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Synthesis and Characterisation of CdS Sensitized TiO_2 Solar Cell

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Abstract

Titanium dioxide TiO_2 nano particles of size around 13nm were synthesized by sol-gel method using titanium (IV) isopropoxide, isopropyl alcohol and NH_3 precursors. The XRD diffraction pattern shows the anatase structure of TiO_2 and FESEM shows the particle size of TiO_2 is 13 nm. Nanostructured TiO_2 thin films were prepared by doctor blade method on an indium tin oxide (ITO) coated glass substrate. The mesoporous TiO_2 thin film was sensitized by cadmium sulfide (CdS) by successive ionic layer absorption and reaction (SILAR) method. CdS sensitized solar cell was fabricated by following standard dye sensitized solar cell fabrication method. It was tested under standard illumination 1.5 AM,100mW cm^{-2}. The photo energy conversion efficiency of the CdS sensitized solar cell was observed as 1.31%.

Keywords: *Titanium dioxide; Sol-gel; Doctor-blade; Solar cell; Cadmium sulfide.*

1. INTRODUCTION

Integration of nanostructured materials in the photo voltaic cells can open up the possibilities of developing low cost solar cells (Arun Kumar *et al.* 2013). TiO_2 in the anatase form appears to be the most photoactive and stable material under UV radiation. By doping or sensitization, it is possible to improve the photoactivity of TiO_2 nanomaterials in the visible region (Holfmann *et al.* 2010). Dye sensitized solar cells (DSSCs) were widely studied in the prospects of low cost investment and fabrication compared with other solar cell technologies (Hagfeldt *et al.* 2010). Recently DSSC reached the solar conversion efficiency of 12.3% (Yella *et al.* 2011). Currently, inorganic photo sensitized solar cells are being considered instead of organic dyes for their thermal stability (Jang *et al.* 2012).

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2. EXPERIMENTAL

2.1 Synthesis of TiO_2 powder

The solution of titanium (IV) isopropoxide $Ti(OC_3H_7)_4$ (Aldrich) was added dropwise in the isopropyl alcohol (Merck) and stirred for 30 min. The metal oxide gel was produced by increasing the pH by dropwise addition of 1 N NH_3 (Merck) solution. The resultant solution was stirred for 24 h and kept 1 day for aging. The precipitate was washed several times with distilled water and ethanol and dried in oven at 100 °C for 3 h to remove the solvent. It was calcinated at 400 °C for 3 h.

2.2 Preparation of Photoanode

A paste of TiO_2 nanopowder was prepared by the addition of few drops of poly vinyl alcohol. It was coated on ITO (15 Ω sq^{-1}, Sigma) substrate by doctor blade method to get approximately 10mm thick film and dried at 450 °C for 2 h (Wang *et al.* 2003).

This thin film was dipped 6 times in the aqueous cadmium chloride $CdCl_2$ (Merck) and sodium sulfide Na_2S (Merck) solutions alternatively which leads to the formation of cadmium sulfide CdS inside the porous structure of TiO_2 thin film and becomes photo sensitive film.

2.3 Fabrication of the solar cell

The photosensitive electrode and the carbon coated ITO counter electrode were separated by a spacer (~50 µm thick) and sealed by a standard Epoxy Adhesive (Araldite, Hindustan). The iodine electrolyte was inserted between the electrodes by capillary action and sealed.

3. RESULT & DISCUSSION

The prepared TiO_2 powderswere characterized by X-ray diffractometer (RAYOS-X) with monochromatic CuK(λ=1.5418 Å) radiation and the planes (101), (004), (200), (105), (211), (204) corresponding to the angles 2θ in the Fig.1 indicates the anatase structure of TiO_2 (JCPDS 73-1764). The FESEM image was taken by F E I Quanta FEG 200 in the Fig.2 shows the prepared thin film contains TiO_2 nano spheres of size 13 nm on the ITO glass plate.

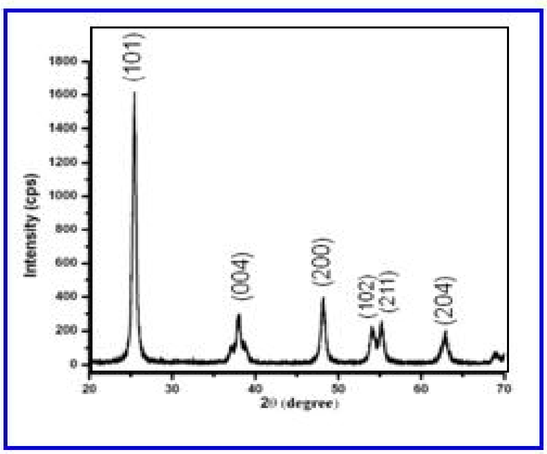

Fig.1: X-ray diffraction pattern of TiO_2

The UV-Vis spectrum in the Fig.3 shows the first absorption maximum at the wavelength 355 nm. The Tauc plot in the Fig.4 shows that the band gap energy of the synthesized TiO_2 powder is 3.2 eV.

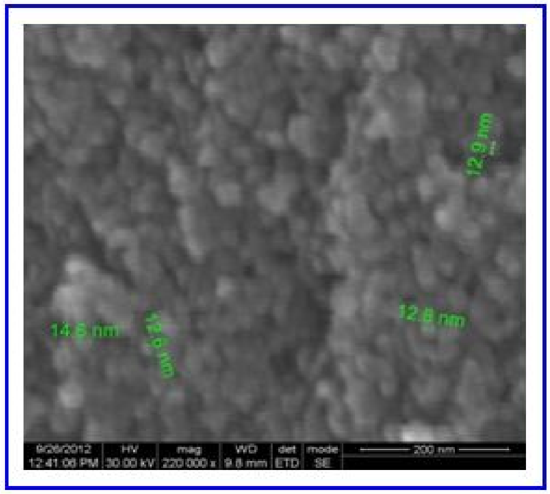

Fig. 2: FESEM image of TiO_2 thin film

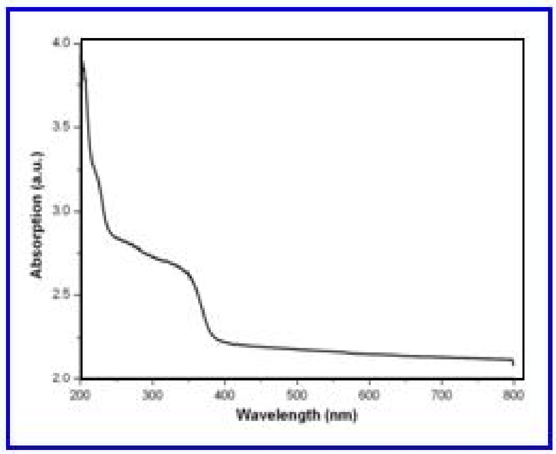

Fig. 3: Absorption spectrum of TiO_2

The I-V characteristics of the photovoltaic cell was observed by applying an external bias to the cell and measuring the generated photo current with a source meter (Keithley 2400) under the illumination of 100 m W cm^{-2} using 450 W xenon lamp (New port 91160 A) which is equivalent to 1.5 A.M of solar spectrum of 1000 Wm^{-2}.

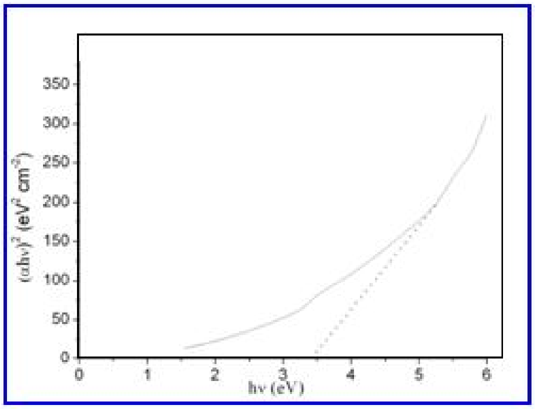

Fig. 4: Tauc plot for TiO_2

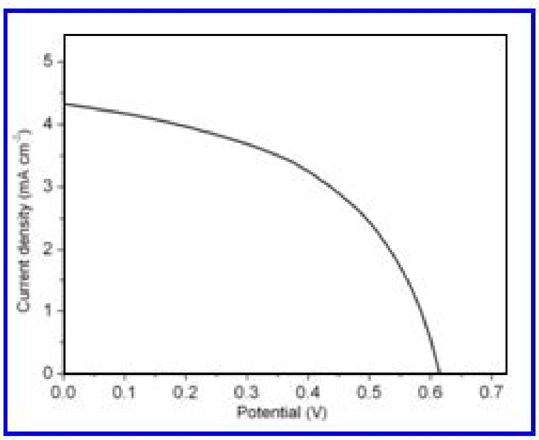

Fig. 5: I-V Characteristics of solar cell

The I-V characteristics of the solar cells with the CdS sensitizer were shown in the Fig.5 and the corresponding, short circuit photocurrent density (J_{sc}=4.329 mA), open voltage (V_{oc}=0.615 V), fill factor (FF=49) and efficiency (h=1.31%) The photo conversion efficiency of the solar cell with CdS sensitizer was due to the photoactivity of the CdS for visble radiation.

Photo excited electrons generated by the CdS sensitizers are injected into the wide band gap semiconductor TiO_2 and reached the ITO, while holes are transferred to the counter electrode via a redox electrolyte. The voltage generated under illumination corresponds to the difference between electrochemical potential of the electron at the two contacts, which is the difference between the Fermi level of the CdS sensitized TiO_2 layer and the redox potential of the electrolyte. Over all, electric power is generated without permanent chemical transformation.

4. CONCLUSION

The anatase form of nano structured TiO_2 thin films were deposited on ITO substrates by doctor blade method. From the XRD and FESEM image the size and structure of the thin film were discussed. CdS sensitized solar cell fabrication technique and working principle were discussed. The solar conversion efficiency and fill factor were calculated from the I-V curve drawn from the data obtained under the standard illumination.

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