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Effect of Solvent type and Annealing Temperature on Efficiency for Eosin -y Dye Sensitized Solar Cells

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Abstract
Dye-sensitized solar cell (DSSC) is one of the photochemical electric cells, which consists of the photoelectrode, the dye, the electrolyte, and the counter electrode. The advantage of DSSC is the low cost of the solar energy conversion into electricity because of inexpensive materials and the relative ease of the fabrication processes. In this study was selected solvent dye resolve to know most efficient in terms of conversion efficiency. A dye solution of water or ethanol and maxing in which eosin – y dissolves behaves like a colloid and explores the effect of sintering temperature of TiO_2 films on the efficiency of dye sensitized solar cells. A study conducted on several samples at different temperatures. Exemplary efficiency of the cell in a water solution of the dye effect of heat annealing 450 ^{0}C was found 0.73%, but after the addition of $AgNO_3$ improved efficiency to 1.1 % .

Keywords: Eosin dye, efficiency, water - soluble, Ethanol-soluble, absorbance, Film thickness, Annealing temperature, Additive.

تاثير حرارة التلدين في الخلايا الشمسية الصبغية ذات ثنائي اوكسيد التيتانيوم بصبغة الايوزين بالاعتماد على نوع المذيب

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الخلاصة
الخلايا الشمسية الصبغية هي واحدة من الخلايا الكهربائية الضوئية التي تتالف من القطب الضوئي الصبغة ،الالكتروليت والقطب العداد ميزة الخلايا الشمسية الصبغية المواد المنخفضة التكلفة والسهولة النسبية في عملية التصنيع . في هذه الدراسة تم اختيار اكثر من مذيب لحل الصبغة لمعرفة الأكفى من حيث كفاءة التحويل.المذيبات من الماء او الايثانول او الاثنين معا في صبغة الايوزين يذوب ويتصرف وكأنه الغروانية وقد أجريت الدراسة على عدة عينات في درجات حرارة تلبيد مختلفة .وجدت الكفاءة القصوى من الخلايا الشمسية الصبغية المصنعة بثنائي اوكسيد التيتانيوم بدرجة تلبيد 450 ^{o}C بنسبة 0.73% مع محلول الصبغة الافضل وهو الماء. تحسنت كفاءة التحويل بعد إضافة نترات الفضة واصبحت 1.1٪.

1. Introduction

Titanium dioxide (TiO_2) is a promising material as semiconductor with high photochemical stability and low-cost production. Well-dispersed titanium nanoparticles with very fine sizes are promising in many applications such as pigments, adsorbents and catalytic supports. In almost all of these cases, when the particle size is greatly reduced, especially to several nanometer scales, due to the

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large surface-to-volume ratio, some new properties can be expected [1] . The structure of a DSSC is made of three main parts; counter electrode, photo anode and an electrolyte. Counter electrode, normally conductive glass and a fluorine- doped tin oxide (FTO) the most commonly used, coated with few atomic layers of carbon or platinum, in order to catalyse the redox reaction of (I^-/I_3^-) reaction with the electrolyte. Photo anode is constructed from semiconductor oxide porous film on a conductive glass substrate anchored amono layer of dye. The electrolyte can be made from organic solvent containing a red-ox couple such as iodide/tri-iodide [2].

The preparation of liquid electrolyte, 10ml of ethylene glycol was added into a beaker. Then, 0.127g of iodine (I_2) was added into the beaker containing ethylene glycol. After that, 0.83g of potassium iodide was added. By using the glass rod, the mixture was mixed until there was no grain of iodine and potassium iodide can be seen [3]. Electrolyte suffers from leakage and vaporization, which results in poor long-term stability. To increase the efficiency, these problems should be avoided and a high conductivity should be maintained by ensuring good interfacial contacts between the porous TiO_2 layer and the counter electrode [4].

The highest efficiency of DSSC was observed for cells sensitized by ruthenium complexes adsorbed on nanocrystalline TiO_2, which reached 11%–12%, but they are still not suitable due to the high cost [5]. Eosin Y is a well-known synthetic dye and can be used in many applications. It has a molecular formula of $C_{20}H_8$ Br_4O_5 and a molecular weight of 647.89. It is a pink water-soluble acid dye. . Eosin Y shows an intense absorption peak in the visible region at 522 nm, which corresponds to the maximum absorption peak of the eosin- Y monomer [6]. Electric additive is another important component in liquid electrolytes for optimizing the photovoltaic performance of DSSC. It is found that the photovoltaic performance of DSSC can be enhanced hugely by adding a small amount of electric additive. The superfluous electric additive will cause a poor photovoltaic performance of DSSC [7]. In this work, TiO_2nanopowder was used as a photoelectrode of DSSC. The fabricated cells were dyed with different synthetic dyes. TiO_2 paste was spread on spectral range from 300 to 800 nm. The J and V characteristic curves of the DSSC were measured and studied. The photovoltaic parameters of the fabricated cells were determined. The performance of the fabricated cells was studied with the sintering temperature and thickness of the TiO_2 layer. To improve cell efficiency of DSSC can be enhanced hugely by adding a small amount of electric additive.

2. Experimental

2.1. Materials

A dye eosin- Y was bought from SCR-china and was used as a sensitizer .The dyeing solution was prepared by adding 0.13 g of the dye powder to20ml of ethanol purchased from Fluka equal($1x10^{-3}$M). Fluorine-doped SnO_2 (FTO) from Solaronix (S.A) conductive plates with sheet resistance of 7 Ω/cm^2 and transmission >80% ,were cut into pieces of dimensions 2 cm×2 cm, transparent conducting uorine-doped tin oxide (FTO) coated glass using the doctor blade method. The absorption spectra of chemical dyes were conducted in the effective work of which is 1 cm×1 cm. Titanium dioxide powder anatase (10 nm MK nano Canada). Ethylene glycol from Aldrich, acetic acid solution-from SCR-china, iodine (I_2) and potassium iodide (KI) was purchased from Erftstadt Germany.$AgNO_3$ and Ethanol purchased from Fluka.

2.2. Preparation of TiO_2 paste

The composition of TiO_2 paste could affect the homogeneity and aggregates concentration of the TiO_2 electrode as well. Contents of acetic acid and water in TiO_2 pastes significantly decreased aggregation of nanoparticles, increased adhesion of layer to substrate and short-circuit current density of DSSC [8]. Suspensions of TiO_2 powders were prepared as follows: Adding drops of nitric acid solution to (6ml) of distilled water until the solution becomes acidic with pH (3-4). This solution is added to (6 g) of colloidal TiO_2 powder, then a drop of transparent surfactant was added to ensure coating uniformity, adhesion to electrodes, and to avoid cracking of the deposited film. Finally, we follow doctor blade method for coating TiO_2 [9].

2.2.1. Doctor blade Technique

which is used to lay a layer of paste with a thickness determined by the spacer. The spacer is an adhesive tape normally with a thickness of 10 μm. It is placed opposite sides of the area where the film is to be laid and the doctor blade dragged across.The surface structure and the thickness depend on how the blade is dragged across, position of the blade during the process and the flatness of the spacer material and the thickness of the film coated is the thickness of the spacer thickness. The limitation of this technique is, it is difficult to find an appropriate spacing material with thickness of 1- 7µm. [10]

2.2.3. Preparation of Dye Solution

Dye-sensitized solar cells were assembled as follows: the TiO_2 film was immersed in solution water, ethanol and mixing ethanol and water respectively. The TiO_2 films were subsequently soaked of three kind 0.1 mM Eosin-Y dye solution at room temperature for (60,20,30) min respectively . The TiO_2 electrode was preheated at 450 ^oC for 30 minutes before it was dipped into the dye solution. According to the following law W= (C * V *Mw)/1000.

Where W: is the weight to the dye needed to obtain the desired concentration in (g). C: is the concentration needed to prepare in mol / litter. V: is the Volume of solvent in litter necessary to add to dye. Mw: is the molecular weight of dye used the concentration of eosin y in water or ethanol and mix.

3. Assembling the DSSC

The system consists of direct sun light ,cables, variable resistance, solar cell and voltmeter.Connect solar cell, variable resistance and voltmeter with cables, Shine the light from the side of TiO_2/dye electrode, Set the resistance at maximum value and record voltage, decrease the resistance and record voltage, repeat preceding step until the voltage reaches nearly zero and turn the light off, Calculate corresponding current at each recorded point, Calculate fill-factor and Calculate power conversion efficiency (η). Dye-sensitized electrode was assembled in a typical sandwich-type cell. The area of the cell was 1 cm^2. power con-version efficiency η of the DSSC is given by

$$\eta = \frac{FF \times J_{sc} \times V_{oc}}{P_{in}} \times 100\ \% \text{..........(1).}$$

In Equation (1), V_{oc}, I_{sc}, and P_{in} represent the open- circuit photo voltage, the short-circuit photocurrent per unit area, and the incident light power (40 mW/cm^2), respectively. Aside from this, the fill factor FF is deter-mined by

$$FF = \frac{I_{max} \times V_{max}}{I_{sc} \times V_{oc}} \text{.................... (2).}$$

In Equation (2), V_{max} and I_{max} represent the voltage and the current per unit area at the maximum output power point, respectively. You can extract information from above through the practical application of the electrical circuit as in Figure- 1.

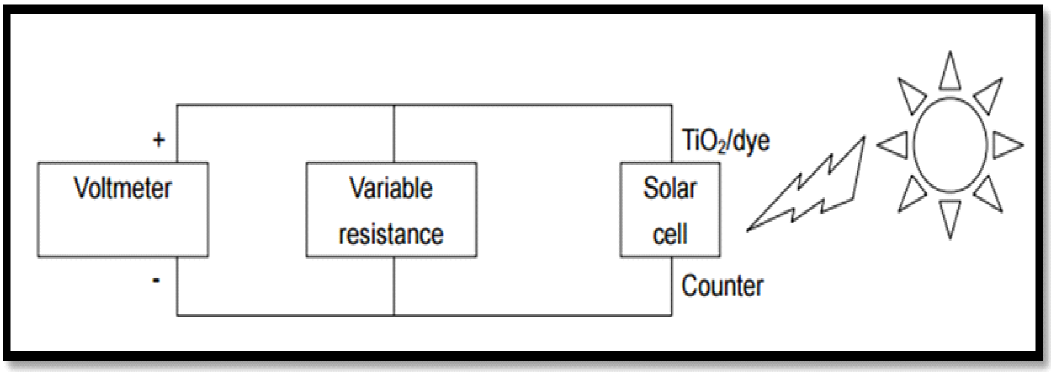

Figure 1- Electrical circuit diagram adapted for measuring the I-V characteristics [11].

4. Results and discussion

4.1. AFM investigation

The optical properties of printed TiO_2 layers were taken from optical microscope of AFM. As shown in Figure- 2, this was prepared with addition of water, had inhomogenous surface and rougher surface with increased occurrence of aggregates. Analysis of the AFM images confirmed that the TiO_2 films consist of little interconnected grain particles with an average diameter of 107 nm. So it decreased efficiency.

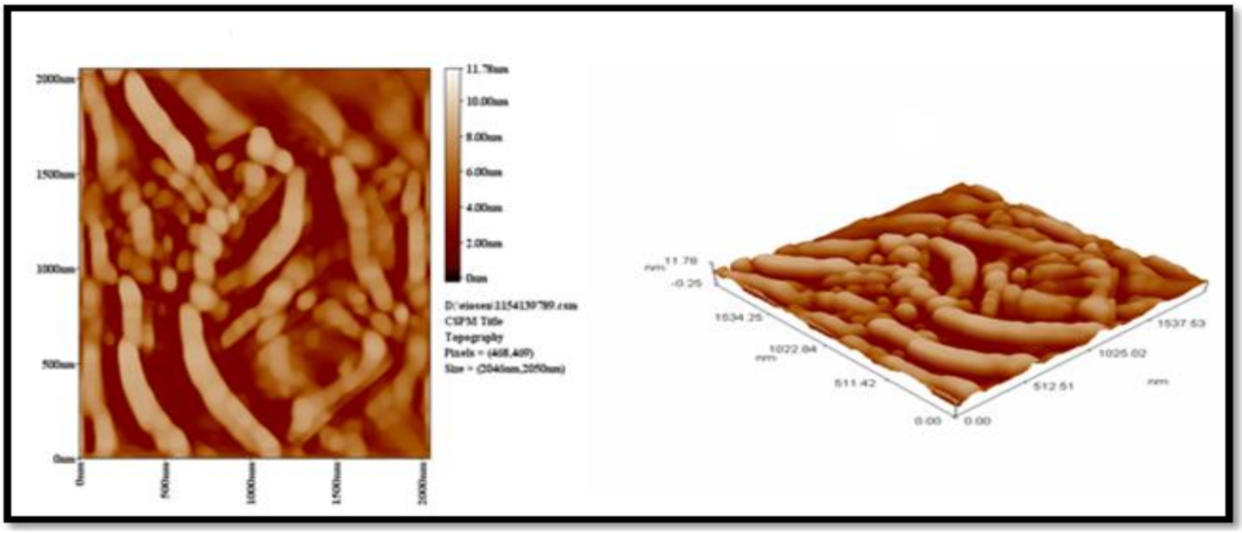

Figure 2- 2D and 3D AFM images of TiO_2 layers at 450 ^oC.

4.2. Absorption spectrum of eosin dye

UV-Vis spectra of absorption the dye in water (red curve) as shown in Figure-3, we got absorption peak at (517 nm) ,therefore the band cover a part of the visible region. Also, It was found that spectra of absorption the dye in ethanol (blue curve) is 528nm. Dye absorption by TiO_2 grains which solvent ethanol is less than in the water, so it was less efficient than when dissolved in water. Based on spectroscopic measurement, it was found that the absorption peak of eosin dye in mixing water and ethanol (green curve) with ratio 3:1 respectively is 524 nm ,so that it has nearly no absorption in the infrared region which lowers the overall solar cell efficiency. The eosin dye has absorption spectrum extends only to 700 nm which cause limit solar cell efficiency.

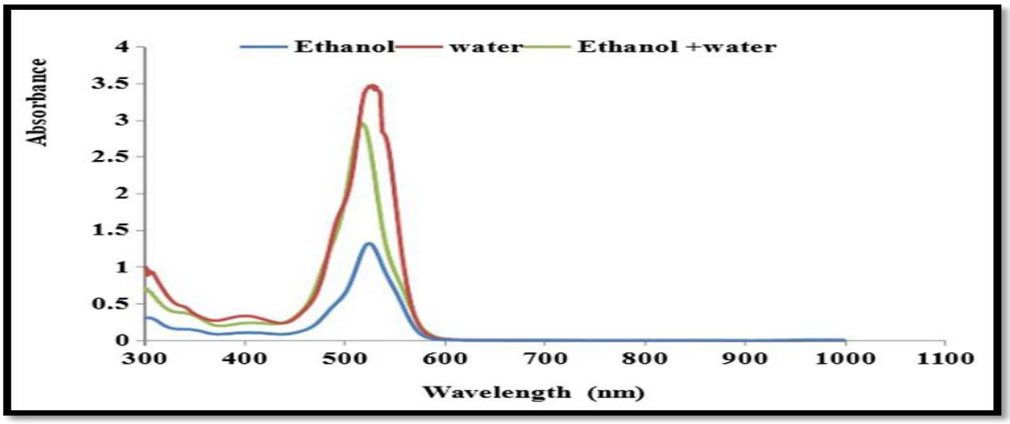

Figure 3- Absorption of eosin dye depending on the solvent type.

5. I-V Characteristics of the Fabricated Dssc

The effect of sintering temperature on the efficiencies of the DSSC was studied by fabricating cells with TiO_2 sintered at 250, 350, 450 and 550 ^oC. Figure- 4 indicates that cell efficiency increased with increase in sintering temperature and maximum efficiency was observed at 450 ^oC under 40 mW/cm^2 illuminations ,In accordance with [12]. The value of I_{sc} and V_{oc} is comparatively very less which may be because of increase in crystallite size and it can be attributed to degradation of nanostructure of TiO_2 films as obvious from Figure-2 which has led to decrease in surface area for dye absorption eventually decreasing the performance of DSSC .

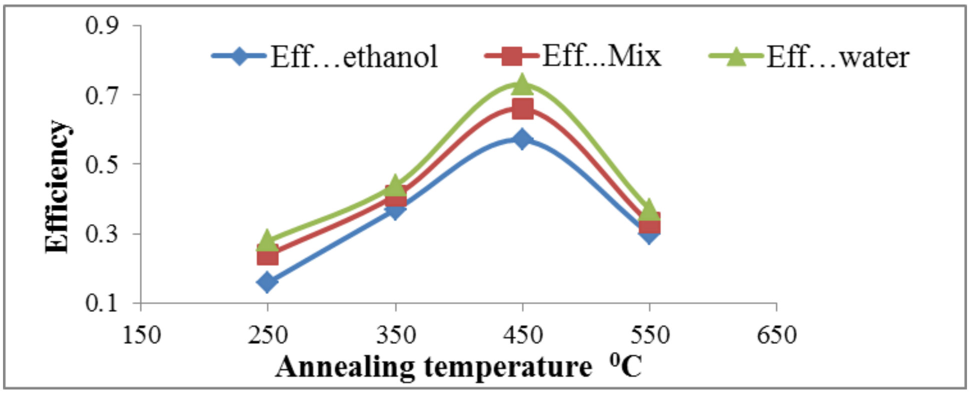

Figure 4- Effect of annealing temperature on efficiency.

It is clear that the highest values of V_{oc} and J_{sc} are obtained for the cell sintered at 450 °C. Values of short circuit currents and open circuit voltages of all cells sintered at various temperatures are presented in Figure-5. There is a decrease in efficiencies of the cells with increase in sintering temperature, which may be because of crak or agragation has led to decrease in surface area for dye absorption eventually decreasing the performance of DSSC. In accordance with that of reference [13].

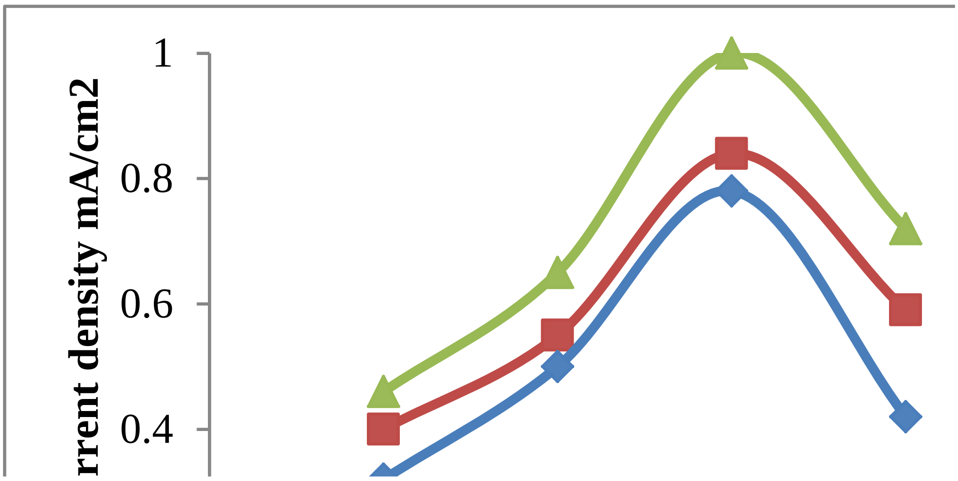

Figure 5- Effect of annealing temperature on current density.

6. Effect of thickness on efficiency

The thickness of TiO_2 film of the photo-electrode is a significant parameter which affects the performance of the DSSC. The limit of the TiO_2 thickness is accompanied by the increase of the efficiency related to the electron transport in the TiO_2/dye/electrolyte interface and the increase of the electron lifetime. A sintering temperature of 450 °C was adopted as it corresponds to the highest photoelectrical response. These cells are shown in Figure- 6 under 40 mW/cm^2 illumination. This causes the improvement of the electron diffusion and transport in the TiO_2 layer, which causes the improvement of the efficiency .The best efficiency obtained in this work is 0.73% cell with TiO_2 film thickness of 12µm.

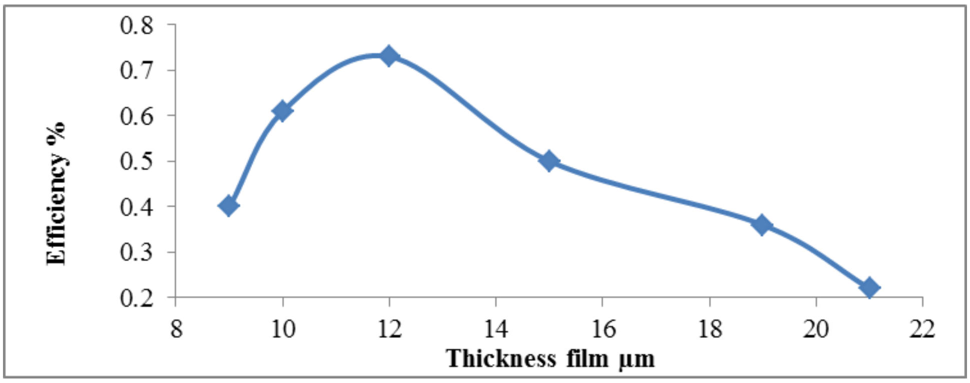

Figure 6 - Relationship with film thickness and efficiency.

7. Effect of $AgNO_3$ additive on efficiency

The effect of addition additives to the electrolyte of DSSC based on an $AgNO_3$ has been investigated. It has been found that the photovoltaic performance of DSSC can be enhanced substantially by adding a small amount of different additives [2].The addition of additive to electrolyte results in an increase in J_{sc} Accompanied V_{oc} is between 4-5 mV; therefore increase the conversion efficiency, as shown in Table-1.

. **Table 1-** comparison efficiency with and without additive depending on the solvent.

Dye solution	Efficiency η % Before additive	Efficiency η % After additive $AgNO_3$
Water	0.73	1.1
Ethanol	0.5	0.62
Mix	0.66	0.69

8. Ideal values to search

The Table -2 ideal values that got from my research.

Table 2- Ideal values obtained from research.

eosin dye solution (water)	0.73 %
eosin dye solution(water) with additive $AgNO_3$	1.1 %
Annealing temperature	450 °C
Thickness film	12 µm

9. Conclusions

A dye solution of water, ethanol and mixing where in eosin y dissolves behaves like a colloid. The conversion efficiency of DSSC fabricated using a thin film deposited by synthesized TiO_2 nanoparticles in a dye solution of water was the highest. From the experimental data, it can be seen that annealing temperature has important role on DSSC performance. The value of electrical properties increases as the value of annealing temperature increase. The annealing temperatures higher than 450°C and less than 450 °C caused the value of electrical properties decrease. These occurred because of failing to the homogeneity of the TiO_2 thin layer, which resulting low dye absorption and reducing electrical-network between the particles. Thickness of TiO_2 film of the photo-electrode is a significant parameter which affects the performance of the DSSC.

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