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Utilizing nano-material in selective surfaces to scalable up the absorptivity

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Abstract

This review article achieves the motivation for utilizing nanostructured materials in the field of solar based energy transformation. Examined quickly some current principal observations on support Nano-clusters and optical properties of embedded metallic Nano-groups in a dielectric lattice; Nanotechnology is a typical word nowadays; this is an innovation that draws a considerable measure of consideration in established researchers as well as among adventurers associated with economic energy creation for this type of renewable energy. Nano-crystal with high surface energy has an open surface structure and has a high thickness of low-planned step and rotation molecules. Nanocomposite thin films created for the application as optically particular for selective absorber coatings in thermal solar collector are described in some more detail to enhancing the properties of the selective surfaces coating as the receiver to represents one of the best opportunities for improving the efficiency of collectors and reducing the cost of the production selective surfaces that absorbing solar energy. A coating on selective spectral surfaces is an essential part that allows the concentration of high temperatures on the concentrated working structures of solar energy.

This paper quickly finds some of the possible usages of nanotechnology for find new strategies about improved energy conversion, And to see the special requirements to manage the production of this energy without harming the community. Substantially, the things that talked about coatings on selective surfaces and objectives summarized the results of all the innovations by researchers in the world on selectivity surfaces and their performance in the industry of flat plate collectors to attain the best coating for this industry for selective surfaces.

Keywords: Nano-Material, Energy Conversion, Selective Solar Absorber, Optical Characterization, Selective Surface Morphology.

1. Introduction

Utilization of fossil fuel-based technologies is likely one of the fundamental causes for a constant increment in contamination and convergence of greenhouse gases. Renewable sources must have a higher commitment in the energetic matrix when it comes to giving more energy available for humanity in a short period, as it has a low environmental impact [1].

Modern science is very interested in Nano systems, with the dimensions command of even some nanometers, which in practical application show their exceptional properties in all areas (electronics, optoelectronics, and high-temperature superconductivity). A need to minimize dimensions is imposed by several mutually dependent on requirements of modern civilization, probably crucial for its further survival and sustainable development, which can be reduced to energetic and environmental requirement.

An interest in the conversion of environmentally-friendly energy foundations led to the growth of several procedures that benefited from continuous evolution in several fields of research, which can result in new materials for already developed devices. A well-known technology was improved due to the development of Nano-materials especially designed for the energy transformation process; their progress allows the use of light and heating to improve the process through a synergic procedure. For example, it is possible to supply human energy requests till 2050 from this growth [1].

Nanomaterials are of huge importance in today's recent society. The progress of chemical manufacturing, ecological safety and new-energy resources (e.g., There are two main methods for creating electricity from sunlight: direct solar-electricity conversion using photovoltaic (PV)

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solar cells and concentrating solar power (CSP) which creates electricity from solar thermal energy) have long relied on Nano-materials with special properties. As particle dimensions reduce towards the Nano-scale, the surface-to-volume ratio proportionally increases and small size effects accompanying with nanoparticles to become more pronounced. Their effects on catalytic and other physicochemical properties are the key to designing Nano-scale materials by nanotechnology. The performance of Nano-crystals used as catalysts depends strongly on the surface structure of facets enclosing the crystals.

For a pure metal, the surface energy relies on coordination numbers (CNs) of surface atoms as well as their density. For a metal oxide, the surface energy increases with increasing density of hanging bonds. Generally, high-energy surfaces have an open surface structure and possess exceptional properties [2].

Solar thermal energy is a technology for harnessing solar energy for thermal energy (heat) as the solar selective absorbing coatings attracted many attentions for its applications in solar photo-thermal conversion [4-5]. The requests for coatings to control spectral selectivity on solar thermal collectors for water heating use a spectrally selective surface that absorbs sunlight and converts it to heat, then the solar absorber is a key part of this application. High performing selective surfaces already exist in the market, but most of these products are produced using complicated manufacturing process and are expensive. The spectral selective surfaces are the most costly component of a solar thermal collector. This means that if one decreases the price of selective solar absorbers one can optimistically reduce the cost of a solar thermal collector [6]. The quality of a solar selective absorbing coating (SSAC) determines to a large degree the overall performance of the corresponding solar heat collector. The main requirements for the SSAC are high absorptance (α) in the wavelength when (λ) is less than the critical value and low emittance of thermal emissivity (ε) when (λ) is greater than critical value in the infrared region this illustrates in diagram (1), shows the decline transition of reflectance from low to high.

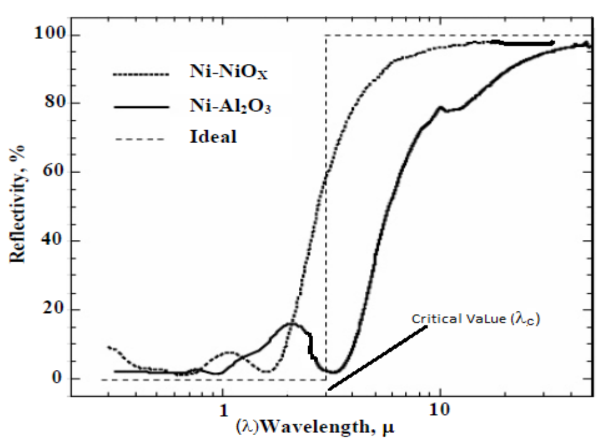

Figure 1: Shows the Wavelength (λc) for Absorptivity (α) and Emissivity (ε).

Consequently, the idea, of applying spectral selectivity, is to make the absorber surface or treat it, in such a way as to boost the absorption of short-wave solar radiation and, at the same time, suppress the emission of long wave thermal radiation. With the objective of selectivity made, it is possible to identify what may be defined as the ideal, or perfect, selective surface. The spectral reflectance, or reflectivity, of such an imaginary surface, is shown in (Fig.1). It should have a zero reflectance all over the domain (0 < λ< λ c); and a reflectance of unity for all wavelengths (λ > λc) where (λc) is a "critical" or "cutoff" wavelength which will be arbitrarily selected in or around the range (2-3μ) depending on the absorber working temperature. Hence, and then the absorber-surface is opaque, the spectral absorptance, or absorptivity, along the left-hand part of (Fig. 1) will be (αsol = 1 for 0 < λ < λc) which means that the surface will be a perfect absorber of the short-wave solar radiation. On the other hand, the spectral absorptivity throughout the right-hand part of (Fig.1) will be: (ε therm. = 0 for λ > λc) where the subscripts (sol) and (therm.) stand for solar and thermal radiation respectively. Then so-called another factor for determining the best selective surface is solar selectivity (the ratio of α/ε) is a key parameter used to evaluate the spectral property of a solar selective absorbing coating (SSAC).

Then the Nano-Material coatings are generally used as rigid coatings due to their exceptional high-temperature stability and high absorptivity for the selective surfaces.

The aim of the present paper is to reveal at least for some potential applications for the motivation for using nanostructured materials in solar energy conversion and to give an overview of current research topics in this field to attain the best absorptivity with low thermal emittance.

2. Manufacturing Nano-Materials:

The Nanomaterial is classified as manufacturing to involve building up of the atom constituents as making smaller and smaller structures through etching from the bulk material as exemplified by the semiconductor industry. Then there are several methods to format Nano material such as:

1- Solid-phase extraction (SPE): this technique is simplicity for low consumption of reagents and ability to combine with different detection techniques whether in on-line or off-line mode
2- Magnetic solid-phase extraction (MSPE): In this process, short equilibrium time is required by fast mass transfer can be easily separated via an external magnetic field.
3- Solid-phase microextraction (SPME): this technique is a solvent free and miniaturized microextraction technique which integrates sampling, extraction.
4- Gas Condensation: In this technique, a metallic material is vaporized using thermal evaporation sources such as a Joule heated refractory crucibles,

electron beam evaporation devices, in an atmosphere of 1-50 m bar [7].

5- Vacuum Deposition and Vaporization: In vacuum deposition process alloys or compounds are vaporized and deposited in a vacuum. The vaporization was by thermal processes.in this process the pressure of less than 0.1 Pa (1 m Torr) and in vacuum levels of 10 to 0.1 MPa. The substrate temperature ranges from ambient to 500°C.
6- Chemical Vapor Deposition (CVD): it is processed in which a solid is deposited on a heated surface via a chemical reaction from the vapor phase. In thermal CVD the reaction is activated by a high temperature above 900oC.
7- Sol-Gel Techniques: The sol gel process involves initially a homogeneous solution of one or more selected alkoxides and then the Sol-gel formation occurs in four stages: Hydrolysis Condensation, Growth of particles and Agglomeration of particles.
8- Electro-deposition: it is also to make these films, which are mechanically strong, uniform and strong.
9- Physical vapor deposition: These methods produce the atoms that deposit on the substrate by Evaporation or Sputtering, Sometimes the process is usually done in an evacuated chamber [8].

3. Nano-Material Characterization

Nanomaterial technologies are being active to their possibly low-cost production and a possibility of higher performance technology. These nanostructured materials offer very attractive advantages in photon absorption to enhanced light absorption. It exhibits distinct in size dependent properties in the (1-100 nm) range where quantum phenomena are involved this explain in figure (2). This is one of the main reasons why nanotechnology has a significant impact on energy conversion and storage because their ability also adds value to materials and products through enhancement of specific properties, such as the following:

1- Mechanical strength: Nanomaterial powders applied as a coating, they lend significant strength and ductility to a variety of conventional materials such as ceramic, composites, and metal alloys.
2- Superconductivity: It involves a deposition of Nano-crystals on substrates, leading to improved optical properties.
3- Covering power: Nanostructure increases the number of active sites, which more atoms to enhance surface area will lead to reducing material requirement, which in turn can lower cost.
4- Environmental value: Improvements in environmental impact are achieved by utilizing nanostructure particulates in coatings and thus eliminating the requirement for toxic solvents.

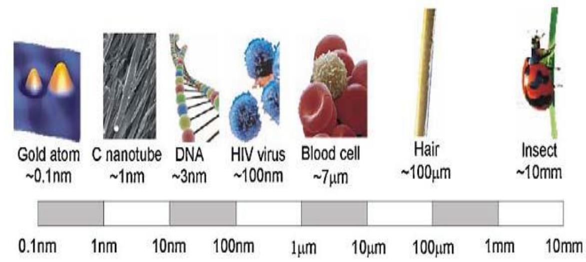

Figure 2. Length scale and some related example [1].

Nanomaterials are those particles that present at least one dimension in the nanometer range giving them special properties. The main advantages of these materials are a high surface-to-volume ratio, easy derivatization procedures, and unique thermal, mechanical or electronic properties, then nanomaterial's were organized into three types: metallic, silica and carbon-based [1].

3.1. Metallic Nano-particles (MNPs)

Nanomaterials can be classified as the origin (natural and artificial), chemical nature (inorganic, organic, and mixed) and homogeneity (single or hybrid composition). MNPs involve a great deal of inorganic and inorganic/organic hybrid nanoparticles, such as metal nanoparticles and metal oxide nanoparticles. Metal organic frameworks (MOFs) are also metallic Nano-materials. MNPs are getting a lot of attention in sample preparation, due to their chemical compositions, sizes, and surface structure characteristics [9].

3.2. Metal oxide nanoparticles

Metal oxide nanoparticles (MONPs), such as TiO2, ZnO, ZrO2, Al2O3, and Cr3O2; have been widely used for the separation pollutants extraction (SPE). In most cases, these MONPs were used in solar selective surfaces also as adsorption surfaces, this undoubtedly adequate for absorption sun light, MONPs offer unique properties and showed improved properties with respect to polymeric coatings commonly used in terms of chemical stability and durability, high adsorption capacity and low-temperature modification ability. In addition, they provide high porosity and large surface area, with subsequent improvement in the extraction capability [10].

3.2.1. Metal organic framework materials (MOFs)

Metal organic frameworks (MOFs) represent a class of organic / inorganic hybrid super-molecular materials which can be self-assembly by metal (oxide) cations with organic electron donor linkers. By changing the structure or size, the materials can exhibit different pore size, and their internal surfaces are easy to be functionalized, which make (MOFs) attract considerable attention over the last decades, showed high efficiency and size selective adsorption [11].

3.3. Silica Nano-materials

Silica is a very appealing material for analytical applications because it is relatively inexpensive, chemically inert and thermally stable. Silica Nano-materials have promising structural properties for an imprinting matrix, as their rigid structures are very suitable for the formation of the dedicated recognition site. Silica nanomaterial also has another name is Siliceous nanoparticles include silica nanoparticles (inorganic SiO2 nanoparticles), and porous silica materials (synthesized with different silanes (compound of silicon and hydrogen)). These siliceous materials also own the characters of a large specific surface area and high adsorption capacity, as well as low-temperature modification ability [12].

3.4. Carbon Nanomaterials

Carbon has long been known to exist in forms, namely, amorphous such as shown in (Figure 3):

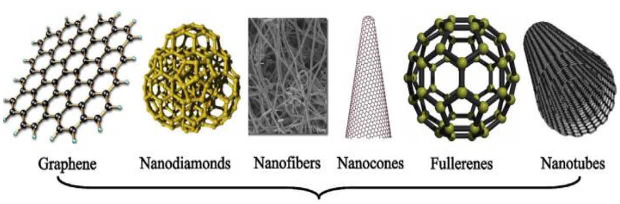

Figure 3: Kinds of Carbon Nano-Materials [7]

Carbon Nanomaterials possess some unusual size / surface-dependent (e.g., morphological, electrical, optical, and mechanical) properties useful in enhancing energy conversion and storage performance.

Including Graphene, Nano-diamonds, Nano-fibers, Nano-cones, fullerenes: Nanotubes (CNTs) [Single Wall Carbon Nano-Tubes (SWCNTs) and Multi Wall Carbon Nano-Tubes (MWCNTs)]; Most of these carbon Nanomaterials have been used and depending on how the carbon atoms are arranged, their properties vary. For example, graphite is soft and black and the stable, common form of carbon with strong covalent bonding in the carbon plane and the much weaker van der Waals interactions in the transverse direction between the layers, Diamond is hard and transparent with each carbon atom bound to four other carbon atoms in a regular lattice [13].

4. *Nano-Materials Utilizing in Solar Energy Conversion*

Utilizing Nanostructured materials emerges from the specific physical and chemical properties of nanostructures. In this case, the electronic states are discrete, the valence electrons cannot form a conduction band and clusters of this type cannot exhibit metallic behavior. In many cases, the interesting size range is located near the transition where properties are changing from molecular to bulk-like, a size range in which properties can be tuned in many cases in a unique way in order to design a material for a particular application [14].

5. *Selective Solar Thermal Absorbers (SSA)*

Selective solar thermal absorbers (SSA) are an essential element of solar thermal collectors and usually consist of two different layers, thus called tandem absorbers. Each of the two layers has unique optical properties. The top layer usually functions as a selective solar irradiation absorber and should be transparent to infrared irradiation. The substrate under the top layer reflects infrared light, to give the absorber low thermal emittance. Highly reflective metals such as aluminum and copper are commonly used and because of their high thermal conductivity, as well as these metals have a high infrared reflectance, which makes them suitable as the infrared reflector in the tandem absorber. Together they give a good spectral selectivity over the solar and infrared spectrum.

The absorbing layer can also be produced using painting and liquid solutions. Painting is an effective and inexpensive way but has a poor control on the coating thickness which often results in a high thermal emittance and the coatings usually have inferior adhesion to the substrates. High performance spectrally selective solar absorbers have been produced using this method of coatings.

6. *Optical characterization*

An efficient utilization of the solar power requires selective surfaces with the following optical and physical properties [14-15]:

- Absorption over the solar spectrum between (0.3-2.0) μm must be high.
- Emissivity wavelengths >2.0 μm must be low.
- The optical and physical properties of the coating must remain stable under long term operation at elevated temperatures.
- Adherence of the coating to the substrate must be good.
- Coating should be easily applied on selective surfaces.
- Coating must be economical.

Then figure (4) explained the Solar Energy Concentrated on the coating to transfer the sun energy to the fluid to convert this energy to the thermal system.

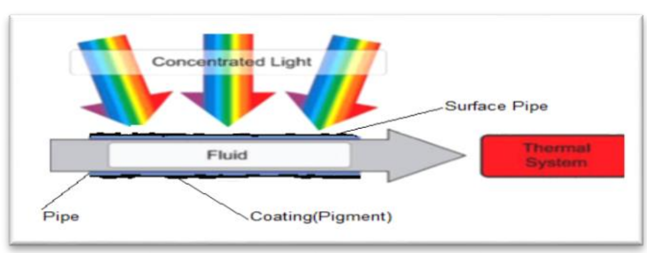

Figure 4: Explained the Effect Sun Energy on Thermal System by Coating.

7. Selective Surface morphology

Porous structures hold one of the kind physical properties (mechanical, thermal and electrical) that are identified with their low thickness and engineering. These features open a wide assortment of potential applications; at present, most porous structures still have an arbitrary morphology. The developing interest for porous structures with extremely controlled design properties, originating from various mechanical and logical applications. A basic perspective in streamlining these creation strategies and they're after generation medications is to control the morphological and mechanical properties from configuration up to the last fabricated structures; since the surface hardness impacts on the materials properties, for example, the optical properties, heat transfer exchange, and mechanical properties [16].

This is infrequently called wave front of a reflective absorber. Under this class the accompanying sorts of surfaces might be considered.

7.1 Surfaces employing textural effects

Textural abnormality of fitting geometry and size the absorptance of a surface can be expanded as an outcome of the various reflections maintained by the incident radiation, without perceptibly adjusting the emissivity of the surface [17].

7.2 Scattering films

Scattering films comprise of little metal particles installed in a dielectric film [18]. Such films utilize finely isolated particles to give forward dispersing and different interior reflections to absorb incident radiations.

7.3 Corrugated surfaces

This comprises of layering the surface into a progression of Vees so that any incident radiation inside a given scope of edges of the rate will endure more than one reflection before rising up out of the Vee [19].

7.4 Mesh surfaces

A framework (lattice) made up of very leading metal goes about as a decent reflector for wavelengths more noteworthy than the network separating. For wavelengths not as much as the matrix dispersing, then recommended that selective surfaces utilizing this rule could be manufactured by scratching a metal sheet to make openings of the best possible size, say 2.0 μm, to permit solar radiations with wavelengths < 2.0 μm to go through, yet not go for a wavelengths >2.0 μm [20].

8. Effect of coating thickness

Selective paint coatings involve little semiconductor particles blended in an appropriate sheath and connected like paint. These coatings allow the conversion of a high extent of the sun powered radiation into heat while lessening the discharge of heat. The vast majority of the pigments are combined from metal oxides and semiconductors. The covers are polyethylene (PE), it is seen from that coating thickness and pigment volume focus is the key parameters for acquiring better optical effectiveness [21].

9. The temperature effect in heat treatment

It can be learned that the coating is a wet gel. The drying of the gel is a procedure of expelling fluid particles from the small pores. Techniques that lessen or wipe cracks incorporate growing, chemical added substances and supercritical drying.

Tests can likewise be heat treated to test the covering's appropriateness in concentrating solar power (CSP) applications. They should be steady at high temperature all together work in these high-temperature conditions. At that depict the phases of drying as:

- Constant rate period, this is a point to a reduction in the volume of the gel is equivalent to the volume of fluid lost by dissipation.
- Critical point, the finish of the principal moment that shrinkage stops and breaking are well on the way to happen.
- First falling rate period, the procedure of fluid course through in part exhaust pores.
- Second falling rate period, the last phase of drying, when the fluid can escape just by dispersion of its vapor to the surface.

The outcome from the above demonstrated an enhanced spectral selectivity with a higher temperature. It is significant that higher pinnacle temperature draws out the span for absorbers remaining in the stove [22].

10. Emittance effect on selective coatings

Emittance is a surface property and relies on upon the surface state of the material, including the surface harshness, surface foils, and oxide layers. Coatings normally recreate to some degree the surface harshness of the substrate. Moreover, selective coatings can degrade at:

- High temperatures due to thermal load.
- High wetness on the absorber surface.
- Atmospheric consumption.
- Chemical responses and poor interlayer cohesion.

The emittance finds out from spectral information consumed at space temperature accept that the spectral attributes don't change with expanding temperature. It is imperative before utilizing high-temperature emittance ascertained from room temperature information, that the figured information is confirmed with high-temperature emittance estimations for each selective coating [23].

The key for high-temperature utilization is low ε, in light

of the fact that the thermal radiative misfortunes of the absorbers increase relatively by the fourth influence of temperature.
Thermal stabilization is some of the time in view of the thermal properties of the individual materials or the handling temperature parameters, and genuine solidness information is once in a while known for high-temperature absorber coatings [24].

11. Types selective solar absorbers coating (SSC)

Sunlight absorptance of selective absorber coatings can be improved by creating a finished surface. There has been a broad scan for mid to high temperature SSC materials. Ordinary SSC structures fall into one or a few of the accompanying plans for selective absorption of energy [25]:

1- Intrinsic selective materials, the selectivity is an inherent property of the materials, natural materials are finding expanding use as a segment in high-temperature absorber multi layers and composite coatings, the thinnest films with reasonable authentic material selectivity.
2- Semiconductor metal pairs, which are produced using semiconductors with reasonable band gap (Eg ~ 0.5eV (2.5 µm) ~ 1.26eV (1.0 µm)) that absorb sunlight radiation pair with a fundamental metal that gives high IR reflectance. For example, chemical vapor deposition (CVD) or vacuum sputtering.
3- Multilayer absorbers, which utilize multilayer loads of metals and dielectrics to accomplish high selectivity because of the obstruction impact, Multilayer impedance heaps have high sunlight absorption, low thermal emittance, for example, sputtering and CVD.
4- Metal dielectric composites, which use an exceptional sunlight absorbent and IR. Explicit material deposited on to an intensely IR reflexive metal substrate. The "dark" absorbing layer is a cermet (ceramic and metal) of fine metal particles in a dielectric grid.
5- Textured surfaces, is a typical system to acquire spectral selectivity by the optical catching of sunlight energy. Which comprises of Nano scale **structures** and porous for the required spectral selectivity through optical catching of sunlight [26].

12. Fabrication Techniques

There are some techniques to fabricate the solar selective surfaces to attain to absorb the solar energy, it follows these steps

12.1Physical Vapor Deposition (PVD)

Sputtering and evaporation are two essential techniques for thin film deposition. They are broadly conveyed and require high vacuum frameworks.
(1)Evaporation: The standard of evaporation is to warm the source material up to an adequately high temperature to vaporize it, and let it gather on the substrate to a layer of thin film.
(2)Sputtering is a procedure that the molecules are thrown because of the passing of lively particles on the source material and afterward deposited on the substrate to frame a thin film; furthermore, the thin film by sputtering is more uniform and has preferred holding the substrate.
(3)Magnetron sputtering has been connected on the sunlight based selective coating because of its better control of the creation and thickness of the thin film, paying little mind to higher cost.

12.2 Electrochemical Methods

Electrochemical strategies, including Electroplating and the Anodic Oxidation Method, can be utilized to get ready different sorts of sunlight based selective coatings.
(1)Electroplating introduces to the way toward moving metal irons in the arrangement by the electric field to coat an.
(2)Anodic Oxidation Method when the metal substrate is saturated in the phosphoric corrosive (H2PO4) arrangement and associated with the anode of the circuit, the surface structures a permeable oxide layer.

12.3 Painting

The painted coating comprises a tiny particles (pigments) blended with ties, which have great specific optical properties because of the high absorption of the pigment, all around dispersed in the coating, and high impression of the substrate by painted, or sprayed, or plunge coated on the substrate to border sunlight based selective absorbers.

12.4 Sol-Gel Process

The sol-gel process is a compound technique generally utilized as a part of the sunlight based selective coating planning, sol-gel process is uniform, then sol-gel utilizing Nano-scale thicknesses [27].
After all, that summarized; the outcome of all Researchers from this review in the table below that they reach to the best absorptivity.

Table 1: Explain the outcome of the researcher about absorptivity and emissivity.

Surface	α_{sol}	$E_{therm.}$	Author/Year
$Si_{0.8}$ $Ge_{0.2}$	90–95%	< 30%	Jaeyun Moon/ 2014
Nickel Alumina	0.83	0.03	Bostrom et al /2007
Black Chrome	0.93	0.10	BJaya Prakash/2013
Black Nickel on Polished Nickel	0.92	0.11	=
Black Nickel on Galvanized Iron	0.89	0.12	=
CuO on Nickel	0.81	0.17	=
Co3O4 on Silver	0.90	0.27	=
CuO on Aluminium	0.93	0.11	=

CuO on Anodized Aluminum	0.85	0.11	=
Solution chrome	0.96	0.12	=
Black cobalt thin films on bright nickel	90%	-	G.Toghdori/2011
C/NiO	90 %.	-	K.T. Roro/2011
TiN/TiSiN/SiN on stainless steel (SS)	0.95	0.04	Junxiao Feng /2015
CdS, black nickel,Au/Al,CdTe,ITe	95 − 97	6-8	F. Kadırgan/2006
NbTiON/SiON	0.94	0.08	Yu Liu/2011
cobalt oxide and Sio_2	0.88	-	Jaeyun Moon/2014
TiNOX	0.95	0.05	ALMICO Company

11. Conclusion

Solar energy is presence discovered as an alternate and sustainable path to fill the gap for the growing request for energy. To predict where and how nanotechnology will have the major impact in sustainable energy manufacture, nanotechnology is one of the fastest growing research fields today. Hopefully, it will help the development of sustainable energy economy leading to a future. Nanomaterials with high surface energy, which possess a high density of reactive surface sites, have already been shown to show especially high electro catalytic action, The study of Nano-materials for high surface energy has now opened a new exciting path to strategy Nano-materials with excellent properties for utilizing in selective surfaces to attain high-performance materials for energy conversion and storage, then another factor that effect on selective surfaces is the Heat treatment of Nano-Material deposited on substrate caused increment in absorption near-IR region, then high absorption suitable for coating on substrate of the solar selective absorber.

The properties of these coatings will involve more advanced before it could be integrated into an existing solar collector for minimum cost domestic water heating in a rural area for public worthy.

From the above, the conclusion must need to the best material with low cost because all this Nano-material that utilized from the researcher above that explained in the table above is very expensive and not found in all countries. The needed material mixed with percentage Nano-material to attain high absorptivity and low thermal emittance in a region has the wavelength greater than the critical wavelength to attain very high-quality absorptance from solar energy.

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