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Preparation of Nano-thin films of ZnO by Sol – Gel method and applications of solar cells Hetrojunction

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Abstract

In this research was to prepare ZnO by sol – gel method and then deposited on the(ITO - glass, Silicon wafer and glass) substrates by spin- coating 2000 rpm and then thermally treated in a furnace heat. Then the samples were examined by X-Ray, as well as UV and then was PMMA deposition at different spin sped by using spin-coating (1000, 2000 and 3000) rpm for Nano-thin film (67, 91, 182) nm respectively. Then the samples were examined to feature current and voltages darkness and light extraction efficiency of the solar cell where they were getting the best efficiency is when the thickness of the oxide42 nm and 91 nm where the polymer was 2.1%.

Keywords: Zinc oxide (ZnO), sol-gel, PMMA polymer, Nano-thin film

1. Introduction

Zinc oxide (ZnO) is one of the most important semiconductor materials with direct wide band gap (3·2– 3.37 eV) and good transparency (Wang 2004) at room temperature and Due to large exciton binding energy of 60 meV (Wang et al.2007), they have potential applications in Optoelectronic devices such as in solar cells (Fortunato et al 2004). Optical wave guide (Kawasaki et al 1998), Light emitting diodes (LED) (Tsukazaki et al 2005).

Zinc oxide thin films are applied in Thin Film Transistors (TFT) (Ohya et al 2001) and have been recognized as Spintronic material (Sharma et al 2004). Various gas, chemical and biological sensors were based on ZnO thin film (Kang et al 1993) .Thin films of Zinc oxide can be prepared by various techniques; among them are Sputtering (Moustaghfir et al 2003), Chemical Vapor. Deposition (CVD) (Haga et al 2000), Laser ablation (Narasimhan et al 1997), Sol-gel (Bao et al 1998), Spray pyrolysis (Paraguay et al 1999) have studied structural & optical properties of nanocrystalline ZnO thin films derived from clear emulsion of monodispersed ZnO nanocrystals (Bao et al 1998 & Inoguchi et al 2009). Recently, ZnO has attracted substantial attention due to its excellent physical properties and potential technological applications (Akkilic1 et al 2012) Zinc oxide is an inexpensive n-type semiconductor having which crystallizes in hexagonal Wurtzite structure (c = 5.025 and a = 3.249) (Jagadish et al 2007). Zinc oxide has the hexagonal wurtzite structure (Fig. 1). The crystal can be described as alternating planes composed of tetrahedrally coordinated O2− and Zn2+ ions, stacked along the c-axis (Risti et al 2005 & Pearton et al 2005).

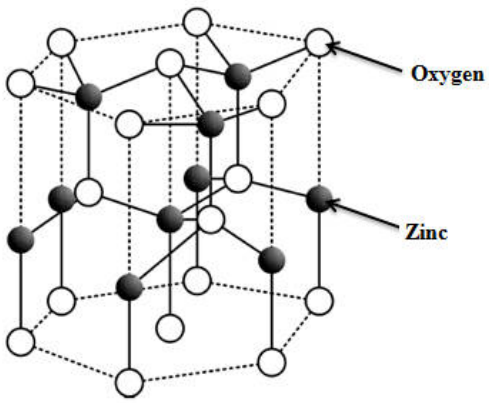

Figure 1: Wurtzite ZnO.

Hybrid polymer solar cell is a promising photovoltaic technology, offering environmental stability, low-cost manufacturing, and versatile applicability (Beek et al 2005, Wienk 2004 & Lee 2009).

Solar cell is a large-area p–n junction designed to convert sunlight into electric current efficiently. Solar cells use the photovoltaic effect, whereby excess photo-generated minority carriers are influenced by the device performance (Ehsan et al 2012). Figure 2 shows the current–voltage (I–V) characteristics of a solar cell in the dark and under illumination (Oman et al 1999).

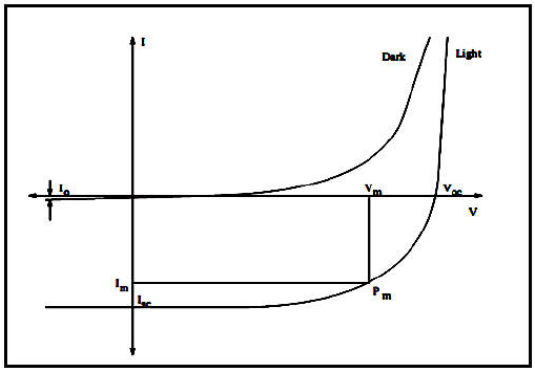

Figure 2: I–V Curve of the Solar Cell in the Dark and under Illumination

The solution processing of polymer organic photovoltaic devices may offer an inexpensive technology to fabricate solar cells with large areas. Hybrid polymer-inorganic solar cells utilize the high electron mobility inorganic phase to overcome charge-transport limitations associated with organic materials. Zinc oxide [ZnO] has been regarded as an excellent semiconductor material for the solar cell due to its high electron mobility as well as the high chemical and thermal stability (Lidan et al 2012). Various polymer /ZnO hybrid solar cells have been reported (Lidan et al 2012 & Krebs et al 2008).

The PMMA is a photovoltaic encapsulation material that has a high transmission particularly in the region where the spectral response of solar cells is higher and the diffusion coefficient is low. At the same time, it presents an optimal environment for the dissolution of the luminescent species. It also supports the heat treatment that solar cells are subjected during their manufacturing and have a photo-stability extended over long periods of 20-25 years It is also recyclable and has an excellent stability against ultraviolet (UV) radiations (Ayad et al 2012, Baileya et al 2007 & Mahfoud et al 2013). Polymethyl methacrylate (PMMA) is an excellent photovoltaic encapsulation material which was introduced recently in the manufacturing process of photovoltaic modules (Znaidi et al 2012).

2- Synthesis of ZnO

ZnO thin film were deposited on glass, ITO-glass and Silicon wafer by using sol-gel method [30]. Zinc acetate ($Zn(CH3COO)_2{\cdot}2H2O$, Sigma-Aldrich – 99.99%) was added in mixture of isopropanol ($((CH_2)_2CHOH$, Sigma-Aldrich – 99%), and monoethanolamine (MEF), ($H_2NCH_2CH_2OH$, Aldrich – 99.99%). The molar ratio of MEF to zinc acetate was maintained at 1, where the amount of zinc acetate was adjusted to 1.0 mole. The mixture was stirred at 60 ^oC for 1 hr and the aged at room temperature (RT) for 24 hrs to yield a homogeneous soluation.The resulting precursor solution was kept overnight for stabilization and used to deposit film. The substrates were cleaned by ultrasonication in acetone for 5 min.The precursor solution was deposited on glass, ITO-glass and Silicon wafer substrates by spin- coating model (VTC-100 vacuum spin coating) at 2000 rpm as shown in figure 3 . As synthesized nano thin films, were preheated at 250 ^oC for 5 min in a furnace to evaporate the solvent and remove organic residuals (Kim 2009) JINYU – 1700 furnace as shown in figure 4.

The films were then post-heated (annealed) in air at 450°C for 2 hr in order to obtain crystallized ZnO. The thicknesses of ZnO films measured by Spectroscopic Ellipsometry. Thickness of the prepared films were 47 nm for spin-coating techniques at 2000 rpm. Fig. 5 showed the Experimental sol-gel and ZnO thin-film formation processes.

Figure 3: spin coting system.

Figure 4: spin coting system.

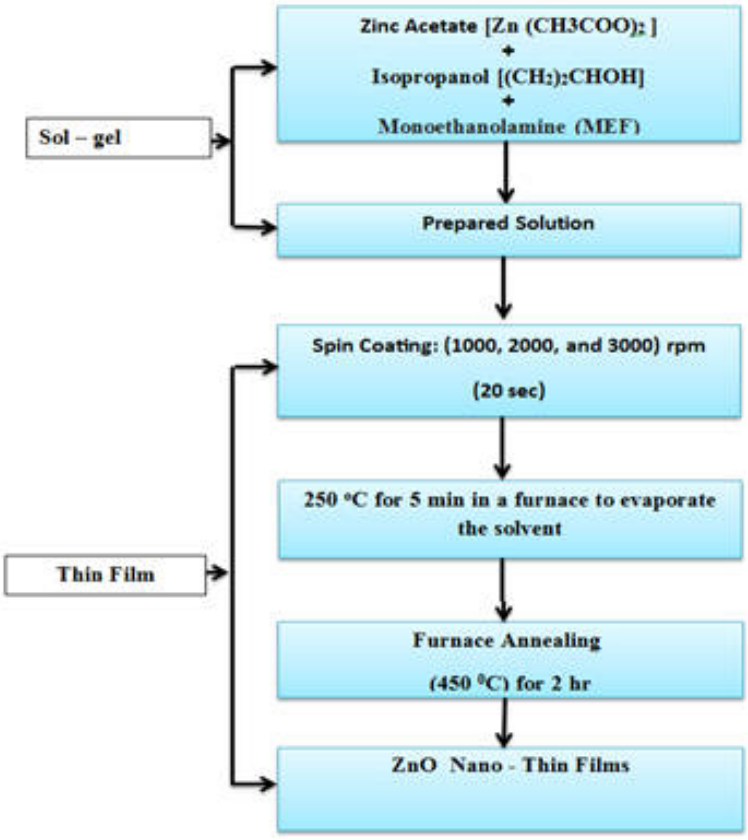

Figure 5: Experimental sol-gel and ZnO thin-film formation processes.

After that deposition of thin films of polymer [Poly(methyl methacrylate) PMMA] by spin coting and different spin speed (1000 , 2000 and 3000) rpm on (ITO-glass), silicon wafer and glass sled who has been Preparation

of Nano-thin films of ZnO . The thickness of the PMMA films can be controlled by the spin coating process as following: Nano-films of (PMMA) were deposited on silicon wafers with 1mm thick (n-type silicon) by using spin coating. The thickness of the PMMA films can be controlled by the spin coating process as shows in figure 3. The thicknesses of ZnO films measured by Spectroscopic Ellipsometry as shown in Table 1 , gold metal was deposited onto the back contact using vacuum coating system on PMMA side, figure 6 show the vacuum coating system . Figure 7: Schematic of PMMA/ZNO –ITO –glass substrates. While PMMA side has been coated with number more than five circular gold electrode and the area of each one is 0.0314 mm2, as shown in figure 7,so that the average J-V characteristics were taken.

Table 1 shows the thickness versus spin speed

Spin speed (rpm)	Thickness of PMMA film(nm)
1000	182
2000	91
3000	67

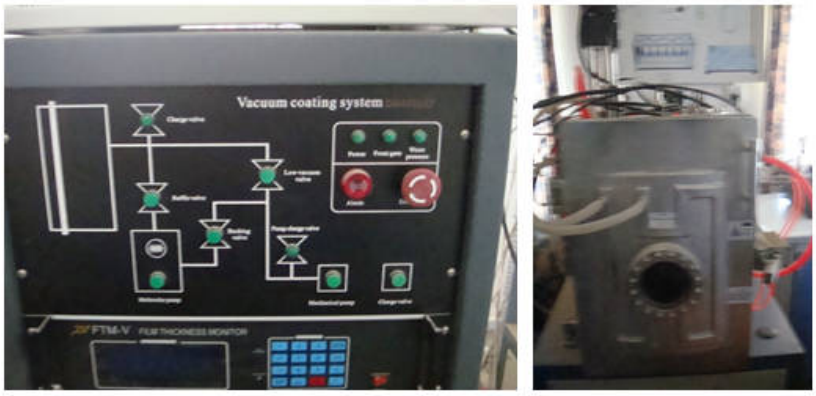

Figure 6 the vacuum coating system

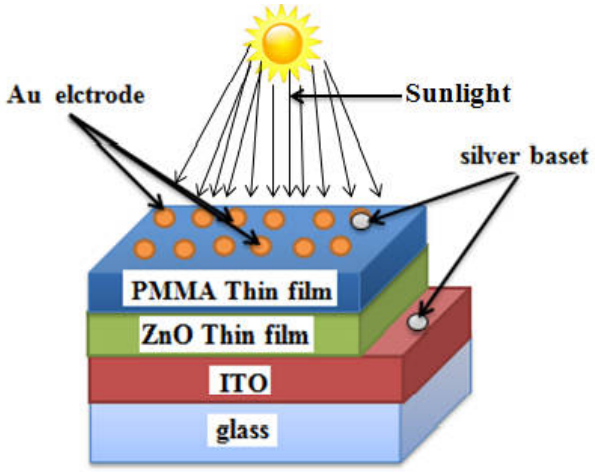

Figure 7: Schematic of PMMA/ZNO -ITO –glass substrates

3-Results and Discussion

3.1 XRD analysis

The crystal structure of ZnO films was investigated through X-ray diffraction (XRD).The X-ray diffraction spectrum of ZnO film annealed at 450ºC with prominent reflection planes is shown in figure 3.The peaks in the XRD spectrum correspond to those of the ZnO patterns from the JCPDS data (Powder Diffraction File, Card no: 36-1451), having hexagonal wurtzite structure with lattice constants a=3.24982Å, c=5.20661Å.The presence of prominent peaks shows that the film is polycrystalline in nature. The lattice constants 'a' and 'c' of the Wurtzite structure of ZnO can be calculated using the relations (1) & (2) given below (Suryanarayana & Norton 1998).

$$a = \sqrt{\frac{1}{3}}\frac{\lambda}{\sin\theta} \qquad 1$$

$$c = \frac{\lambda}{\sin\theta} \qquad 2$$

For (002) plane calculated values are a= 3.15 and c= 5.29 which agrees with the JCPDS data. The crystallite size of the ZnO films annealed at different temperatures was calculated by using Scherer's Formula relation 3 (Cullity & Stock 2001).

$$D = \frac{0.9\lambda}{\beta\, cos\theta} \qquad 3$$

Where D is the crystallite size, wavelength of the X-ray used is λ =1.54059Å, β is the broadening of diffraction line measured at the half of its maximum intensity in radians and θ is the angle of diffraction (Ghosh et al 2009) as shown in figure 8.XRD pattern of ZnO .

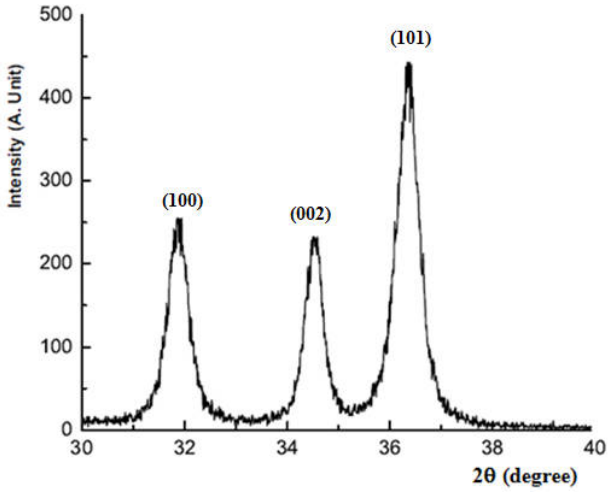

Figure 8 XRD pattern of ZnO

3-2 Uv-Vis studies

The JENWAY 6800 UV/vis spectrophotometer used the UV of ZnO. Fig 9 shows the UV-Vis spectra of Nano-thin films of ZnO obtained by Spin coating method. ZnO shows the absorption peaks at 364.. The band gaps (Eg) of ZnO were calculated by using the formula $E = \frac{hc}{\lambda}$ where h is plank's constant, c is the velocity of light and λ is the wavelength. The band gap of ZnO was found to be 3.374 eV.

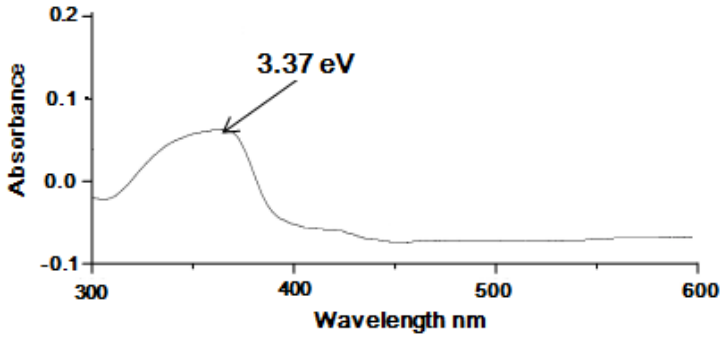

Figure 9 UV-VIS of ZnO

3.3 J-V Characteristic of (PMMA)

J-V Characteristic of polymer (PMMA) devices 182 nm, 91 nm, 67 nm thickness and deposited ZnO with 42 nm thickness in the dark and xenon illumination with intensity of 100 W/cm^2 and is shown in Figures (10) , (11) and (12)Respectively.

Through the shapes above it is clear that the best efficiency of the solar cell can be obtained when the thickness of 47 nm obtained at the speed of 2000 rpm in spin coating and because the thin membrane at this speed be homogeneous (Haug et al 2009), Table 2 shows the efficiency values obtained for the various thickness. The polymer is naturally excitonic, whereas electron-hole pairs in the a-Si are probably unbound because of the extraction of binding energies under 0.1 eV (Street 1984).

Table 2 shows the efficiency values obtained for the various thicknesses

Spin Speed (rpm)	Thickness(nm)	Voc	Jsc	Vp	Jp	Pmax	FF	Efficiency
1000	182	0.35	5.63	0.25	4.7	1.175	0.25	1.175
2000	91	0.4	10	0.3	7	2.1	0.52	2.1
3000	67	0.35	8.1	0.29	5.5	1.595	0.56	1.595

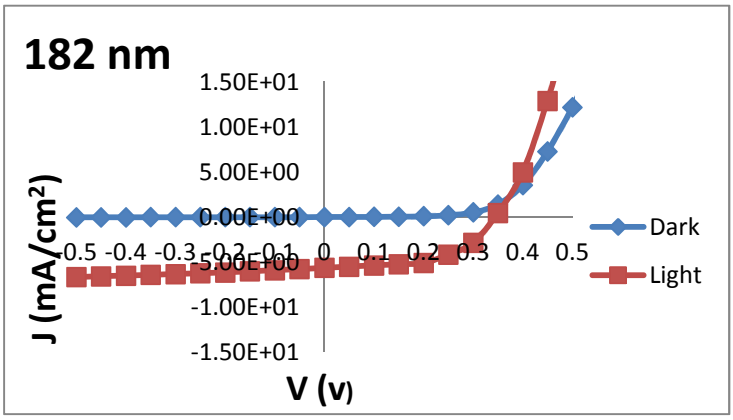

Figure 10: Current density as function of voltage for PMMA solar cell at 1000 rpm spin speed

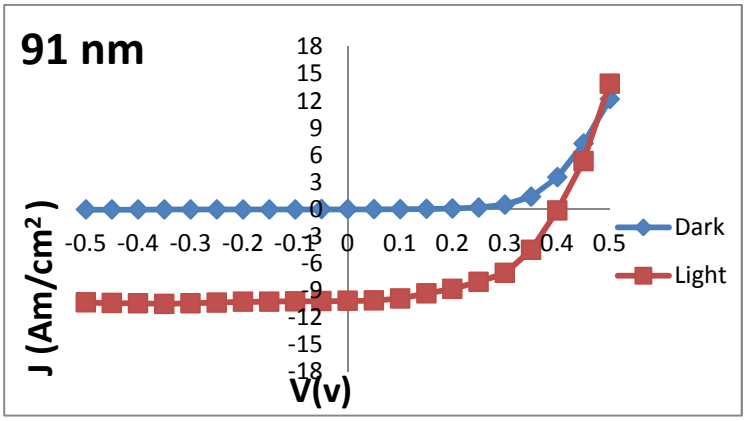

Figure 11: Current density as function of voltage for PMMA solar cell at 2000 rpm spin speed

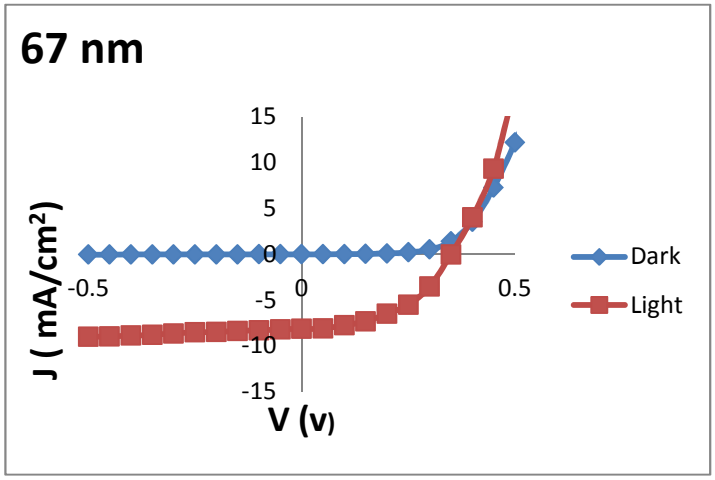

Figure 12: Current density as function of voltage for PMMA solar cell at 3000 rpm spin speed

4. Conclusion

From I-V HJ can conclude that the best efficiency of the solar cell is obtained when the thickness of the polymer 67 nm. That's where this polymer when this thickness helps to improve the structure of the solar cell and also helps to increase the current density and the ones we get the best efficiency.

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