EPJ Web of Conferences **133**, 03003 (2017) DOI: 10.1051/epjconf/201713303003
IC SeNOB 2016

Synthesis of dye-sensitized solar cells. Efficiency cells as a thickness of titanium dioxide

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Abstract. Defying the influence of the thickness of TiO_2 efficiency of dye-sensitized solar cell. It was confirmed that the compatibility of printed layers with the parameters closely related with the DSSC. It was found that the increase in thickness of the titanium dioxide layer, increases the distance between the electrodes, determined by the thickness of the Surlyn foil. With the rise of thickness of dyed layer of TiO_2 established decrease in the value of its transmittance. Greatest transparency and aesthetic value obtained for photovoltaic modules with a single layer of titanium dioxide. The improved performance efficiency and preferred yields maximum power were noticed and exhibited by the cells covered with three layers of TiO_2. It was established that the behaviour of economic efficiency in the production process, provides a range of cells with two layers of oxide, showing a similar performance and greater transparency.

1. Introduction

The development of technology and the continuous growth of population results in a dynamic demand for electricity. However access to conventional energy sources, which include coal, natural gas and oil is limited. It's worth pointing out, that their usage is associated with high levels of harmful emissions to the environment. For these reasons, in recent years they began to look for new solutions, paying great attention to alternative energy sources. Solar energy belongs to that group and it is used by the photovoltaic cells, converting it into electrical energy. History of dye solar cells dating back to 1887. However the breakthrough discovery was the year 1991. Gräetzel and his colleagues developed a cell structure of dye-sensitized solar cell. Low production cost and high efficiency caused that cells DSSC became the main object of research worldwide [1, 2]. The aim of the study was to investigate and determine the effect of influence of titanium dioxide thickness on efficiency of printed photovoltaic solar cells (DSSC).

2. Experimental Details

The first step was to cut glass sample using a diamond cutter. Prepared glass substrates were washed using ultrasonic cleaner in special detergents according to the procedure established in the photovoltaic Center Research and Development Company Ml System S.A. The next step was the ablation of the upper and lower glass made using a semiconductor laser of the fiber, in order to isolate each cell. Using a drill, holes were drilled located at the top and bottom edges of the glass. The layer is printed on the prepared glass substrate by screen printing. This is a technique in which the print form template is applied to the fine woven mesh, metal or made of synthetic fibers. Making a print is to paint by the swaging die. For samples without openings a titanium dioxide paste and silver paste, and the sample with holes platinum paste and silver paste were applied. In studies substrate glass was printed successively with one, two, three and four layers of the paste of TiO_2, in an effort to check if the thickness of the layer has influence on the efficiency of DSSC. The sample was subjected to a drying process in a drying tunnel each time. The purified stream of air samples were tested for the profilometer and then want to remove the organic material and combine grain active layers, were sintered processed at a temperature of about 480 ° C. After the heat treatment process surface topography was determined once again and profile layers of titanium dioxide. In a next step the immersion technique, the sample with printed layers of TiO_2 were stained in the solution of the dye N719 for 24h. Lamination process is carried out by combining a counter (representing the upper glass with holes) with photoanode (lower glass without holes) using Surlyn foil as an encapsulant. The final stage of the production was to fill the solar cells with electrolyte dye, based on a pair of redox I^- / I_3^- [3, 4].

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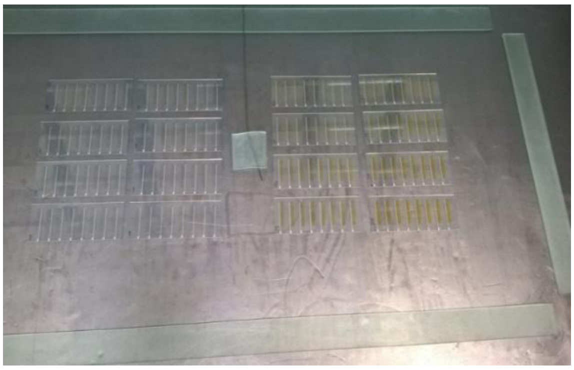

Fig. 1 Distribution of the samples in an industrial furnace in the sintering process.

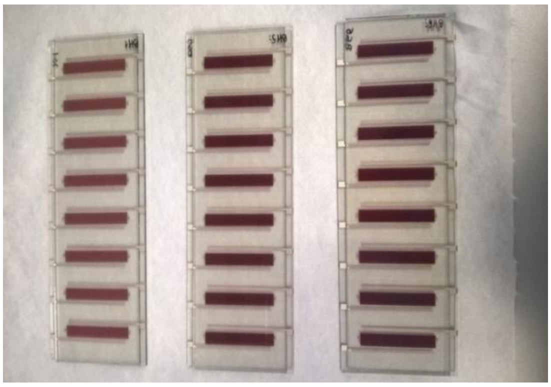

Fig. 2 Laminated photovoltaic modules.

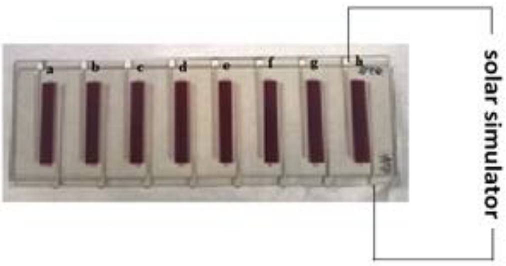

Fig. 3 Photovoltaic module with a description of individual cells and the way of connecting when removing the current-voltage characteristics.

The picture below presents a way of naming the individual cells (8), the photovoltaic module and method of removing the voltage signal.

3. Results and Discussion

The table shows the results of measurements of obtained TiO_2 layer thickness, before and after sintering process. Each module having one, two, three and four layers of titanium dioxide was measured on three cells. It was noticed that the thickness after firing decreased from 0.5-1 µm [5].

Table 1. The topography of the surface. The thickness of the layer of TiO_2, for photovoltaic modules with one, two, three and four layers of oxide.

THE TOPOGRAPHY OF SURFACE-THICKNESSES OF TiO_2 LAYER				
Name of cells	1 layer of TiO_2 [µm]	2 layers of TiO_2 [µm]	3 layers of TiO_2 [µm]	4 layers of TiO_2 [µm]
AFTER THE DRYING PROCESS				
a	5,5-6,0	9,0-10,0	15,0	20,0
d	5,5-6,0	9,0-9,5	14,0-14,5	20,5
g	6,0	8,5-9,0	15,0	21,0-22,0
AFTER THE FIRING PROCESS				
a	4,0-5,0	8,0-8,5	14,0	17,0-18,0
d	4,5-5,0	8,0-8,5	13,5-14,0	18,0
g	4,5-5,0	8,0	14,5	19,0-19,5

Using the SENSOMAP program made three-dimensional imaging topography surface and presented profile of the titanium dioxide layer. On its basis, it was found that layer is characterized by a much greater roughness before firing. After firing it shows a greater homogeneity.

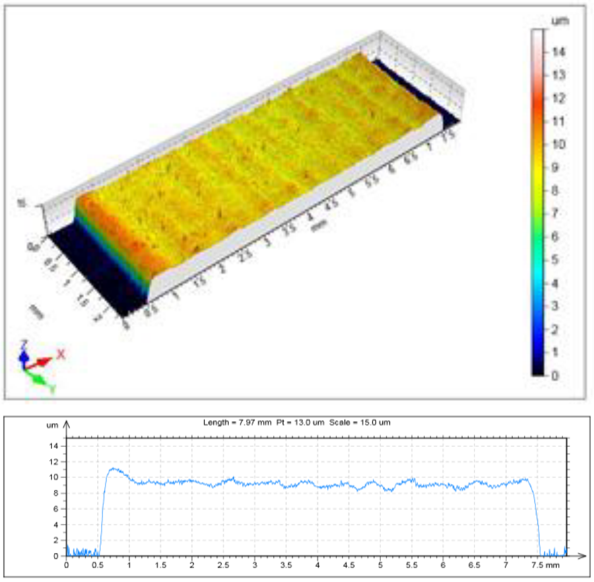

Fig. 4 The topography surface and profile of TiO2 glass layer substrate with two layers of oxide after the drying process.

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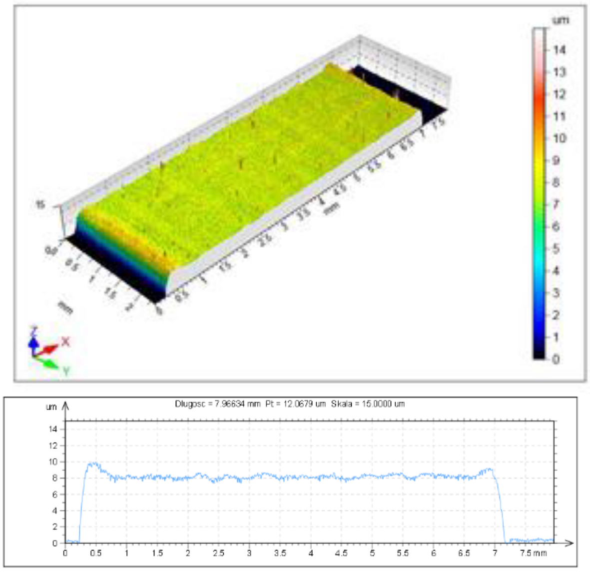

Fig. 5 The topography surface and profile of TiO2 glass layer substrate with two layers of oxide after the firing process.

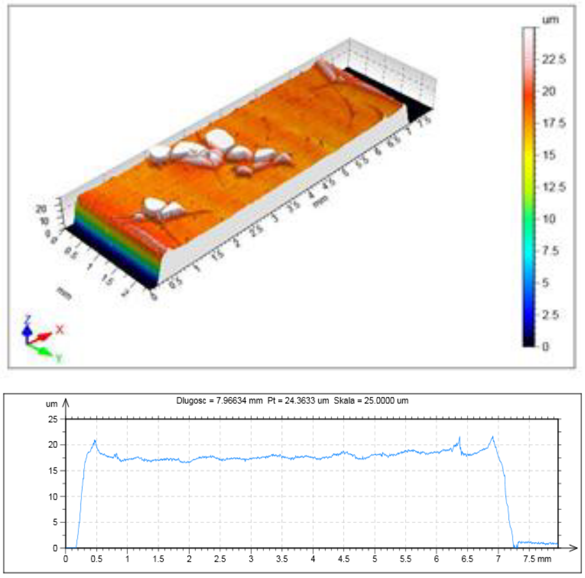

Fig. 6 The topography surface and profile of TiO2 glass layer substrate with four layers of oxide after the firing process.

The presence of defects in the case of photovoltaic cells with four layers of oxide was due to shrinkage of the fire and had a significant influence on the measuring results. In the high temperatures inside the industrial furnace, the water evaporated, organic matter degraded and particles of the raw material came closer to each other. Too much shrinkage caused mechanical deformation of the article [5].

Measurements of current-voltage characteristics were made using standard testing conditions (STC): (1000W / m^2, AM = 1.5, T = 25 ° C). The shape obtained characteristics in the case of cells of two or three layers of oxide it is virtually identical. For the remaining cells the chart starts with smaller current value. Based on the reports generated by special software simulator of the solar, containing current-voltage characteristics and electrical parameters for single cell of photovoltaic module, tables were prepared. The most important parameters were summarized there. In the recording accuracy of the median values, the value of the maximum probable error (d_x) using the methods of the Student-Fisher [6]. Obtained similar values of open circuit voltage and short circuit current for each cells of test modules with one, two and three layers of TiO_2 were obtained. In the case of cells of the four-layers oxide a value of short circuit current varied, and it was much lower. The highest maximum power equal to an average of 13.85 mW was obtained for a cell with three layers of titanium dioxide. This cell also showed the highest efficiency in the range of 3,76-4,04% [5].

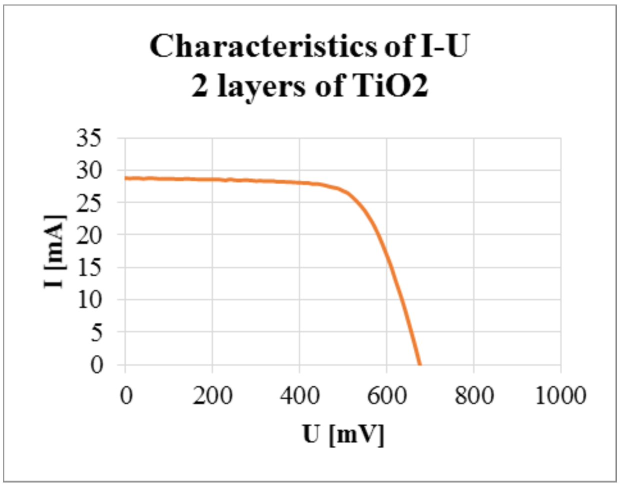

Fig. 7 Current-voltage characteristics for the cell of photovoltaic module with two layers of titanium dioxide.

Averaging other electrical parameters of particular cells of photovoltaic modules has been observed that increasing the thickness of the layer of TiO_2 causes a linear increase in short-circuit current (I_{sc}), maximum power (P_{max}) and efficiency (η). The results concerning the cell covered with four layers of titanium dioxide was excluded due to the inaccuracy caused by the cracking of the oxide layer during firing [5].

Table 2 Record the average values of individual parameters of photovoltaic cells, taking into the maximum probable error

Name of parameter	Test module- 1 layer of TiO_2	Test module- 2 layers of TiO_2	Test module- 3 layers of TiO_2	Test module- 4 layers of TiO_2
U_{oc} [mV]	677 ± 18	682 ± 22	673 ± 20	603,6± 7,1
I_{sc} [mA]	25,9 ± 1,2	28,2 ± 3,3	30,2 ± 2,2	5,0 ± 0,9
P_{max} [mW]	11,85 ± 0,31	13,0 ± 1,2	13,85 ± 0,72	1,95 ± 0,37
FF	0,68 ± 0,03	0,68 ± 0,02	0,682 ± 0,011	0,64 ± 0,03
η [%]	3,266± 0,081	3,57 ± 0,38	3,84± 0,22	0,53 ± 0,10

Based on the survey, it was found that the transmittance measurement of a dyed layer of TiO_2 decreases along with increasing of thickness. Transmittance indicates how much of the incident radiation is passed through materials. In the case of photovoltaic cells with three layers of TiO_2, it was observed that the light transmittance ranged from 8-10%. The highest value of transmittance of the order of 26-27% were obtained for the cells with one layer of oxide. It is worth noting that the decrease in the coefficient of transparency increases the efficiency of the module [5].

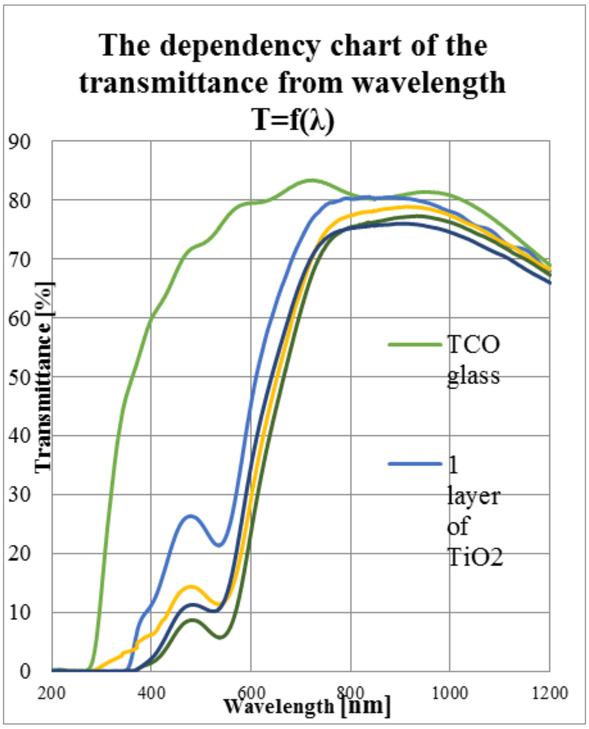

Fig. 8 Transmittance measurement for TCO glass and manufactured photovoltaic modules

4 Conclusions

In the manufacture of printed photovoltaic solar cells (DSSC) each stage of the production has a significant impact on the final result of product. We could list a lot of reasons such as correct cut glass substrate, the accuracy of laser ablation, drilling, proper selection of the thickness of the active layer, encapsulant, and screen printing process. Relating to a screen printing method, which was prepared photovoltaic modules with one, two, three and four layers of TiO_2, highlighted the rheological parameters of paste. Determining the quality of the products is the corresponding viscosity of the paste against to the size of the holes in sifter. In the case of too high viscosity of the paste which could occur in order in the printing inaccurate due to the lack overcome of flow resistance and the paste not connecting with each other. In addition, the thickness intensify of the reproducible relatively constant value was claimed. The topography of the surface of the active layer of TiO_2 solar cells was analyzed. The compliance of the printed layers with strict parameters regarding cells DSSC was confirmed. The cracking layer of titanium dioxide was noticed for cells with four layers of TiO_2 produced after firing. The presence of defects in the sintering was the result of contraction and had a significant impact on the results of measurements. Current-voltage characteristics was prepared. Comparable performance was observed for modules with the three and two layers of titanium dioxide, with a slight predominance of the former. It can therefore be concluded that with an increasing layer thickness of the titanium dioxide is advisable to use a larger distance between the electrodes which is assessed the thickness of Surlyn foil. Imposition of each layer of titanium dioxide is associated with additional costs connected with usage of a higher amount of dye or the electrolyte. In order to maintain the efficiency in the process, two layers of oxide could be used. Despite the better performance of efficiency and maximum power for cells with three layers. It was agreed that decreasing in the value of transmittance with a dyed layer of TiO_2 with increasing their thickness. In the case of photovoltaic cells with three layers of TiO_2 along, it was observed that the light transmittance ranged from 8-10%. The highest value of transmittance of the order of 26-27% were obtained for the cells with one layer of oxide. It is worth noting that the decrease in the coefficient of transparency increases the efficiency of the module [5]. To obtain photovoltaic cells characterized by greater transparency and aesthetic. It is recommended to choose the modules covered with a one layer of TiO_2. Taking into account the location and preferred yields power is better to use photovoltaic cells with three layers of TiO_2, showing the greatest efficiency. Referring to the economy it is worth to choose modules covered with two layers of TiO_2. They show a very similar performance with reference to the cells with three layers of titanium dioxide, moreover they are more transparent. However the final decision of the choice should belong to a potential buyer. In the Photovoltaic Centre for Research and Development still do research, which aim is to receive printed photovoltaic cells, in which it will be possible connection of performance, economy and aesthetics of products [5].

Aheartfelt thank you for Dr. hab. prof. UR Małgorzata Pociask-Biały for help, valuable advice and understanding when writing the work.

Thank you, Mr. Chairman Dawid Cycoń for the opportunity to undergo training in laboratory Photovoltaic Research and Development Center of ML System S.A. in which I had the opportunity to perform set of studies included in my thesis.

Mr. Dr. Michał Inglot, thank you for the tips, care and kindness during my stay in the laboratory of ML System S.A.

I offer my gratitude for the laboratory team workers of the Photovoltaic Research and Development Center, in particular: MSc. Natalia Trawka, MSc. Paweł Ciołkosz, MSc. Sławomir Chrobak, MSc. Michał Grudzień for the immense warmth, friendly working atmosphere, help in the synthesis of photovoltaic cells and valuable advice in mastering new techniques.

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