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Published version

ALRASHIDI, Hameed, GHOSH, Aritra, ISSA, Walid, SELLAMI, Nazmi, MALLICK, Tapas K and SUNDARAM, Senthilarasu (2018). Evaluation of solar factor using spectral analysis for CdTe photovoltaic glazing. Materials letters, 237, 332-335.

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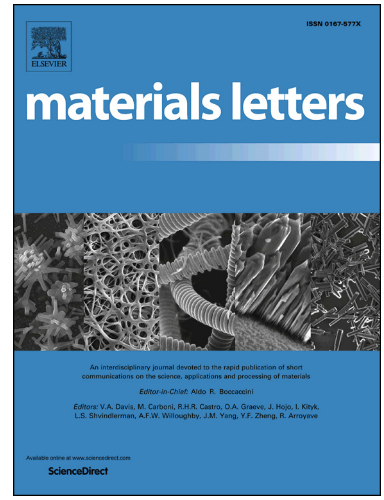

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PII: S0167-577X(18)31899-8
DOI: https://doi.org/10.1016/j.matlet.2018.11.128
Reference: MLBLUE 25350

To appear in: *Materials Letters*

Received Date: 1 November 2018
Revised Date: 21 November 2018
Accepted Date: 22 November 2018

Please cite this article as: H. Alrashidi, A. Ghosh, W. Issa, N. Sellami, Tapas.K. Mallick, S. Sundaram, Evaluation of solar factor using spectral analysis for CdTe photovoltaic glazing, *Materials Letters* (2018), doi: https://doi.org/10.1016/j.matlet.2018.11.128

Evaluation of solar factor using spectral analysis for CdTe photovoltaic glazing

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Abstract

Solar and luminous light transmission control using Cadmium Telluride (CdTe) based PV glazing systems (15cm × 15 cm × 0.6 cm) were evaluated in this work. Indoor spectral characterisation showed that average solar transmission for investigated three different CdTe glazing systems were 5.77% (CdTe1), 9.54% (CdTe2) and 12.34% (CdTe3). Spectral behaviour of reflections in the range of solar and visible wavelengths was similar for these three different transparent CdTe glazing. Near infrared (NIR) reflection was higher compared to luminous reflection after 1500 nm for all three glazing systems. Solar factor (SF) for CdTe1, CdTe2 and CdTe3 glazing were 0.23, 0.28, 0.26. CdTe3 is the best candidate for glazing application as it has 113% higher luminous transmission while SF only increases by 21% compared to CdTe1.

Key Words

Cadmium Telluride (CdTe); thin film solar cell; transmission; reflection; solar factor; glazing;

Introduction

Excessive penetration of solar radiation through a transparent façade enhances a building's cooling load demand. This penetration can be limited by using solar control material in a glazed façade or glazing. Currently, solar control solar energy materials [1] include, metallic low emissivity coating, switchable electrochromic, suspended particle [2], liquid crystals [3], thermochromic, thermotropic, photochromic and constant transparent photovoltaic [4]. Semi-transparent photovoltaic (PV) glazing has the potential to reduce solar heat gain and generate solar electricity while adequate incoming daylight and view to the outdoors are possible [5].

PV glazing material includes first generation crystalline silicon (c-Si) solar cell, second generation thin film and third generation dye sensitized solar cell (DSSC) and perovskite [6]. PV glazing made by crystalline silicon (c-Si) is the most promising due to its high durability and efficiency. However, zero transmission, high absorption and negative temperature coefficient make c-Si less attractive for glazing applications [7]. DSSC and perovskite has durability issue under outdoor exposure. Thin film technologies are advantageous for PV glazing applications due to their tuneable transparency, higher durability compared to third generation solar cell materials.

Amorphous silicon (a-Si) enables light to pass through while it is extremely thin or laser grooved. Thus it is the most investigated thin film PV glazing material [8–10]. Thin film a-Si band gap of 1.7 – 1.8 eV makes it suitable for receiving sunlight. Non-crystalline structure of a-Si, capable to absorb sunlight higher than c-Si material. Due to Staebler–Wronski effect, initial power drop around 16% is possible from a-Si PV glazing. However, in the hot season part of the decreased efficiency can be recovered [11]. Semi-transparent a-Si PV glazing offered energy saving and electricity generation for an office building in Brazil [12]. Optimized window to wall ratio was investigated using see through a-Si PV glazing in Singapore climate [13].

Another promising thin film material for PV glazing application is CdTe which is formed by nCdS and p-CdTe film. The band gap of CdTe is 1.5 eV which is optimally matched to the solar spectrum to generate photovoltaic energy conversion. Absorption coefficient of 5×10^5 /cm indicates 99% of photons with energy greater than the band gap can be absorbed within 2 μm of CdTe film [14]. CdTe as a glazing material can trim down the building energy demand by allowing or reducing the visible light and solar transmission. Theoretical analysis showed that CdTe glazing can reduce 60.4% building energy compared to low emissivity coated glazing for an Indian city Jaipur [15]. CdTe glazed roof on buildings in Brazil offered surplus energy, which was proposed to recharge electric vehicle [16].

Te is a humble non-metal, actually abundant in the universe and as rare as many of the other precious metals of Earth's crust. Actually, with the long-term potential of CdTe PV modules, it will not be bleak, given realistic developments in module technology and Te recovery. With the passage of time, the cost of CdTe module production have dropped. A key advantage of CdTe for thin-film devices is that it can be deposited rapidly. In contrast, other thin-film PV materials use the vapor-phase composition and must be carefully adjusted and controlled, which slows down the process and adds costs. However, CdTe can be deposited at micrometers per minute rate, over large substrates, compared to that of nanometres per minute for amorphous silicon. It is believed that Te supply and its use will be nearly static during the next few years.

A suitable solar control glazing material for low energy building applications requires high luminous transmission, low solar transmission to reduce solar heat gain. Investigation of glazing application using CdTe PV material is rare. In this work, hemispherical spectral analysis of three different transparent CdTe based PV glazing systems was investigated and solar factors were calculated.

1. Experiment and methodology

Experiments were carried out using three different types of CdTe glazing systems marked as CdTe1, CdTe2, and CdTe3 based on their different transparency. These systems were provided by PW solar power, China. Photographic view of these glazing systems is shown in Figure 1. Nominal power for CdTe1, CdTe2 and CdTe3 were 1.53W, 0.815W and 0.99W respectively whereas efficiencies were 12.6%, 8.23% and 6.7% respectively. Spectral characterisation of these glazing systems was performed using Perkin Elmer® Lambda 1050 spectrophotometer. Solar control potential of these glazing systems was evaluated by calculating the solar factor using equation 1.

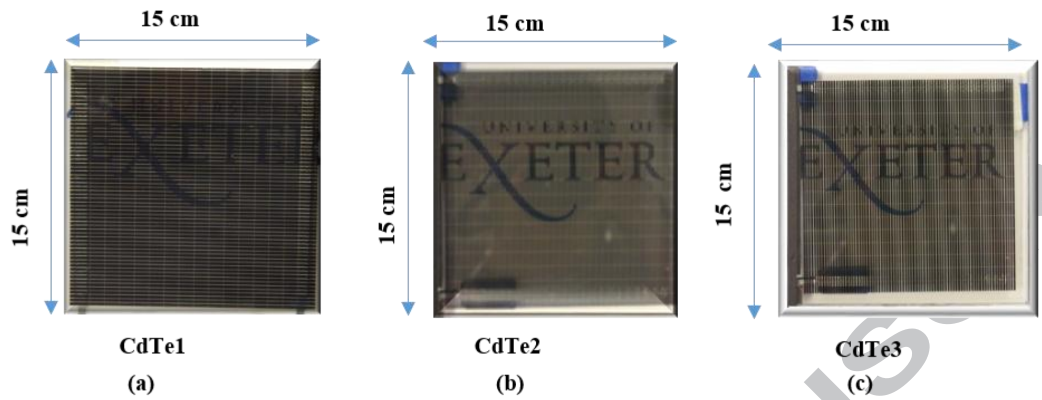

Figure 1: Photographs of three different CdTe glazing panels.

Solar factor (g) or solar heat gain coefficient indicates the transmitted solar energy through the glazing panel. This is the sum of the solar transmittance (τ_s) and entering infrared radiation (q_i) to a building's interior. In the equation h_i is the internal heat transfer coefficient, and h_e is the external heat transfer coefficient [17].

$$g = \tau_s + q_i = \tau_s + (1 - \tau_s - \rho_s)\frac{h_i}{h_i + h_e} \quad (1)$$

2. Results & Discussion

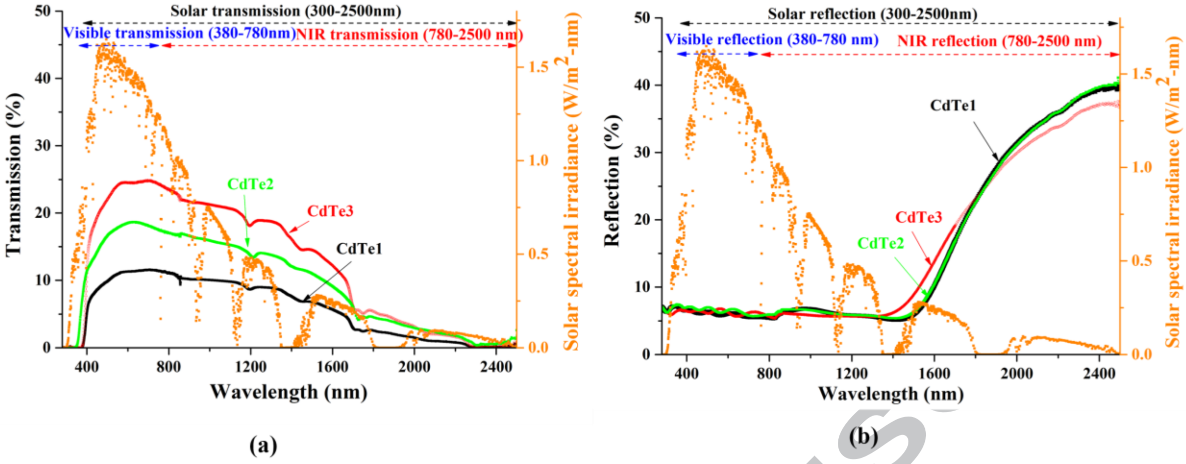

Figure 2: Spectral (a) transmittance and (b) reflection of three different semi-transparent CdTe PV glazing.

Figure 2 (a) indicates the total transmittance and (b) reflectance of three different CdTe based PV glazing (CdTe1, CdTe2 and CdTe3) between 280 and 2500 nm. Details of different transmission ranges are listed in Table 1. Average solar transmission for CdTe3 was 113% and 25% higher than CdTe1 and CdTe2 respectively. Thus for comfortable daylight CdTe3 is suitable. In the near infra-red (NIR) range CdTe3 showed 52% higher transmission compared to CdTe1 and 28% higher than CdTe2. From the reflection spectrum of three CdTe PV glazing systems, it is evident that this type of glazing has similar reflectance irrespective of the transmission. Higher NIR reflection was found after 1500 nm which indicates that CdTe PV glazing is potential for solar gain control. Low transmission and high absorption in the UV range of CdTe glazing systems indicates UV protective coating at the external surface of this glazing is essential to enhance the durability of this glazing.

Table 1: Solar, UV, luminous, NIR transmittance, reflectance and absorption for CdTe1, CdTe2, CdTe3

STPV module	Optical properties	Solar (300-2500)	UV (250-380)	Visible/luminous (380-780)	NIR (780-2500)
CdTe1	Transmission	5.77	0.02	10.03	5.05
	Reflection	16.00	7.06	6.00	18.68
	Absorption	79	92.92	83.97	76.27
CdTe2	Transmission	9.54	0.83	16.60	8.30
	Reflection	15.82	6.71	6.24	18.50
	Absorption	74.64	92.46	77.16	73.2
CdTe3	Transmission	12.34	0.03	21.87	10.70
	Reflection	16.11	7.14	6.43	18.78
	Absorption	71.56	92.83	71.17	70.58

Figure 3 shows the SF with solar and luminous transmission for three different CdTe based PV glazing. In a European climate, a vertical glazing with an external heat transfer coefficient of 25 W/m^2K and internal heat transfer coefficient (h_i) of 7.7 W/m^2K should be considered [17]. SF was calculated using equation 1. SF for CdTe 3 was 21% higher than CdTe1 and 7% higher than CdTe2. Thus, for solar control CdTe1 is promising. However, CdTe3 can be the best choice for glazing application of low energy building due to its higher luminous light penetration capability while the maximum increment of SF is only 21% compared to CdTe1.

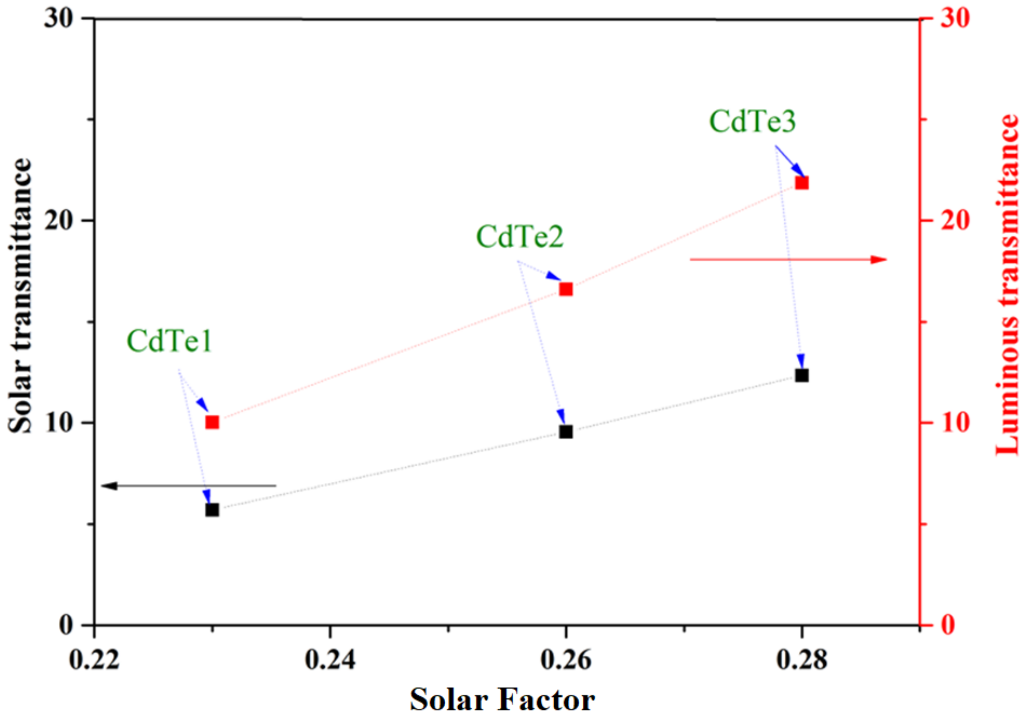

Figure 3: Variation of SF with luminous and solar transmission of three CdTe PV glazing.

3. Conclusion

Solar and luminous control potential was investigated using indoor spectral characterization for three different transparent CdTe (CdTe1, CdTe2, CdTe3) based PV glazing. For solar control glazing applications, higher luminous and low solar factors are required. Maximum luminous transmission of 21.87 % and a solar transmission of 12.34% were found for CdTe3 glazing. These transmission values were highest compared to the luminous and solar transmission of CdTe1 and CdT2. The variation of reflection between CdTe1, CdTe2, CdTe3 were negligible. CdTe glazing has higher reflectance after wavelength of 1500 nm which make it suitable for solar control glazing application. Three different solar factors for CdTe1, CdTe2 and CdTe3 were 0.23, 0.26 and 0.28 respectively. CdTe3 is the best choice for glazing application as it offers 113% and 25% higher luminous transmission while solar factors are only 21% and 7% higher compared to CdTe1and CdTe2 respectively.

Acknowledgement

This work is funded through PhD fellowship by Kuwait Fund for Development is greatly acknowledged.

The authors declare no competing financial interest.

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Highlights

- Three different CdTe based photovoltaic glazing were characterised using spectrometer
- Solar factors of CdTe based photovoltaic glazing were calculated.
- Higher luminous and low solar factor are required for solar control glazing

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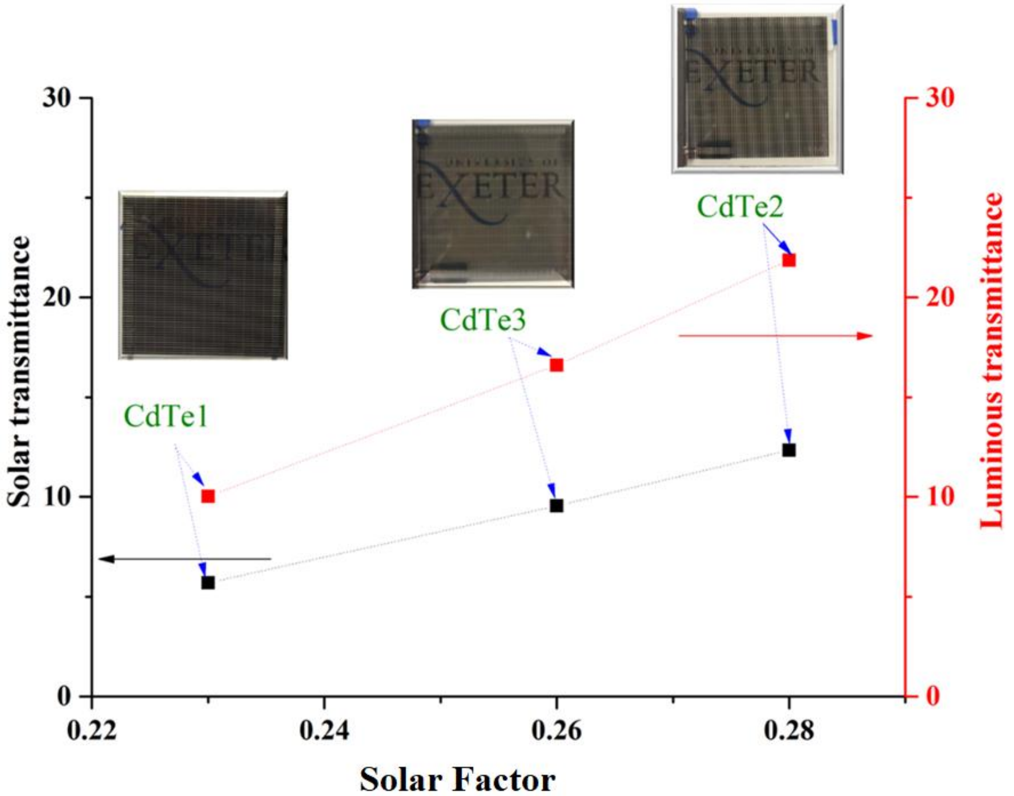

CdTe2 has 113% higher luminous transmission and 21% higher solar factor compared to CdTe1

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Conflict of Interest

This article doesn't have any conflict of interest with the authors listed and beyond.

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