

The Effect of Solar Cell Surface Area when Coated with Titanium on Current Intensity, Voltage and Efficiency

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Abstract:

The aim of the research is to study the electrical circuit variables and the performance efficiency of solar cells with different surface areas when these cells were coated with titanium solution. The surface area of the first cell was 5.88 cm^2 , the surface area of the second cell was 6.09 cm^2 , and the surface area of the third cell was 7.04 cm^2 . The surfaces of all cells were coated with titanium solution and each one was connected to an electrical circuit containing a rheostat, ammeter and voltmeter. Each cell was illuminated with a light intensity of 0.55 MW/cm^2 perpendicular to the surface. The

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values of the current intensity, voltage and open circuit voltage were recorded. The charge density in the closed circuit and the efficiency of the cell performance were calculated and the average for each variable was taken. The results showed that the cell with an area of 5.88 cm² recorded a current intensity of 8.65 mA, the cell with an area of 6.09 cm² recorded 7.867 mA, while the cell with an area of 7.04 cm² recorded 3.933 mA as the lowest value. The cells of 5.88 cm², 6.09 cm² and 7.04 cm² recorded a voltage of 0.0538 mV, 0.0534 mV and 0.0532 mV respectively. The highest voltage value was recorded by the cell The area was 5.88 cm², while the lowest value was recorded by the cell with 7.04 cm². The highest open circuit voltage value was 0.0544 mV and was recorded by the 5.88 cm² cell and the lowest value was 0.0541 mV and was recorded by the 7.04 cm² cell. The 6.09 cm² cell recorded 0.0543 mV. The 5.88 cm² cell recorded the highest charge density value in the closed circuit and was 1.86 coulomb/s. The 6.09 cm² and 7.04 cm² cells recorded 1.62 coulomb/s and

0.70 coulomb/s. The 5.88 cm² cell and the 6.09 cm² cell showed the highest performance efficiency and were 1434.0 and 1247.0 while the 7.04 cm² cell showed 0.05370.0 as the lowest efficiency. It is concluded from the study that the cell surface area inversely affects the current intensity, voltage, open circuit voltage and charge density. Closed circuit charge and cell efficiency, further research is recommended to study the effect of coating solar cells with different types of other materials on the circuit parameters and cell efficiency.

Key words: Circuit, Efficiency, Titanium, Current, Voltage.

الملخص:

هدف البحث إلى دراسة متغيرات الدائرة الكهربائية وكفاءة أداء خلايا شمسية ذات مساحات أسطح مختلفة عند طلاء هذه الخلايا بمحلول التيتانيوم، كانت مساحة سطح الأولى 5,88 سم² ومساحة سطح الخلية الثانية 6,09 سم² أما مساحة سطح الخلية الثالثة 7,04 سم². تم طلاء أسطح جميع الخلايا بمحلول مادة التيتانيوم ووصلت كل منها بدائرة كهربية تحتوى على ريوستات و أميتر و فولتميتير و سُلط على كل خلية ضوء بشدة 0,55 ميغاوات/ سم² عمودياً على السطح وسُجلت قيمة كل من شدة التيار والفولتية وفولتية الدائرة المفتوحة وحُسبت كثافة الشحنة فى الدائرة المغلقة وكفاءة أداء الخلية وأخذ المتوسط لكل متغير، أظهرت النتائج أن الخلية ذات المساحة 5,88 سم² قد سجلت شدة تيار مقدارها 8,65 مللي أمبير والخلية ذات المساحة 6,09 سم² سجلت 7,867 مللي أمبير، أما الخلية ذات المساحة 7,04 سم² قد سجلت 3,933 مللي أمبير كأقل قيمة، سجلت الخلايا 5,88 سم² و 6,09 سم² و 7,04 سم² فولتية بقيم 0,0538 ملي فولت و 0,0534 ملي فولت و 0,0532 ملي فولت على التوالي وأعلى قيمة فولتية قد سُجلت بواسطة الخلية ذات المساحة 5,88 سم² أما أقل قيمة فقد سجلت بواسطة الخلية ذات 7,04 سم². أعلى قيمة فولتية للدائرة المفتوحة كانت 0,0544 ملي فولت وقد سُجلت بواسطة الخلية ذات المساحة 5,88 سم² وأقل قيمة كانت 0,0541 ملي فولت وتم تسجيلها بواسطة الخلية ذات المساحة 7,04 سم² أما الخلية 6,09 سم² فقد سجلت

0,0543 فولت، سجلت الخلية ذات المساحة 5,88 سم² أعلى قيمة كثافة شحنة في الدائرة المغلقة و كانت 1,86 كولوم / ثانية أما الخليتان 6,09 سم² و 7,04 سم² فقد سجلتا 1,62 كولوم / ثانية و 0,70 كولوم / الثانية، أظهرت الخلية ذات المساحة 5,88 سم² والخلية ذات المساحة 6,09 سم² أعلى كفاءة أداء وكانت 01434. و 01247. بينما أظهرت الخلية ذات المساحة 7,04 سم². 005370 كأقل كفاءة، يُستنتج من الدراسة أن مساحة سطح الخلية تؤثر عكسياً على شدة التيار والفولتية وفولتية الدائرة المفتوحة وكثافة الشحنة في الدائرة المغلقة وكفاءة الخلية، يُوصى بإجراء مزيداً من البحوث لدراسة أثر طلاء الخلايا الشمسية بأنواع مختلفة من المواد الأخرى على متغيرات الدائرة الكهربية وكفاءة الخلية.

الكلمات المفتاحية: الدائرة الكهربية، كفاءة، التيتانيوم، شدة التيار، الفولتية.

1.Introduction:

A solar cell or photovoltaic cell (PV cell) is an electronic device that converts the energy of light directly into electricity by means of the photovoltaic effect [1]. It is a form of photoelectric cell, a device whose electrical characteristics (such as current, voltage, or resistance) vary when it is exposed to light. Individual solar cell devices are often the electrical building blocks of photovoltaic modules, known colloquially as "solar panels". Almost all commercial PV cells consist of crystalline silicon, with a market share of 95%. Cadmium telluride thin-film solar cells account for the remainder.[2] The common single-junction silicon solar cell can produce a maximum open-circuit voltage of approximately 0.5 to 0.6 volts [3].

Photovoltaic cells may operate under sunlight or artificial light. In addition to producing energy, they can be used as a photodetector (for example infrared detectors), detecting light or other electromagnetic radiation near the visible range, or measuring light intensity.

-The absorption of light, generating excitons (bound electron-hole pairs), unbound electron-hole pairs (via excitons), or plasmons.

-The separation of charge carriers of opposite types.

-The separate extraction of those carriers to an external circuit.

Application of solar cells as an alternative energy source for vehicular applications is a growing industry. Electric vehicles that operate off of solar energy and/or sunlight are commonly referred to as solar cars. These vehicles use solar panels to convert absorbed light into electrical energy that is then stored in batteries. There are multiple input factors that affect the output power of solar cells such as temperature, material properties, weather conditions, solar irradiance and more [4].

The first instance of photovoltaic cells within vehicular applications was around midway through the second half of the 1900's. In an effort to increase publicity and awareness in solar powered transportation Hans Tholstrup decided to set up the first edition of the World

Solar Challenge in 1987. It was a 3000 km race across the Australian outback where competitors from industry research groups and top universities around the globe were invited to compete, General Motors ended up winning the event by a significant margin with their Sunracer vehicle that achieved speeds of over 40 mph, Contrary to popular belief however solar powered cars are one of the oldest alternative energy vehicles [5].

Current solar vehicles harness energy from the Sun via Solar panels which are a collected group of solar cells working in tandem towards a common goal. These solid-state devices use quantum mechanical transitions in order to convert a given amount of solar power into electrical power, The electricity produced as a result is then stored in the vehicle's battery in order to run the motor of the vehicle [6]. Solar energy production in the U.S. has doubled from 2013 to 2019 [7]. This was driven first by the falling price of quality silicon [8][9][10], and later simply by the globally plunging cost of photovoltaic modules In 2018, the U.S. added 10.8GW

of installed solar photovoltaic energy, an increase of 21% [11,12].

Titanium is a chemical element; it has symbol Ti and atomic number 22. Found in nature only as an oxide, it can be reduced to produce a lustrous transition metal with a silver color, low density, and high strength, resistant to corrosion in sea water, aqua regia, and chlorine, Titanium was discovered in Cornwall, Great Britain, by William Gregor in 1791 and was named by Martin Heinrich Klaproth after the Titans of Greek mythology. The element occurs within a number of minerals, principally rutile and ilmenite, which are widely distributed in the Earth's crust and lithosphere; it is found in almost all living things, as well as bodies of water, rocks, and soils [13]. The metal is extracted from its principal mineral ores by the Kroll and Hunter processes [14]. The most common compound, titanium dioxide, is a popular photocatalyst and is used in the manufacture of white pigments [15]. A stream of titanium tetrachloride gas is added to a stream of molten

sodium; the products (sodium chloride salt and titanium particles) is filtered from the extra sodium. Titanium is then separated from the salt by water washing. Both sodium and chlorine are recycled to produce and process more titanium tetrachloride [16], The most important use of titanium is in alloying, where the metal is added to steel, adding strength and making it more resistant to corrosion (rust). Titanium also has another advantage in alloying: its density is less than half that of steel. Therefore, a steel alloy containing titanium weighs less than a pound compared to a pure steel alloy.

Methods for electrolytic production of Ti metal from TiO_2 using molten salt electrolytes have been researched and tested at laboratory and small pilot plant scales. The lead author of an impartial review published in 2017 considered his own process "ready for scaling up"[17]. A 2023 review "discusses the electrochemical principles involved in the recovery of metals from aqueous solutions and fused salt electrolytes", with particular attention paid to titanium. While some metals such as

nickel and copper can be refined by electrowinning at room temperature, titanium must be in the molten state and "there is a strong chance of attack of the refractory lining by molten titanium"[18]. Zhang et al concluded their Perspective on Thermochemical and Electrochemical Processes for Titanium Metal Production in 2017 that "Even though there are strong interests in the industry for finding a better method to produce Ti metal, and a large number of new concepts and improvements have been investigated at the laboratory or even at pilot plant scales, there is no new process to date that can replace the Kroll process commercially"[19].

The titanium is recently become very important in solar cells applications. This encourages many researchers to try to improve the performance of solar cells using titanium and other materials. One of them is the study done by Awadiya Ibrahim Mohamed Mahdi [20] ,where she used Carbon 60 in studying solar cells to improve their efficiency. This study aims to study the effect of

carbon60 on solar cells efficiency. The results showed that changing carbon 60 physical properties changes the efficiency.

One of the most important problems of the world today is the energy problem. The world has turned to many sources to obtain clean energy with high efficiency, which has made scientists make a great effort through scientific research and to reach energy with distinctive specifications. Solar cell systems suffer from many problems, especially in the variables of the electrical circuit and the absorption of solar rays, which negatively affects the efficiency of the solar cell. Therefore, this study is concerned with knowing the effect of titanium on the efficiency of solar cells with different surface areas when these cells are coated with titanium solution. efficiency. Section 2 is concerned with the method, while sections 3 ,4 and 5 are devoted for results, discussion and conclusion.

2. Materials:

Titanium dioxide, Methanol, (FT0) Glass, Rhodamine G6, Iodine.

The devices used are voltmeter and ammeter to study

Voltage and current characteristics of the circuit.

The details are

- Electrometer Model (642) from the American company KTHLEY to read the current and works accurately to read currents up to (10^{-13} A).
- (Micro voltDMM) Model 177 from the American company KTHLEY to read the voltage accurately up to nanovolt.
- Rheostat from the Dutch company Albert with a resistance of up to 300 $\mu\Omega$.
- Lighting source with a capacity of (0.55 MW. cm^{-2})

In order to calculate the effect of the surface area of a solar cell when coated with titanium and determine the efficiency by obtaining both the current and voltage, the following steps must be followed:

- A paste of titanium dioxide was prepared after adding methanol to it.
- The paste was spread on the conductive face of the glass (FTO) and left to dry.
- The glass and the paste were heated at a temperature of (50C⁰) for a quarter of an hour.
- Another slice of (FTO) was taken and graphite was deposited on it.
- The slice with the paste on it was immersed in Rhodamine G6 dye and then left to dry.
- Some drops of iodine solution were placed on the slice on which the graphite was deposited.
- The two faces of the slice were connected and fixed with clips and part of the ends were left clean and connected in the voltage and current characteristics circuit.
- Using the previous steps, 3 cells were made with different areas 7.04, 6.09, 5.88.

– The voltage and current readings of the prepared cells were taken in the voltage and current characteristics circuit.

The area A of each solar cell is calculated from which the current density for closed circuits can be found which is equal to the open circuit current over the area.

$$J_{sc} = \frac{I_{sc}}{A} \quad (7 - 1)$$

Through which the efficiency of each solar cell of the three cells can also be calculated, the average for each cell is taken and high efficiency results can be reached that can be used. Where the efficiency can be calculated through this law:

$$\eta = \frac{J_{sc} V_{oc} FF}{P_{in}} \quad (7 - 2)$$

Then find the coefficient of the law:

$$FF = \frac{V_{max} I_{max}}{V_{oc} I_{sc}}, V_{oc} = \frac{V_{max} I_{max}}{FF I_{sc}} \quad (7 - 3)$$

Efficiency η

Circuit current density J_{sc}

Open circuit voltage V_{oc}

Power factor FF

Internal energy of the source P_{in}

Note that P_{in} equals

$$P_{in} = 0.55 \text{ MW.cm}^{-2}$$

The following images show some of the equipments used in the experimental work.





Figure (2.1) some of the equipments used in the experimental work

3. Results:

The following tables and graphs showed the experimental results

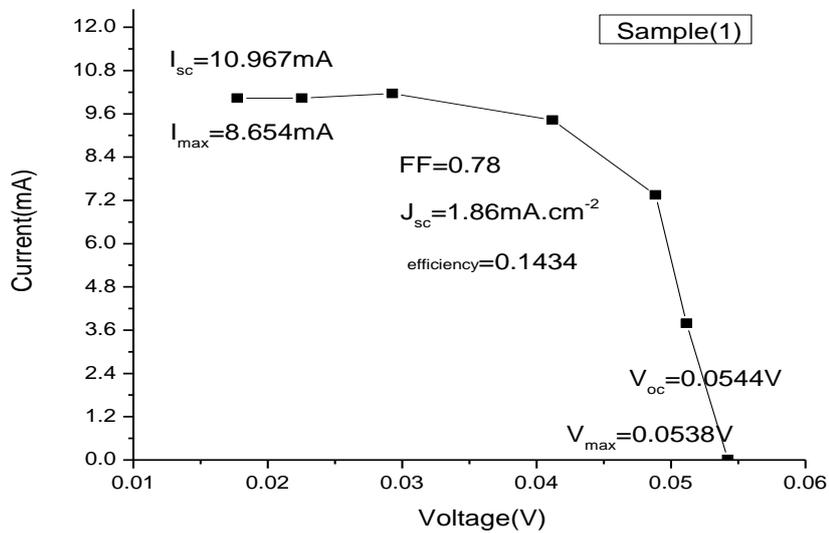


Figure (3.1) The relationship between current and voltage for the first sample

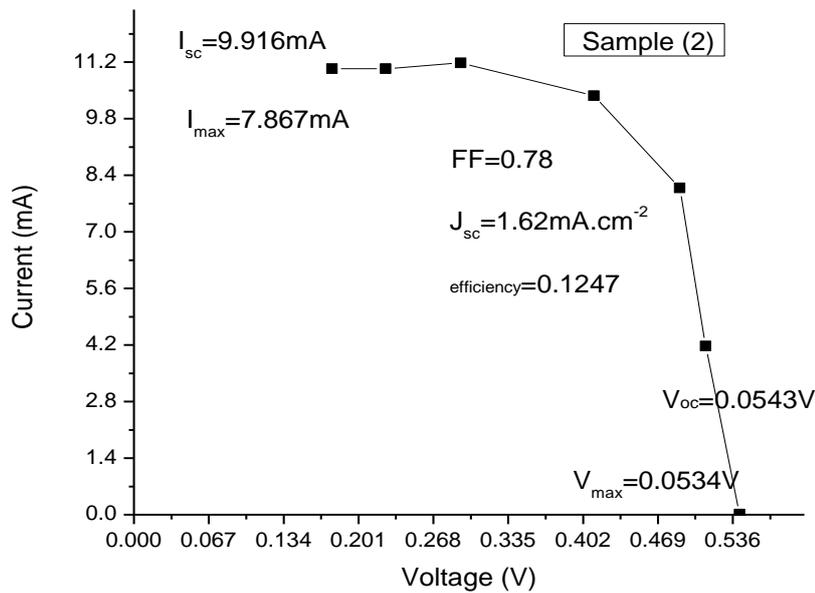


Figure (3.2) The relationship between current and voltage for the second sample

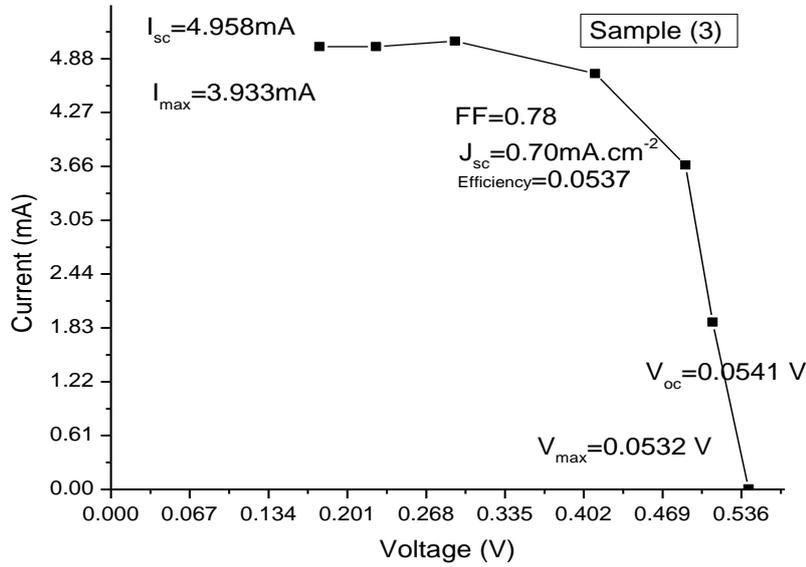


Figure (3.3) The relationship between current and voltage for the third sample

Table (3.1) shows the relationships between area, efficiency, voltages and currents

A cm^{-2}	η %	FF (%)	V_{oc} mV	V_{max} mV	I_{max} mA	J_{sc} mA. cm^{-2}	I_{sc} mA	Sample
5.88	0.1434	0.78	0.0544	0.0538	8.654	1.86	10.967	First
6.09	0.1247	0.78	0.0543	0.0534	7.867	1.62	9.916	Second
7.04	0.0537	0.78	0.0541	0.0532	3.933	0.70	4.958	Third

4. Discussion:

From figures (3.1) (3.2) (3.3) which represent the relationship between current and voltage for the first, second and third samples with areas of $7.04\text{cm}^2, 6.09\text{cm}^2, 5.88\text{cm}^2$ respectively, we find that the closed circuit current density J_{sc} for the first, second and third samples is $0.70\text{mA.cm}^{-2}, 1.62\text{mA.cm}^{-2}, 1.86\text{mA.cm}^{-2}$ respectively, inversely proportional to the area A for the first, second and third samples $7.04\text{cm}^2, 6.09\text{cm}^2, 5.88\text{cm}^2$ respectively, in light of the theoretical relationship:

$$J_{sc} = \frac{I_{sc}}{A} \quad (4 - 1)$$

We also find that the open circuit voltage V_{oc} for the first, second and third samples is $0.541\text{V}, 0.0543\text{V}, 0.0545\text{V}$ respectively, which is directly proportional to the efficiency η for the first, second and third samples is $0.054\%, 0.108\%, 0.013\%$ respectively, according to the following theoretical relationship:

$$\eta = J_{sc} V_{oc} \quad (3 - 2)$$

As for the open circuit voltage V_{oc} for the first, second

and third samples 0.542V, 0.545V, 0.0545V respectively, it is directly proportional to the maximum voltage V_{max} with values for the first, second and third samples 0.0532V, 0.0538V, 0.0538V respectively, according to the following theoretical relationship:

$$V_{oc} = \frac{V_{max}I_{max}}{FFI_{sc}} \quad (3 - 3)$$

5. Recommendations:

The efficiency of solar cells can be studied for more compounds to gain valuable information about alternative energies.

6. Conclusion:

This research demonstrates that titanium used to study the efficiency of solar cells when coated on glass panels gives reliable results.

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