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SOLAR CLOTH USING TiO2 NANOSTRUCTURES BASED DYE SENSITIZED SOLAR CELL TECHNIQUE

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ABSTRACT

Titanium dioxide (TiO_2) nanostructures have been synthesized via hydrothermal method by manipulating some parameters to determine which condition show better performance. In general, TiO_2 Degussa, P25 dissolve in alkaline solution. The solution was mixed by stirring for 15-30 minutes and put into Teflon sealed into an autoclave stainless steel tank and put in an oven without shaking or stirring during heating. After that, the autoclave is cooled at room temperature, the obtained sample was stirred with dilute hydrochloric acid (HCl) aqueous solution for 24 hour and then the sample was washed by using deionized water for several times until the pH values decreased. TiO_2 nanostructures act as network in solar cloth to perform the movement of electron in the device to generate electricity. Solar cloth is describe as non-woven fiber cloth in which a dye-anchored wide band gap semiconductor, which is the electron conductor forms a percolating network in polymeric medium. Because of principles in dye sensitized solar cell is same as solar cloth where dye sensitized solar cell consists of dye-anchored metal oxide in the presence of electrolyte and two conducting glass plates (such as fluorine-doped indium tin oxide (FTO)). Dye sensitized solar cell (DSSC) will be used TiO_2 nanostructures to fabricate the device. Moreover, the electrical conductivity of TiO_2 nanostructures in the present of polymeric medium will be measured.

Keywords: titanium dioxide nanostructures, hydrothermal method, dye sensitized solar cell.

INTRODUCTION

Dye-sensitized solar cell is p-n junction photovoltaic device [1] which is have been widely investigated as a next generation solar cell because they are made from cheap materials that do not need to be highly purified and low manufacturing cost [2][3]. The DSSC is fabricated by sandwiching a dye-anchored semiconductor material known as photoanode such TiO_2, ZnO, and Nb_2O_5 in the existence of an electrolyte between two conducting glass plates (such as fluorine-doped indium tin oxide (FTO)) [4]. DSSC can be categorized as a liquid/solid junction type solar cell that is referred as photoelectrochemical cell [5] [6]. The interface between a redox electrolyte containing iodide and triiodide (I-/I3-) ions and a dye-anchored metal oxide [7] as proof chemical reaction for electron to generate electricity from the solar energy. Solar cloth is described as a non-woven fiber cloth that consist a network of metal oxide in the presence of polymeric medium. Solar fabric have been synthesized using electrospinning method that involve Nb_2O_5 fibers as a metal oxide, the poly (3-hexylthiophene-2, 5-diyl) (P3HT) as hole conductor polymer, polyaniline-emeraldine base (PANI-EB) as conducting polymer [8]. The combination of P3HT and PANI-EB in solar fabric makes a polymeric hole-conducting medium for electron movement. The Nb_2O_5 fibers were dispersed into dye-sensitized light for 24hour to ensure the fibers can absorb photon from the solar energy. The electrospun solar fabric was measured using a transparent conducting FTO glass and the aluminum substrate of the electrospun fibers to be tested same as DSSC [8]. Compare other types of metal oxide, TiO_2 is choose to create the network in the device because of TiO_2 is good chemical stability under visible irradiation in solution, nontoxic and inexpensive [6]. There are a lot of methods to synthesize TiO_2 nanostructures but only one method will be used to synthesis nanostructures. This paper will discuss about the process of synthesize TiO_2 nanostructures by manipulating some parameters, performance of TiO_2 nanostructures in the DSSC and the reaction of TiO_2 nanostructures in polymeric medium.

MATERIALS AND METHODS

Materials

Titanium dioxide (TiO_2), Degussa P25, Sodium hydroxide (NaOH) and potassium hydroxide (KOH) as an alkaline solution, hydrochloric acid, deionized water, polyaniline emeraldine base, N-Methylpyrrolidone (NMP), microscope glass, fluorine-doped tin oxide (FTO), ethyl cellulose, α-terpinol, ethanol, acetic acid and titanium tetrachloride.

Methods

Firstly, hydrothermal method have been chosen to produce TiO_2 nanostructures which is promising approach due to its simple process, high reaction velocity, low cost [9] and nanostructures can be obtained in relatively large amounts [10]. The treatment of TiO_2 in an alkaline solution is a way to prepare titanate nanostructures [9]. By reviewing [9] [11] [12] [13], there are some various experiment were conducted in this method by changing the parameter involved such temperature and time for heat treatment and an alkaline solution. As an example, Xu *et al*. have reported an effective method to prepare TiO_2 nanowires in a mixed solvent of alkaline solution via hydrothermal [13]. Thus,

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some various experiments were conducted to develop the fine TiO_2 nanostructures by changing the temperature treatment, the alkaline solution and the time treatment. Besides that, the final pH value for each sample also is different, respectively. In general, 1-2g of TiO_2 degussa, P25 white powder was mixed with 50mL of 10M alkaline aqueous (aq) solution. The solution was mixed by stirring for 15-30 minutes and put into Teflon sealed into an autoclave stainless steel tank and put in an oven without shaking or stirring during heating. The temperature and the time of the heating process as shown in Table-1. After that, remove the autoclave and cooled it at room temperature. Next, the obtained sample was stirred with dilute HCl aqueous solution for 24 hour and then the sample was washed by using deionized water for several times until the pH values decreased like in the Table-1.

Table-1. The different of parameter to synthesis TiO_2 nanowires.

Sample	The alkaline aqueous solution	Temperature (˚C)	Time (days)	Washing treatment	pH value
A	10M of mixed solution (NaOH:KOH;3:7)	170	3	Stirred 24hr with 1M of HCl aq and wash with deionized water	7
B	10M of mixed solution (NaOH:KOH;3:7)	170	3	Wash with deionized water	2-3
C	10M of NaOH	105	1	Stirred 24hr with 0.1M of HCl aq and wash with deionized water	4-5
D	10M of NaOH	150	5	Stirred 24hr with 0.1M of HCl aq and wash with deionized water	9

Usually, the solution's pH value is 13-14 before soaked in HCl aqueous solution. The white precipitate obtained was dried in oven at 60-70˚C. Finally, the soft fibrous powder with white color was obtained. Table-1 shown the changing parameters involve developing fine TiO2 nanostructures.

Then, the TiO_2 nanostructures are used as a network in the DSSC. DSSC is fabricated for all samples of TiO_2 nanostructures. The TiO_2 nanostructures paste is made by mixing with ethyl cellulose, α-terpinol and ethanol. The solution is stirred in 30 minutes. Then remove the solution to the sonication process with heat treatment at 70˚C until the solution became viscous paste. In addition, the solution is added a few drop acetic acid and triton-x-100. The paste is spread onto the FTO by applying doctor blade technique and it known as photoanode and dried at 450˚C for 30 minutes. Next, the photoanode is soaked in N3 dye or N719 dye for 24hour. After that, add some electrolyte and put platinum FTO as counter electrode onto the photoanode to complete the device. Lastly, test the device to measure performance. To develop solar cloth with high efficiency, the reaction of the network and surround medium play important roles. The next step is the conductivity of TiO_2 nanostructures in polymeric medium is measured. First, TiO_2 nanostructures were measured the conductivity by using basic solvent, NMP and second, continued measured with PANI-EB which is dispersed in NMP. All samples are mixed in pastille mortar until the paste became viscous. Then spread onto microscope glass by using doctor blade technique.

RESULTS AND DISCUSSIONS

Synthesis of TiO_2 nanostructures via hydrothermal

The characteristics of all samples were Figure out by analyzing with x-ray diffraction (XRD) and Brunauer, Emmett and Teller method (BET). From this analyze, all samples is compared with P25. By comparing the reading, the estimated characteristic of TiO_2 nanostructures will be determined. In Table-2, the reading show surface area of the samples. From that, sample A and B is lower or nearly equal to original sample, P25. Different with sample C and D, the reading is too high. It shown the area is bigger than the other sample. Figure-1 is show the comparison of XRD pattern for all samples with P25. As can be seen, the starting material of TiO_2, Degussa P25 is well crystallized and composed of anatase and rutile phase structures. The XRD pattern corresponding to the samples are shown. Both sample A and sample B show crystalline structure and the pattern same as the P25 compare the others samples (C and D). Refer to Table-1, sample A and sample B react with combination of NaOH:KOH (3:7) solution while sample C and sample D only react with NaOH solution. The diffraction peaks (25.47, 37.96 and 48.20) of anatase gradually became strong, when the concentration of NaOH reduced and the concentration of KOH increased. The reaction activity of KOH with TiO2 is better than that of NaOH, because the radius of K (1.33 A˚) is significantly larger than that of Na (0.97 A ˚) contrast with [13] reported.

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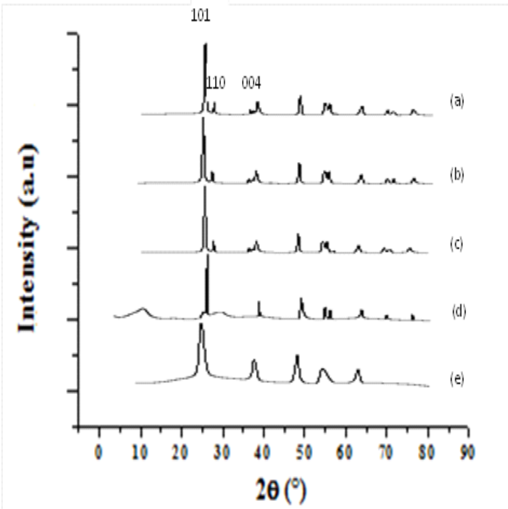

Figure-1. XRD pattern of a) Commercial b) sample A c) sample B d) sample C e) sample D.

Table-2. The surface area for all samples.

Sample	Surface area
P25	40.6281 m²/g
A	38.9655 m²/g
B	31.6255 m²/g
C	113.0732 m²/g
D	258.2911 m²/g

$$\rho = \frac{RA}{l} \quad (1)$$

$$\sigma = \frac{1}{\rho} \quad (2)$$

Dye sensitized solar cell

Photovoltaic performance data obtained with a sandwich cell under illumination by simulated AM1.5 solar light shown in Figure-2 and Table-3. As can be seen in Figure-2, the JSC-V characteristics of dye-sensitized all samples films are compared. Open-circuit voltage C (740mV) is higher than B (725mV), A (688 mV) and D (611mV). The fill factor, FF is defined as the ratio of the maximum power Pmax obtained with the device and the theoretical maximum power, is $Pmax=J_{SC}\times V_{OC}\times FF$ is the short circuit current and V_{OC} is the open-circuit voltage. The fill factor, FF can then take values between 0 and 1[14]. It reflects electrical and electrochemical losses occurring during operation of the DSSC [14]. As a result, the higher energy conversion efficiency is device B is 1.46%.

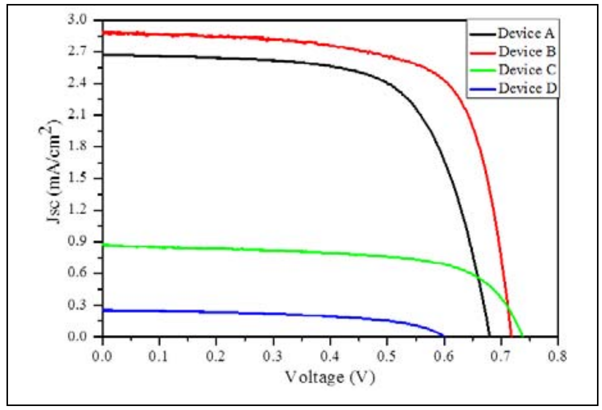

Figure-2. J_{SC}-V characteristics of dye-sensitized TiO_2 nanostructures solar cells as a function of film thickness under simulated AM1.5 light.

Table-3. J_{SC}-V characteristics of dye-sensitized nanostructures solar cells under simulated AM1.5 Light.

Device	J_{SC}	V_{OC}	FF	H
A	2.6673	0.6886	0.6608	1.2137
B	2.8793	0.7250	0.6999	1.4611
C	0.8700	0.740	0.4100	0.4100
D	0.2540	0.611	0.0798	0.0798

Conductivity testing

Sample B shown a better efficiency compare others. This experiment has been conduct to determine the conductivity of only for sample B react with PANI-EB. Firstly, the reaction between sample B and NMP is measured. Then, PANI-EB is dispersed in NMP to react with sample B. The reading is recorded. Sample B is mixed in pastille mortar with NMP and NMP: PANI-EB. In this experiment, digital multimeter is used to measure the resistance. To develop solar cloth, the performance of electron movement in nanostructures in the existence of polymeric medium play important roles, so that the electrical conductivity testing is important to determine whether the nanostructures has high conductivity or not [15]. In the band theory of solids, the conduction process is whether or not there are electrons in the conduction band; more electrons on conduction band more conductive a material [16]. Conductivity is increased when electrons in valence band supplied with external energy so that the electrons have enough energy to excite into conduction band. By applying equation (1) and (2), the conductivity values will be determined as shown in Figure-3. As increase the amount of TiO2 nanostructures, the conductivity also increase. In Figure-4, the conductivity is higher than in Figure-6. It shows the PANI-EB, conducting polymer supports the electron movement.

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Table-4. The average values of resistance, resistivity and conductivity of Sample B react with NMP.

Weight of Sample B, mg	Resistance, MΩ	Resistivity, kΩm	Conductivity, $\mu\Omega^{-1}m^{-1}$
5	5.0	10.0	72.6
10	4.0	10.6	95.8
20	2.7	8.08	126
40	2.2	6.46	156

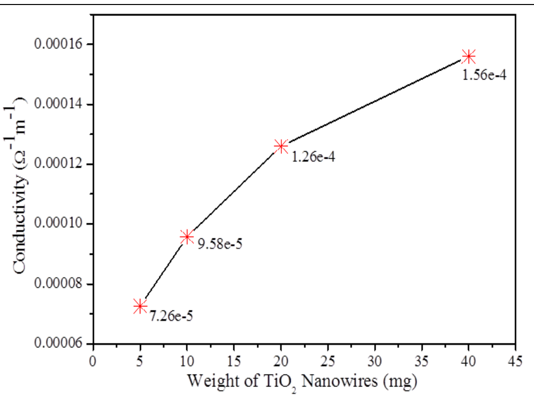

Figure-3. Sample B reacts with NMP.

Table-5. The average values of resistance, resistivity and conductivity of Sample B react with PANI-EB.

Weight of Sample B, mg	Resistance, MΩ	Resistivity, kΩm	Conductivity, $\mu\Omega^{-1}m^{-1}$
5	3.58	1.07	93.4
10	3.03	9.09	110
20	2.54	7.61	132
40	1.48	4.43	228

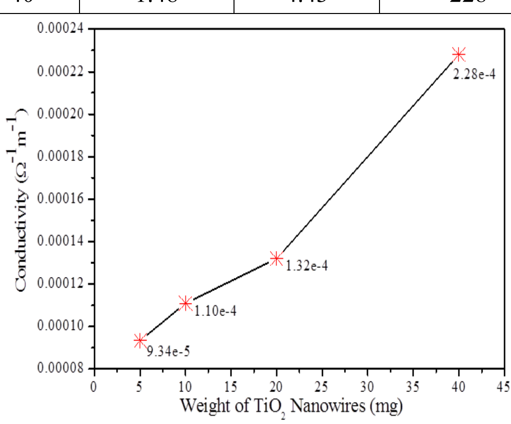

Figure-4. Sample B reacts with PANI-EB.

CONCLUSIONS

TiO_2 nanostructures were successfully synthesis by using hydrothermal method by manipulating some parameters. The characteristics of TiO_2nanostructures have been Figure out by analyzing with XRD and BET. All samples have been fabricated by using DSSC to analyze the performance of TiO_2 nanostructures. As a result, the efficiency is 1.46% is successfully achieved. In order to develop solar cloth which is the network of metal oxide in the present of polymeric medium, the metal oxide (TiO_2 nanostructures) is tested in term of electrical conductivity. In the present of polymeric medium, the conductivity is higher than in the present of basic solvent. As mention earlier, solar cloth is made from non-woven fiber cloth. It can be create using some combination reaction of polymer which is combination of conducting polymer and hole-conducting polymer.

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