Effect of nano coating and nano fluid on photovoltaic module performance

Salloom A. Al-Juboori[1], Qais K. Mahmoud[2]
Engineering Faculty, Applied Science Private University, Amman, Jordan[1,2]
Emails: s_ dawoud@asu.edu.jo[1], qais@gmail.com[2]

***Abstract**: Recent researches have shown that Nano-coating materials play a vital role in improving the performance of the PV cell operation, enhancing the life span and reducing its surface temperature. In addition to that, the Nano-coating can achieve many benefits such as making a smoother surface, stronger and less adhesive of externous on the surface of PV panel. In this work, the effect of nanomaterials coating using Titanium dioxide, silicon dioxide and Nano fluid Titanium dioxide on performance and temperature of PV cell when coated by these Nano particles separately with different thicknesses (0.5µm, 50µm,100µm and 300µm). To achieve these objectives ANSYS software technology (version.1) was used. The results showed that there is a significant effect specifically when using TiO_2 Nano fluid. The maximum improvements were when using Nano coating TiO_2 and SiO_2 which are (0.62%) and (0.135%), respectively, at thickness 300µm and ambient temperature16 ^oC in case without externous particles. But the minimum improvement was with TiO_2 and SiO_2 of coating thickness 0.5µm which are (0.0937%) and (0.0937%), respectively, at ambient temperature 23 ^oC in presence of dust. The results of TiO_2 Nano fluid with concentration and flow rate which are (5%and 0.01 kg/s), respectively, showed that the maximum improvement was (39.88%) in case without externous particles at ambient temperature 23 ^oC, but the minimum improvement was (37.84%) in case with dust at ambient temperature 16 ^oC.*

***KEYWORDS:** PV, NAO-COATING, ANSYS, TITANIUM DIOXIDE, SILICON DIOXIDE, NANO-FLUID*

Introduction:

The Nano research is concerning mainly about advance aspects of the Nano science and nanotechnology. Nano research journal has large scope as it tries to support research ideas in the field of Nano science with scientific inventions, discoveries and developments. Nano technology is modern multidisciplinary technique that includes an application that depends on the composition of molecules in Nano scale, size and range. The nanotechnology is referred to the Greek word Nano (means dwarf), Nano technology field that includes manufactured application of structure and system through controlling shape and size in nanometer scale Nano coating is a coating made by various materials which generated at the Nano scale to investigate the specific properties. The main purpose for Nano Coating on solar panels is to protect, preserve, and achieve higher energy output. The form of coating material is usually in powder state, paste, or liquid. [1-4]. The progress and the advanced imagination for human led to create new science and technology, Nanotechnology appeared in a 21st Century. It is known as understanding and controlling of things in dimensions from 1 to 100 nm, the Nano particles have largely increased due to the industrial revolution, the expression of "Nano meter" was initial proposed by Richard Zsigmondy. who he had a noble prize in 1925 in the chemistry, he put the term of nanometer to describe particle sizes. Modern nanotechnology was very important for Richard Feynman, who he had a Nobel prize in 1965 in physics and he presented the concept of handling matter at the atomic level, so he is considered the father of modern nanotechnology. After that the Japanese scientist Norio Taniguchi was the first to use nanotechnology to depiction semiconductor processes which happens because of a nanometer, he think the Nano technology is a group of processing, Consolidation, separation and deformation of materials through one atom or a molecule. Many scientists cared about nanotechnology by the beginning of 1980s. One of these scientists replaced the term of Nano technology to be known as "molecular nanotechnology". [6-8]. The Nano coatings have several types such as: Super hydrophobic coatings; scientists can make super hydrophobic Nano coating which protects equipment and solar materials from corrosion, contamination and hazardous chemicals. Due to development in technology in Nano coating led to the invention of responsive Nano coating which respond to environmental triggers such as light or heat. Since some sunlight reflected and reducing uptake a new type of Nano coating appeared that is called anti-reflective Nano coating which achieved more efficiency for solar panel. There are many types also for example: Anti-corrosion Nano coatings and tribological Nano coating which contribute in the development of the system and protection it. [9-10]. Nano coating is used for covering the surface with Atom-Thin-Nano Sheltering layer. Most surfaces have tiny holes and scratches, if these surfaces were put under microscope the hole's structure will be clear, so this shape of structure will allow water and pollution to bond on surface. However, the Nano particles are tiny. They can fill into all those tiny holes in uniform shape that make the solar panel surface smooth and slippery off, fats, dirt, oil, water and all containment. Nano coating goes in many applications such as: solar panels, kitchen surfaces, cars mirrors, clothes, furniture and electronics

Research problem: The development of renewable energy became essential in these days because the fossil fuel emits a lot of CO_2 globally which cause the global warming phenomenon, so this thesis deals with this issue to find the best enhancement for efficiency of solar panel by Nano coating, to make renewable energy more compatible with fossil fuel. To solve that issue there are many questions and points that should be exposed as: Which Nano coating material should be chosen , what is the material phase when using it? Determining the properties of Nano coating material, thickness of Nano coating that should be limited. If this work can do as an experiment then more question will be take, how stability of Nano coating? What is the best way to coating determining the climate (nature) of the country? How much does coating cost? Does coating cost matches with stability? Diy Nano coating or readymade also will be determined, cheek if solar panel have been coated perfectly or not [11-13]. In this work may will obtain answers to some of these questions, especially in solar renewable energy when using Nano materials to improving the PV performance.

Research objectives: The main aim of this work is to improve the PV panel performance by using Nano coating, while the sub-objectives are studying the followings:

- The effect of Nano-coating on PV cell performance by using different materials and coating thickness.
- The effect of Nano-coating on PV thermal properties.
- The effect of Nano-coating on externous adhering on PV panel surface.
- The effect of cooling efficiency of Nano-fluid with different concentration on PV panel.
- The effect of Nano-coating of the PV performance under various ambient temperature and raining weather.

Research Methodology:

Figure (1) shows flow chart of the main steps of this work. [3] These steps of the research such as the thickness, where four values will be taken but these values are subject to iterations If they cannot achieve the required (increase and decrease in the efficiency of solar panels), the ambient temperature variable has three values in this study, the condition of the solar panels will also vary such as a layer of dust to denote the location of the dust and the area of rain is also provided as a variable here. Some variables will be taken as constant, such as: internal solar radiation, which has one value throughout the study, this value represents continuous radiation in the city of study, also any variables that are not important and far from a focused study can be considered constant.

Transmittance proprieties for SiO_2 and TiO_2:

The transmission is the main point when choose Nano coating materials to be applied in PV field, figure (2) illustrates why these materials selected and transmittance percentage when each one is alone and when combined together also.

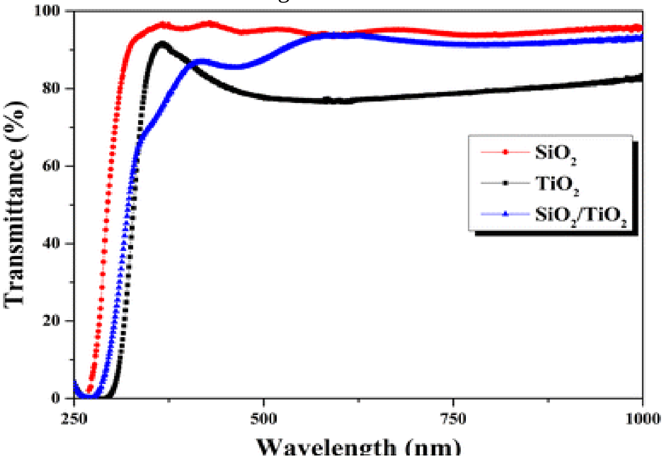

Figure (2): *Transmission for SiO_2 and TiO_2 [19]*

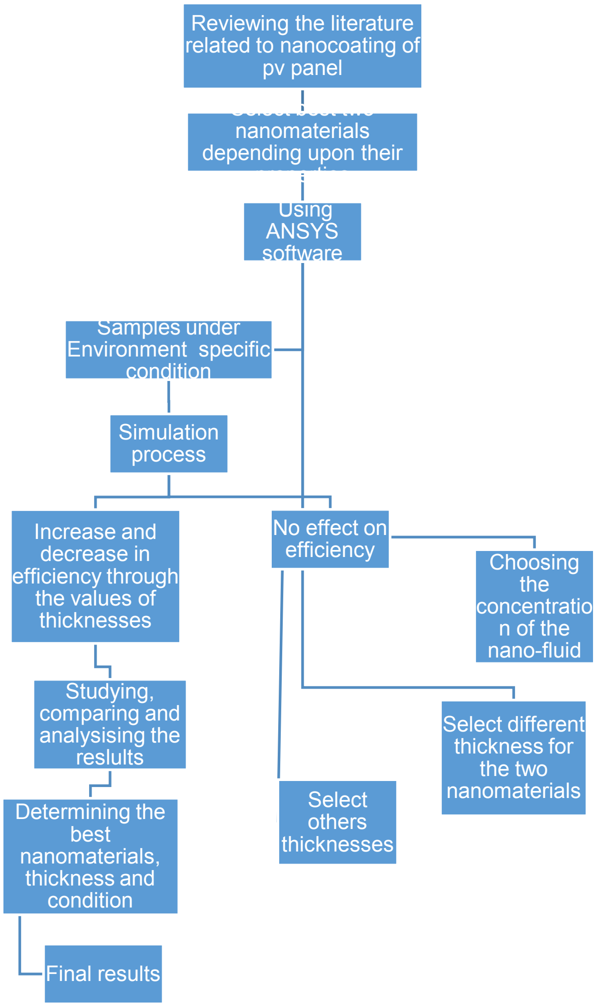

Figure (1): *Flow chart of the main steps of this work*

Research Design:

The solar PV system components are set of devices which are illustrated in figure (3),

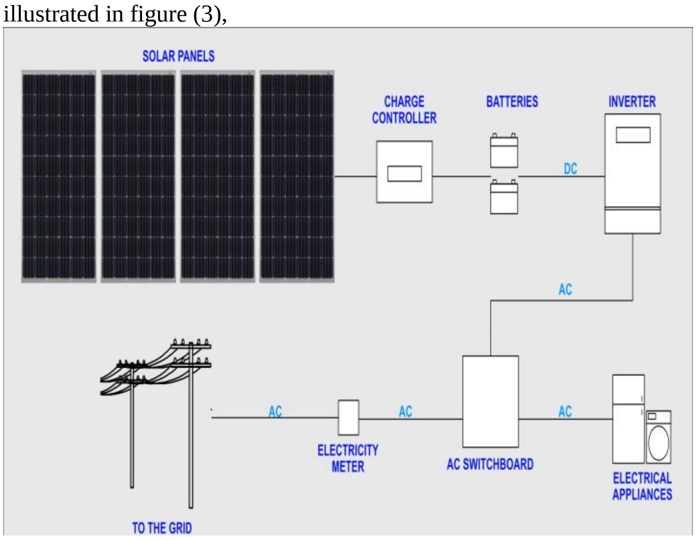

Figure (3): *Components of PV system. [20]*

which contains:

• *Solar Panels*: also called solar modules that consist of a number of solar cells that produce electricity, these solar panels are protected between the front glass and the back polymer plate with an aluminum frame, these solar panels are easily connected to each other, the figure (4) shows the solar panel of the following parts:

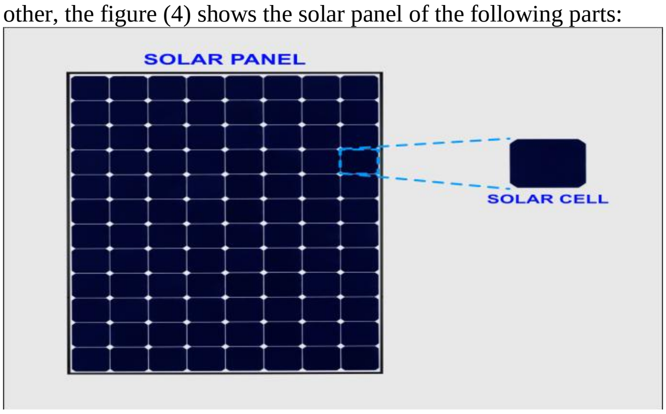

Figure (4): *solar panel contains. [20]*

• *Inverter:* this device in the system converts the DC current produced by the solar panels into AC current, which is usually used in homes. The main functions of the inverter are:

- Improving the power output of the solar panels.
- Battery charge control.
- Controlling the system.
- Work as a safety device.

• *Batteries*: if it is found in the PV system the power can be stored for use at sunset, it is important in an off-grid system.

• *Charge controllers*: this device is used when the system includes batteries and when there is no hybrid inverter, the important functions are:

- prevent the batteries from being overcharged as well also from overly discharged.
- Monitoring batteries and solar panels.

Geometric model: Geometric model give details about model such as dimensions, main part of model and properties of it.

(a) *Dimensions of photovoltaic panel:*

The main dimensions of panel are length and width, they are controlled the area which receive solar incident radiation, figure (5) show the dimension of PV panel.

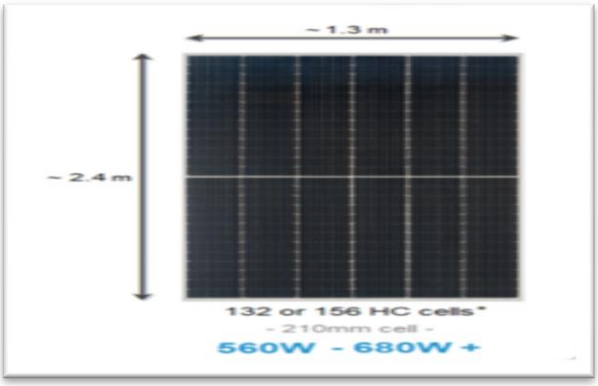

Figure (5): *Dimensions of photovoltaic panel. [21,22]*

(b) *Layers of photovoltaic panels and their properties*: photovoltaic panels have six layers, each one has a function with specific properties which enable it to do her function, figure (6) show these layers.

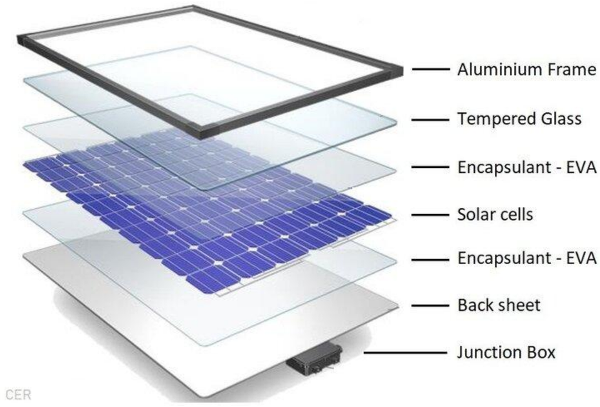

Figure (6): *Layers of photovoltaic panels. [21]*

• *solar PV cells*: It converts sunlight into DC electrical energy, and the base of the photovoltaic cell is a very thin plate, which is made either positive (p-type) or negative (n-type).

• *Glass:* this layer protects the cells from harsh weather conditions and hazardous pollutants, this glass has high strength, and the important suitability for high-transmittance glass.

• *Aluminum frame*: it is important for protection the edge of section house the cells and give solid structure when amount the solar panel, it is very light weight and able to stand in loading and stress.

• *EVA film*: the EVA refers to "ethylene vinyl acetate", which is a polymer layer with high transparency, it is used to encapsulate and install the cell, and this film is important in preventing inter the moisture and dirt.

• *Back Sheet*: this layer is most common in solar panels and acts as a moisture block to protect the mechanical and electrical in the solar panels.

• *Junction Box*: it is located at the back of the solar panels; it is a central point where all the cells are connected together by it. [21]

There are multi layers in solar panel, so in this study these layers must be defined and determined the main properties.

Results:

In this section, the samples classification in three case (a, b and c) which different between them in precipitation (water, dust) or without precipitation, where this different follow him change in amount of solar radiation, this amount finding by using equation (1) for dust and equation (2) for water.

$$y = 4.39 X + 0.507 \quad (1)$$

Y: Solar energy reduce (%)

X: precipitation of dust or water (gr/m^2)

$$y = 0.6762 X - 10.017 \quad (2)$$

y: net radiation (w/m^2)

x: solar radiation (w/m^2)

For each case specific solar radiating depended upon percentage of precipitation in Irbid city which is 79%. [21]

Case (a): **Without precipitation of dust or water on panel:**

The results of Nano coating by (TiO_2 and SiO_2) without externous dirt at two ambient temperatures and four thicknesses are show in figure (7), the solar radiation remains as it in this case. The results with thermal distribution are show in figures (8-18).

Q= 650 kW/m^2

Q: solar radiation (kW/m^2)

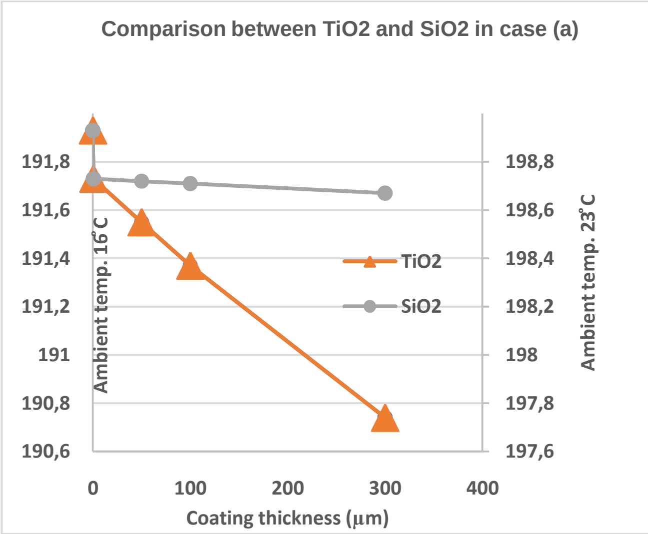

Figure (7): *Comparison ambient temp. (Y—axis) at different thicknesses (μm) for* TiO_2 *and* SiO_2 *in case (a)*

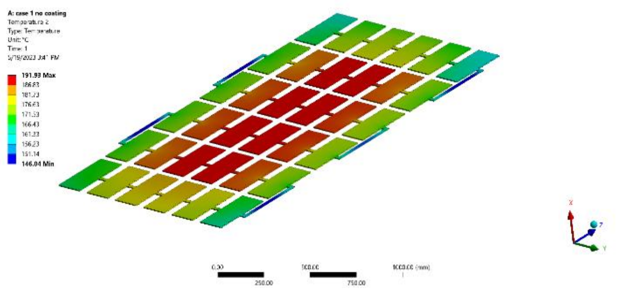

Figure (8): *Thermal distribution without coating (standard) at ambient temp. (16°C).*

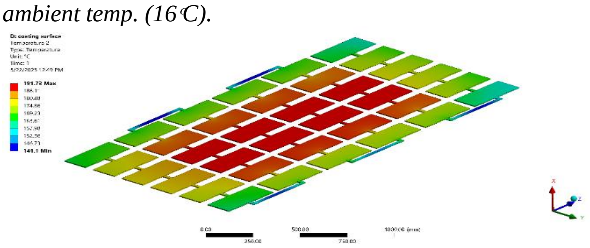

Figure (9): *Thermal distribution with (0.5μm)* TiO_2 *coating at ambient temp. (16°C)*

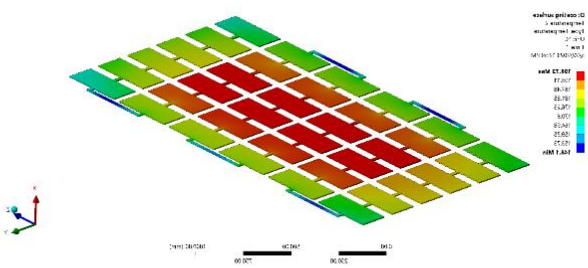

Figure (10): *Thermal distribution with (0.5μm)* TiO_2 *coating at ambient temp. (23°C)*

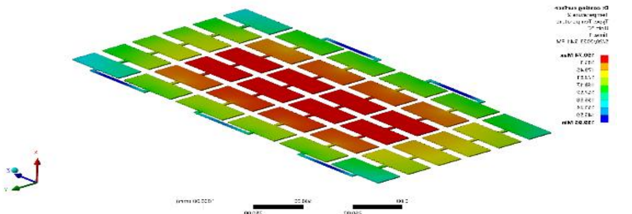

Figure (11): *Thermal distribution with (300 μm) TiO_2 coating at ambient temp. (16 ^oC)*

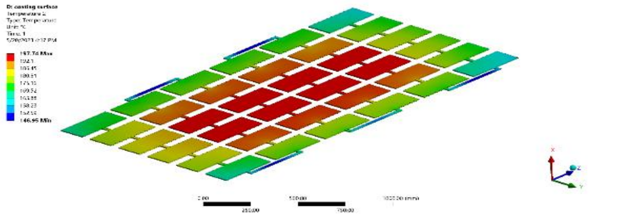

Figure (12): *Thermal distribution with (300μm) TiO_2 coating at ambient temp. (23 °C)*

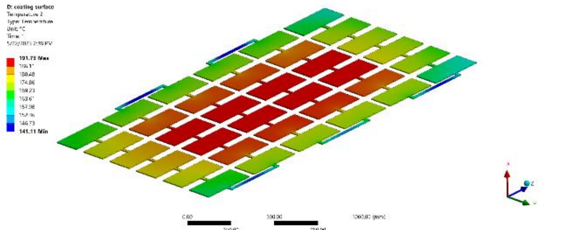

Figure (13): *Thermal distribution with (0.5μm) SiO_2 coating at ambient temp. (16 °C)*

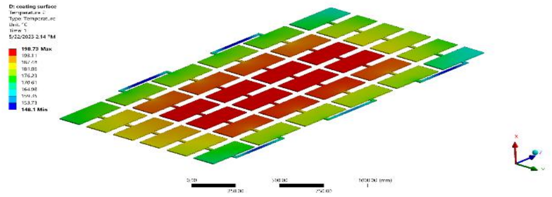

Figure (14): *Thermal distribution with (0.5μm) SiO_2 coating at ambient temp. (23 ^{o} C).*

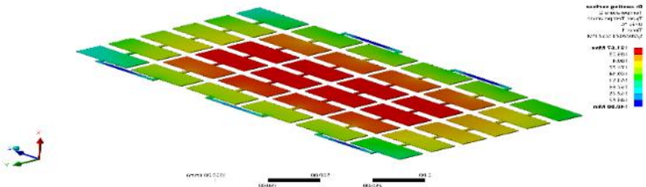

Figure (15): *Thermal distribution with (300μm) SiO_2 coating at ambient temp. (16 ^{o} C)*

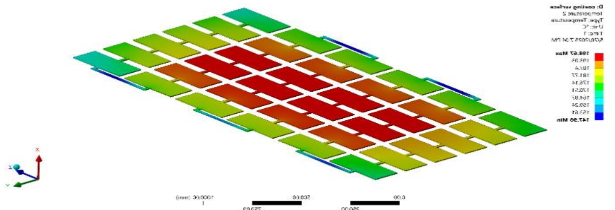

Figure (16): *Thermal distribution with (300μm) SiO_2 coating at ambient temp. (23 ^{o} C)*

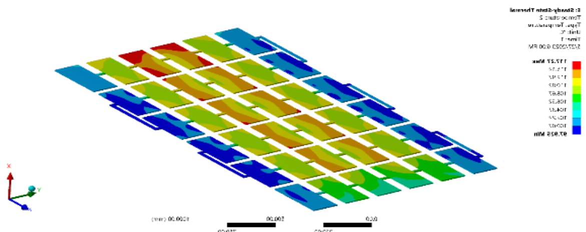

Figure (17): *Thermal distribution with Nano fluid TiO_2 at ambient temp. (16 ^{o} C)*

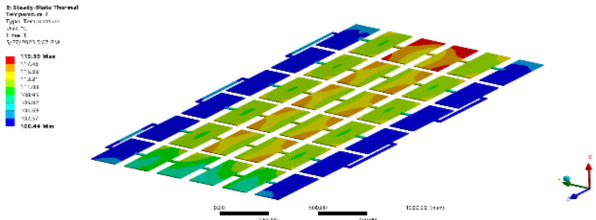

Figure (18): *Thermal distribution with Nano fluid TiO_2 at ambient temp. (23 ^{o}C)*

Case (b): With precipitation of dust: The results of Nano coating by (TiO_2 and SiO_2) with precipitation dust at two ambient temperatures and four thicknesses are show in figure (19). The results with thermal distribution are show in figures (19-29), the solar radiation decrease in this case as show bellow:

Y= 3.97 %

Q= 650 – 25.83 = 624.16 kW/m^2

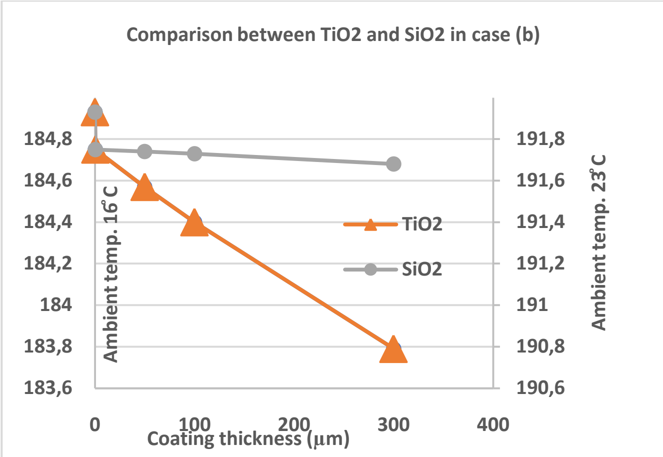

Figure (19) :) *Comparison ambient temp. (Y—axis) at different thicknesses (μm) for TiO_2 and SiO_2 in case (b)*

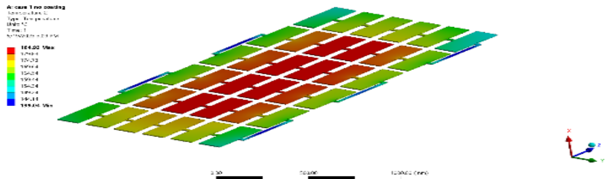

Figure (20): *Thermal distribution without Nano coating at ambient temp. (16 ^{o}C)*

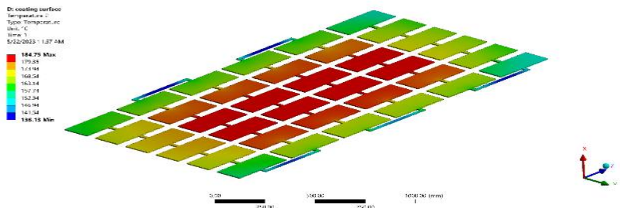

Figure (21): *Thermal distribution with (0.5 μm) TiO_2 Nano coating at ambient temp. (16 ^{o}C)*

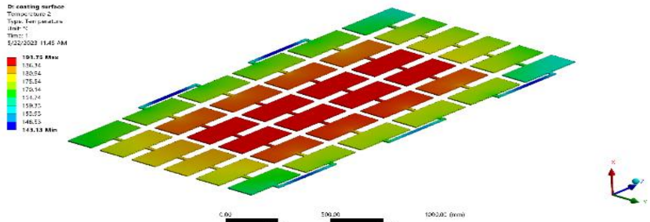

Figure (22): *Thermal distribution with (0.5 μm) TiO_2 Nano coating at ambient temp. (23 ^{o}C)*

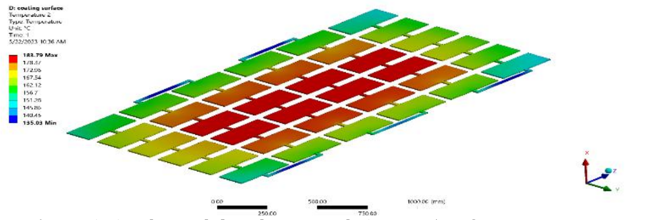

Figure (23): *Thermal distribution with (300 µm) TiO_2 Nano coating at ambient temp. (16 ᵒC*

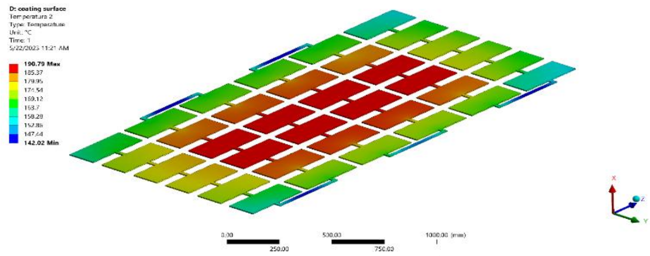

Figure (23): *Thermal distribution with (300 µm) TiO_2 Nano coating at ambient tem Figure (33): p.(23 ᵒC)*

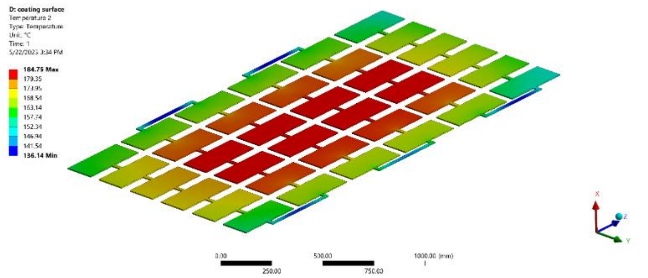

Figure (24): *Thermal distribution with (0.5 µm) SiO_2 Nano coating at ambient temp. (16 ᵒC)*

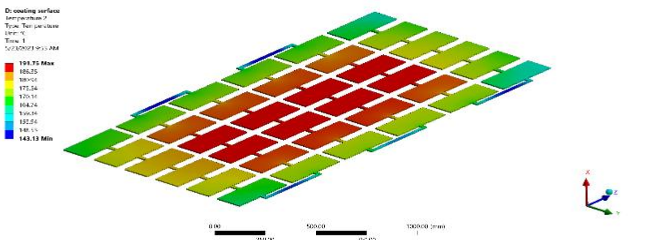

Figure (25): *Thermal distribution with (0.5 µm) SiO_2 Nano coating at ambient temp. (23 ᵒC)*

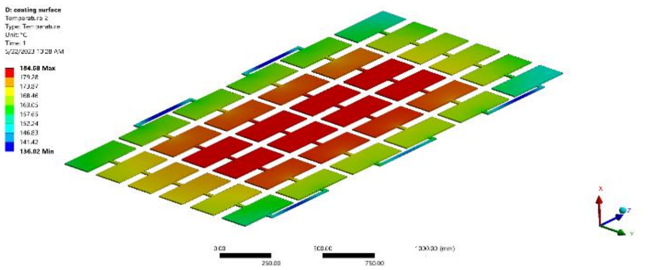

Figure (62): *Thermal distribution with (300 µm) SiO_2 Nano coating at ambient temp. (16 ᵒC).*

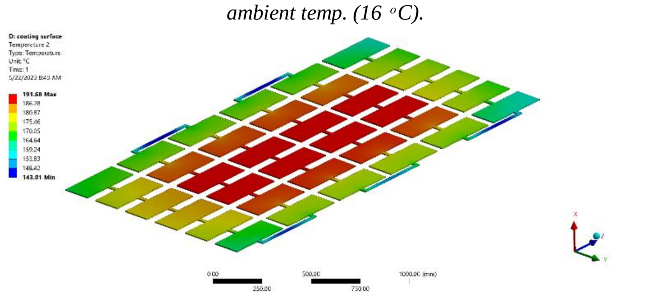

Figure (27): *Thermal distribution with (300 µm) SiO_2 Nano coating at ambient temp. (23 ᵒC)*

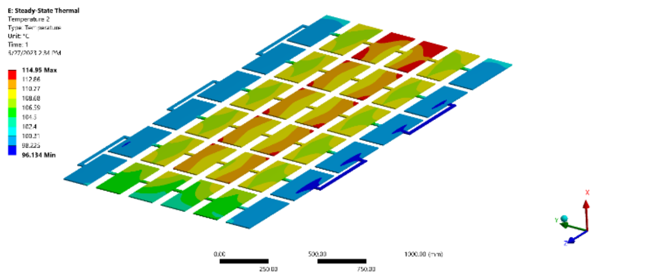

Figure (28): *Thermal distribution with Nano fluid TiO_2 at ambient temp. (16 ᵒC)*

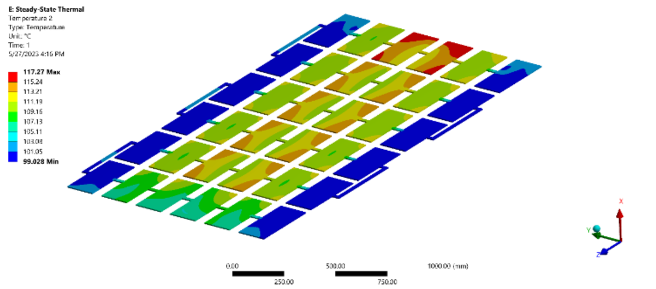

Figure (29): *Thermal distribution with Nano fluid TiO_2 at ambient temp. (23 ᵒC)*

Case (c): With precipitation water: The results of Nano coating by (TiO_2 and SiO_2) with precipitation water at two ambient temperature and four thicknesses are show in fig.(30). The results with thermal distribution are show in figs.(31-42), the solar radiation decrease in this case as show bellow:

Y_{TOTAL}= 33.9 %   Y= 3.05 %

Q = 650 – 19.82 =630.17 kW/m^2

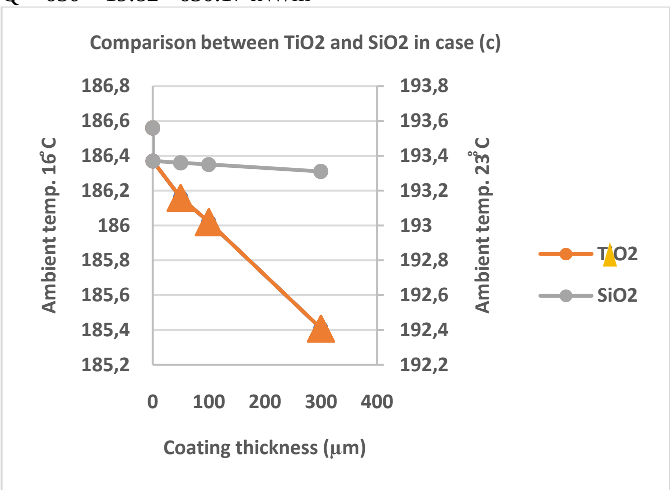

Figure (30) :) *Comparison ambient temp. (Y—axis) at different thicknesses (µm) for TiO_2 and SiO_2 in case (c)*

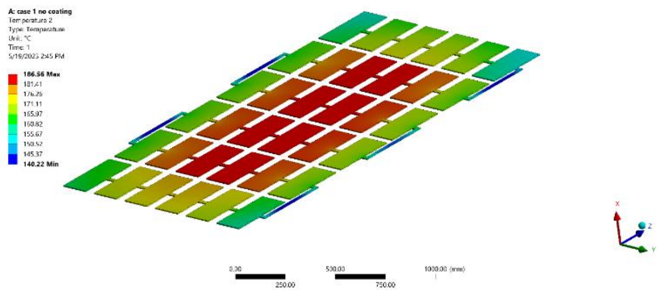

Figure (31): *Thermal distribution without Nano coating at ambient temp. (16 ᵒC)*

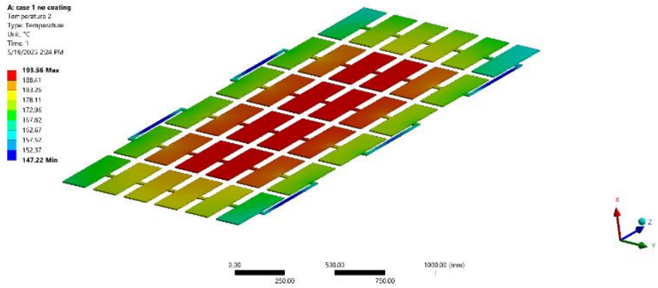

***Figure (32):** Thermal distribution without Nano coating at ambient temp. (23 °C)*

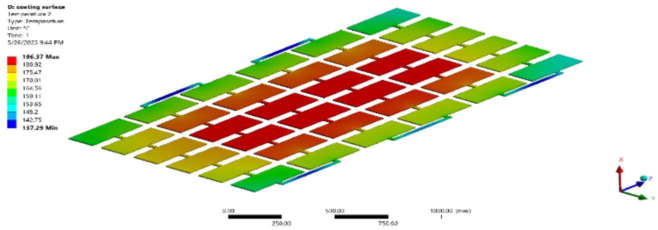

***Figure (33):** Thermal distribution with (0.5m) TiO_2 Nano coating at ambient temp. (16 °C)*

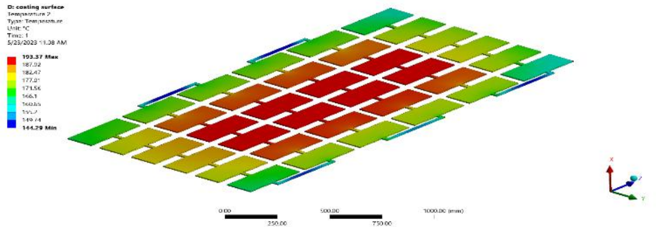

***Figure (34):** Thermal distribution with (0.5μm) TiO_2 Nano coating at ambient temp. (23 °C)*

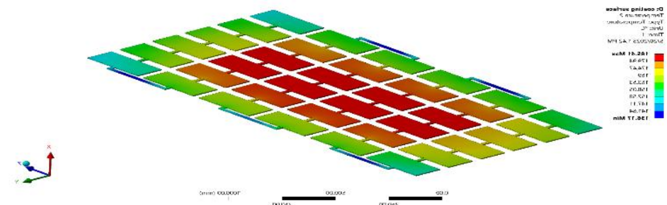

***Figure (35):** Thermal distribution with (300μm) TiO_2 Nano coating at ambient temp. (16 °C).*

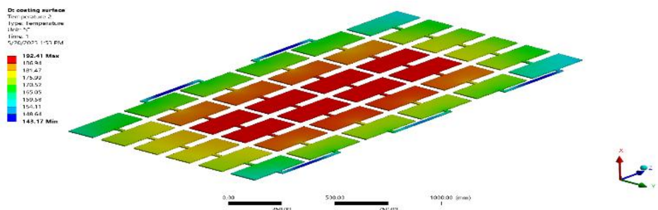

***Figure (36):** Thermal distribution with (300μm) TiO_2 nanocoating at ambient temp. (23 °C*

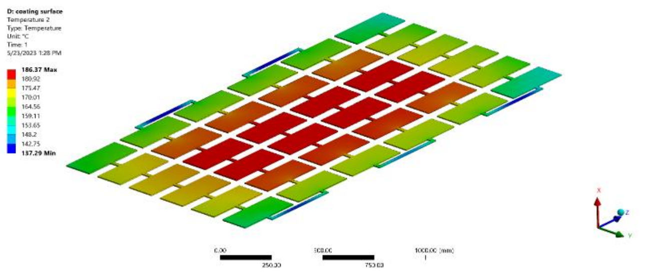

***Figure (37):** Thermal distribution with (0.5μm) SiO_2 Nano coating at ambient temp.*

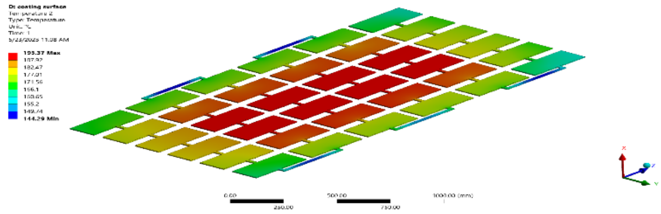

***Figure (38):** Thermal distribution with (0.5μm) SiO_2 Nano coating at ambient temp. (23 °C)*

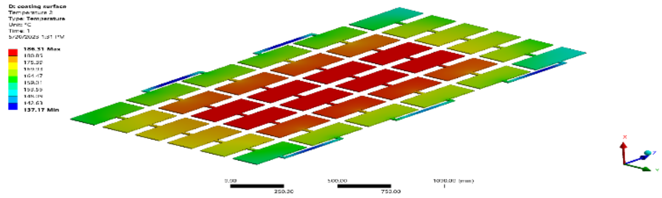

***Figure (39):** Thermal distribution with (300μm) SiO_2 Nano coating at ambient temp. (16 °C)*

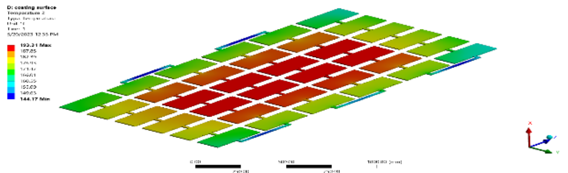

***Figure (40):** Thermal distribution with (300μm) SiO_2 Nano coating at ambient temp. (23 °C)*

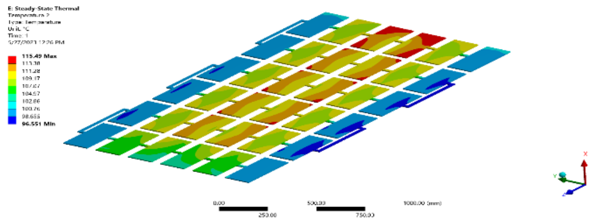

***Figure (41):** Thermal distribution with Nano fluid TiO_2 at ambient temp. (16 °C)*

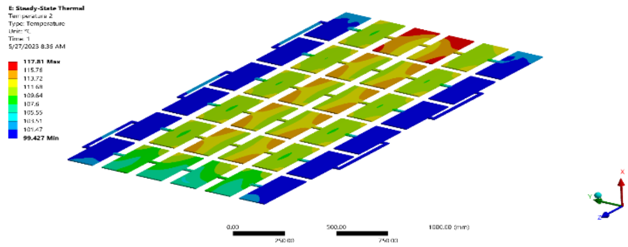

***Figure (42):** Thermal distribution with Nano fluid TiO_2 at ambient temp. (23 °C)*

Summary of the Main Results:

From table (1), can see that the maximum improvement with TiO_2 was in case (a) at thickness 0.5 micrometer and ambient temperature 16℃, for SiO_2 the maximum improvement was in case (a) at thickness 300 micrometer and ambient temperature 16℃, but the Nano fluid gave a large improvement, where the maximum improvement was without dust or water at ambient temperature 23° C. [14]

Table (4.13): *Main Results*

Samples with thickness [micro]			Ambient temp. [16 ℃]	Improvement At [16 ℃] %	Ambient temp. [23 ℃]	Improvement At [23 ℃] %
Case(a): without dust or water	Standard		$T_{max\ PV\ cell}$ =191.93	0	$T_{max\ PV\ cell}$ =198.93	0
	TiO_2	0.5	$T_{max\ PV\ cell}$ = 191.73	0.10420466	$T_{max\ PV\ cell}$ =198.73	0.10053788
		300	$T_{max\ PV\ cell}$ =190.74	0.62001771	$T_{max\ PV\ cell}$ =197.74	0.59820037
	SiO_2	0.5	$T_{max\ PV\ cell}$ =191.73	0.10420466	$T_{max\ PV\ cell}$ =198.73	0.10053788
		300	$T_{max\ PV\ cell}$ =191.67	0.13546606	$T_{max\ PV\ cell}$ =198.67	0.13069924
	Nano-fluid TiO_2		$T_{max\ PV\ cell}$ =117.27	38.8995988	$T_{max\ PV\ cell}$ =119.59	39.8833761
Case(b): with dust	Standard		$T_{max\ PV\ cell}$ =184.93	0	$T_{max\ PV\ cell}$ =191.93	0
	TiO_2	0.5	$T_{max\ PV\ cell}$ = 184.75	0.09733413	$T_{max\ PV\ cell}$ =191.75	0.09378419
		300	$T_{max\ PV\ cell}$ =183.79	0.61644947	$T_{max\ PV\ cell}$ =190.79	0.59396655
	SiO_2	0.5	$T_{max\ PV\ cell}$ =184.75	0.09733413	$T_{max\ PV\ cell}$ =191.75	0.09378419
		300	$T_{max\ PV\ cell}$ =184.68	0.13518629	$T_{max\ PV\ cell}$ =191.68	0.13025582
	Nano-fluid TiO_2		$T_{max\ PV\ cell}$ =114.95	37.8413454	$T_{max\ PV\ cell}$ =117.27	38.8995988
Case(c): with water	Standard		$T_{max\ PV\ cell}$ =186.56	0	$T_{max\ PV\ cell}$ =193.56	0
	TiO_2	0.5	$T_{max\ PV\ cell}$ = 186.37	0.10184391	$T_{max\ PV\ cell}$ =193.37	0.09816078
		300	$T_{max\ PV\ cell}$ =185.41	0.61642367	$T_{max\ PV\ cell}$ =192.41	0.59413102
	SiO_2	0.5	$T_{max\ PV\ cell}$ =186.37	0.10184391	$T_{max\ PV\ cell}$ =193.37	0.09816078
		300	$T_{max\ PV\ cell}$ =186.31	0.13400515	$T_{max\ PV\ cell}$ =193.31	0.12915892
	Nano-fluid TiO_2		$T_{max\ PV\ cell}$ =115.49	38.0949828	$T_{max\ PV\ cell}$ =117.81	39.1351519

Conclusions:

From the above results, the following main points can be concluded:

- The maximum improvement in reduction PV temperature when using TiO_2 is (0.1042%) with coating of thickness 0.5 micrometer without externous dirt on panel.
- The maximum improvement in reduction PV temperature when using SiO_2 is (0.1354%) with coating of thickness 300nmicrometer without externous dirt on panel.
- The Nano fluid of TiO_2 in reducing the panel temperature has a better improvement in all conditions, which was a maximum improvement of (39.88%) without externous dirt on panel.
- All Nano coating thicknesses had better improvement in lower ambient temperature which was 16℃.
- Also, results showed the amount of change in ambient temperature reflects the same change in temperature of PV cell in all cases of Nano coating, but that isn’t apply on Nano fluid.
- The Nano coating for both TiO_2 and SiO_2 at thickness 0.5 micrometer and any ambient temperature have the same improvements.
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