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Investigating and studying the effects of coating converter colors with the approach of converting solar energy into electric current in solar cells on porous silica

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Abstract

The dye sensitized solar cells (DSSC) is third generation of solar technology that use in recent years has increased dramatically. The purpose of this research is evaluation component of the energy efficiency of light-sensitized solar cells based on porous silica. Unique properties of porous silica substrate, such as high surface area, mechanical and thermal stability, volume and diameter of the high risk makes to the solar colors (Dye Solar) Cells of this type of structure used effectively in the context of crystalline silica dispersed porous and due to this type of substrate volume with a specific morphology, which will increase efficiency. The solar colors (Dye solar) based on a porous substrate is detected by SEM, XRD and XRF techniques and the tin oxide coating on a porous silica substrate has been studied by techniques of SEM and efficiency of solar energy components factors such as type, color and, temperature, surface area, the coating were examined and appropriate amounts in each case was optimized.

Keywords: Photo voltaic cells, Porous substrates, Color conversion coating, DSSC

1. Introduction

Dye-sensitized solar cells (DSSCs) are actually a type of low-cost solar cells that belong to the group of thin-film solar cells. In the past, these types of cells were known as Grätzel cells because they were discovered by Grätzel in 1991 [1]. Semiconductor materials have good stability when exposed to light radiation. However, most of these semiconductors cannot sufficiently absorb visible light due to their high energy gap. Therefore, semiconductors such as TiO_2 and ZnO with a coating of organic dyes can absorb a small spectrum of visible light and be used in dye-sensitized solar cells [2]. Recently, a review based on the research on dye sensitized solar cells: recent advancement toward the various constituents of dye sensitized solar cells for efficiency enhancement and future prospects presented by Rahman et al. [2]. As well as, the organic/metal-organic photosensitizers for dye-sensitized solar cells (DSSC) with all developments in this field such as new trends, and future perceptions, demonstrated by Yahya et al. [3]. To increase the amount of collected light and improve the performance of these cells, two approaches can be employed. Firstly, an increase in the effective surface area of the photo electrode to enhance the absorption of a higher amount of dye. Secondly, dyes designing that can absorb a broader range of visible light. The use of TiO_2 electrodes on a porous surface leads to a higher absorption of dyes on the electrode surface [3-5]. Room-temperature processable TiO_2 solar paint for dye-sensitized solar cells investigated by Roy et al. [6]. Seithtanabutara et al. [5] studied the potential of combined natural dye pigments extracted from ivy gourd leaves, black glutinous rice and turmeric for dye-sensitised solar cell.

In this study, three experimental groups were defined based on the level of porosity and the coated lead oxide. In addition to the structural and optical characterization of thin lead oxide and titanium oxide layers, the properties and efficiency of the cells were tested.

2. Experimental

2.1. Materials

2-2-dicarboxylic acid 4.4-bipyridine (98%) was purchased from Sigma-Aldric. Silica (200 m/g, 12 nm), potassium iodide, graphite, Tin(IV) chloride pentahydrate as source of SnO_2, Titanium(IV) isopropoxide as source of TiO_2, ammonium fluoride, potassium iodate, triton X-100 as stabilizer agent was purchased from Merck.

2.2. Fabrication of solid electrode of solar cell

One of the most important steps in manufacturing dye-sensitized solar cells is the manufacturing of conductive glasses (TCO). In the structure of these glasses, transparent conductive layers are used, which is usually SnO_2 doped with F (FTO) or other tin-like oxides (ATO). In this project, a layer of tin oxide was deposited on a porous silica substrate as a substrate.

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Thin layers of tin oxide and titanium oxide as blocking layer are prepared by spray pyrolysis (SPD) method, which are given in Table 1-(a) specifications and conditions of the layer. The initial solution for the spray was prepared by dissolving solid 1% $SnCl_4$-$5H_2O$, double ionized distilled water and 10 mL Each of pure ethanol. The obtained solution was stirred and impurity of F with determined sizes was added to this solution using solid NH_4F dissolved in distilled water.

Table 1. Layer conditions of SnO_2:SiO_2

stages	solution volume (mL)	Silica substrate temperature	Spray rate (milt/min)	Nozzle-Subtrate height (cm)	Impurity percentage (F)
First	20	470	4.5	40	10
Second	20	760	4.5	40	10

2.3. TiO_2 marking layer by SPD method

For the titania coating, the main composition of solutions includes titanium isopropoxide and ethyl alcohol with volume ratios of 1 to 3. All the steps of titania layering on the prepared porous substrate were controlled at temperature, Table 2.

The values obtained from measuring the voltage and current components of the solar cell and calculating their efficiency are presented in Table 3.

Table 2. Layering parameters of titanium oxide thin layers based on porosity and substrate dimensions

stages	(V) volume (TTIP/ethanol) (mL)	Nozzle-subtrate height (cm)	Spray rate (mL/min) (mL/min)	Silica substrate temperature	volume of solution (mL)	Porosity percentage of SiO_2 in SnO_2 (%) layer
First	10 /30	37	3.5	500	40	0
Second	10/30	37	3.5	500	40	60

2.4. Characterization of the solid electrode of the solar cell

XRD analysis using (Philips) was use used to confirm the formation of the caustic phase and the orientation of the substrate crystals in both samples including SnO_2:SiO_2 layers and TiO_2:SiO_2 layers. To study the particle size and morphology TEM analysis using (Zeiss EM900) was used. X-ray Fluorescence (XRF) is an analytical technique that uses the interaction of X-rays with a material to determine its elemental composition in both prepared samples using BRUKER.

2.5. The setting up the solar cell and calculating the efficiency of the cells

To calculate the efficiency factor, a simple set up based on the Fig. 1, equipped with circuit including a rheostat, voltmeter, ammeter and a strong light source with a radiation power of at least 40,000 lux is needed. To measure the efficiency factor after forming the circuit and the required data, the current voltage diagrams of each cell were drawn and then equation (1) was used to obtain the energy conversion efficiency and dispersion factors (*ff*).

$$\eta = \frac{v_{oc} \times i_{sc} \times ff}{I_{photocurrent}} \times 100 \qquad (1)$$

$$ff = \frac{v_m \times i_m}{v_{oc} i_{sc}} \qquad (2)$$

$I_{photocurrent}$ is the radiant power in mw/cm^2. To calculate v_{oc}, both ends of the cell were directly connected to the digital voltmeter as shown in Fig. 1.All measurements were made with radiant power of 22.6 mW/cm equivalent to 50.000 lux.

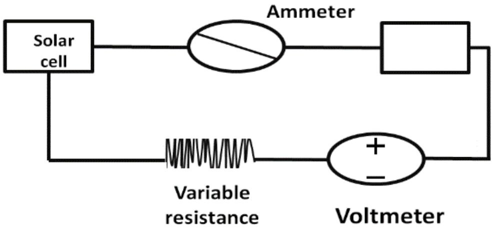


Fig. 1. A schematic photograph of applied set up for measuring the voltage and current components of the designed solar cell

3. Results and discussion

3.1. XRD and TEM study

The X-ray diffraction spectrum prepared SnO_2:SiO_2 layers in Fig. 2 shows the formation of the caustic phase of tin oxide in the crystal direction (200). The corresponded XRD shows the diffraction pattern of SnO_2 peaks at (110), (101), (200), (211), (220), and (301) at 2θ diffraction angle 26.7º, 33.97 º, 38 º, 51.8 º, 54.8 º, 66.1 º consecutively. These peaks is belong to cassiterite crystal phase with tetragonal rutile structure (JCPDS No. 41-1445) [10]. XRD spectra for Titania thin films are shown in Fig. 2. The XRD pattern confirms the presence of TiO_2 nanoparticles on the surface of silica. The prominent peaks were compared with JCPDS data (JCPDS 21-1272) and the peaks obtained in the pattern coincides well with the literature. The intensity of the peak is high and the width of (101) plane at $2\theta=25.313°$ becomes narrow [11,12]. The sharpness of the peak uncovers that the samples possess a good crystalline nature. The strong diffraction peak around 25.313° and 48.089° indicates TiO_2 is in anatase phase. The spacious diffraction peak is not found in the pattern. Controlling the substrate temperature causes the preferred orientation of the substrate crystals and increases the porosity, as well as improving the photocatalytic properties.The small size of the grains indicates their high porosity and also the denseness of these layers, which is a necessary condition for its role in solar cells.

As can be seen from Fig. 3 for TEM images, it is clear that the SnO_2 nanoparticles with an average particle size of 45 nm and semi-spherical morphology, and spherical TiO_2 nanoparticles with an average particle size of 50 nm are decorated on the surface of silica with good monodispersity.

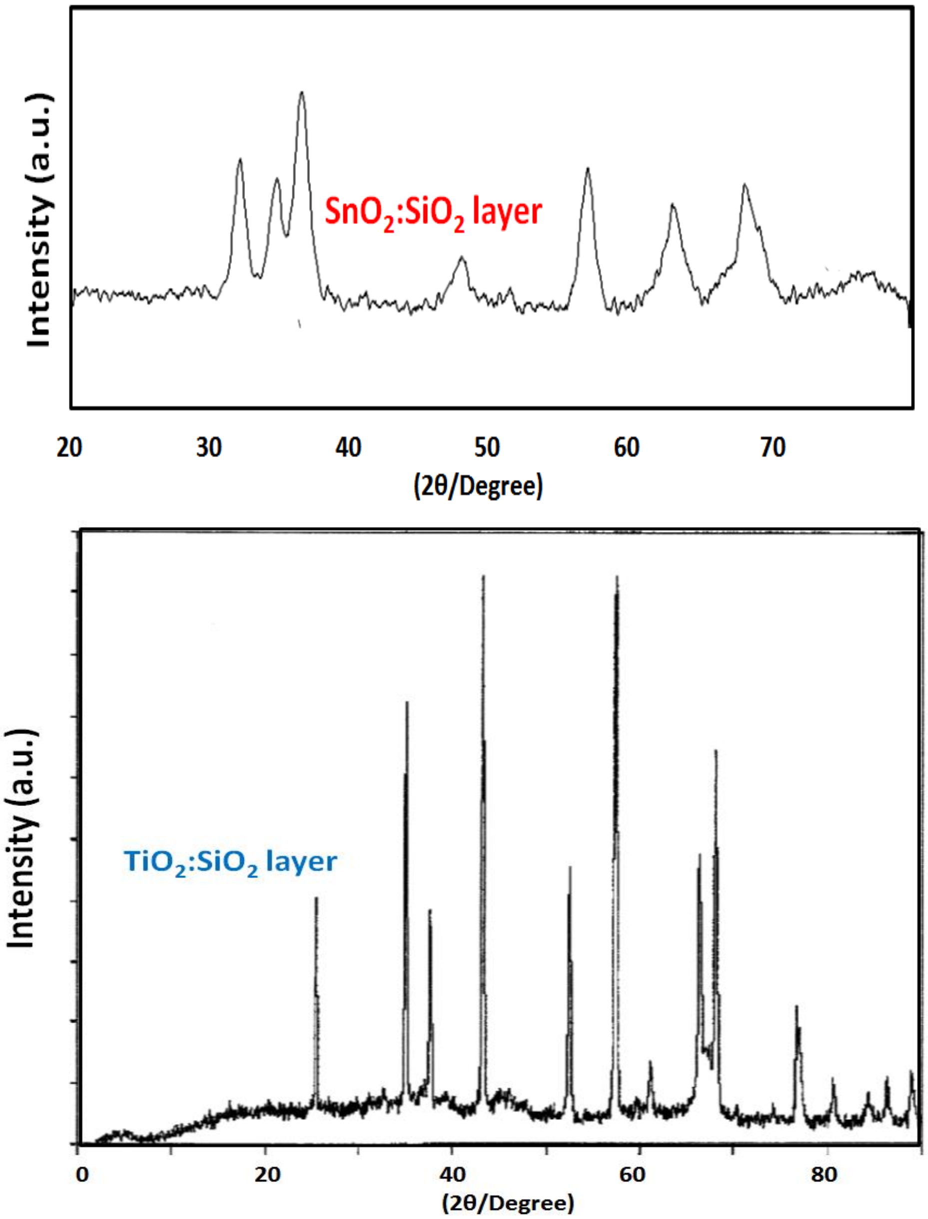
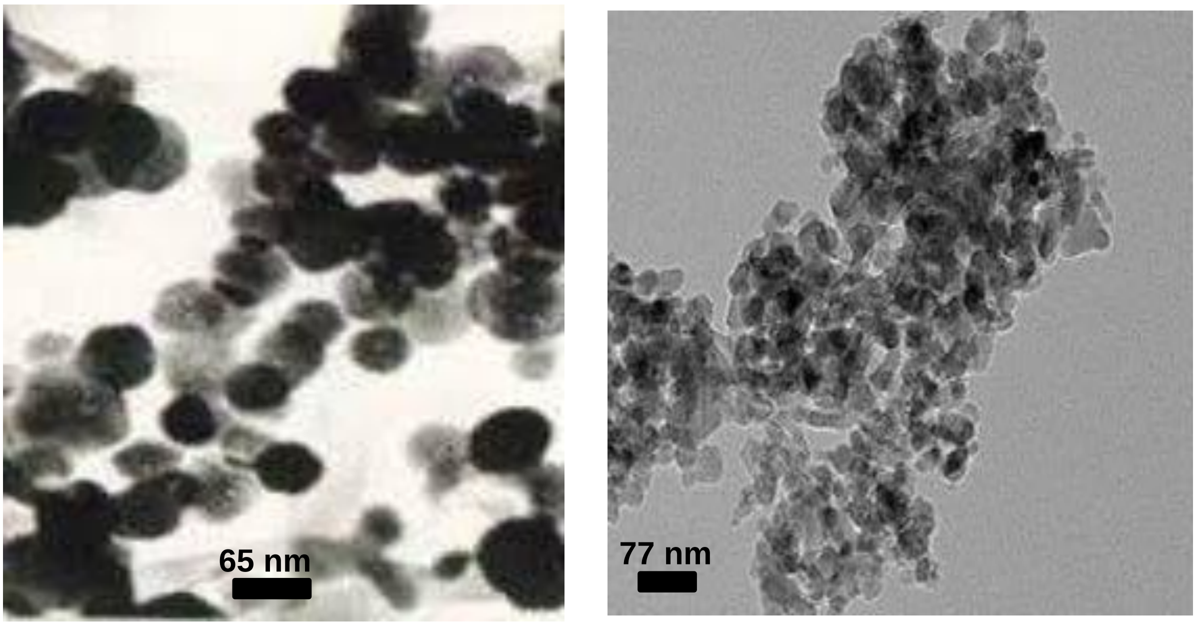


Fig. 2. XRD patterns of both prepared samples oxide layers on porous silica



TiO_2:SiO_2 layer **TiO_2:SiO_2 layer**

Fig. 3. TEM images of both prepared samples oxide layers on porous silica

3.2. XRF analysis

X-ray analysis confirmed the presence of SnO_2 and TiO_2 nanoparticles in the applied silica pores and the percentage of elements in the prepared layers is shown in the Table 3.

Table 3. Structural analysis of porous silica substrate with titanium and tin oxide layer

	TiO_2	Cr	V	Ce	La	W	SnO_2	Y	Rb
Unit	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Composition	38	3	16	16	8	14	177	20	14

3.3. Solar cell and photocatalytic activity investigation

A solar cell based on tin and titanium oxide layers using light-sensitive synthetic dye such as 2,2-dicarboxylic 4,4-bipyridene has been prepared in order to produce clean solar energy. The results Table 4, showed that by increasing the porosity of the SiO_2 based on the substrate and also making this substrate as a conductive matrix, the amount of obtained current increases significantly, which indicates the increase in surface area in porous surfaces. This phenomenon leads to an increase in energy production during the photovatalytic procedure. The tin oxide/silica substrate with an average particle size of 45 nm shows the most efficiency compared to titanium/porous silica.

It must be noted that the use of small amounts of Dye solar, which included more surface area due to the porosity of the substrate, resulting the more production of charge carries and reduce of charge carriers recombination as main limitation of photocatalytic systems [13-15]. On the other hand, the amount of current produced in this cell in relation to the dimensions indicates the high ability of this type of cells, compared to other solar cells that are made on a non-porous conductor bed.

Table 4. Cell values in radiant power 6.2 mW/cm^2

Type of substrate	$V_{oc}(mV)$	$I_{sc}(\mu A)$	ff	$\eta(\%)$
Pure SnO_2	470	92	24	11
SnO_2:SiO_2	995	92	37	21
Pure TiO_2	290	63	39	9
TiO_2:SiO_2	585	56	13	11

4. Conclusion

The fabrication of solar cells from tin oxide and titanium layers using light-sensitive synthetic dyes such as 4,4-dimethyl-2,2-bipyridine provides a safe and environmental-free way to provide clean solar energy. In this research, it was observed that by increasing the porosity of the SiO_2 base substrate and also making this substrate conductive, the amount of current produced increases to a significant amount, which indicates the increase in surface area to volume in porous surfaces, which leads to an increase in Energy will be produced.What attracted more attention was the use of small amounts of Dye solar, which included more surface area due to the porosity of the substrate, which greatly reduced costs. Also, the amount of current produced in this cell compared to the dimensions indicates the high ability of this type of cells, compared to other solar cells that are made on non-porous conductive substrate.

Conflicts of Interest

The author declares no conflict of interest.

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