

Deposition methods of TiO_2 on the glass and characterisation of conductive layer in DSSC

(Metody osadzania TiO_2 na szkło i charakteryzacja warstwy przewodzącej w ogniwach DSSC)

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Abstract

This work is dedicated to dye – sensitized solar cells (DSSC) with particular emphasis on the structure of photoanode with conductive TiO_2 layer, deposition methods of TiO_2 , optical and morphological characteristics of obtained films. The test results of DSSC cells produced in the ML System Laboratory concerning the influence of the thickness of active layers on a number of parameters determining the efficient operation of the cell. Research conducted by many scientific communities around the world confirms that such cells have a big advantage over commonly used silicon cells. The main reason is the relatively low cost of materials and the lack of the need for advanced manufacturing technologies. In addition, the use of a wide range of colors and opportunity to control a transparency creates the possibility of using DSSC as an element integrated with the facade of the building.

Keywords: TiO_2 , DSSC, screen printing, doctor blade, nanotechnology, photovoltaics

Streszczenie

Praca poświęcona jest barwnikowym ogniwom słonecznym (DSSC) – ich strukturze, ze szczególnym naciskiem na budowę fotoanody z warstwą półprzewodnika, metodom osadzania TiO_2 , charakterystyce optycznej i morfologicznej otrzymanych filmów. Zamieszczono wyniki badań testowych ogniw DSSC wytworzonych w Laboratorium ML System S.A. dotyczących wpływu grubości warstw aktywnych na parametry określające ich sprawne działanie. Badania prowadzone przez wiele ośrodków naukowych potwierdzają, iż takie ogniwa mają dużą przewagę nad powszechnie stosowanymi ogniwami krzemowymi. Głównym powodem jest stosunkowo niski koszt materiałów i brak zapotrzebowania na zaawansowane technologie produkcyjne. Ponadto zastosowanie szerokiej gamy kolorów i kontrola transparentności stwarza możliwość wykorzystania DSSC jako elementu zintegrowanego z elewacją budynku.

Słowa kluczowe: TiO_2 , DSSC, sitodruk, doctor blade, nanotechnologia, fotowoltaika

The use of renewable energy sources is currently one of the greatest challenges for humanity [1–4]. Dye – sensitized solar cells (DSSCs) constitute a group of cells in which the process of converting solar energy directly into electricity takes place [5–7]. The construction of these cells is based on semiconductor materials (including TiO_2) sensitized with organic dyes to increase the range of electromagnetic radiation absorption [2, 8–10]. An important parameter is the specific surface of the semiconductor, which determines the degree of dye adsorption [1, 11, 12]. In DSSC, TiO_2 layer functions as nanoparticles with anatase crystal structure, thanks to which the active surface of light absorption is much higher. Nanopores TiO_2 layers on the surface of the glass substrate are deposited, e.g. by screen printing [13], sol – gel [14, 15], sputtering [16] and doctor blade techniques. When it comes to the advantages of DSSC, the biggest one is undoubtedly a slight reduction of efficiency in low light and the ability to work at a wide angle of radiation. It is possible to extend the applications of this type of cells by modeling their shape and using different colors of dye in the production [4]. What's more, thanks to the sandwich construction of DSSC cells, in which the outer coating is made of glass, the panel is resistant to changing weather conditions and mechanical damage [17].

cm^2 were subjected to a laser-structured process ($\lambda = 1064 \text{ nm}$) to form electrical breaks, thereby separating individual cells from each other. The applied ytterbium laser with high energy and short pulses does not cause microcracks in the glass. Next, holes were made in the plates, through which the dye and electrolyte were introduced in subsequent stages. Before applying the active layers, the glass was cleaned with organic solvents. The next step was the deposition of Pt, TiO_2 and Ag layers on a glass substrate. Commercially available TiO_2 paste – 18 NR-T from Great Cell Solar supplier were used. The layers were dried, sintered and fused in a furnace according to given temperature profiles. The TiO_2 layer dyeing process was carried out by a flow method using a ruthenium dye solution. Cell electrodes were laminated using Surlyn foil. The last stage was filling the free space between the electrodes with a liquid electrolyte solution and sealing the cell. In this work two meth-

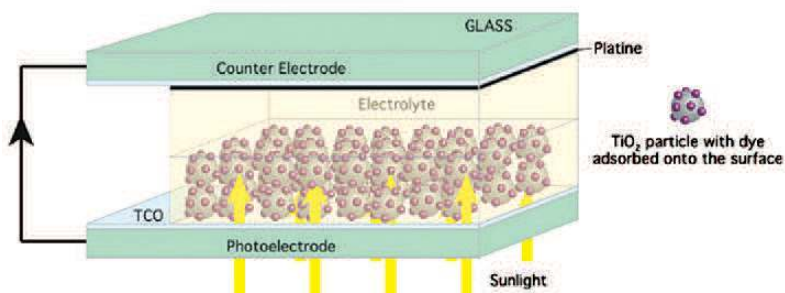


Fig. 1. Scheme of DSSC architecture
Rys. 1. Schemat budowy ogniwa DSSC

Experimental

The DSSC test cells were prepared as follows: glass plates with a TCO layer (SnO_2 : F) with the thickness 3,2 mm and a resistivity about 10 Ohm/

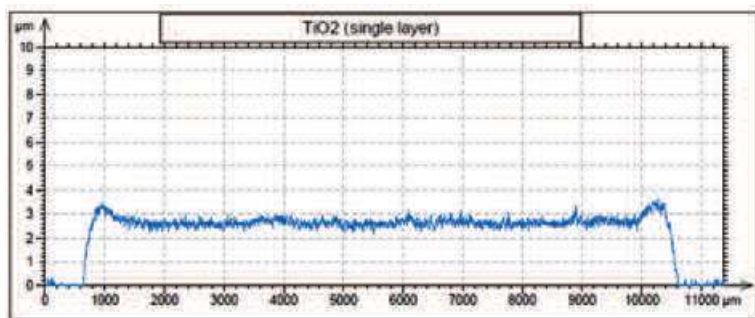


Fig. 2. Profile of a single TiO_2 layer applied by screen printing method (after sintering process)

Rys. 2. Profil pojedynczej warstwy TiO_2 naniesionej metodą sitodruku (po procesie wypalania)

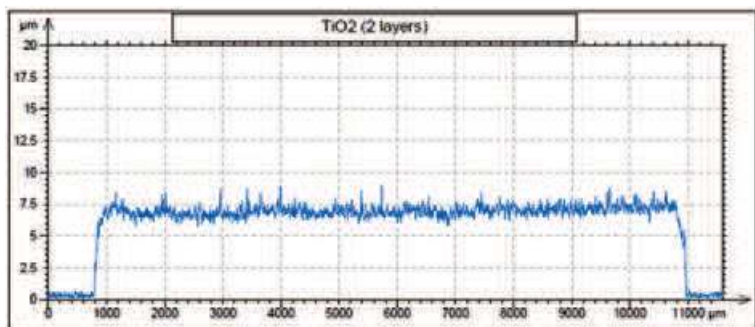


Fig. 3. Profile of 2 TiO_2 layers applied by screen printing method (after sintering process)

Rys. 3. Profil podwójnej warstwy TiO_2 naniesionej metodą sitodruku (po procesie wypalania)

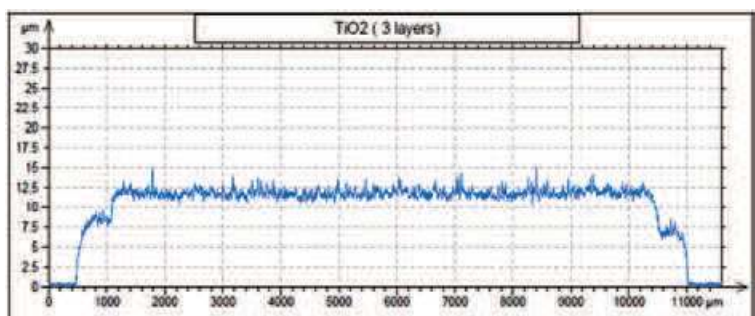


Fig. 4. Profile of 3 TiO_2 layers applied by screen printing method (after sintering process)

Rys. 4. Profil potrójnej warstwy TiO_2 naniesionej metodą sitodruku (po procesie wypalania)

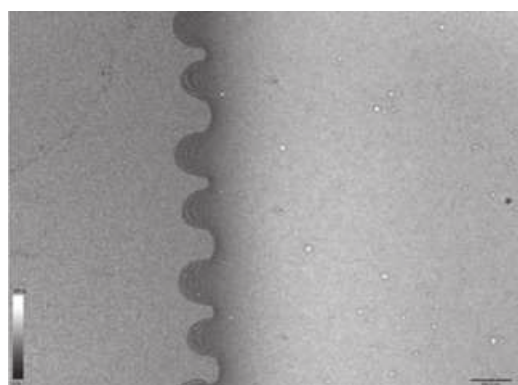


Fig. 5. Single TiO_2 layer deposited by screen printing method (sample after sintering process, 10x magnification)

Rys. 5. Pojedyncza warstwa TiO_2 naniesiona metodą sitodruku (próbka po procesie wypalania, powiększenie 10x)

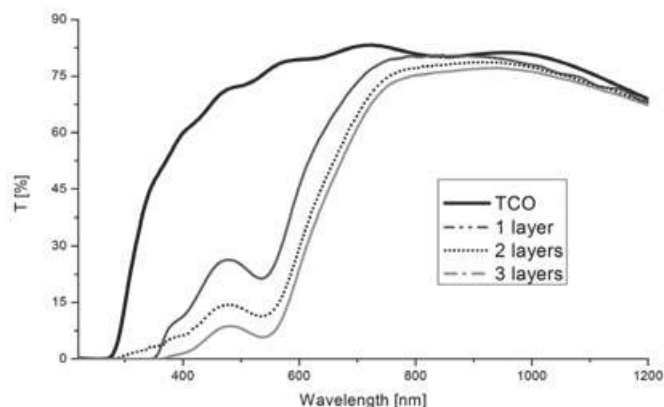


Fig. 6. Transmittance measurements of TiO_2 layers deposited on TCO glass by screen printing method (samples after sintering process)

Rys. 6. Pomiary transmitancji warstw TiO_2 naniesionych na szkło z TCO metodą sitodruku (próbki po procesie wypalania)

ods of TiO_2 deposition on the glass have been described and compared. By choosing the appropriate parameters of the screen printing and Doctor Blade technique, TiO_2 layers differing in thickness were obtained, and as a result different degrees of the photoanode transparency were obtained. Figure 1 illustrate the architecture of DSSC.

Results and discussion

Optical properties for glass samples with a TCO layer differing in the thickness of TiO_2 layers deposited by screen printing and doctor blade technique were tested. The exact layer height was determined using the Sensofar PLU Neox optical profilometer. To illustrate the defects and differences of layers obtained using these two methods, Morphology G3 optical microscope were also used. In order to determine the effect of layer thickness on the radiation transmission, spectrophotometric tests of glass samples with TCO and TiO_2 were made. Light transmission measurements were carried out using a Jasco V670 UV-VIS-NIR spectrophotometer in the range of 220–1200 nm. The results are presented in Figs. 2–9.

Profilometer measurements (Figures 2–4) shows that the thickness of layers changes in a linear way and confirms the legitimacy of the screen printing method, quite high precision and repeatability of the process. When it comes to UV – VIS studies it is worth to note that the height of the TiO_2 semi conductive layer is closely related to the cell's transparency – the greater the thickness, the transmission of light decreases. In turn, taking into account the application of the Doctor Blade method, obtained layers were very uneven (Figure 7) which does not provide the required precision. What's more, in Figs 8 and 9 there are numerous impurities (illustrated by Morphology G3 optical microscope) which is very undesirable in the further stage of cell preparation.

Conclusion

On the basis of the determined topography and profiles of TiO_2 layers (Figures 2–9), it can be concluded that both techniques allow the application of thin layers, however the screen printing method is the domi-

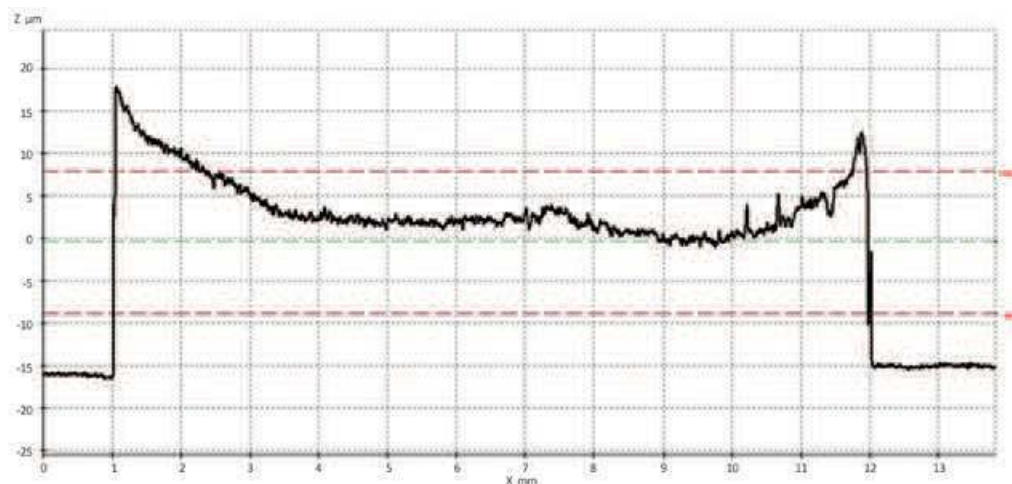
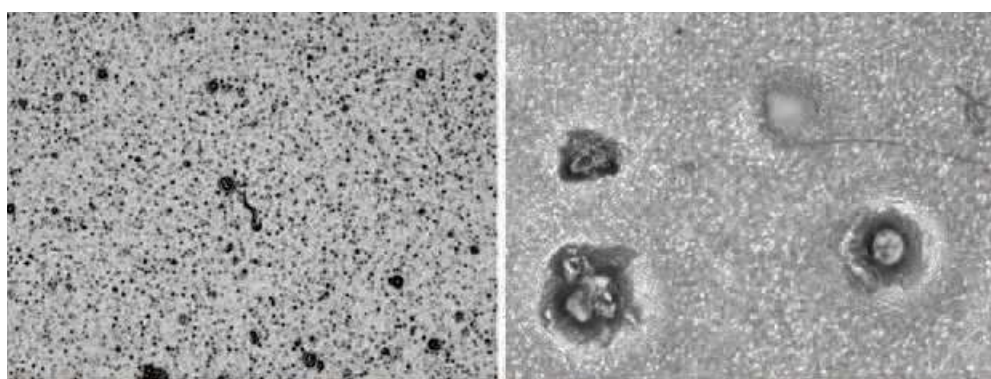


Fig. 7. Profile of TiO_2 layer applied by the Doctor Blade technique (after sintering process)
Rys. 7. Profil warstwy TiO_2 naniesionej metodą doctor blade (po procesie wypalania)



Figs. 8, 9. Porosity (8) and defects (9) in TiO_2 layer applied by the Doctor Blade technique (sample after sintering process)

Rys. 8, 9. Porowatość (8) i defekty (9) w warstwie TiO_2 naniesionej metodą doctor blade

nant technique – it allows applying layers with high precision to surfaces of any size, and obtained layers have the same height over their entire surface (Figures 2–6), which is not provided by the Doctor Blade technique (Figures 7–9). The screen printing method is partly automated and allows for the production of large amounts of test samples, unlike in the Doctor Blade technique which is very time-consuming. If the print time is too long, it's not advisable due to the exposure of the organic paste that is responsible for the rheological properties during the printing process. Doctor Blade does not ensure even thickness of layers, because maintaining the same pressure force is problematic, moreover, the obtained layers are too thick, which is associated with the difficulty in choosing the mask. Layers with high thickness subjected to heat treatment cracked – it is very disadvantageous for the manufacturing process. What's more, in Doctor Blade technique there is very high probability of samples contamination during application to glass. Due to the required precision of applying layers during the construction of DSSC cells, first of all layers must have the same thickness over their entire surface, the screen printing technique was chosen for the production of test cells. It is also worth to note that the Doctor Blade method is applicable only in the laboratory scale, whereas screen printing can be transferred with great precision to the industrial scale.

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