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Comparative analysis between Commercial and Hydrothermal TiO_2 films for their use in Dye-sensitized Solar Cells

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ABSTRACT

A comparison has been drawn between purely crystalline single phase mesoporous anatase TiO_2 film synthesized via hydrothermal sol-gel process and mixed TiO_2 film containing both anatase and rutile phases deposited by using commercial P25 TiO_2 powder. Phase confirmations have been made by x-ray diffraction analysis. Dye-sensitized solar cells have been built by using these two kinds of films and a comparative study has been made in context of their current-density, voltage performance curve under 1 sun illumination. It has been observed that the open-circuit voltage (V_{OC}) for both the cells is approximately similar but there exists a large difference between the values of short-circuit current density (J_{SC}). The conversion efficiency for the commercial TiO_2 based cell is about 27.5% of the efficiency value for anatase based cell. Thus, anatase TiO_2 films prove their better candidature for dye-sensitized solar cells.

Keywords: Anatase Rutile, Mesoporous, Current-density, Sol-gel

INTRODUCTION

Researchers have been making considerable efforts for the development of dye-sensitized solar cells (DSSCs).[1] Mesoporous photoelectrode film is a key component of DSSC. Mesoporous films help to increase electron transport thereby enhancing photocurrent.[2] Titania films are frequently used as photoelectrodes in DSSC because of their non toxicity and favorable energetics with the dye molecules.[3-5] Anatase and rutile are the major allotropic forms of TiO_2. It has been found that rutile based solar cells owed lower value of photocurrent because of smaller surface area than anatase films. Smaller surface area leads to lesser adsorption of dye molecules on to its surface. Time resolved photocurrent measurements have been proved that electron diffusion coefficient of rutile electrode is smaller than that of anatase one.[6]

Commercial P25 TiO_2 is now used to make photoelectrodes for dye adsorption in DSSCs. P25 is a mixture of 76 wt.% anatase and 24 wt.% rutile.[7] It is obvious to think that pure anatase based DSSCs exhibit better performance than P25-based cells.[6,8] However such a direct comparison between these two types of cells can not be done. In the presented work mixed (anatase and rutile) and pure anatase TiO_2 sols have been made from commercial P25 powder and hydration of titanium iso-propoxide (TTIP), respectively. Crystal structure and DSSC performance has been discussed.

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EXPERIMENTAL

Anatase TiO_2 film was fabricated by using sol-gel dip coating technique. Titanium iso-propoxide (TTIP) was used as precursor along with glacial acetic acid and ethanol as reported.[9] The film was calicinized at a temperature of 150 ^{O}C. P25 film was synthesized according to the procedure in literature.[10-12] Both the films were immersed into N719 dye solution for 12 hours to sensitize. Electrolyte was prepared by dissolving LiI and I_2 in acetonitrile solution. Dye-sensitized solar cells were build up using Pt counter electrode.

RESULTS AND DISCUSSIONS

X-ray diffraction (XRD) analysis[13] confirmed the crystalinity and phase character of the films. In each spectrum shown in Fig. 1, all the diffraction peaks can be indexed in terms of a unique crystalline phase (anatase or rutile).

It is clear from the Fig. 1 that in P25 film both anatase and rutile phases are present which have been designated by A (anatase) and R (rutile), while sol made film contain only anatase character.

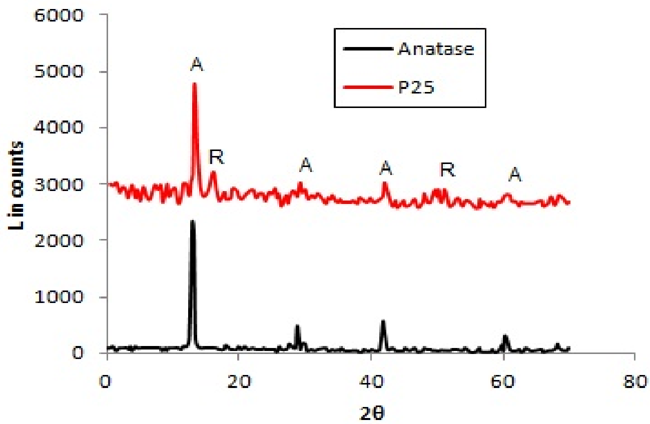

Figure 1. XRD spectra of purely anatase and P25 films prepared by dip coating technique.

Raman spectrum measurements were made on RM100 Raman instrument using 514nm wavelength. The Raman spectrum of sol made film confirms its anatase phase as shown in Fig. 2.

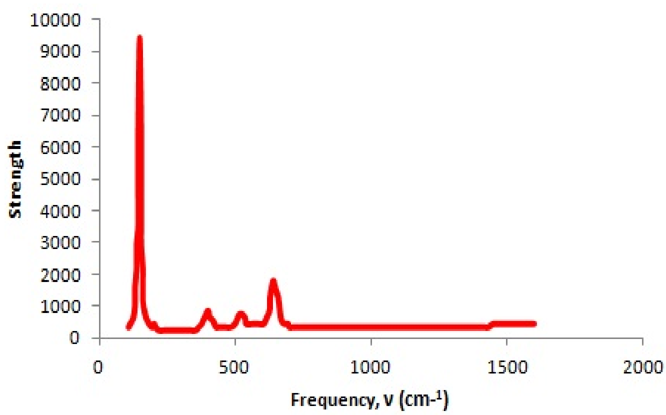

Figure 2. The Raman spectrum of the sol made film.

Photocurrent-voltage measurements were made using a Keithley model 4200 semiconductor characterization system with real time plotting and analysis. A 500 W xenon lamp was served as light source and its intensity was adjusted to 100mW/cm^2.

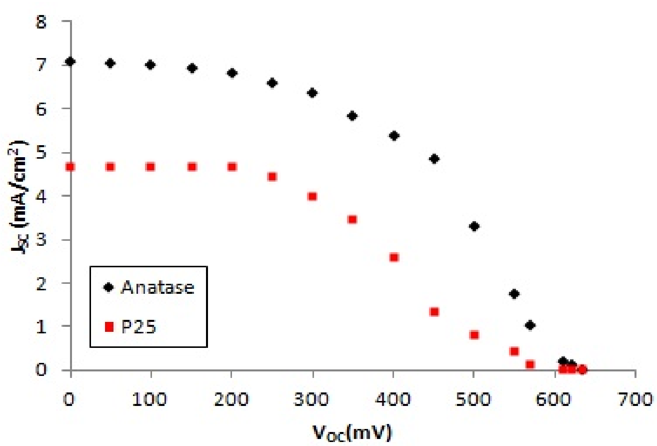

Figure 3. *J-V* characteristics of both types anatase and P25 based DSSCs

Figure 3 illustrates current-density and voltage (*J-V*) characteristics of both types of DSSCs.

Figure 3 clearly indicates that open-circuit voltages (V_{OC}) for both the cells are almost same. The V_{OC} values for the anatase and P25 based cells are 0.633 and 0.621 respectively. However short-circuit current density (J_{SC}) for P25 cell (4.65 mA/cm^2) is about 27.5% of the value for pure anatase based cell (7.1 mA/cm^2). The short-circuit current intensity of anatase-based cells has been enhanced because the electron diffusion coefficient of the anatase film is one order of magnitude larger than that of the rutile one, so the anatase electrode can let the injected electrons migrate across the film faster than the P25 based electrode with anatase and rutile mixed crystalline structure. In this way the photocurrent increases, which finally leads to the enhancement in energy conversion efficiency. The overall energy conversion efficiency of the anatase-based and P25 cells is 2.18% and 0.6%, respectively. And the fill factors of the anatase-based and P25 cells are 49% and 21%.

CONCLUSIONS

We have synthesized mixed P25 and pure anatase TiO_2 colloids, and then fabricated quasi-solid state dye-sensitized solar cells using both P25 and anatase. Using anatase TiO_2 film as electrode, the photocurrent of the device can be enhanced by 27.5% and the energy conversion efficiency can also be improved. This fact proves our hypothesis that anatase is better in electron transfer than mixed crystalline structured P25. The possible reason is the crystalline structure of mesoporous titanium films. It indicates that the crystalline structure is the most important part leading to the improvement of the photocurrent.

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