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Prunus domestica dye extraction for fabrication of zinc oxide based dye-sensitized solar cells

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Abstract

Aluminium doped Zinc Oxide (AZO) seed layers were deposited on Fluorine doped Tin Oxide (FTO) substrates using a spin coating technique. These were then immersed in growth solutions of zinc nitrate, hexamethylenetetramine and distilled water to develop nanoplates of Zinc Oxide (ZnO). The nanostructures of ZnO grown on FTO were studied using X-ray diffraction techniques. Dye-sensitized solar cells (DSSC) were fabricated using two prepared electrodes, one of dye-loaded zinc oxide and another that was platinum coated. The electrolyte used was potassium iodide iodine solution. The performance of the assembled DSCCs was tested by drawing an IV curve. The results showed that the short circuit current and open circuit voltages were about 10 microamperes and 270 millivolts respectively.

Keywords: Zinc Oxide; Seed layers; Spin coating; Hydrothermal; Solar cells.

1. Introduction

In recent years a wide band semiconducting material ZnO has been an attractive and efficient material to be utilized in fabrication of dye-sensitized solar cells [1-5]. ZnO can be prepared using several methods, spin coating [6], spray pyrolysis [7], chemical bath deposition [8], dip coating [9]. Its morphology, electronic as well as optical properties depend on method of preparation. ZnO is a very versatile material because it's electrical and optical properties can be tailored by doping with different elements such as Aluminium, Boron, Fluorine [10-12]. The fabrication of DSSC with various types of ZnO nanostructures such as nanowires, nanoflowers, nanoribbons has been reported [1]. Another vital component which affects the performance of DSSC is the type of dye extraction used to sensitize high band ZnO. Because of low cost and environmentally friendly material the different types of natural dyes from fruits and

flowers can be used to fabricate solar cells [13-14]. This work reports the measurement on performance of DSSC fabricated with nanoplates of ZnO and prunus domestica dye extraction.

2. Experimental

ZnO nanostructured films were grown by using a two-step spin coating and hydrothermal process on glass as well as FTO substrates. A precursor solution was made using zinc acetate, diethanolamine, and ethanol solution for spin coating [6]. Before coating the solution substrates were ultrasonically cleaned using acetone and rinsed with distilled water several times. The growth solutions were prepared by mixing equal molar concentrations of zinc nitrate and hexamethylenetetramine in distilled water at room temperature. The AZO coated substrates were dipped into the growth solution at the constant temperature of 90±5^{o}C for 2 hours for the ZnO nanostructures to grow [15]. After taking out from the solution these were rinsed with distilled water and dried in air at 400±5^{o}C for 30 minutes. Investigation on effect of thickness of seed layer on optical property of ZnO has also been made in this work. Dye extraction from the bark of prunus domestica is used to sensitize the ZnO layer. To extract the dye from prunus domestica locally called as plums, we first collected few pieces of bark of prunus domestica. It is then cleaned and dried in air. A 50gm of this is then dropped into ethanol and heated at constant temperature of 60±5^{o}C for 2 hours which gives the nice red color solution. As-prepared ZnO films were characterized by using x-ray diffraction, and ultra-violet visible spectrophotometer. We have measured the short circuit current and open circuit voltage of assembled DSSC using Digital Fluke Multimeters. The absorbance spectrum of dye extraction is measured using spectrophotometer. Above developed ZnO films were then dipped into the dye solution at constant temperature of 60±5^{o}C for 6 hours for dye loading. Finally, we assembled the dye loaded ZnO electrodes and platinum coated counter electrode prepared by spin coating method using 5mM potassium iodide iodine liquid electrolyte solution [16]. The I-V curve of assembled DSSCs was measured using two digital Fluke Multimeters Model 179.

3. Results and Discussion

3.1 Structural Properties

Figure 1 shows the X-ray diffraction pattern of ZnO film deposited on FTO substrate. The peaks observed at 2θ = 35.38^{o} (d = 2.53Å), 37.84 ^{o} (d= 2.37Å) and 48.65 ^{o} (d=1.86 Å) corresponds to ZnO peaks orientating along (002), (101) and (102) planes respectively when comparison was made with standard spectrum of Joint Committee on Power Diffraction Standards (JCPDS) values from PDF card # 361451 [6]. The XRD pattern also shows other low intensity ZnO peaks at 2θ = 56.14 ^{o}, 63.19 ^{o}, 64.38 ^{o} and 67.17^{o} which corresponds to (110), (103), (200), and (112) planes respectively. The d spacing values were found to be slightly shifted from standard values which may be due to either Al doping in zinc acetate solution or stress produced in the film. The FTO peaks were also significantly observed in the diffraction pattern at 2θ = 28.16^{o} (d = 3.16Å), 39.46^{o} (d = 2.28Å), 53.16^{o} (d = 1.72Å) respectively. We calculated the average crystallite size of ZnO film by measuring the full width half maximum of peaks using the Debye

Scherrer's formula, D= 0.9 λ/β cosθ [6-7]. The symbol λ, β, and θ represent the wavelength of X-ray (1.54Å), width of peak, and bragg's angle respectively. The average value of crystallite size was calculated by measuring the full width half maximum (FWHM) of first two ZnO peaks of (002) and (101) orientations and it was found to be of 239Å.

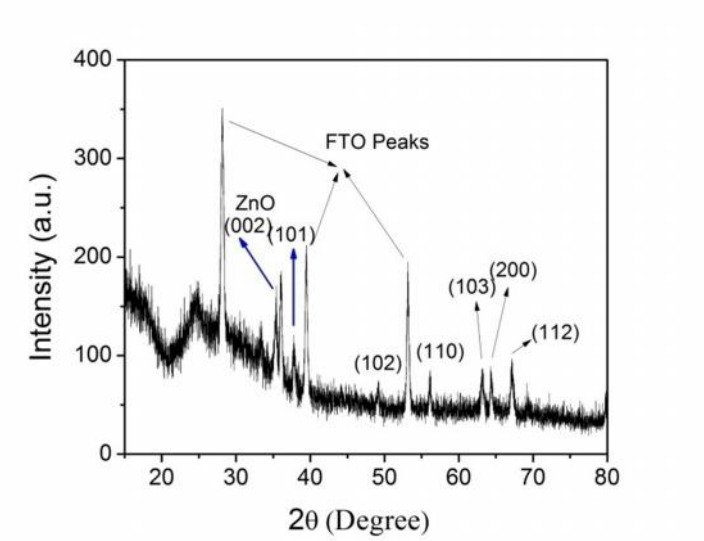

Fig. 1: X-ray diffraction pattern of ZnO film grown on FTO substrate at 90±5^{o}C (Sample A5).

3.2 Scanning Electron Microscope

The previous report on study of morphology of the ZnO film prepared on glass substrate from 0.3M Al doped zinc acetate precursor solution and 25mM growth solution is shown in Figure 2 below. It shows the formation of nano-plate like structures. The average thickness and breadth of ZnO plates are of 96nm and 480nm respectively [17].

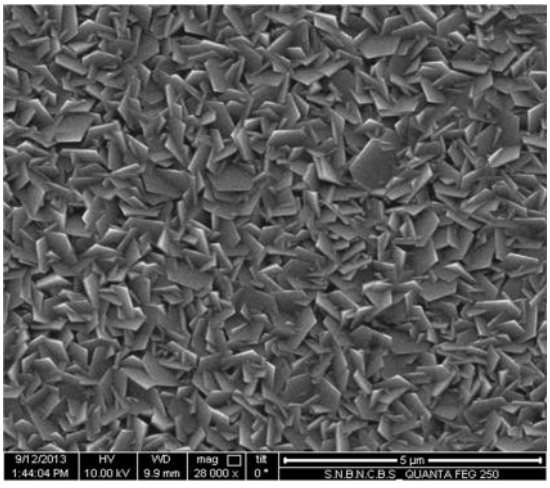

Fig. 2: A scanning electron microscope image of ZnO film grown on glass substrate.

3.3 Optical Properties

The optical transmittance curves as a function of wavelength for hydrothermally grown ZnO films on FTO substrates at 90±5^{o}C were shown in figure 3a (sample A1) and 4a (sampleA5) respectively. The transmittances (T %) of all films were about 60% in the visible region. The band gap values were estimated by the Manifacier method for the deposited ZnO films [6-10].To calculate band gap of ZnO the graphs of $(\alpha h\nu)^2$ versus photon energy hn (eV) for films A1 and A5 were plotted where a represents the absorption coefficient of ZnO. These graphs were shown in figure 3b and 4b respectively. By extrapolating the linear portion of energy curves on hν axis gives the band gap of ZnO. The calculated values of band gap of A1 and A5 are found to be 3.04eV to 3.08eV respectively. It is inferred that no significant change in transmittance (T%) as well as band gap on increasing AZO thickness from 1 coat to 2 coats while depositing ZnO films on FTO substrate in hydrothermal process.

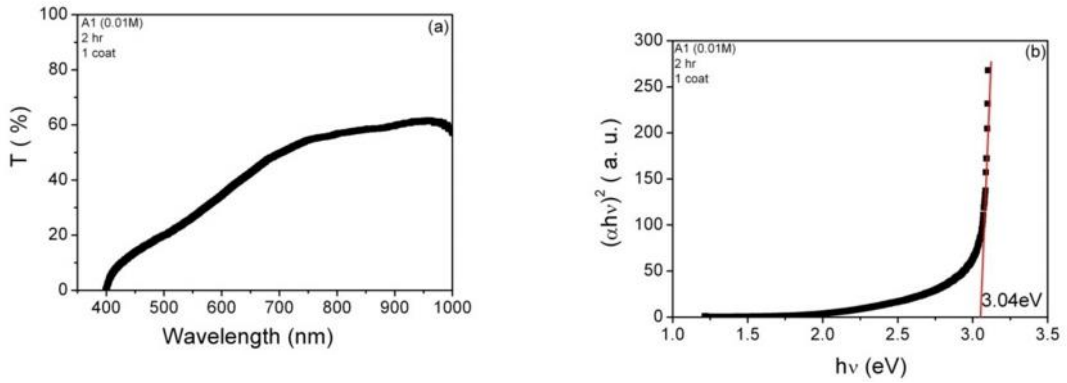

Fig. 3: (a) Transmittance versus wavelength (b) $(\alpha h\nu)^2$ versus hν of ZnO film grown on FTO substrate (Sample A1).

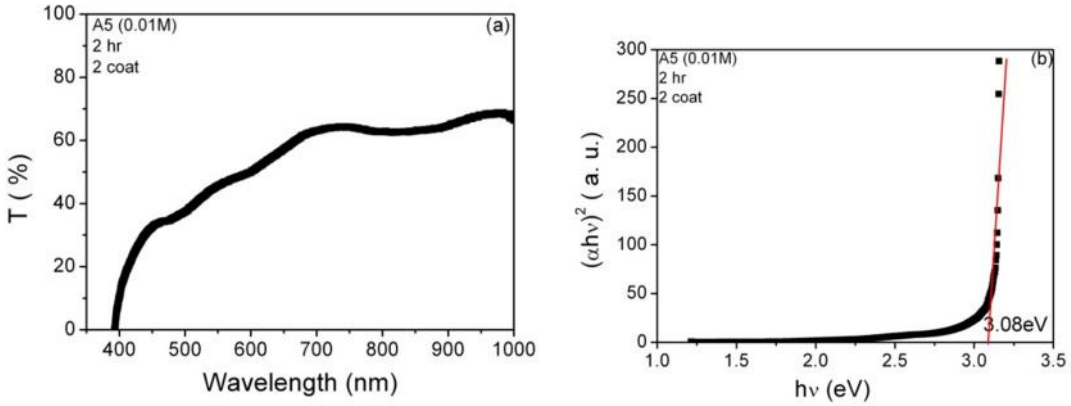

Fig. 4: (a) Transmittance versus wavelength (b) $(\alpha h\nu)^2$ versus hν of ZnO film grown on FTO substrate (Sample A5).

In this paper we have used the prunus domestica dye extraction to assemble DSSC. The captured absorption spectrum of dye extraction is shown in figure 5a. The spectrum shows the absorption peak at 365nm. The ZnO nanostructured films dipped into the dye solution for 6 hours at 60^{o}C for sufficient amount to be adsorbed. Finally, the solar cell is assembled using as prepared ZnO photoanode, platinum coated counter electrode of FTO and potassium iodide iodine redox electrolyte [16]. The performance of encapsulated DSSC is tested by measurement of current voltage characteristic curve shown in figure 5b. It clearly shows the same behavior of I-V curves for two different light intensities. Black colored filled squares symbol in the figure represent the power generation from assembled dye-sensitized solar cell with and 500W halogen light source and red filled circles represent the dark light of room only respectively. The result showed the maximum short circuit current of about 10 microampere and open circuit voltage of 270 millivolts respectively.

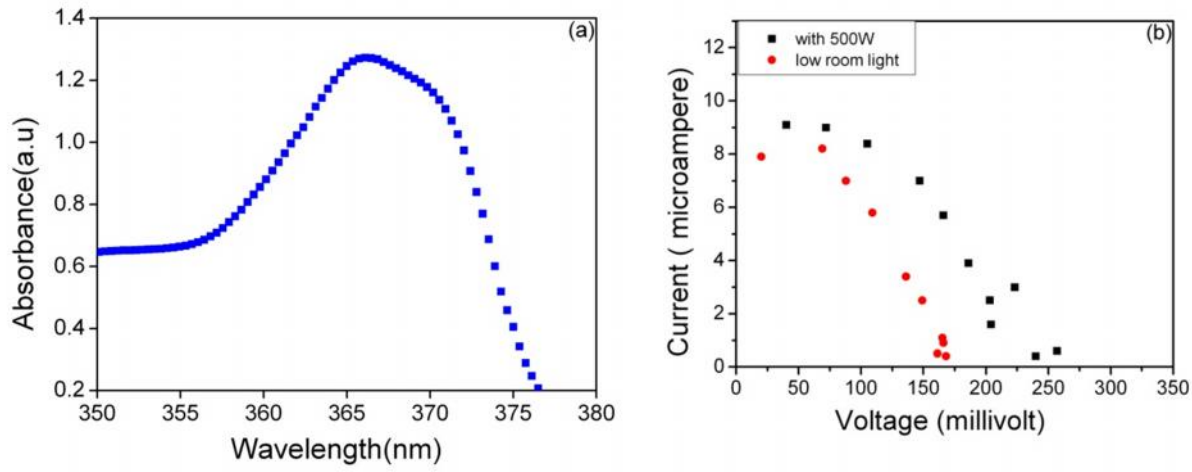

Fig.5: (a) The absorption spectrum of prunus dye extraction solution.(b) Current voltage characteristic curve of fabricated dye sensitized solar cell.

4. Conclusions

ZnO films were successfully deposited on glass and FTO substrates using an economic two step spin coating followed by hydrothermal method. X-ray diffraction analysis confirms that the ZnO deposited was of polycrystalline wurtzite structure. The average crystallite size of ZnO was 239Å. An Optical analysis showed that band gap of ZnO film was only slightly increased from 3.04eV to 3.08eV as the thickness of seed layer was increased from 1 coat to 2 coats. The measurement on current voltage curve of assembled ZnO based solar cell using prunus domestica dye extraction shows the short circuit current of 10 microampere and open circuit voltage of about 270millivolts respectively.

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