Advanced Study of the Parabolic Trough Collector Using Aluminum (III) Oxide

Mostafa Esmaeili Shayan*, Gholamhassan Najafi**‡, Farzaneh Ghasemzadeh***

* Ph.D. Student of Renewable Energy, Mechanical and Biosystem Engineering Department, Tarbiat Modaress University, Tehran, Iran.

** Mechanical and Biosystem Engineering Department, Associate Professor, Tarbiat Modaress University, Tehran, Iran.

*** Ph.D. Student Condensed Matter of Physics, Physics Department, Iran University of Science and Technology, Tehran, Iran.

(Mostafa.Esmaeili@modares.ac.ir, G.Najafi@modares.ac.ir, fgh.7192@yahoo.com)

‡ Corresponding Author; Second Author, Postal address, Tel: +98 4829 2004,

Fax: +98 4829 2004, G.Najafi@modares.ac.ir

Received: 04.07.2020 Accepted:11.09.2020

Abstract- Solar energy is the primary source of all sorts of energy present in nature, i.e., all energy produced from it. So the direct use of solar energy as useful energy is significant. There are numerous solar thermal projects in which the concentrated type collector heats up to 100 to 400 degrees Celsius. It is used in a wide range of applications, including power generation, industrial steam generation, and hot water supply. Parabolic trough collector is chosen for steam production since high temperatures can be achieved. The temperature of the inlet and outlet water, the mass flow rate, the usable heat gain, and also the thermal efficiency of the collector are calculated. Theoretical values for heat loss of vacuum as the annulus gas is measured and compared with other values for heat loss of air as the annulus gas. Therefore, preserve the vacuum within the annulus gap, a substitute glass-metal seal was created. The seal helped increased the heat loss and thereby improved the overall efficiency of the collector. It can be deduced from the band structure and density of the states of Aluminum (III) Oxide and is an excellent insulator content. Besides, the assessment of the absorption coefficient showed a low energy range of 5.34 eV to 11.88 eV, with a median value of 11.50 eV and 11.88 eV respectively for parallel and perpendicular polarizations.

Keywords Heat loss, increase efficiency, parabolic trough, vacuum seal.

1. Introduction

HIS Climate change and the green gas effect are the most significant threats for the sustainability of the Planet. Humanity has a near-zero reliance on fossil fuels and other wasteful forms of resources. Current energy sources, including oil, gas, coal, and nuclear power, are exhaustible. Energy consumption increases at an alarming rate exacerbating the social and environmental impacts and accelerating depletion [1]. In the coming future, therefore, we are expected to focus more on renewable energy sources. Energy usage today can be categorized by industry, and about one-fourth of the world's energy usage, today is contained in the industry sector, as seen in the illustration in Figure 1.

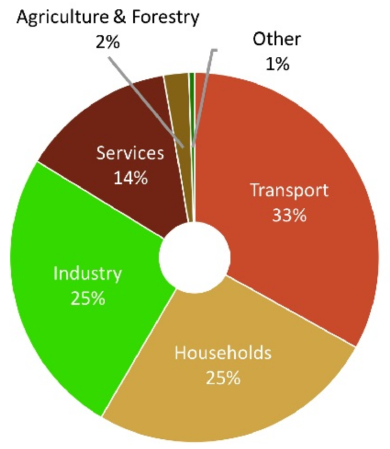


Fig. 1. The world's carbon use. Divided into six sectors:

Transport, households, industry, services, agriculture & forestry, and others.

There are various explanations for why the world should clean energy resources for their power production [2]. The critical explanation between them can be listed as:

- Fast loss of fossil sources such as oil, coal and so on.
- Many other forms of fuel generate emissions.
- Enhanced energy uses in all countries.
- Climate destruction induced by issues such as acid rain, destruction of ozone, Greenhouse impact.

Solar energy has an enormous potential of all alternative energy sources [3]. As seen in Figure 1, nearly 74% of energy is often used to fulfill the thermal needs of the industry, including heating water or process heating, in which significant sections are mainly powered by fossil fuels [4,5]. The solar thermal energy provides a more environment-friendly solution in concentrated solar energy (CSP). The solar energy where the sunlight enters the atmosphere is 1,017 watts [6]. The theory of CSP is to rely on sunlight in order to heat a fluid, also referred to as heat transfer fluid (HTF), which is either used directly or through a steam engine to generate energy [7]. Parabolic trough technology has proven that solar thermal technology is the most thoroughly developed and the lowest priced [8]. Consequently, much of the building projects of industrial solar power plants focus on this kind of collector. Many parabolic trough power plants are planned to be installed in the United States, the Middle East, and Spain, as the solution, as mentioned earlier to the usage of parabolic trough solar collectors, is the most mature technology [7]. Without question, the next parabolic trough plants should have storage systems since the routine of hourly operation can be configured automatically [9]. This is constructed of flat sheet metal (G.I. sheet) with a subtle surface finish or buffer, or mirror surface finishes such that the full intensity of solar radiation can be concentrated on the focal side[10]. The rigid support system was built for the stability and accuracy of the collector. The construction frame is used to support the parabolic reflection axis of rotation of the ground[11]. This is designed to rotate the horizontal axis in order to track the sun on a regular schedule. The heat-collecting device or receiver is made of high absorption content. The stainless steel is chosen as a collector insulator coated in black. Usually, the absorber pipe is constructed of stainless steel enclosed by an evacuated gas stream to reduce convective and radiative heat losses[12]. The heat transfer fluid that passes into the receiver conduit absorbs power from the solar radiation[13]. The seal has been tested in various materials and silver and aluminum sheets as a significant parameter influencing the thermal performance of parabolic trough solar collectors. Their work has shown that the use of aluminum foil can improve the performance of the system by up to 15% [14]. Researchers have distributed the residual stress of pipe-to-metal seals in the Solar Receiver utilizing the Finite Element Method (FEM). The results of the research had significant consequences for refining the design of the seal in the solar receiver tubes[15]. In specific, researching ammonia borate anodic film on aluminum, he observed by electron diffraction that the pseudo-amorphous structure of the surface layer was transformed to boehmite, but that this change did not occur when the separated film was submerged in boiling water[16]. Anodizing is a method of passivation to raise the thickness of the natural oxide coating on the metal sheet[17]. Aluminum anodizing is done where the aluminum material itself serves as an anode in an electrolytic solution. Vaccumulation of the annulus gap instead of air improves productivity as the convection across the annulus gap reduces. Traditional methods, such as vacuum tube use, are not cost-effective and are thus not industrially relevant. Due to this, the cleaning of the vacuum is another problem[18]. For another review article, the researchers studied some of the material properties of the sealing cap for the shield tunnel. Ultimately, ideas for the potential production of innovative technologies or forms of improving the efficiency of seal gaskets have been suggested[19–21]. As a consequence, the topic of the materials that can be used for such components is very critical for every manufacturer of parabolic trough solar collectors, and the aim of this research would be on commercially accessible materials for the solar collector receiver, reflector, seal, and others. The focus of this research is to develop a parabolic trough collector using an aluminum (III) oxide seal.

2. Materials and Method

The limitation of the heat loss of the parabolic trough solar collector is essential because that would improve the performance of the solar collector. I the heat loss in the solar collector is also in three forms.

1. Convection
2. Conduction
3. Radiation

Conduction losses are small, as opposed to convection and radiation. The reduction of convective and radiative heat loss is the fundamental purpose of raising heat loss in parabolic trough development. The receiver, which has the duty of concentrating the light from the sun on the receiver, as seen in figure 1, must retain strong reflective properties in order for the incoming light to reach the receiver.

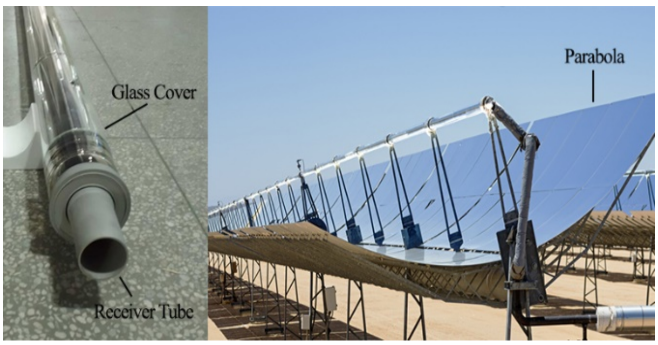


Fig. 2. Parabolic and Receiver in a concentrated solar parabolic trough

2.1. Analysis of Energy and Exergy

Every incoming sunlight in the collector that is not concentrated in the receiver, through the reflector, is an immediate loss in the process. Due to the first thermodynamics law, all the energy that falls to the surface must go somewhere.

In the case of energy absorption, this may be achieved in three ways: by absorbing (α) into the substance, by reflecting (β), and by transmitting (τ). Consequently, the radiation quickly passes into the material. These three phenomena, at each wavelength of incoming radiation, are related to each other, according to (1).

$$\alpha + \beta + \tau = 1 \quad (1)$$

Useful reactor material will absorb and transmit sunlight at a minimum and reflect at a peak, ideally providing β=1 for all wavelengths in the solar spectrum. The energy balance of the solar collector receiver can be determined according to (2).

$$\dot{Q}_{usefull} = \dot{E_{opt}} - \dot{Q}_{loss} \quad (2)$$

Where $\dot{Q}_{usefull} =$ Rate of energy to be used entering the absorber (W) and $\dot{Q}_{loss} =$ The Rate of loss of thermal energy of the absorber (W) and $\dot{E_{opt}} =$ the Rate of optical radiation incident to the absorber (W) and, therefore, the usable energy of the solar thermal collector is the amount of thermal energy entering the collector that can be calculated from (3).

$$Q_{usefull} = mC_p\Delta T \quad (3)$$

Where $m =$ Heat transfer fluid mass flow rate (kg / s) and $C_p =$ Specific heat transfer fluid (J / kg. K) and ΔT =change in Temperature (Kelvins, K) $= (T_{out} - T_{in})$. Where $T_{out} =$ temperature of the heat transfer fluid that exits the absorber (K) and $T_{in} =$ temperature of the heat transfer fluid flowing through the absorber (K). From this perspective, the section of the collector where the solar irradiance is dropping is considered the (opening) area of the collector. The solar resource incident is defined by (4).

$$E_{incident} = I_a A_a \quad (4)$$

Where $I_a =$ The solar irradiance hitting the collector's opening is capable of absorbing both direct and diffuse irradiance (W / m^2) and $A_a =$ The net opening area typically contains just the glazed (glass-covered) area of the collectors (m^2). This solar power is reduced by some losses when it moves from the collector's opening to the absorber. The Rate of optical (short wavelength) energy entering the absorber or receiver is the sum of the received solar resource divided by various factors, all of which are less than 1.0.

$$E = \Gamma\rho\alpha T I_a A_a \quad (5)$$

Where $\Gamma =$ capture fraction. Measurement of both the quality of the shape of the reflecting surface is the fraction captured and the size of the receiver. Additionally, $\rho =$ Reflectance on every variable reflective element, $\alpha =$ Angular solar absorbance of absorbers employed in solar thermal collectors, and $T =$ transmittance of specific sheets or mirrors covered in glass or plastic.

If the solar energy fuel has found its way down to the absorber or collector surface, the temperature of the absorber increases above the atmospheric temperature. It, in effect, begins the cycle of heat loss from the absorber, as in every surface heated above the temperature of the ambient environment. Such loss mechanisms are convection, radiation, and conduction, both of which rely on, among other factors, the difference in temperature between the absorber and the surrounding environment.

$$\dot{Q}_{loss} = \dot{Q}_{loss,conv} + \dot{Q}_{loss,rad} + \dot{Q}_{loss,cond} \quad (6)$$

Through thermodynamics law $\dot{Q}_{loss,conv}$ equal to $h_c A_r(T_r - T_a)$ and $h_c =$ average overall convective heat transfer coefficient (W/m^2.K), $T_r =$ average temperature of the receiver (K), $T_a =$ ambient air temperature (K), $A_r =$ surface area of receiver or absorber (m^2). The performance of the solar thermal collector is directly related to heat losses, and the heat loss of radiation is essential for collectors operating at temperatures significantly above the ambient temperature and is influential for collectors operating at higher temperatures.

$$Q_{loss,rad} = \varepsilon\sigma A_r(T_r^4 - T_{sky}^4) \quad (7)$$

Where $\varepsilon =$ Emittance of the absorber surface, $\sigma =$ the Stefan-Boltzmann constant ($5.670 \times 10^{-8}\ W/m^2.K^4$), T_{sky}= the relative temperature of the black body of the atmosphere changes with zenith and azimuth angles (K). It is typically defined in terms of the constant material, the thickness of the substance, and its cross-section area.

$$Q_{loss.cond} = k\Delta x A_r(T_r - T_a) \quad (8)$$

Thermal conduction is the flow of heat of internal energy by microscopic collisions of particles and the passage of electrons inside the body. Conduction of heat, also known as diffusion, in (8) k Equivalent mean conductivity (W / m. K) and Δx is the maximum width of the insulation content.

2.2. SIMULATION OF Al2O3 AS AN INSULATOR

This efficiency is the most critical feature of the insulation material. The final efficiency can be measured by how easily a manufacturer may build a material utilizing conventional techniques. Aluminum reacts with oxygen to create an aluminum oxide layer on its surface, but its thickness (0.01μm) is insufficient to have enough protection to corrosion. The model of the seal we use is the aluminum cap, which is very efficient and gives due importance to thermal expansion during high-temperature operation. The properties of aluminum oxide as an insulator have been examined in this section. Electronic and optical properties of Al_2O_3 have been investigated within the first principles of full potential augmented plane-waves (FP-APW) via the density functional theory as implemented in WIEN-2k code [22]. The construction of this substance has been configured. The Al2O3 structure can be seen in Figure 3.

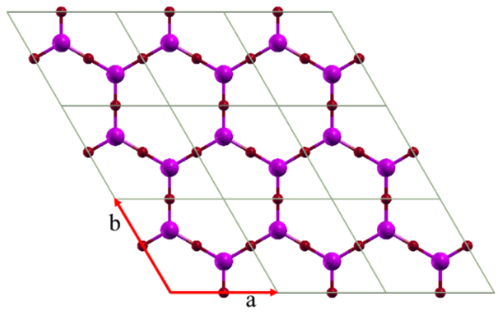


Fig. 3. Optimized Al_2O_3 structure from the top view (both axes and b axes: zig-zag direction; red ball: o, pink ball: al atom)

The stable lattice constant and bond length of Al_2O_3 were obtained 5.85Å and 1.69Å, respectively, which are in good agreement with previous calculations [23]. Also, the band structure of Al_2O_3 along the high-symmetry M-K-Γ-M path and the partial density of states are presented in Figure 4.

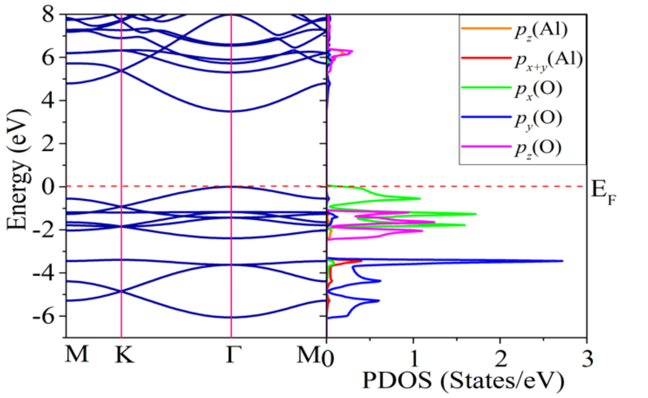


Fig. 4. Electronic band structure and corresponding partial density of the Al_2O_3 states.

As shown in Figure 4, the band structure of Al_2O_3 shows a direct bandgap of 3.59 eV with both VBM (valence band maximum) and CBM (conduction band minimum) located at Γ. The partial density of states for Al and O atoms is also seen in Figure 4. The main contribution of edges of valence and conduction bands are from P_x and P_y sub-orbitals of oxygen atoms, respectively. From the band structure and density of states of Al_2O_3, This can be deduced and is an excellent insulator material. The study of the optical properties of Al_2O_3 is vital to practical applications in fabrication and optoelectronics. The optical properties of Al_2O_3 ,such as real and imaginary parts of the dielectric function, reflectivity, and absorption, are calculated using the random phase approximation (RPA) method[24].

The optical properties are determined by the complex dielectric function $\varepsilon(\omega)$ to describe the optical response of the medium to the electromagnetic field at all energies:

$$\varepsilon(\omega) = \varepsilon_1(\omega) + i\varepsilon_2(\omega) \quad (9)$$

The real and imaginary parts of the dielectric function of Al_2O_3 are depicted in Figure 5. The dielectric constant of Al_2O_3 is 1.21 and 1.18 for parallel and perpendicular polarizations, respectively. From the imaginary part of the dielectric function, it can be found that the most absorption occurs at the energy ranging from 5.26 eV to 11.85 eV. The highest energy of absorbing for parallel polarization is 7.41 eV, which its value is 0.72, this value for perpendicular polarization is 0.52, which occurs at the energy of 6.79 eV.

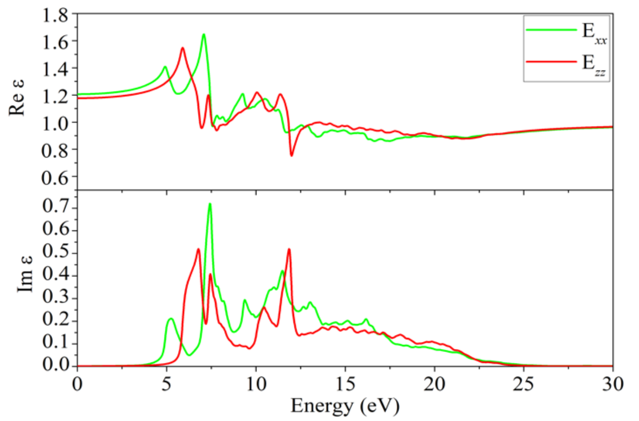


Fig. 5. The real and imaginary part of the dielectric function of Al_2O_3 for parallel and perpendicular polarizations.

2.3. Modeling Al2O3 Seal

Fig. 6. Receiver tube and aluminum (III) Oxide Seal

The thick porous layer of aluminum oxide is formed during the anodizing phase. The original aluminum oxide seal model was developed and designed into SolidWorks 2018 software. Air and water can reach the aluminum substrate through the pores and, if not sealed, cause corrosion. The seal is applied at all ends of the glass cover. It is fixed to a glass envelope with the support of Vacseal and Silicon sealing, which are used as an adhesive between the cap and the glass seal or the receiver tube.

2.4. System Thermal Loss

By utilizing aluminum (III), an oxide seal is maintained in the annulus gap. Convection heat transfer across the annulus gap Reynolds airflow is insignificant, while wind speed is 4 m / s. This function, equation 6, will be used to measure system losses.

$$Re = \frac{\gamma \vartheta D}{\mu} = \frac{1.127 \times 4 \times 0.05}{16.97 \times 10^{-6}} = 13282.2$$

$$Nu = 0.30Re^{0.6} = 0.30 \times 13282.2^{0.6} = 89.34$$

$$Nu = \frac{hD}{k}$$

$$h_x = \frac{89.34 \times 0.027}{0.05} = 48.245\, {}^{W}/_{m^2 {}^\circ C}$$

When the system temperature is 50 ° C, and the ambient temperature is 27 ° C, the substitution of h_x and equations 7 and 8 in equation 6 would be as follows:

$$\begin{aligned} Q_{loss} &= \pi D_{co} l h_x l h_x (T_{co} - T_0) + \varepsilon_c \pi D_{co} L \sigma (T_{co}^4 - T_{sky}^4) \\ &= \pi \times 0.05 \times 1.8 \times 48.24(323 - 303) \\ &+ 0.88 \times 3.14 \times 5.67 \times 0.5 \\ &\times 10^{-8}(323^4 - 300^4) = 312.07W \end{aligned}$$

If the system does not use the aluminum (III) oxide seal in the annulus gap, the Convection heat transfer in the gap and A = area in the annulus gap could be determined as follows:

$$\begin{aligned} Q_{loss} = hA(T_r - T_{conv}) &= 16.55X0.2159(423 - 385) \\ &= 135.77W \end{aligned}$$

$$h = 0.30Re^{0.6} = 16.55$$

The decrease in heat loss when the aluminum (III) oxide seal is used:

$$\frac{Q_{loss}}{Q_{loss,v} + Q_{loss}} \times 100 = 30.3\%$$

It was also known that a significant amount of convective heat loss could be reduced by employing aluminum (III) oxide seal. It is therefore noticed that the use of aluminum (III) oxide seal in the parabolic trough receiver is beneficial. Often adding an extra element or a component construction method will optimize system efficiency. However, the industries may question, is this switch going to cost anything? When this impact is not fair, this adjustment would be eliminated from the list of choices. The cost-benefit evaluation of the device indicates that the correct decision may be taken to utilize this subsystem.

2.5. Cost of sealing

Aluminum (III) Oxide Seal cap and its development = 0.39 USD

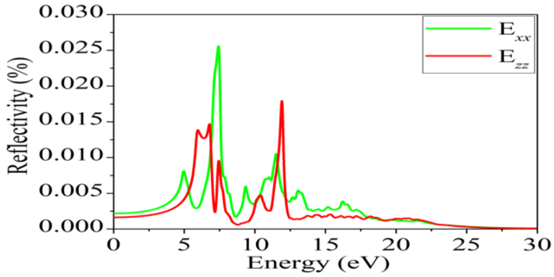
Vacseal for 30 to 35 caps = 27.52 USD for 14ml pack

Silicon seal for 30 to 35 caps = 1.9 USD

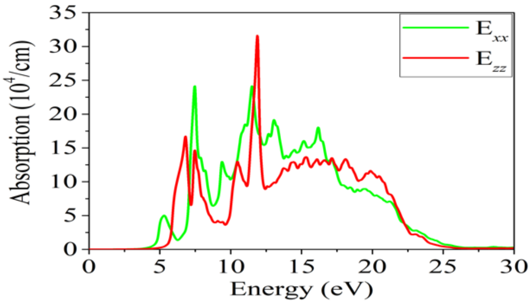
Maximum price for the application of a single cap is equal to 0.39 + 0.92 + 0.06 + vacuumization process charges = 1.37 USD + vacuumization charges.

3. Results and Discussions

The absorption coefficient of Al_2O_3 for both polarizations is shown in Figure 7. The absorption coefficient in low energy ranging from 5.34 eV to 11.88 eV is the most, and the highest peak occurs at the energy of 11.50 eV and 11.88 eV for parallel and perpendicular polarizations, respectively. Also, in this range of energy, the transmission is lost. The optical investigation shows a red-shift at lower energy. Therefore, by illustrating the high absorption of aluminum oxide, the by-products of the subsystem, such as the adhesive holder and the vacuum tube, has a longer lifetime. As seen in Figure 7, the reflectivity spectra of Al2O3 value for both low-energy polarizations ranging from 4.97 eV to 11.90 eV is very negligible and trivial.



(a)



(b)

Fig. 7. The reflectivity (a) and absorption (b) spectra of Al_2O_3 parallel and perpendicular polarizations.

Eventually, the assessment of the limitation of the heat loss in the Parabolic Trough Collector using aluminum (III) oxide the heat loss analysis of the seal depended on the structural properties and the temperature shift. Figure 8 reveals the real relevance between heat loss (vertical axis) and energy loss by reflectivity spectra of Al2O3 (Figure 7).

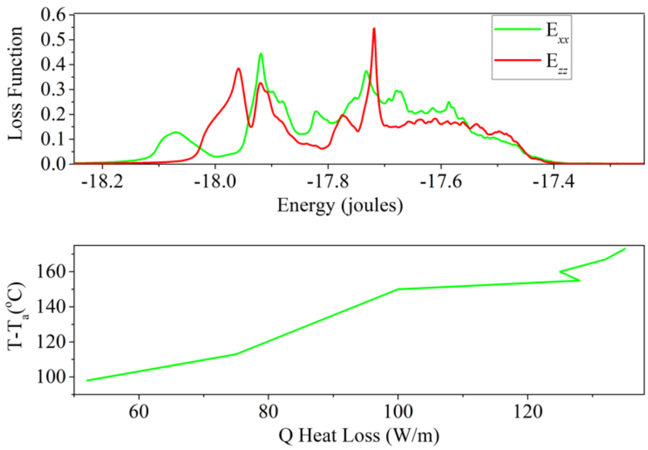


Fig. 8. Loss of heat and temperature shift.

4. Conclusion

Analysis of the Al_2O_3 structure showed the band arrangement and thickness of the Al_2O_3 bands, which can be deduced and excellent insulator content. Also, the analysis of the optical properties of Al_2O_3 is essential for practical applications in engineering and optoelectronics. As a consequence, from the theoretical part of the dielectric equation, it can be observed that the most absorption happens at an energy range of 5.26 eV to 11.85 eV. The maximum absorption energy for parallel polarization is 7.41 eV with a value of 0.72; the value for perpendicular polarization is 0.52 and occurs at 6.79 eV. The cost-benefit calculation of the system suggests that an appropriate decision can be made to include it in the solar-powered subsystem. Calculation of the dissipation of power by heat transfer demonstrated that the efficiency of the system improved by more than 30% with the usage of aluminum oxide seal. The new model of seal proved to be an effective way to reduce heat loss.

References

[1] C.K. Chanda, D. Bose, Challenges of Employing Renewable Energy for Reducing Greenhouse Gases (GHGs) and Carbon Footprint, in: Encycl. Renew. Sustain. Mater., Elsevier, 2020: pp. 346–365. https://doi.org/10.1016/b978-0-12-803581-8.11170-1.

[2] E.N. Fobissie, F. Inc, The role of environmental values and political ideology on public support for renewable energy policy in Ottawa, Canada, Energy Policy. 134 (2019) 110918. https://doi.org/10.1016/j.enpol.2019.110918.

[3] M.S. Esmaeili, G. Najafi, Energy-Economic Optimization of Thin Layer Photovoltaic on Domes and Cylindrical Towers, Int. J. Smart Grid - IjSmartGrid. 3 (2019) 84–91. https://www.ijsmartgrid.ijrer.org/index.php/ijsmartgridnew/article/view/61 (accessed July 8, 2019).

[4] R.Z. Zhong, L. Cheng, Y.Q. Wang, X.Z. Sun, D.W. Luo, Y. Fang, R.D. Bush, D.W. Zhou, Effects of anthelmintic treatment on ewe feed intake, digestion, milk production and lamb growth, SPRINGER Verlag, SINGAPOR, 2017.

[5] A.M. Ekoe A Akata, D. Njomo, B. Agrawal, Assessment of Building Integrated Photovoltaic (BIPV) for sustainable energy performance in tropical regions of Cameroon, Renew. Sustain. Energy Rev. 80 (2017) 1138–1152. https://doi.org/10.1016/j.rser.2017.05.155.

[6] G. Li, Q. Xuan, M.W. Akram, Y. Golizadeh Akhlaghi, H. Liu, S. Shittu, Building integrated solar concentrating systems: A review, Appl. Energy. 260 (2020) 114288. https://doi.org/10.1016/j.apenergy.2019.114288.

[7] O. Achkari, A. El Fadar, Latest developments on TES and CSP technologies – Energy and environmental issues, applications and research trends, Appl. Therm. Eng. 167 (2020) 114806. https://doi.org/10.1016/j.applthermaleng.2019.114806.

[8] M. Azadbakht, E. Esmaeilzadeh, M. Esmaeili-Shayan, Energy consumption during impact cutting of canola stalk as a function of moisture content and cutting height, J. Saudi Soc. Agric. Sci. 14 (2015) 147–152. https://doi.org/10.1016/j.jssas.2013.10.002.

[9] mostafa esmaeili shayan, Solar Energy and Nuclear Power. Economic Requirements and Hindrances, GRIN Verlag, (2020). https://books.google.com/books?id=KkL8DwAAQBAJ.

[10] S. Luo, H. Li, Y. Mao, C. Yang, Experimental research on a novel sun shading & solar energy collecting coupling device for inpatient building in hot summer and cold winter climate zone in China, Appl. Therm. Eng. 142 (2018) 89–99. https://doi.org/10.1016/J.APPLTHERMALENG.2018.06.081.

[11] J.J. Michael, S.M. Iqbal, S. Iniyan, R. Goic, enhanced electrical performance in a solar photovoltaic module using V-trough concentrators, Energy. 148 (2018) 605–613. https://doi.org/10.1016/J.ENERGY.2018.01.101.

[12] B.M. Ziapour, M.B. Khalili, PVT type of the two-phase loop mini tube thermosyphon solar water heater, Energy Convers. Manag. 129 (2016) 54–61. https://doi.org/10.1016/J.ENCONMAN.2016.10.004.

[13] M. Genedy, U.F. Kandil, E.N. Matteo, J. Stormont, M.M. Reda Taha, A new polymer nanocomposite repair material for restoring wellbore seal integrity, Int. J. Greenh. Gas Control. 58 (2017) 290–298. https://doi.org/10.1016/j.ijggc.2016.10.006.

[14] K. Rahbar, A. Riasi, H. Khatam Bolouri Sangjoeei, N. Razmjoo, Heat recovery of nano-fluid based concentrating Photovoltaic Thermal (CPV/T) Collector with Organic Rankine Cycle, Energy Convers. Manag. 179 (2019) 373–396. https://doi.org/10.1016/J.ENCONMAN.2018.10.066.

[15] D.Q. Lei, Z.F. Wang, Z.J. Wang, Effects of geometry and material properties on the residual stress of glass-to-metal seals in solar receiver tubes, in: Energy Procedia, Elsevier Ltd, 2014: pp. 418–427. https://doi.org/10.1016/j.egypro.2014.03.045.

[16] M. Boukar, A. Harmim, Performance evaluation of a one-sided vertical solar still tested in the Desert of Algeria, Desalination. 183 (2005) 113–126. https://doi.org/10.1016/J.DESAL.2005.02.045.

[17] M.A. Rehan, M. Ali, N.A. Sheikh, M.S. Khalil, G.Q. Chaudhary, T. ur Rashid, M. Shehryar, Experimental performance analysis of low concentration ratio solar parabolic trough collectors with nanofluids in winter conditions, Renew. Energy. 118 (2018) 742–751. https://doi.org/10.1016/J.RENENE.2017.11.062.

[18] M.A. Paya-Marin, Solar Air Collectors for Cost-Effective Energy-Efficient Retrofitting, Cost-Effective Energy Effic. Build. Retrofit. (2017) 141–168. https://doi.org/10.1016/B978-0-08-101128-7.00005-8.

[19] C. Yang, S.L. Shen, D.W. Hou, S.M. Liao, D.J. Yuan, Material properties of the seal gasket for shield tunnels: A review, Constr. Build. Mater. 191 (2018) 877–890. https://doi.org/10.1016/j.conbuildmat.2018.10.021.

[20] D. Prakash, B. Murthy, R. Chandra Mohan, N. Karteek, Effect of Material Mismatch on Static behavior of Flex Seal, in: Mater. Today Proc., Elsevier Ltd, 2017: pp. 2290–2297. https://doi.org/10.1016/j.matpr.2017.02.077.

[21] T. Pervez, F.S. Al-Jahwari, Mechanical Properties, Sealability, and Recyclability of Elastomeric Materials in Petroleum Industry, in: Encycl. Renew. Sustain. Mater., Elsevier, 2020: pp. 131–147. https://doi.org/10.1016/b978-0-12-803581-8.11291-3.

[22] H.D. Kambezidis, The Solar Resource, Compr. Renew. Energy. (2012) 27–84. https://doi.org/10.1016/B978-0-08-087872-0.00302-4.

[23] M.R. Salem, M.M. Elsayed, A.A. Abd-Elaziz, K.M. Elshazly, Performance enhancement of the photovoltaic cells using Al2O3/PCM mixture and/or water cooling-techniques, Renew. Energy. (2019). https://doi.org/10.1016/J.RENENE.2019.02.032.

[24] R. Zarmiento-García, A. Reyes-Serrato, M. Xiao, First principles study of electronic structure and optical properties of beryllium nitride in β phase (β-Be3N2), Optik (Stuttg). 160 (2018) 109–115. https://doi.org/10.1016/j.ijleo.2018.01.134.