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Structural and Electrical properties of ZnO Nanorod based dye sensitized solar cell

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ABSTRACT:

ThePreparation of nanorod involves simple and novel design of sol-gel process. Further, by using the prepared nanorods, working electrode will be prepared and it will be sensitized with ruthenium dye. A platinum coated FTO electrode will be used as a counter electrode. Dye sensitized solar cell will be assembled by using the working electrode and counter electrode. FE-SEM and UV characteristics have been carried out at 250°C, 350°C&450°C. The size and band gap of nanorod at these temperatures has been found out to be 1µm and 2.95eV, 200nm and 2.86eV, 100nm and 2.79eV respectively. The power conversion efficiency and the fill factor have been obtained as 2.72% and 0.722 respectively.

KEYWORDS:

ZnO, Nanorods, Dye-Sensitized Solar Cell, Characterization Techniques

ACADEMIC DISCIPLINE AND SUB DISCIPLINE:

Electrical and Electronics Engineering

SUBJECT CLASSIFICATION:

Advanced third generation solar cell

TYPE (METHOD/ APPROACH) :

Sol-Gel Process

1.INTRODUCTION:

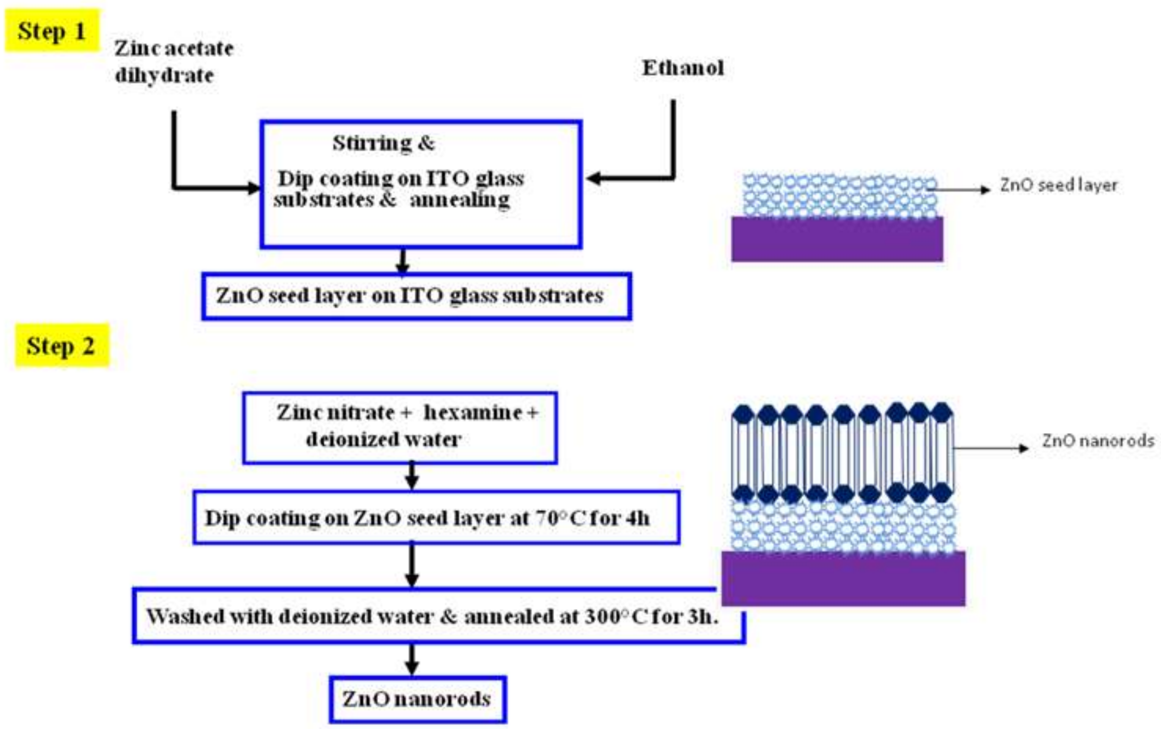
The Electrophoresis Deposition method was used for the photo electrode fabrication of a Dye Sensitized Solar Cells with different thickness of Platinum used as counter electrodes with the photo electrode substrate being titanium sheet and flexible stainless steel sheets **[1]**. Syrrokostas et al., have reported that usage of stored paste would lead to less cracks during drying of films when compared to freshly prepared films. Counter electrodes prepared using electrodeposition of aqueous solution of chloroplatinic acid improved the photocurrent and fill factor of solar cell when compared to thermal decomposition of chloroplatinicacid**[2]**. Kim et al., have reported a conversion efficiency of 0.44% and 1.54% for nano particulate electrode and oriented nanorod electrode of ZnO respectively with the cell area being 1.5*1.5 cm^2 for both types **[4]**. Lenzmaan et al., have reported a coversion efficiencies and fill factors in the range of 6.3%-11.4% and 60%-74% respectively using N-719 and N-749 dyes at various sizes with Titanium oxide as electrode**[5]**. Sokolsky et al., have reported that it is possible to use flexible plastic as support substrate instead of glass with the conducting electrode being made of ITO or FTO. Sokolsky et al., also have reported that drag coating or casting slurry of nano crystals using spray as the method of fabricating thin films and subjecting the films to calcinations at 400-450°C and also the photostabilityof the sensitizer must be good **[7]**. Regan et al., have reported a conversion efficiency in the range of 7.1%-7.9% in simulated solar light and 12% in diffuse daylight with the thickness being 10-µm and the size of the TiO_2 particles in nanometers **[9]**. Raja et al., have studied the solar cell applications of bundle like ZnO nanorods and have found the conversion efficiency and average diameter to be 0.83% and 200-nm respectively compared to vertically aligned nanorods whose parameters are 0.74% and 100-nm respectively **[11]**.

2. EXPERIMENT:

The ZnO nanorods will be synthesized by the following well-documented procedures. All chemicals will be used in this study are of high purity which were purchased from Junsei Chemical, Tokyo and is going to be used without further purification unless otherwise stated. To synthesize ZnO nanorods, a two step chemical method will be used. In the first step, ZnO seed layer is going to prepared using sol–gel dip coating method. For the fabrication of ZnO seed layer, 0.2 M zinc acetate dihydrate ($Zn(CH_3COO)_2 2H_2O$) will be dissolved in a mixture of 10 ml ethanol and 0.2 M ethanolamine ($NH_2CH_2CH_2OH$). The dip coating method is going to used to prepare ZnO thin film using the prepared solution on to FTO coated glass substrates. The prepared thin films will be heated at 200°C for 30 min and these films form the ZnO seed layer. To prepare ZnO nanorods, an aqueous precursor solution will be prepared by dissolving 0.1 M zinc nitrate ($Zn(NO_3)_2 6H_2O$) and 1 M hexamine ($(CH_2)_6N_4$) in deionized water. Then, the seed layer will be vertically dipped in the aqueous solution, and it is going to maintained at a particular bath temperature for 4 h. At the end of the growth period, the substrates will be removed from the solution and is going to thoroughly washed with deionized water to remove the residual salt from the surface of the film. After this, the prepared film is going to annealed at 450°C for 30 min, and this may resulted in the formation of ZnO nanorods. In cell assembly section, the prepared ZnO nanorod electrodes areimmersed in aN719 dye solution for the adsorption of the dye. A Pt-coated FTO electrodewill be then placed over the dye-adsorbed electrode, and the edges of the cellare sealed with a sealing sheet (PECHM-1, Mitsui-DupontPolychemical). A drop of redox electrolytesolution will beinjected into the

drilled hole in the counter electrode. Finally, the hole is sealed using additional cello tapes and the size of the electrode used will be around0.4 cm^2.

The prepared ZnO nanorodswill be characterized by FE-SEM to determine the size and structure of ZnO nanorod using ZEISS scanning electron microscopy, UV- Visible absorption spectroscopy to find the band gap of aligned ZnO nanorod, EDAX to determine the composition of the elements present in sample, X-Ray Diffraction technique to determine the size and structural properties of coated material, V-I curves were obtained using white light from xenon lamp(max 150W) using sun 2000 solar simulator where the incident light intensity was one sun illumination(100mW per cm^2).



3. RESULTS AND DISCUSSION:

3.1 X-ray diffraction

X-ray diffraction technique has been used to study the structural properties of the prepared ZnO films. The ZnO films formed using a single coating was found to be very thin and amorphous in nature. The x-ray diffraction pattern of the films prepared using a single coating is shown in Figure 1. The diffraction pattern shows no peaks clearly depicting that the films formed using a single coating are amorphous in nature and it has been found that even annealing does not help the nucleation and growth of the grains. So in the present study ZnO thin films have been deposited onto glass substrates, the film allowed to dry by heating and then allowed to cool to room temperature. The diffraction peaks are located at the angle (2θ) of 31.73, 34.48, 36.31, 47.76, 56.76 and 63.23 which correspond to (100), (002), (101), (102), (110) and (103) planes of ZnO and indicates that the ZnO nanorods are of hexagonal phase **(JCPDS No. 36-1451)**. The diffraction pattern shows that the intensity of the peaks increases with increase in annealing temperature. This is due to the improvement in the crystalline nature of the prepared ZnO films on annealing. The peaks are observed to become narrower with annealing indicating the grain growth on annealing. The lattice parameter values a and c have been calculated using the relation $\{1/d^2 = (h^2+k^2)/a^2 + l^2/c^2\}$, and the calculated values are a = 3.236 Å, c = 5.194Å and are in good agreement with the standard values. Particle size of ZnO thin films prepared using ethanol and annealed at 450 temperatures is 35 nm.

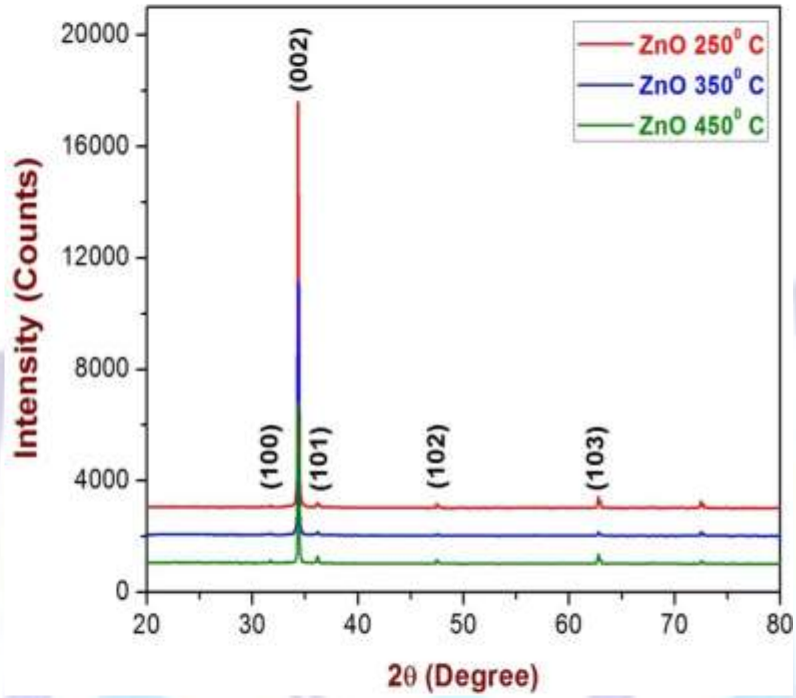
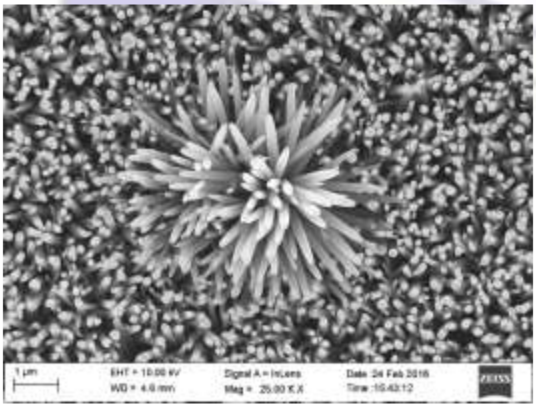


Fig 1: X –ray diffraction pattern of ZnO film at different temp.

3.2 Field emission scanning electron microscope

The field emission scanning electron microscope image of flower like structured ZnO thin films annealed at 250°C, 350°C 450°C are shown in Figure 2, figure 3 and figure 4 respectively.



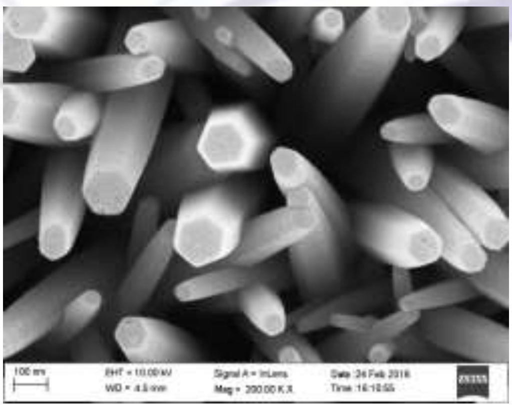


Fig2: 250°C annealedFig 3: 350°C annealed **Fig 3: 350°C annealed**

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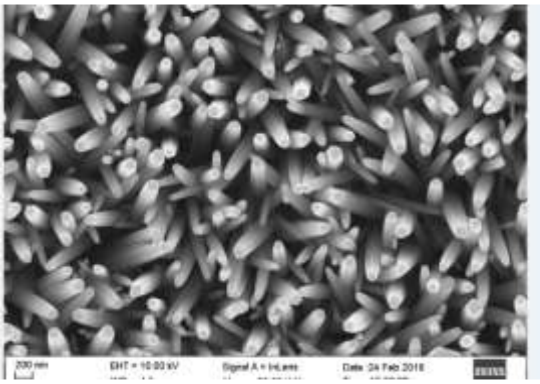

Fig4: 450°C annealed

The films are found to have flower like arrangement. The film annealed at 450°C is found to have more branches of flowers than 350°C & 250°C annealed films. When the annealing temperature was decreased, there was a decrease in size of the flower like structure. This is due to the fact that during annealing the branches of flowers are formed .So the 450°C annealed flower films are more suitable for CdS quantum dot absorption compared with 350°C annealed flower films, because the branches of the flower introduces large surface area paving way for the absorption of quantum dots and light-quantum dot interactions. Each small crystal in the typical flower-like ZnO grows from the individual crystalline nucleus. From the FE-SEM image it is concluded that the flower like structured ZnO is composed of nanocrystalline ZnO grown homocentric instead of a simple aggregation of small crystallites.

3.3 UV-visible absorption spectroscopy

The optical properties of ZnO films have been studied using the transmittance spectra recorded using a UV-Vis spectrophotometer. Figure 5 shows the optical transmittance spectra of the ZnO films prepared using Constant amount of ethanol and annealed at different temperatures.

Table-1: Band gap value of the ZnO films

Annealing Temperature (° C)	Band gap for constant amount of ethanol (eV)
250	2.95
350	2.86
450	2.79

From the table 1 it is found that the band gap energy of the ZnO films decreases with increasing annealing temperature. This is due to the increase in grain size on annealing. If the band gap energy of ZnO film decreases then a very small amount of energy is needed to transfer the electrons from valence band to conduction band.

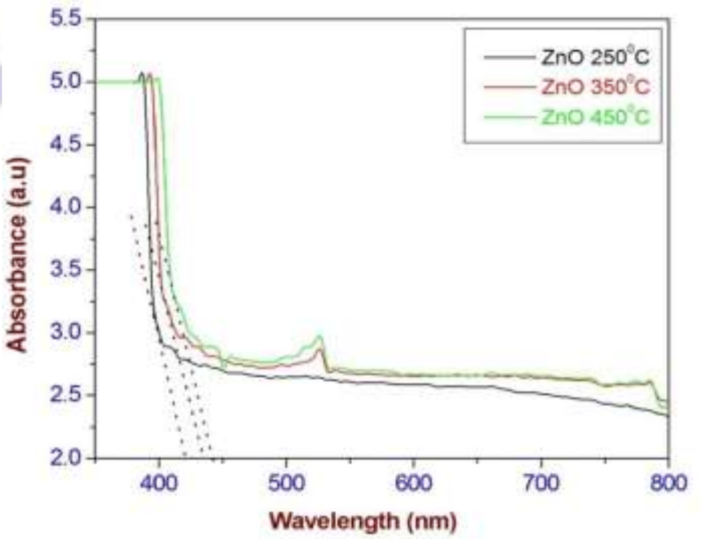

Fig5: UV-Visible Spectrum of ZnO film at Various annealing temp

3.4Energy dispersive analysis of x-rays

The chemical composition of the ZnO nanorods has been studied using energy dispersive analysis of X-ray (EDAX) and the EDAX pattern is shown in Figure 6 The result shows the presence of 86.04 at.% of Zn and 13.96 at.% of O.

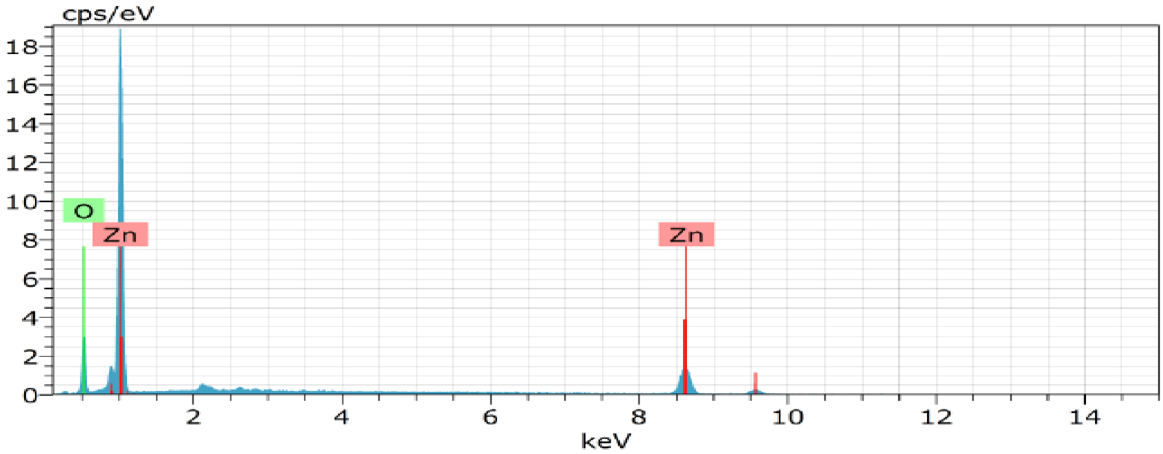

Fig6: EDAX pattern of ZnO thin film

3.5 V-I characteristics

The voltage, current and current density are listed in table 2. Using the table 2 the graphs are plotted between voltage Vs current and voltage Vs Current density are shown in Figures 7 and figure 8. The dye sensitized ZnO thin film based solar cell using liquid electrolyte exhibited a power conversion efficiency (η) of 2.72% with a short circuit current density (Jsc) = 49.88 A/mm2, open circuit voltage (Voc) = 0.7541 V , fill factor (FF) = 0.722 and (Isc) short circuit current= 1.24mA.

Table-2: Voltage Vs Current, Voltage Vs Current density characteristics

E/V	I/mA	J(A/mm^2)	E/V	I/mA	J(A/mm^2)
0	5.052	12.63	0.4	4.916	12.29
0.05	5.04	12.6	0.45	4.88	12.2
0.1	5.032	12.58	0.5	4.828	12.07
0.15	5.02	12.55	0.55	4.732	11.83
0.2	5.008	12.52	0.6	4.548	11.37
0.25	4.996	12.49	0.65	4.06	10.15
0.3	4.968	12.42	0.7	2.812	7.03
0.35	4.952	12.38	0.75	0.284	0.71

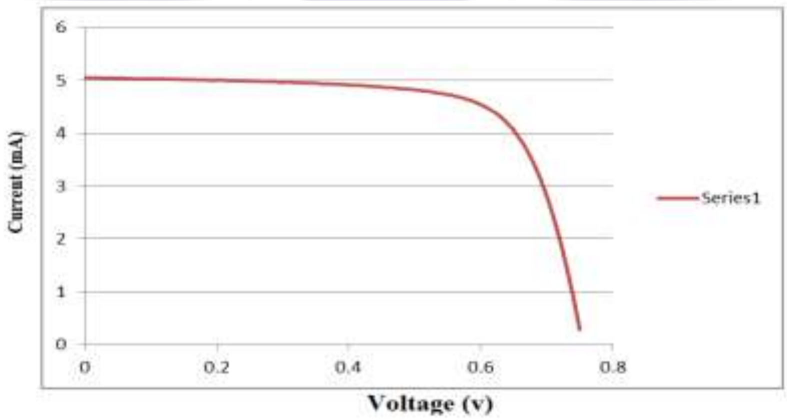

Fig7: Voltage Vs Current graph for 450° C

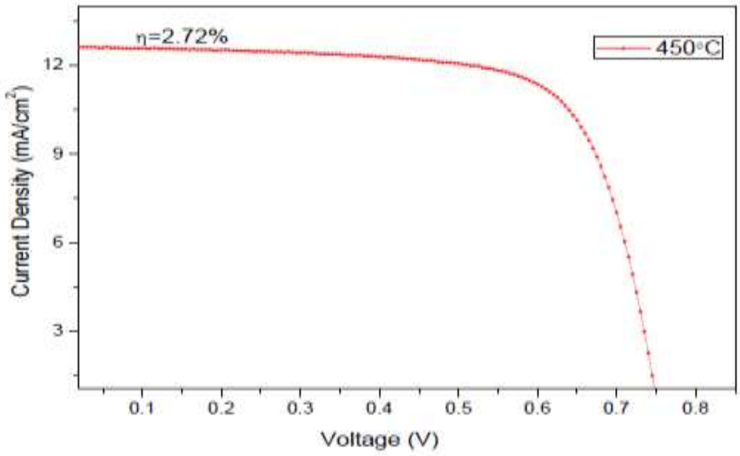

Fig8: Voltage Vs Current density graph for 450°

4. CONCLUSION:

A well aligned and uniform morphology ZnO nanorod based Dye Sensitized Solar Cell has been prepared and different characterization techniques like XRD, EDAX, FE-SEM and UV along with V-I characteristics have been performed. XRD technique shows the size of ZnO nanorods as 35-nm with the film aligned at 450^oC. The band gap energy of the ZnO film is found to be 2.79eV at 450^oC. The conversion efficiency and the fill factor of the solar cell have been found out as 2.72% and 0.722 respectively. The values of V_{oc} andI_{sc} has been determined as 0.75V and 5.052 mA respectively.

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