INFLUENCE OF ANNEALING TEMPERATURE OF PLATINUM COUNTER ELECTRODE ON THE PHOTON TO ELECTRON CONVERSION EFFICIENCY OF DYE SENSITIZED SOLAR CELLS

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ABSTRACT

In present research paper dye sensitized solar cells based on TiO_2 film coated ITO (indium doped tin oxide) glass photoanodes were successfully fabricated. The XRD pattern confirms the anatase and rutile phase of TiO_2. Crystallite size of TiO_2 powder was found 28.36nm. However, UV- Visible absorbance of T1/ITO (300^{o}C) glass and T2/ITO glass (400^{o}C) were obtained 9-17 % and 7-15% respectively in the wavelength range of 350-800nm.The fill factor values were obtained 0.53 and 0.55 for platinum T1 and T2 counter electrode of DSSCs respectively. The efficiency of DSSC with T1/ITO and T2/ITO electrode were found 0.97% and 1.1% respectively.

Keywords: Structural Properties Of Tio_2 Film, Annealing Temperature Of Counter Electrodes And Performance Of Dsscs.

I. INTRODUCTION

Dye-sensitized solar cell (DSSC) has become an alternative photovoltaic device, which provides a more technical and economical light-to-electric converting mode than that based on p-n junction [1-3]. Nowadays, this kind of solar cell reaches a photoelectric conversion efficiency exceeding 11% under sunlight irradiation [4-5], which shows a good prospect for application in solar conversion. For practical application, the traditional electrolyte, based on the iodide/triiodide (I/I3) redox couple, works effectively in DSCs [6–8]. This is evident despite its disadvantages, such as corrosion of metal-based current collectors (for example silver, copper), sublimation of iodine and absorption of visible light, which limit the large-scale production and commercial application of DSCs [9] Thus, finding alternative redox couples to develop high efficiency and cheap DSCs, [10–12] without the use of FTO, Pt and I/I3, isan important issue to be addressed. To enhance the photo electrochemical behavior of DSSC, several key issues have been identified, including a desired semiconductor oxide mesostructure, development of novel sensitizing dyes and electrolytes (both liquid and solid types), and

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employment of new alternative counter electrodes [13-17]. TiO_2 nanoparticles have been used as the photo electrode in DSSC because of its high surface area and allow the adsorption of a large number of dye molecules. These nanoparticles have been prepared by several synthetic routes in a variety of particle sizes, pore size distributions and crystallinities. These factors affect the electron transport and as a consequence, the charge recombination kinetics and the dark current of these cells [18]. It consists of a porous nanocrystalline TiO_2 (Titanium dioxide) layer coated onto a Transparent Conducting Oxide (TCO) glass substrate using Doctor Blade technique [19]. Our main objective is to study the influence of counter electrode fabrication process (mainly annealing temperature) on the performance of DSSCs. In present course of research work we have successfully fabricated the DSSC with different platinum film coated counter electrode synthesized at different temperature 300^{o}C and 400^{o}C and the performance of DSSCs were found.

II. EXPERIMENTAL DETAIL

2.1 Preparation of Tio_2 Paste

TiO_2 powder was prepared by taking Titanium Isopropoxide (TTIP, Sigma Aldrich> 97%, USA), distilled water and ethanol (Merck, USA) as the starting precursors. Heat the synthesized powder at 450^{o}C with a temperature gradient 10^{o}C/minute for one hour. For preparation of TiO_2 film, binder were prepared by the following steps first ethylene glycol, Titanium isopropoxide (TTIP) and citric acid were mixed to form solution A. The molar ratio of ethylene glycol, citric acid and TTIP is taken as 24:7:1.TiO_2 powder were mixed solution A in pestle mortor to form TiO_2 paste [20-21]. However, ITO glasses were used as substrate material for photoanode and counterlelctrode. The film prepared with this binder is highly adhesive in nature with ITO glass substrate. The components of DSSC are shown in fig. 1.

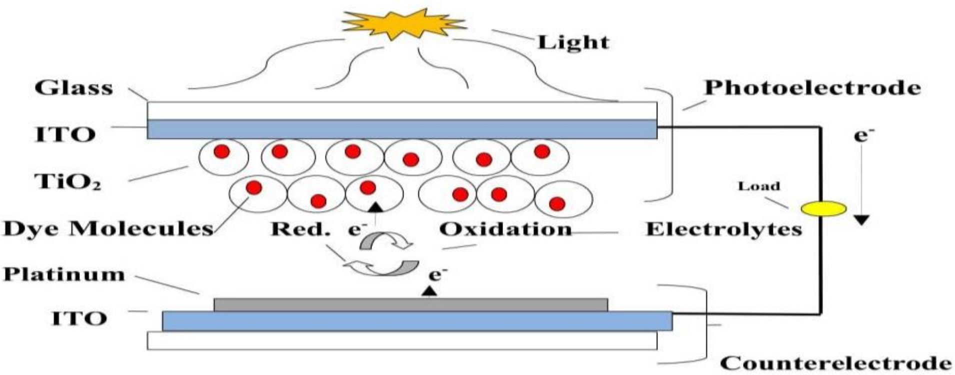

Fig.1 Structure of DSSC

2.2 Preparation of Photoanode And DSSC

Indium doped Tin (ITO) act as a substrate for both photoanode and counter electrode of the dye- sensitized solar cell. The substrate was first washed with acetone with ultrasonic bath for 10 minutes to dissolve unwanted organic materials so that contamination material was removed which was left on the substrates during preparation. Another 10 minutes of ultrasonic bath in ethanol was followed in order to remove the acetone and materials that were not cleansed or dissolved by acetone. Finally, a 10 minutes ultrasonic bath in isopropanol was also needed to further remove the residual particles on the substrates. The TiO_2 paste was coated onto an ITO glass substrate using a doctor blade technique and annealed at 450°C for one hour [22]. After annealing the cooled film were immersed in a 5mM ethanolic N719 (Sigma Aldrich, 99.9%) solution for 24 hrs, and the dye adsorbed films were rinsed with absolute ethanol.

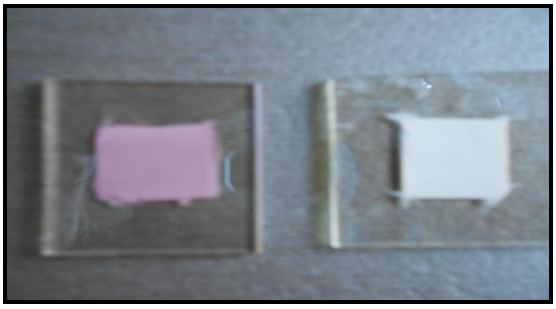

Fig. 2 dye loaded TiO_2 film and TiO_2 film on ITO/Glass substrate

For preparation of platinum film, 5mM $PtCl_4$ (Sigma Aldrich 99.9%) and Isoproponal were mixed to make platinum solution. Pt film was coated on ITO/Glass by spin coater (MTI corporation) and then heated at 130°C for 10 minutes. After this films annealed at 300°C (T1) and 400°C (T2) with 10°C/minute for 15minutes. The sensitized TiO_2 photoanode and the counter electrode was stacked together face to face. Further the Iodine electrolytes solution was also prepared from Lithium Iodide (LiI, Sigma 99.9%) and Iodine in acetonitrile. The drops of prepared electrolyte solution drop penetrated into the space between photoelectrode and counter electrode. The dye adsorbed photoanode shown in figure 2.

2.3 Characterization Techniques

Structural properties were measured by the XRD set up type model (Panalytical's X'Pert Pro,) The SEM measurement were taken on (SEM, JEOL). The Hitachi 330 Model was used to record the UV-Visible Spectra of prepared samples. The photocurrent-voltage (J-V) measurements were also performed by using Solar Simulator (Xenon Lamp, 150W, AM 1.5) at room temperature. The active area of the sample is taken 1cmx1cm.

III. RESULTS AND DISCUSSIONS

3.1 XRD

The XRD patterns of TiO_2 film have been taken in the angle range from 20^0-60° as shown in the 3. The XRD of TiO_2 film shows the planes (101), (110), (101), (103), (004), (112), (200), (105) and (211) at angle 25.90°, 27.73°, 36.45°, 37.38°, 37.93°, 38.92°, 48.53°, 54.61°, 55.76° respectively. The peaks at angles 25.90(101), 37.38(103), 37.93(004), 38.92(112), 48.53(200), 54.61(105), 55.76(211) and 27.73(110), 36.45(101) corresponding to anatase and rutile phase respectively. The TiO_2 film was observed to be anatase and rutile phase The Scherrer's equation (1) was used to calculate crystallite size, where k is the shape factor, λ is the x-ray wavelength, β is the line broadening at half the maximum intensity (FWHM) in radians, and θ is the Bragg angle, D is the mean size of the ordered (crystalline) domains, which may be smaller or equal to the grain size [23]. The full width at half maxima (FWHM) for TiO_2 (101) plane shown in fig. 4.

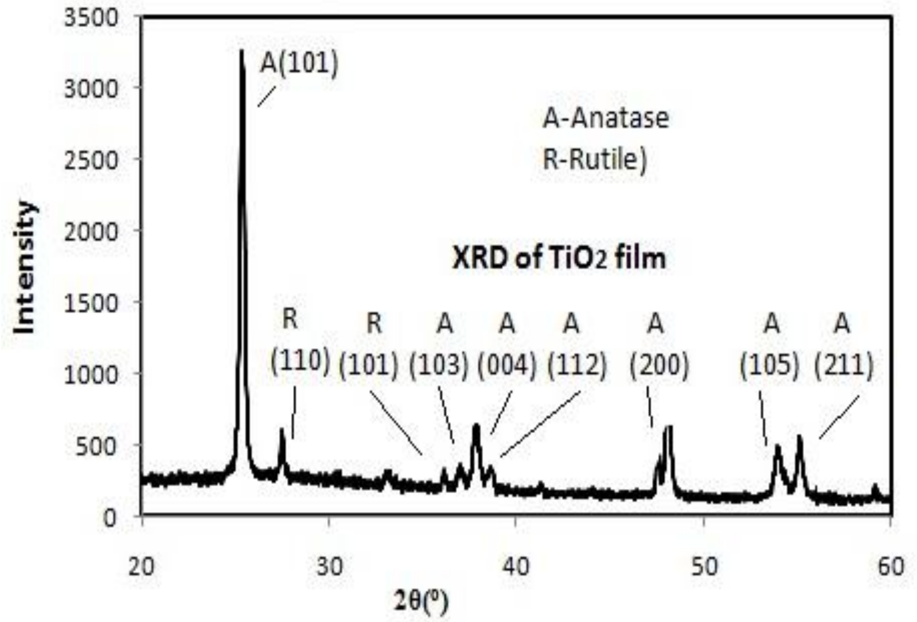

Fig.3 XRD pattern of TiO_2 film

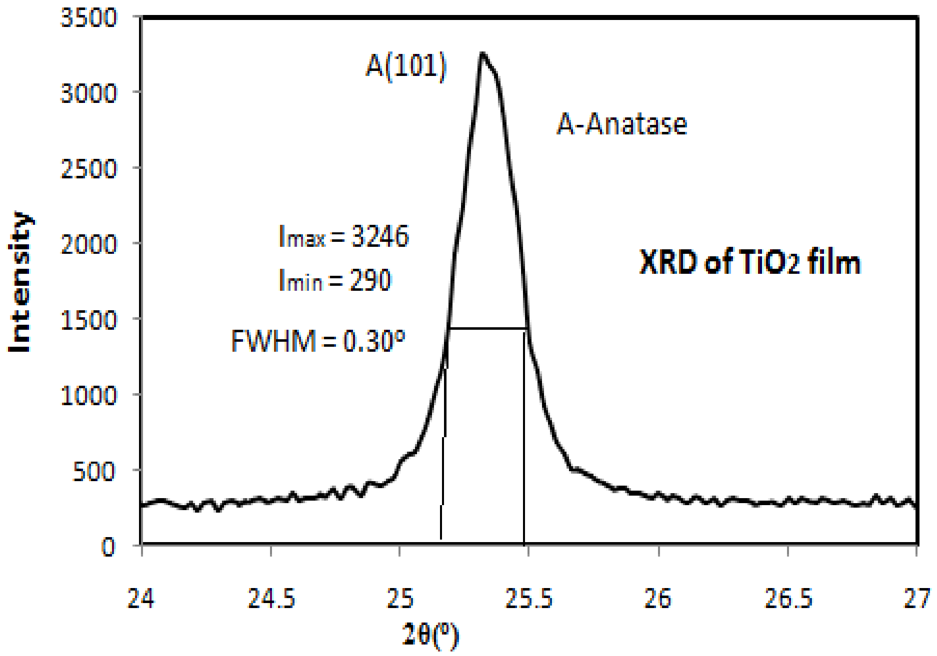

Fig. 4 FWHM of TiO_2 film

$$D = \frac{k\lambda}{\beta cos\theta} \quad \text{---- (1)}$$

The crystallite size of TiO_2 film was 28.36nm

3.2 FE-SEM image of TiO_2 film

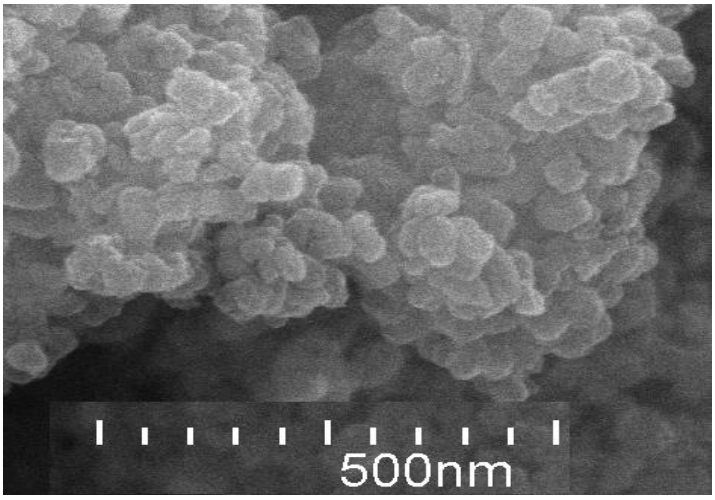

Fig.5 FE-SEM image of TiO_2 film

Field emission scanning electron microscopy (FE-SEM) of TiO_2 film was also used to investigate the morphology shown in the fig. 5. FESEM image in fig.5 show that film is porous in nature. The grain size calculated from fig .5 is 50.4nm. The grains are irregular in shape

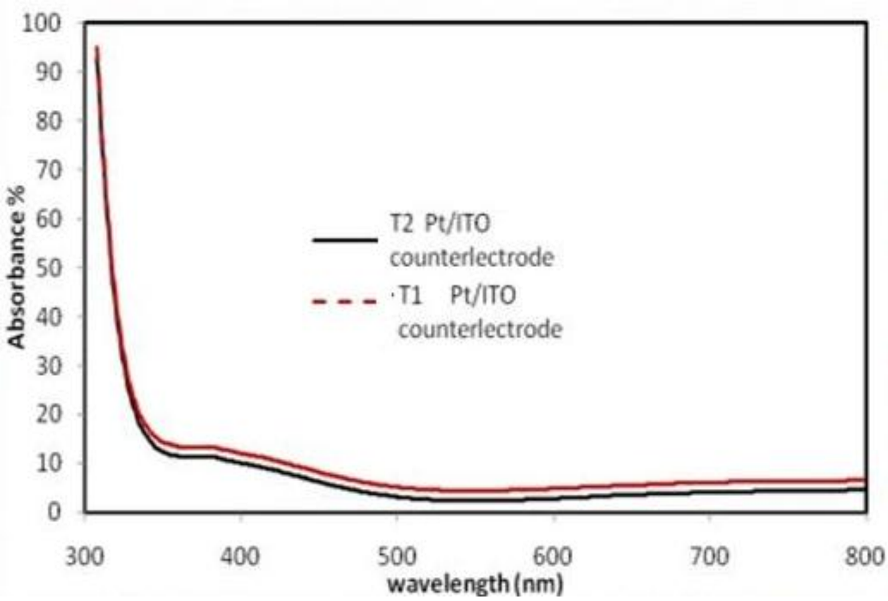

Fig.6 Absorbance Spectra of T1/ITO Glass and T2/ITO Glass Counter Electrode.

The optical absorbance spectra of the T1 and T2 platinum electrodes were measured to investigate their potential use for the transparent counter electrodes in DSSC. Fig.6 shows the absorbance spectra of T1/ITO glass and T2/ITO glass in the wavelength region 300-800nm. The absorption spectra of T1 and T2 as a counter electrode in wavelength range 350-800nm were found 9-17% and 7-15% respectively.

3.3 Performance of DSSCs

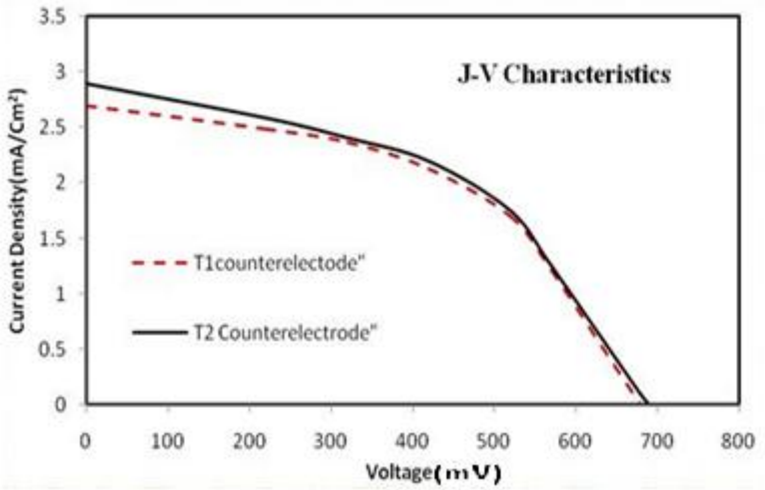

Fig.7 J-V characteristics of DSSCs.

Table.1 performance of T1 and T2 based DSSCs.

Sample	**Voc(mV)**	**I_{sc} (mA)**	**FF**	**Efficiency (%)**	**J_{sc}(mA/cm^2)**
T1	680	2.70	0.53	0.97	2.70
T2	690	2.90	0.55	1.10	2.90

The value of fill factor (FF) and **(mV)** efficiency of solar cell were calculated by following eq.

$$FF= I_m x V_m / I_{sc} x V_{oc} \quad --- \quad (2)$$

$$\eta = FF\ x I_{sc} x V_{oc} / P_{in} (mW/cm^2) \quad --- \quad (3)$$

Here FF is the fill factor, η is the efficiency and J_{sc} is current density of DSSC. The performances of DSSCs were characterized at 100mW/cm^2 intensity. The V_{oc} of T1 and T2 based DSSC are obtained 680 mV and 690mV respectively. The short circuit current is I_{sc} is found 2.7mA and 2.9mA for T1/ITO glass and T2/ITO glass respectively. A mask with a window of 1cmx1cm was also clipped on the TiO_2 side to define the active area of the cell. The value of FF is 0.53 and 0.55 for T1 and T2 electrodes respectively. The efficiency of DSSC with T1 and T2 counter electrode were found 0.97 % and 1.1 % respectively. The electron transport between the T2 and conducting substrate is low as compared to T1 as counter electrode and this hinders the overall performance of the DSSCs. Similar type of behavior also reported by J. U. ddin et. al.[24].

IV. CONCLUSIONS

TiO_2 pohotoanode of DSSC were prepared successfully prepared. Prepared TiO_2 film has a mixture of anatase and rutile phases. FESEM confirmed that surface of film is porous in nature. The grain size was found 50.4nm. The fill factor values for T1 and T2 based DSSC are obtained as 0.53 and 0.55 respectively. The efficiency of T1 and T2 counter electrode based DSSCs were found 0.97% and 1.1 % respectively. Comparison of the efficiency and fill factor of the counter electrodes fabricated with different annealing temperature measured under similar conditions showed that T2 DSSC have high efficiency as compared to DSSC with T1 electrode.

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