cell GaAs Rev. Energ. Ren. Vol.7 (2004) 13-21.

[6] M. E. Klausmeier-Brown, (1995) "Status, Prospects and Economics of Terrestrial Single Junction GaAs Concentrator Cells'', in: "Solar Cells and their Applications", Wiley, New York.

[7] K. Barnham, J. Barnes, G. Haarpainter, J. Nelson, M. Paxman, T. Foxon and J. Roberts, "Quantum-Well Solar Cells" , Materials Research Society Bulletin, Pittsburg, (1993), pp.51-55.

[8] T. Aramoto, F. Adurodija, Y. Nishiyama, T. Arita, A. Hanafusa, K. Omura,
A. Morita, Sol. Energy Mater. Sol. Cells 75 (2003) 211–217.

[9] A. de Vos, J.E. Parrot, P. Baruch, P.T. Landsberg, in: Proceedings of the 12th European Photovoltaic Solar Energy Conference, 1994, pp. 1315–1318.

[10] J.D. Major, R.E. Treharne, L.J. Phillips, K. Durose, Nature 511 (2014) 334–337.

[11] L. Kranz & al, Nat. Commun. 4 (2013) 2306.

[12] M.A. Flores Mendoza, R. Castanedo Pérez, G. Torres Delgado, J. Márquez Marín, A. Cruz Orea, O. Zelaya Angel, Sol. Energy Mater. Sol. Cells 95 (2011) 2023–2027.

[13] J.M. Kestner, S. McElvain, S. Kelly, T.R. Ohno, L.M. Woods, C.A. Wolden, Energy Mater. Sol. Cells 83 (2004) 55–65.

[14] H. Hernández-Contreras, G. Contreras-Puente, J. Aguilar-Hernández, A. Morales- Acevedo, J. Vidal-Larramendi, O. Vigil-Galán, Thin Solid Films 403–404 (2002) 148–152.

[15] H. Matsumoto, K. Kuribayashi, H. Uda, Y. Komatsu, A. Nakano, S. Ikegami, Sol. Cells 11 (1984) 367–373.

[16] M.A. Green, K. Emery, Y. Hishikawa, W. Warta, E.D. Dunlop, Prog. Photovolt: Res. Appl. 22 (2014) 701–710.



ISSN 2356-5608

[17] J.A. Duffie and W.A. Beckman, 'Solar Engineering of Thermal Processes', New York, Etats-Unis, Wiley-Interscience, 1980.
[18] K. Touefek, M Haddadi, et al. Numerical simulation of the thermal behavior of thermal solar photovoltaic hybrid collector; Reviews of Renewable Energies Vol. 11 No. 1 (2008) 153-165.
[19] K. Touafek, 'Study of a Hybrid Photovoltaic Thermal Solar collector', Magister Thesis, National Polytechnic School, Algiers, 2005.
[20] A. Khelifa, Study and Modeling of Hybrid Photovoltaic Thermal Collector (PVT) 'Magister Thesis, University of Batna, 2011.
[21] K. Touafek, M. Haddadi, and A. Malek, Modeling and Experimental Validation of a New Hybrid Photovoltaic Thermal Collector, IEEE TRANSACTIONS ON ENERGY CONVERSION, VOL. 26, NO. 1, MARCH 2011.
[22] A.Khelifa and K.Touafek, Study of the influence of external parameters on thermal photovoltaic hybrid sensor (PVT), Renewable Energy Review Vol. 15 No. 1 (2012) 67-75.


ISSN 2356-5608