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Development of Nano-composite Coating for Silicon Solar Cell Efficiency Improvement*

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Abstract

In this study, various nano-composite materials were investigated with an aim to improve the solar cell efficiency. The application of the nano-composite materials shows very promising improvement in surface passivity, antireflection and desired energy band gap of the materials. From the investigation, CNT-TiO_2-SiO_2 composite shows high performance. Detailed experimental inference and scanning electron microscopy analyses are used to characterize the composite material coated Si solar cell. It is shown that proposed surface texturing technique gives the increase in conversion efficiency of solar cells by 31.25% when compared with the uncoated cells.

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Keyword: Solar cell; surface modification; carbon nano tube composite; efficiency improvement.

The world depends on sources of energy for electrification and utilization. The conventional energy sources are a non-renewable in nature and getting depleted day by day. The renewable energy sources such as solar and wind are available infinite in nature. Even-though the extraction of energy from renewable energy is costlier, maintenance cost is low and energy can be extracted for a long time without any demand. Solar power extraction is pollution free

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and cost effective energy sources compared to other energy sources [1]. The Sun creates its energy through thermonuclear process which converts 650,000,000 tons of hydrogen into helium. This process creates heat and electromagnetic radiation, later streams into the atmosphere in all direction. In these radiations only 57% hits the earth surface which 1.6×10^{18} units of energy from sun [2].

The energy of photon and wavelength of light is inversely proportional to each other. The sunlight in ground level consists of 44% visible light, 3% ultraviolet light and the remaining is infrared light. Since the atmosphere blocks 77% of the sun's UV-radiation, only Infrared light radiation hits earth. Photovoltaic cells absorbs high frequency radiations such as ultra violet and visible lights which converts radiation into electricity whereas the infrared radiation is a low frequency radiation is generally converted to heat or thermal radiation. In normal silicon solar cell, IR radiations just pass through the photovoltaic cell that converts into heat and hence affect the efficiency.

Nomenclature

$C_9H_{21}AlO_3$	Aluminium Iso-propoxide
TiO_2	Titanium dioxide
ZnS	Zinc Sulphide
CNT	Carbon Nano Tube
I_{SC}	Short Circuit Current
V_{OC}	Open Circuit Voltage

2. Antireflection coating on solar cell

2.1Antireflection coating

The silicon has a high surface reflection characteristics hence, reflects nearly 30% of the incident light. This reflection affects the PV panel efficiency. Reducing this reflection by applying anti-reflection coating to the solar cell surface helps in dragging power effectively. The anti-reflective coating reduces the photons reflected to the atmosphere and hence, increases the solar cell performance [3]. A thin layer anti-reflective material such as SiO_2, SiN, SiON and TiO_2 are deposited on the surface of the solar cell [4.5].

2.2 .Nanomaterials and Nanocomposites

The use of nano-materials and nano-composites for solar cell application has several benefits such as reduced manufacturing cost as a result of using a low temperature process similar to printing instead of the high temperature vacuum deposition process. It is typically used to produce conventional solar cells made with crystalline semiconductor materials. It can also be coated over flexible rolls instead of rigid crystalline panels [6.7].

3. Chemicals used for antireflection coating

The chemicals that are used for the antireflection nano composite coating are Aluminum Iso-propoxide, Carbon Nano tube (CNT), Zinc sulphide, Tetra-ethoxy silane and Combination of Silver nitrate and Aluminum iso-propoxide.

4. Coating and experimental testing procedures

4.1 Preparations of nano-composites for coating

The nano-composites are prepared from chemical solutions with an appropriate amount of titanium iso-propoxide and tetra-ethoxy silane in pure alcohol, which act as base materials due to better adhesive and refractive index properties. This solution was sonicated in an ultrasonic cleaner for 30 minutes at 37^0C to break the minute particles and the solution is added with various materials like CNT, ZnS, Aluminium iso-propoxide. Then this solution was stirred for 30 mins using a magnetic stirrer. Fig.1 represents the CNT dispersed solution which contains titanium isopropoxide and tetra-ethoxy silane.

Fig. 1. CNT-Titanium Iso-propoxide dispersed Silane solution

4.2 Coating methodology

The nano-composite coating on the solar panel involves the following steps,

Step 1: The commercially available panel shown in Fig. 2 is first to be de-coated to remove the polymer coated on the panel.

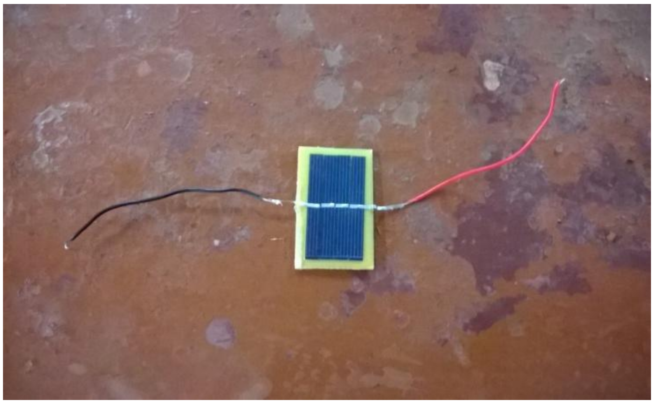

Fig. 2. Commercially available panel

Step 2: The surface of the solar cell is cleaned with alcohol and HF to remove the dead layer.

Step 3: The solar cell is coated with prepared solution. This coating can be done by using atomiser to have a fine spray so that coating can be done in even manner.

Step 4: After coating, the panel is dried by keeping it under tungsten lamp for nearly half an hour. Then it is allowed to cool to room temperature and used for solar cell characterization. CNT- Nano-composite coated solar panel is shown in Fig. 3.

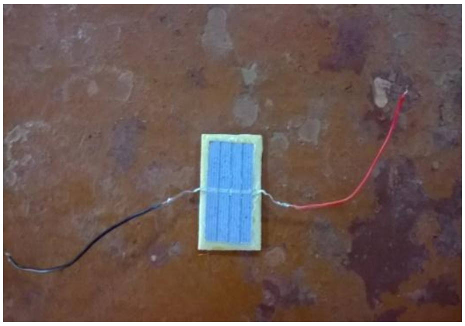

Fig. 3. CNT–Nano composite coated panel

5. Experimental result and analysis

5.1 SEM analysis

Fig. 4 (a) and (b) shows the scanning electron microscope (SEM) images of polymer de-coated commercial Si solar cell and CNT-Nano-composite coated commercial Si solar cell. These tests help us to understand the structure modifications of the solar cell after coating with anti-reflection coating. It is clearly observed that the uncoated one show an etched silicon surface with un-removed polymer particles whereas coated one shows the deposition of jelly structure over the inner surface of the etched silicon. This coated layer enhances the sunlight absorption capability of the solar cell.

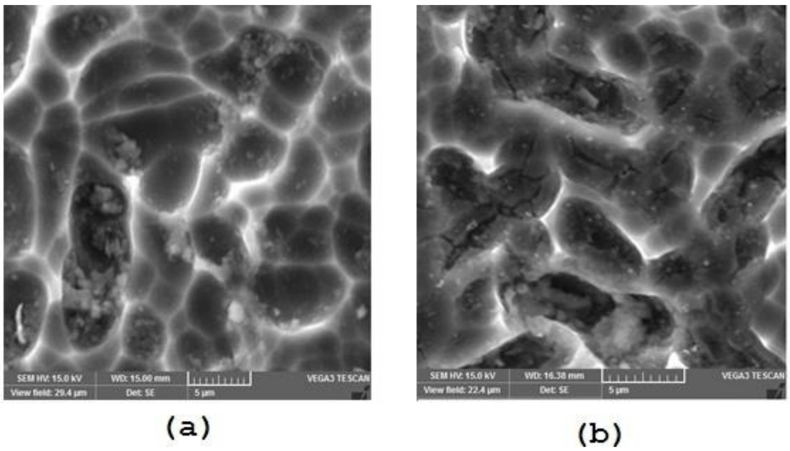

Fig. 4. (a) Polymer de-coated commercial Si solar cell (b) CNT-TiO_2-coated Si - solar cell

5.3 Experimental observation

The improvement in the solar cell efficiency of nano-composite coated with uncoated can be better understood by I-V study as a function of resistance. For this study, solar cell with a rating of 2 Volt 100 milli-amperes is kept under sunlight during of 12-1 PM. The experimental observation of uncoated and Carbon Nano Tube (CNT) coated cell power is obtained and are depicted in Table. 1. I-V curve can be obtained by taking voltage in the X-axis and current in Y-axis, as shown in Fig. 5. Only when the right resistance is connected across the solar cell, there will be an optimal voltage generated with an optimal current flowing. With this value of resistance across the solar cell, the maximum electrical energy available from the solar cell is being delivered to the resistor. Under these conditions, the solar cell is said to be operating at its "Maximum Power Point".

Table. 1. Experimental observation of uncoated and Carbon Nanotube (CNT) coated cell

S.NO	Resistance (ohm)	Power from uncoated cell (mW)	Power from CNT coated cell (mW)
1	40	49.5	72
2	50	44.17	61.8
3	60	40	54.57
4	70	35.2	50.76
5	80	32	43.7
6	90	29.7	39.9
7	100	19.5	38
8	200	14.45	19.8
9	300	10.5	12.4
10	400	7.2	10
11	800	3.6	5
13	1000	2.7	4
14	2000	0.18	0.2

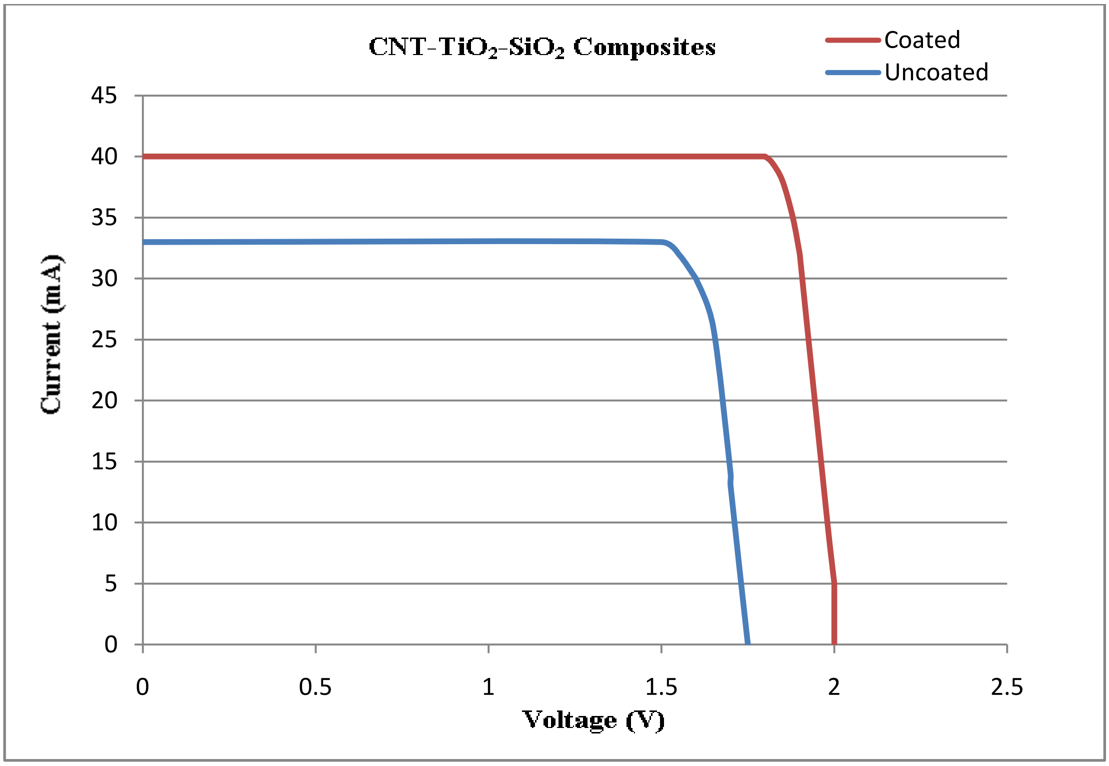

Fig. 5. I-V Curve for CNT coated cell

5.4 Comparison of various nano-composites

In-order to develop various nano-composites and to compare with the CNT coated materials; we have chosen aluminium iso-propoxide, ZnS as one of the composite materials along with the titanium iso-propoxide and silane. By comparing the results of all nano-composite coated cells shown in Table. 2, it is clear that CNT gives the best result with 72 mW power which is 31.25 % higher than the normal cell

Table. 2. Comparison of power obtained using various coated cells

S.no	**Ω**	**Uncoated**	**CNT**	**ZnS**	**$C_9H_{21}O_3Al$**
1	40	49.5	72	56.7	64.43
2	100	19.5	38	32.4	35.15
3	400	7.2	10	8.46	9.36
4	800	3.6	5	3.8	4.95
5	1000	2.7	4	2.85	3.56
6	2000	0.18	0.2	0.19	0.2

Note: Power in mW

6. Conclusion

In this work, commercially available solar cells are coated with anti-reflective material. The chemicals used are CNT (Carbon Nano Tubes), Aluminium isopropoxide and Zinc sulphide. Among these the CNT Nano-composite type of materials has shown excellent improvement due to its optical properties like provision of multiple reflections and reduction of recombination losses. In all these chemical composites, titanium iso-propoxide and tetraethoxy silane are used as a base materials. By comparing the results of various coated cells the CNT coated gives the best result of 31.25% improvement.

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