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A Review Improve the Solar Collectors Efficiency by Thin Films Techniques

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ABSTRACT

In most parts of the world. Thermal technologies are mainly relied upon to provide the heat needs of various household, residential and solar applications. This study reviews the thermal performance improvement processes of the most widely used low temperature solar collector (LTSCs) including flat plate collectors (FPCs), by reviewing problems and challenges and discussing the possibilities for future research. In this regard, an analysis of the thermal energy of the solar collector is presented in addition to the latest technologies developed to enhance the possibility of collecting heat in the LTSCs that have been discussed in the previous studies. The steps reviewed in this study completely cover the main modifications, the surfaces of the absorption layers, and the further collection of heat to be used in different areas.

KEYWORDS

Solar Collectors, Various Nanomaterials, Review, Sedimentation Method.

INTRODUCTION

The sun is the main source and is environmentally friendly. This source can be used to convert solar radiation into energies that can be used in generating electricity or heat that can be used in the processes of heating water for use in many areas, through the special solar collectors in this work [1,2] . one of the methods Deposition known for the purpose of forming these thin films, which in turn increases the amount of absorption of solar radiation and thus we have obtained a high percentage of heat as well as an increase in the efficiency of the solar collector [3,4] . Where the TiO_2 thin films were first prepared, the TiO_2 thin films were deposited on Corning glass substrates using reactive RF-Sputtering technology. Solar energy is generated by heat engines or photovoltaic converters. Once solar energy is converted into electrical energy, only human ingenuity controls its use. Among the applications that are made using solar energy are heating and cooling systems during architectural designs that depend on the exploitation of solar energy, potable water during distillation and disinfection, the exploitation of daylight, water heating, solar cooking, and high temperatures for industrial purposes. The technologies that adopt solar energy are generally characterized as either passive solar energy systems or positive solar energy systems according to the way in which sunlight is exploited, transformed and distributed. Technologies that rely on the exploitation of positive solar energy include the use of photovoltaic panels and a solar thermal collector, along with mechanical and electrical equipment, to convert sunlight into other useful sources of energy. This, while technologies that rely on the exploitation of passive solar energy include directing a building towards the sun, choosing materials with appropriate thermal mass or light-scattering properties, and designing spaces that naturally circulate air.

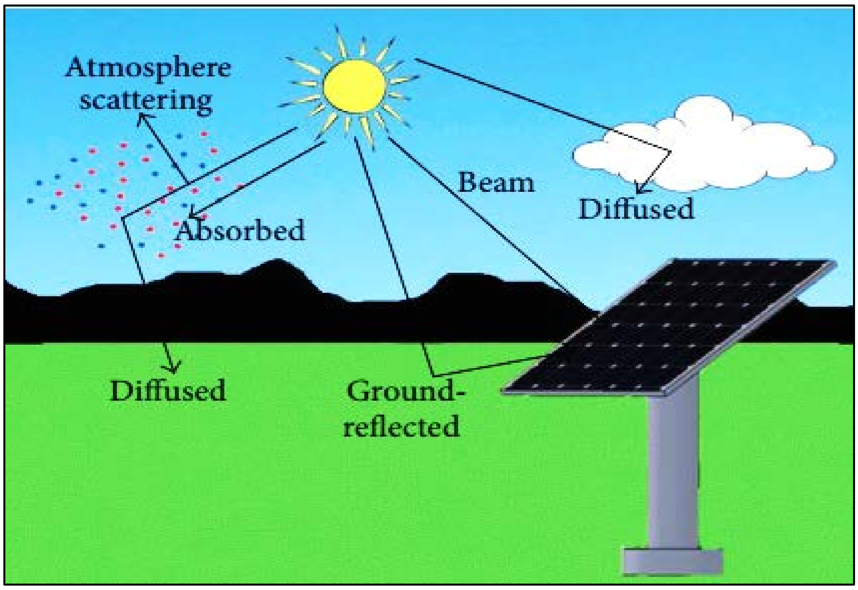

Figure 1. The incoming solar radiation

SOLAR THERMAL COLLECTOR

It is a collector that is designed to collect heat by absorbing sunlight, and the collector is a device that aims to convert the thermal energy in sunlight or solar radiation into a more usable and storage form, as shown in Figure (2). This energy is in the form of electromagnetic rays whose wavelengths range from infrared (long) to ultraviolet (short) rays. The amount of solar energy that hits the surface of the earth is about 1000 watts per square meter under the clear sky, depending on the weather conditions, the location and the direction of the surface. . In a solar powered heating system, sunlight is used to heat the water. In the geographical depressions that fall below (40 degrees), it can be provided (60 to 70%) of the hot water used in the house and most types of water heaters rise to 60 degrees Celsius which are powered by solar energy and the flat polished collectors that are generally used to heat Water in homes. A solar thermal collector is a device that receives and stores heat from sunlight in the form of solar radiation. It absorbs radiation from the sun and converts it to heat. It basically comprises an absorber that attracts and transmits solar radiation, and collectors that enable the circulation of fluids. These fluids assist in the transfer of heat from one point to another. Fluids that can be used include; water, air or an antifreeze mix such as propylene glycol.

CLASSIFICATION OF SOLAR COLLECTORS

Flat solar collector

They are the complexes by which the use of direct and diffuse radiation falling on the collector can also be used in systems that do not require high temperatures such as heating and water heating for domestic purposes. These complexes are characterized by their simplicity of installation, ease of manufacture and maintenance as well as low cost. Compared with other types [51].

Figure 2. A planar solar collector

The flat solar collector consists of three main parts

Absorber plate

It is the active part of the solar collector and it consists of a metal plate welded to a network of tubes that the fluid passes through, which is usually water or air. The first in terms of its thermal conductivity, but it is expensive, so the plate is usually made of aluminum, stainless steel or brass. The absorbent plate is usually coated with an opaque black coating to absorb the largest amount of solar radiation, thus we obtain an increase in the efficiency of the absorbent plate as it absorbs most of the rays falling on the absorbent plate [52] , as in Figure (3).

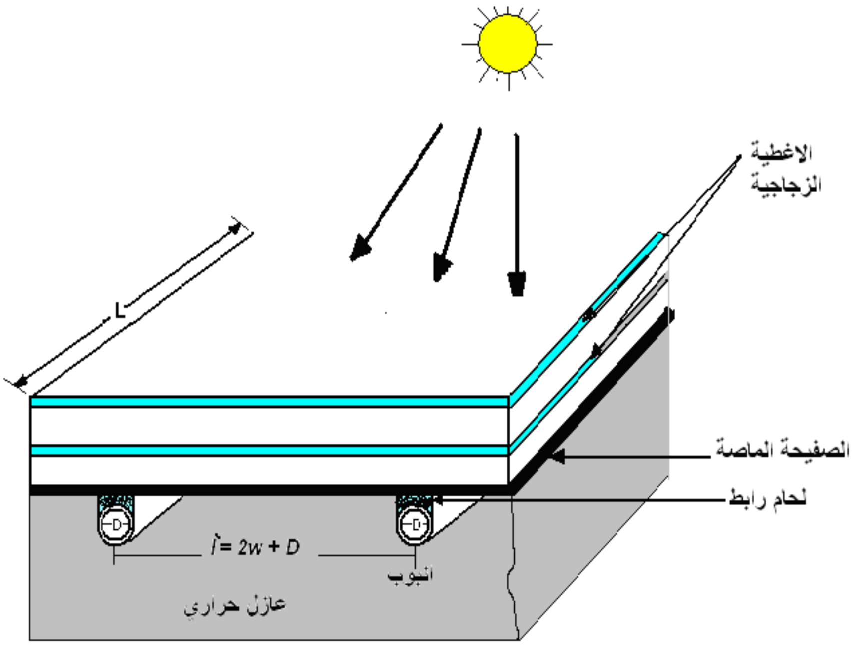

Figure 3. Scheme of a planar solar collector

Glass cover

The absorbent plate is covered with a transparent cover, preferably made of glass, as it leaves a distance of 2- 5 cm between it and the absorbent plate, and the glass used is of the pure type without color, although the glass plate constitutes a barrier to all solar rays reaching the absorbent plate as the glass is Short-wave rays are allowed to penetrate through it, while long waves are intercepted and are not allowed to pass through, and this feature is known as the greenhouse effect. In addition, it reduces thermal losses caused by load and radiation, and saves the absorbent plate from rain, dust, etc

The external structure of the complex and insulation materials

The parts of the solar collector shall be installed inside a box made of wood or stainless steel so as not to be affected by the weather conditions and the solar collector is covered with a layer of insulation to reduce thermal losses in all its aspects except for the side exposed to the sun from the insulators used are mineral and glass fibers, foam insulators and others.

Concentrating collector;

Concentrated solar collectors are used in applications that require temperatures higher than the boiling point, but they can be used in low-temperature applications as well, and in order to obtain high temperatures, the solar radiation must be focused on a small area. Consequently, it raises the temperature of the operating fluid to high temperatures, as experiments have shown that it is possible to raise the temperature of the liquids with it to 500 C^0 or more and at such degrees, it is possible to produce steam at relatively high pressures and use it in various industrial processes.

Basic materials:

Different materials are used in the fabrication of solar thermal collectors. The most common ones include:

A- Polyurethane or mineral wool for thermal insulation flat-plate collectors.
B- Aluminum or galvanized steel for the frame.
C- Coated metal (e.g. Aluminum, Steel, Copper) for the absorber Plate.
D- Glass or (glass-metal) for the tubes in evacuated-tube collectors

The main parts in concentrated solar collectors are:

Reflector

It is the one that reflects the direct rays of the sun that fall on it and focuses it at a focal point or along a focal line and concentrates the rays using mirrors or lenses in some eyes, where it is expensive to manufacture, especially large-size lenses, which are heavy and difficult to erect and absorb some energy during the passage of rays through them, but mirrors are less Cost, lighter weight and less energy absorption than lenses because they focus the rays with reflection.

Absorber

It is he who absorbs the reflected solar radiation from the reflector and absorbs the thermal effect and then transfers it to the liquid to be heated.

Tracking device

Which tracks the movement of the sun to increase the amount of direct radiation falling on the reflecting surface.

Total solar radiation incident on a horizontal surface outside the atmosphere:

The distances between the earth and the sun change during the days of the year, which affects the amount of solar radiation reaching the earth, and this can calculate the amount of this radiation falling on the horizontal surface outside the Earth's atmosphere through the following equation [54] :

$$I = 1367 * \left(1 + 0.033 * \mathrm{COS}\frac{360 * \mathrm{ND}}{365}\right) * \sin(\beta)$$

Or

$$I=1367*(1+0.033*COS\,(360*ND)/365)*(\cos(d)*\cos(\alpha)*\cos(h)+\sin(d)*\sin(\alpha) \quad (1)$$

It is sometimes necessary to calculate the amount of daily solar radiation falling on the horizontal surface outside the atmosphere, and this is done through the integration of equation (3-6) over the period of the required period, and by this the hourly radiation is calculated from the equation:

$$H = \int_{t1}^{t2} I \, dt \tag{2}$$

Where t1 & t2 are the time according to the solar time at the beginning and end of the clock required to calculate the intensity of solar radiation falling on it and by integrating it, we get the following equation:

$$H = \frac{12*3600}{\pi} * 1367 * \left(1 + 0.033 * COS\frac{360*ND}{365}\right) * \left[\cos(d)\cos(\alpha)\left(sinw2 - sinw1\right) + \frac{\pi(w2-w1)}{180}\sin(d)\sin(\alpha)\right] \tag{3}$$

Where (w1 & w2) represents the hourly angle at the beginning and end of the required hour. In the same way, we can calculate the amount of daily radiation D0 to obtain the following equation:

$$\mathrm{D0} = \frac{24*3600}{\pi} * 1367 * \left(1 + 0.033 * cos\frac{360*ND}{365}\right) * \left[\cos(d)\cos(\alpha)\sin(h) + \frac{\pi.h}{180}\sin(d)\sin(\alpha)\right] \tag{4}$$

Where (h) is the hourly angle at sunset.

Beam and diffused radiation

A large part of the solar rays are scattered upon entering the Earth's atmosphere as a result of the processes of refraction, reflection and absorption by some components of the gaseous atmosphere. All these percentages represent the amount of loss of solar radiation that does not contribute to heating the surface of the earth or the gaseous atmosphere [55], or the solar radiation that contributes to heating the air, it is 65% of it, 51% of it is absorbed by the surface of the earth, while the rest is absorbed by the atmosphere and is estimated at 14% and directly contributes to heating the air.

The effective optical properties of the panels

Comprehensive equations can be used to calculate transmittance, absorbance, and reflectivity for any outlet medium:

$$\tau = \tau a * \tau r \tag{5}$$

That is, the total permeability is the product of the reflective permeability and the absorbance permeability, while the total absorbance is calculated from the following equation:

$$\alpha = 1 - \tau a \tag{6}$$

The total reflectivity is calculated from the equation:

$$\rho = 1 - \alpha - \tau \tag{7}$$

Which can be approximated to the following equation:

$$\rho = \tau a - \tau \tag{8}$$

Coating Technologies

To apply the appropriate coating for absorber production, some of these methods can be employed. (Ogbonnaya et al. 2013) [56]:

a- Electrochemical deposition
b- Sputtering
c- Chemical Vapour Deposition
d- Chemical Oxidation
e- Sol gel and painting

The most popular process nowadays is the physical vapour deposition, especially sputtering. It utilizes materials like aluminum oxide, titanium and chromium ox nitride. Factors that are considered in the process of thin film deposition on an absorber plate include the following (Kumar et al. 2013) [57]:

a- The chemical composition of material
b- Film thickness
c- Deposition rate
d- Substrate heating during deposition
e- For sputtering –oxygen partial pressure, sputtering pressure, sputtering power, distance between the target and the substrate

Thin films

Researchers have developed a transition-metal (oxi) nitride/reflector selective absorber that has high solar absorbance as well as low thermal emittance (Vogelzang et al. 1984) [58] . The thin films were produced with chromium and titanium ox nitride using the process of reactive DC bias sputtering in a nitrogen, argon and oxygen environment. Also the absorbance were increased while maintaining the same level of emittance by using rough copper substrates with around 0.5µm roughness dimension. Selective layers have also been developed that reflects just a little of the solar spectrum in the visible range when the radiation heats the absorber or piping (Roecker et al. 2007) [59] .The reflected part of the spectrum gives a visible color that covers the glass cover and therefore hides the items underneath. The essence of this development is to give the collector a pleasing appearance and make the piping less visible.

This technology makes it possible for solar thermal collectors to be mounted on building wall facades and be integrated into glasses without making the building less attractive. For this technology, selective layers or filters are produced with separate thin films of TiO2 and SiO2 that are deposited either by dip-coating or by magnetron sputtering (Roecker et al. 2007). The film thickness and the number of layers determine the range of color that can be obtained and reflected. The filters work with the principle of interference and hence their usability depends a lot on the angle of vision. The color generated needs to remain stable at any angle. The masking effect given by the generated color needs to remain active both in the presence of direct sunlight, and in its absence. The latter part, however, is a challenge at present.

Other thin films developments in solar thermal collectors include:

a- Nanostructured cupric oxide; gives high absorptivity and low emittance when used on a copper substrate (Kumar et al. 2013). It is applied through direct current reactive magnetron sputtering. Its optical and structural properties are determined by the temperature of the substrate during deposition as well as the oxygen to argon gas ratio, which invariably determines the solar-to-thermal conversion efficiency of the absorber.
b- Diamond-like carbon (DLC) thin films, with no metal inclusions, deposited on Aluminum substrate. This consists of 5 sublayers with a total thickness of only 0.88µm (Tinchev et al. 2010) [60] . This eliminates the need for use of heavy metals like chromium which is environmentally unfriendly.
c- C:H/Cr; a new material with good potentials is metal- containing amorphous hydrogenated carbon. It contains nano-size structured layers and has no grain boundaries making it corrosion-resistant. The material is based on a multilayered C:H/Cr nanocomposite (Oelhafen, Schuler 2005). Its optical properties could be tailored by adjusting the metal (e.g. chromium) content during deposition. It has a lifetime of more than 25 years.

TABLE 1

References	**Year**	**Type of study**	**Major finding**
Previous studies on nanomaterials (Tio2)			
E. Herna´ndez-Rodrı´guez et al [5]	**2016**	Thin film preparation study	Preparation of TiO2 thin films using RF-Sputtering technology The RFS power was set to 80 watts and the distance between

			target and substrate was 50 mm.
G.D. Rajmohan et al [6]	**2016**	A study on the investigation of solar collectors.	Achievement of high performance solar collectors using a shielding layer that requires sintering at high temperatures (450 ° C). A high performance of 8.7% energy conversion efficiency of perovskite solar cells was obtained with a 76 nm thick TiO2 blocking layer.
Takayuki Kuwabara et al [7]	2008	Development of solar collector cells	Development of inverted heterogeneous organic solar collector cells with active area 1 cm 2 using tin oxide The cell containing TiO2 showed energy conversion efficiency (2.5%)
Previous studies on nanomaterials (Sio_2)			
Felipe S. Alencastroa et al [8]	2019	Stability study for thermal treatment of membranes	Heat treatment of thin absorbent Ti-SiO2 films produced with Ti and SiO2 targets.
Corsin Battaglia et al [9]	2000	Demonstration of thin-film silicon solar cells	High Efficiency Thin Film Silicon Solar Collector Cells Conversion efficiencies of up to 12.0% are achieved for tandem tandem cells of fine shapes.
José Felix Silva Neto et al [10]	2019	Black chromium production by electrostatic precipitation	Black chromium production by electrostatic deposition allows Mo-SiO2 to form coatings in layers of more controlled thickness.
Y. Yuan et al [11]	2016	Preparation of coatings via the sol-gel process	Preparation of coatings via the sol-gel process by modifying silica-sol. Silica was cross-linked and reconfigured to partially assemble the aggregate molecule.
Maatouk Khoukhi et al [12]	2016	A study of a flat glazed solar collector	Flat glazed solar collector enhances the thermal efficiency of the solar collector by creating a greenhouse effect.
I.M. El Radaf et al [13]	2018	Manufacture of thin films for tin dioxide and tin dioxide	Fabrication of thin films of tin dioxide and tin dioxide using spray pyrolysis technology. Energy increased. The refractive index and absorption coefficient were increased.
K.C. Wilson et al [14]	2013	A study of surface changes of nanostructures of tin-saturated cadmium sulfide.	Surface changes of nanostructures of cadmium sulfide saturated with tin (CdS) using chemical bath deposition technique resulting in the

			formation of Nano cracks as well as a significant increase in electrical conductivity.
Mohammad Hossein Pourdadash et al [15]	2015	Study the production of solar cell material	The production of CdTe solar cell material as a thin layer through the thinning oxide (SnO2) as the contact, cadmium sulfide (CdS) as the window layer, and CdTe as the absorbent layer.
C. Mrabet et al [16]	2016	A study of some physical investigations on thin films of tin oxide	Physical investigations on thin films of tin oxide show the dispersion of the refractive index.
H.A. Mohamed et al [17]	2014	Study a theoretical analysis of a new type of thin film solar cell with a glass structure	A theoretical analysis of a type of thin film solar cell with a glass structure in which an insufficient absorbent layer (2 μm thickness) was obtained.
S. Lugo-Loredo et al [18]	2013	Manufacture of indium sulfide films	Fabrication of indium sulphide thin films by chemical bath deposition technique. After the annealing treatment at 400 ° C, a slight improvement in the crystallization of the films was observed.
Frank Lungwitz et al [19]	2019	The development of a selective coating for solar transmission was studied	Development of a selective coating to transmit absorbed solar energy where the absorbance was calculated as (95%) and emissivity was (30%).
Qi HuaFan et al [20]	2009	Improvement of solar collector cells	Optimization of silicon and germanium solar collector cells that are deposited at a rate of (4 amps / second) in a pressure range of (2-4 torr) by chemical vapor deposition and the thickness of the thin layer is 38 mm.
J. Carrillo-Lo´ pez et al [21]	2011	A comparative study of the electrical and optical properties of silicon solar cells with silicon oxide	Comparison of electrical and optical properties of silicon solar cells with silicon oxide as SRO and SiO2 were deposited on a silicon subtype (100) with a resistance of 9.5 cm and 2 inches.
D.M. Herrera-Zamoraa et al [22]	2020	A study of electrophoresis of selective coatings for nickel / cobalt black	Electrophoresis of black nickel / cobalt selective coatings and obtaining a thin film thickness between (488 nm and 633 nm).

Sebastian Müllera et al [23]	2019	Comparative simulation to assess the efficiency of coatings for thermal solar panel collectors	Comparative simulation to assess the efficiency of coatings for collectors. Solar thermal panels in a solar home heating system Volume (100 liters) We report an increase in additional power up to (6% with black chrome and 7%) with thermal coating and (21%) with solar coatings.
Marwa Fathy et al [24]	2020	Thin film of tin sulfide (SnS) electrophoresis	Thin-film of tin sulfide (SnS) is electrostatically deposited as a film thickness of about 650 nm.
Yalin Lu et al [25]	2018	The selective coating of the nanostructure was prepared with chemical oxidation	The nanostructure selective coating with chemical oxidation, the CuO coating becomes thicker and more compact as the oxidation time becomes longer. A compact structure is formed (about 105 mm^2) and the thickness of the structure will increase with time.
A. Bhaumik et al [26]	2014	Manufacture of high-efficiency solar cells	Manufacture of high-efficiency solar cells introduces the use of copper oxide nanostructures on a thin film increases energy conversion efficiency by 80%
Necmi Serin et al [27]	2005	The effect of annealing on the composition, optical and electrical properties of copper oxide films	The effect of annealing on the composition, optical and electrical properties of CuO films with CuO formation after annealing at 350 ° C. Where the thickness of the layer is 0.15 μm by chemical precipitation.
Tarek Kh Abdelkader et al [28]	2019	On my own I use flat panel solar air heaters	Using solar selective coatings to incorporate carbon nanotubes (CNTs) and copper oxide nanoparticles (CuO) in black plating The results show that energy efficiency improved by about 24.4%.
N. Murugesana et al [29]	2020	Preparation of reduced copper oxide-coated graphene thin films	Preparation of reduced copper oxide-coated graphene thin films The reaction state had a significant effect on the formation of CuO nanostructures. The thickness of the thin films was found between 1 to 3 mm.
Mool C. Guptaa et al [30]	2018	Optical nanostructures can control optical absorption and surface emission	The ability of optical nanostructures to control optical absorption by optical

		characteristics	nanostructures, and to obtain a thin film with a thickness of between 65 -67 -70 -80 nm.
D. M. Borsa et al [31]	2012	Recognition of thin Mg - Ti - H films having attractive optical properties	Recognition of Mg - Ti - H thin films as they absorb 87% of the solar radiation in the hydrogenated state and only 32% in the metallic state. In the absorbed state Mg - Ti - H has low emissivity at 400 K only 10%
K. Xerxes Steirer et al [32]	2010	Study the requirements for organic solar cell complexes	Requirements for organic solar cell complexes are suitable anode surface rates for selective assembly of positive charge carriers. We use nickel metal to manufacture NiO hole layers on indium tin oxide anodes.
Guoying Xu et al [33]	2016	Solar thermal collector using magnetic nanoparticles	Solar thermal collector uses magnetic nanoparticles to enhance and increase thermal efficiency.
S.A. Vanalakar et al [34]	2015	Deposition from CZTS thin films	Thin film precipitation increases the thickness of the thin films from 0.16 to 1 nm.
Sawanta S.Mali et al [35]	2012	Thin Film Deposition (CZTS) Cu2ZnSnS4, Semiconductor	Semiconductor thin film deposition The optical absorption spectrum of all CZTS samples was recorded in the wavelength range and thicknesses (350-800 nm)
Amun Amri et al [36]	2020	Study of solar absorption and thermal efficiency	Solar absorption (α) and thermal efficiency (η) of the thickness of the nickel-dyed alumina layer (Ni-AlO) on the fin was α having a similar value of about 0.94 with a maximum thermal efficiencies of 71%
Yanyan Cao et al [37]	2012	A study for the fabrication of (Cu2ZnSn) thin films	For the manufacture of (Cu2ZnSn) thin films. with triple chalcogenide nanoparticles, with an efficiency of 9.6%.
Previous studies on nanomaterials (ZnO)			
Seok Yong Byun et al [38]	2013	Optical absorption efficiency (OAE) assay of thin-film crystalline solar collectors	The absorption efficiency of thin-film crystalline solar collectors shows a decrease in the absorption loss due to increased internal reflection.
M.A. Islama et al [39]	2017	Highly efficient CdS manufacturing	Manufacture of high-efficiency (CdS) and CdTe thin-film solar

			cell collectors achieved the highest efficiency (10.3%).
E.M. Mkawi et al [40]	2014	Electrochemical Cu2ZnSnS4 CZTS thin films	Electrochemical thin film Cu2ZnSnS4 CZTS with an efficiency (2.3%).
Yanli Liu et al [41]	2013	The use of thin films of indium oxide	The use of thin films of indium oxide and tin in transparent electrode applications where the conductivity increases due to an increase in the grain size and a decrease in the dispersion of the grain boundaries.
Said Benramache et al [42]	2012	Precipitation of transparent conductive indium-coated zinc oxide	Deposition of transparent indium-coated zinc oxide DRX analyzes indicated that ZnO films have a polycrystalline nature and a hexagonal structure.
Shiva Gorjian et al [43]	2020	Performance improvement for low temperature solar collectors	Improved performance of low temperature solar collectors thermal behavior with fin. The solar absorption (α) and the thermal efficiency reaches 71%, 72%, and 81% for thicknesses of 11, 12 and 16 μm respectively.
M. Bilokur et al [44]	2019	Deposition of solar absorbent coatings	The deposition of solar absorbent coatings was considered to be highly efficient for solar thermal energy conversion and where an absorption of the sun's heat was kept at 92%.
N.P. Klochko et al [45]	2015	Formation of arrays or layers of quasi-unidimensional ZnO as separate nanoscale disks	Formation of semi-unidimensional ZnO arrays or layers as separate nanoscale disks The effective selective solar absorption surface should have good optical properties over the spectral range of the solar spectrum (0.3-2.5 μm).
A. Schu¨ lera et al [46]	2015	Study of the most important colors for solar thermal collectors	The most important color for solar thermal collectors. Concern about the integration of solar energy systems in buildings, which 85% prefer black.
Hanxiao Ge et al [47]	2012	Study of polymer thin films and tubes as materials for use in solar thermal collectors	Thin polymer films and tubes as materials for use in solar thermal collectors, where the toughness of the thin films is shown in terms of fracture and cracking.
A. Baldia et al [48]	2008	Thin-film transmission study	The use of a switchable absorber

			in solar collectors allows to reduce the stagnation temperature from 180 to 80 C^0 .
Sanjay Kumar Swami et al [49]	2014	Deposition of (Cu2ZnSnS4) (CZTS) thin films with spray technique	Thin films deposition of (Cu2ZnSnS4) (CZTS) with spray technique resulting in total energy conversion efficiency (6.4%).
F.I. Lizama-Tzeca et al [50]	2019	A study of the selective coating that is the heart of a solar heating system	The selective coating that is the heart of the solar heating system, as the paint needs to efficiently absorb the sunlight and heat the substrate
MOHD ZAMIR PAKHURUDDIN et al [51]	2012	Study the properties of aluminum thin films	Aluminum (Al) thin films on polyimide plastic substrates upon increasing annealing the temperature leads to a decrease in surface reflection with a minimum of reflectivity of (73%).

CONCLUSION

Through previous studies, we observe through the use of different nanomaterials that cause one of the known sedimentation methods in the coatings of these nanomaterials on the absorbent surface of the solar collector, and each material we observe has an effect that differs from another material as well as differs in the amount of heat absorbed by the nanomaterials For the absorbing surface, and with this, we obtain a variable increase in efficiency and improvement in increasing the absorption of the amount of heat absorbed by the absorbing surface of the compound, and through these previous studies, the use of nanomaterials from Tio2-Sio2-Zno-Cuo and other materials. All these materials increase the efficiency of the solar collector, as well as the amount of heat absorbed by the solar collector. Different methods have been used in the sedimentation process. Each method has a characteristic of work that differs from the other, including physical and chemical methods, each of which has a special work that differs from the other. Likewise, the deposition rate of nanomaterials varies from one job to another, as well as the type of coating used, including 20 nanometers - 24 nm - 50 nm were used. Changes in this thickness produced varying rates in terms of the amount of heat and an increase in the efficiency of the solar collector.

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