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Performance probe for Nanostructured and Nanotube TiO_2 Photoelectrodes in Dye-Sensitized Solar Cells

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ABSTRACT: *Dye-sensitized solar cells (DSSCs) have been fabricated by incorporating nanostructured and nanotube anatase based TiO_2 photoelectrodes grown by a simple modification in hydrothermal technique. Morphological characteristics have been confirmed by using scanning electron microscopy (SEM). Performance investigations of anatase nanocrystalline and nanotube based DSSCs have been made by obtaining current density-voltage curve and incident photon to current conversion efficiency (IPCE) spectra. It has been found that nanotube based DSSC has a higher efficiency (7.28%) than nanocrystalline anatase based DSSC (6.6%).*

KEYWORDS: *nanocrystalline; nanotube; photonaode.*

I. INTRODUCTION:

Dye-sensitized solar cells (DSSCs) have been widely recognized as one of the most promising several substitutes to challenge the existing conventional silicon solar cells over the past decade because of its minimal cost to performance ratio [1-4]. The major components of DSSCs are *n*-type semiconductor film deposited on transparent conducting glass, a sensitizing dye, a redox couple electrolyte and a catalyst film spread over transparent conducting glass. The sensitizer is chemically tethered to semiconducting surface by a carboxyl functional group. In the operating mechanism, dye molecules absorb photons from sunlight and a photoexcited electron is generated in the HOMO level of the sensitizer. This electron is imparted into the conduction band of the semiconductor which is lying just below the HOMO level of the dye. This electron penetrates through TiO_2 film to generate photocurrent. The oxidized dye recovers its original state via redox couple electrolyte at dye/electrolyte interface. The electrons forming photocurrent finally reach at counter electrode through external circuit where the redox couple gets reduced which was oxidized in the dye regeneration process. Thus, overall efficiency of DSSC is affected by many factors viz. the capacity of dye to help a swift electron generation and a rapid regeneration [5-6], quick diffusion and fast recovery of the electrolyte [7-8], an agile electron transport in the semiconducting TiO_2 layer [9-10].

TiO_2 is an intensively used *n*-type semiconductor having a wide band gap of 3.2eV [11]. TiO_2 nanocrystalline film plays a very determinant role in DSSC because of its outstanding chemical and physical properties results from nanostructures [12-14]. TiO_2 nanocrystalline films have high surface area to volume ratio favorable for a good deal of dye loading, high transparency and scatter negligible light because of small particle size that can become a cause of poor light harvesting [15]. It is now well established that large surface area for increased dye loading is not the only criteria for raising efficiency of DSSCs but tailored microstructures also enhance light harvesting and rate of electron transport [16-19].In the light of these requirements, we systematically explored the performance of dye-sensitized solar cells based on nanocrystalline and nanotube TiO_2 films in anatase phase. TiO_2 nanocrystalline films have been prepared by a mild change in hydrothermal sol-gel process. The grown films have been characterized by x-ray diffraction (XRD), scanning electron microscopy (SEM). Their performances as DSSC photoanodes have been studied by obtaining current density-voltage characteristics, incident photon to current conversion efficiency (IPCE) variation with the wavelength.

II. EXPERIMENTAL:

20mL of titanium tetra isopropoxide (TTIP) has been taken in a flask and 120mL of 0.1M HNO_3 has been added drop wise under vigorous stirring for half an hour followed by stirring the solution at 80^OC for 10 hours. The flask has been put in microwave at 180^OC for 4 hours. Afterwards, 14.8% poly ethylene glycol (PEG) has been added in both the solutions and stirred for homogeneous mixing. The sol has been stirred until it reached at room temperature before coating and then deposited on indium tin oxide (ITO) coated glass plates using dip coater

(MTI Corporation) at a dipping rate of 8cm/min kept there for 10 minutes and removed at the same rate and dried at 125^{O}C for 1 hour. The film has been calcinized at 250^{O}C. To obtain TiO_2 nanotubes, already fabricated nanoparticle film has been kept immersed in 0.1M HCl and 0.1 M NH_4OH for 6 hours and followed by treatment with 5 M NaOH for 10 hours. Further, the film has been heated at 200^{O}C. To fabricate dye-sensitized solar cells, the deposited films have been kept immersed in N719 dye solution overnight. 0.5M lithium iodide (LiI), 0.05M iodine (I_2) in acetonitrile solution has been used as electrolyte. Nanocrystalline and nanotube structures have been confirmed by x-ray diffraction (XRD) analysis quoted elsewhere [11]. Investigations of surface properties have been made with the help of scanning electron microscopy (SEM). Solar cell characterizations have been executed by using Keithley unit (2400 source meter). A Newport AM1.5 solar simulator (91160 A) equipped with xenon arc lamp has been employed as source meter. Light intensity of the source meter has been calibrated to 100 mW/cm^2.

III. Results And Discussions:

Rough and porous structure of nanocrystalline and nanotube based TiO_2 thin films have been clearly visible in scanning electron microscopy (SEM) images as shown in Figure 1 and Figure 2. Porosity value for anatase nanocrystalline film has been obtained by poroellipsometry and has been found to be 40.4. the tube diameter of titania nanotubes has been calculated 90nm.

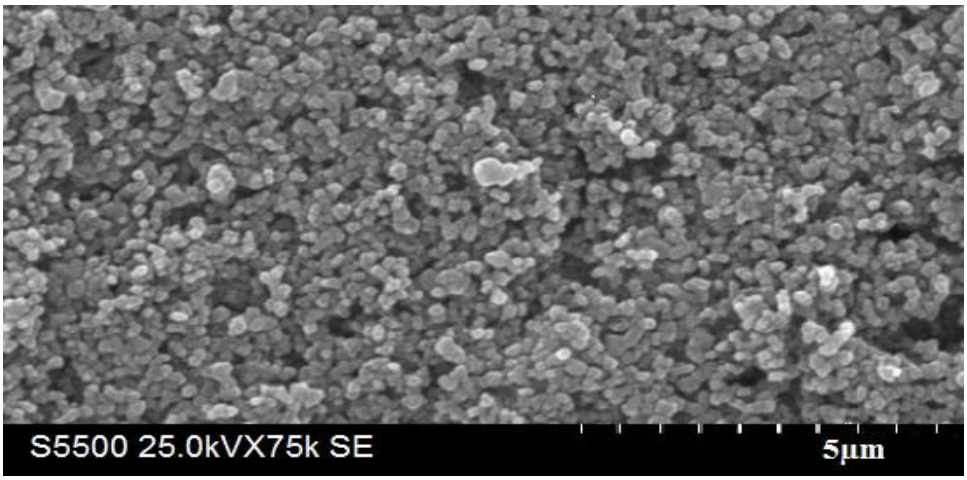

Figure 1. SEM image of nanocrystalline TiO_2 film

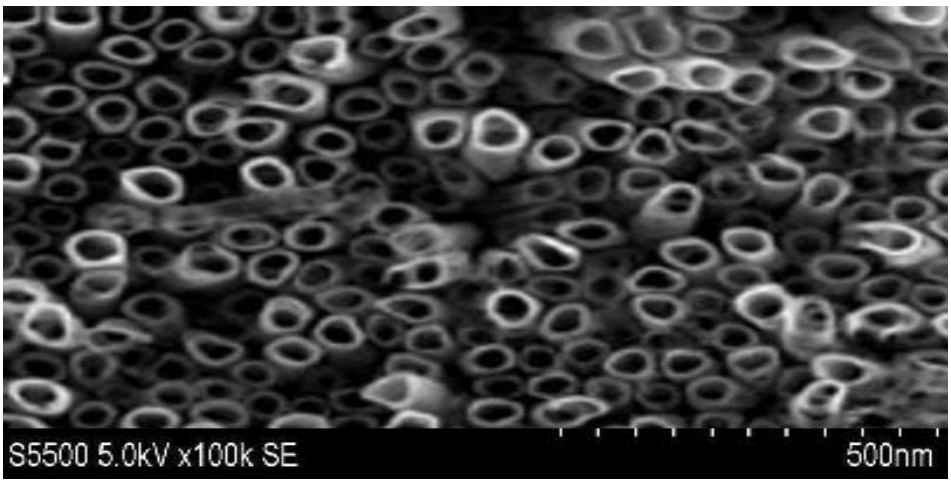

Figure 2. Morphology of TiO_2 nanotubes

Figure 2 reveals that grown nanotubes do not possess ordered structure but are disordered ones but still suitable for better transportation of the photoelectrons in dye-sensitized solar cells.

Figure 3 unveils the comparison between current density-voltage characteristics of nanocrystalline and nanotube based DSSC. It is very well clear that short-circuit density (J_{SC}) and open-circuit voltage (V_{OC}) values are not very much different for both the morphologies. But obtained efficiency values are 6.6% and 7.28% for nanocrystalline and nanotube based DSSC respectively.

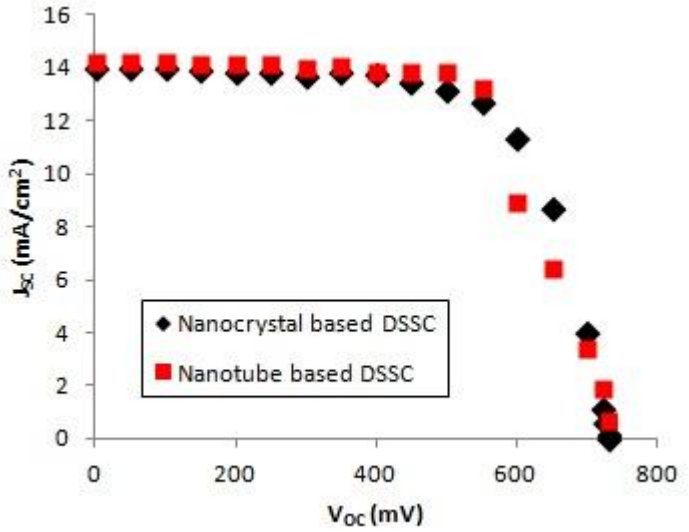

Figure 3. JV characteristics of fabricated DSSCs

Figure 4 presents a performance comparison of both the cells on the basis of incident photon to current conversion efficiency (IPCE) value.

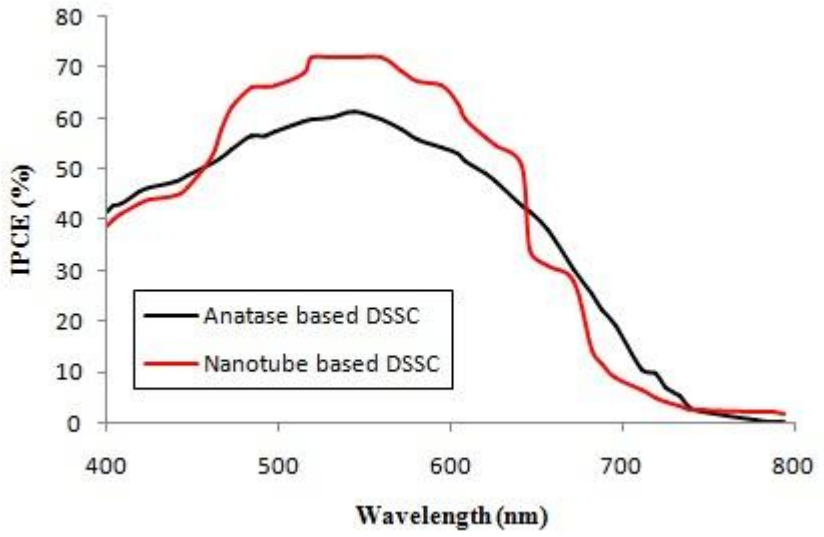

Figure 4. IPCE curves for nanocrystalline and nanotube based DSSCs

These plots serve the reason of the popularity of nanotubes over nanocrystalline based DSSC. It indicates that both the cells perform in visible region of electromagnetic spectrum but nanotube based dye-sensitized solar cell has high value of IPCE in the wavelength range corresponding to maximum output. At very low and high wavelengths in visible spectrum nanocrystalline based DSSC has better performance. It may be due to the percolation of electrolyte solution in the nanotubes to enhance recombination thereby reducing IPCE value.

IV. CONCLUSIONS:

A very simple technique to build dye-sensitized solar cells based on nanocrystalline and nanotubes has been presented. This type of manufacturing has an advantage that nanotube based DSSC can be illuminated both from front and back side that normally is not possible in case on other titania nanotube based DSSCs. SEM image reveal favorable structures to be used as photoanodes for better dye anchoring in DSSCs. From JV characteristics overall conversion efficiencies of both the cells have been calculated and the values for nanocrystalline and nanotube based DSSCs are 6.6% and 7.28% respectively. The results are further supported by IPCE curves declaring titania nanotubes as better candidates to be used as photoanodes in DSSCs. In the future efforts will be made to tailor the parameters of nanotubes to get even higher value of efficiency.

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