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FABRICATION OF ZnO/a-SiH/polymer THIN FILMS HETEROJUNCTION FOR ORGANIC SOLAR CELLS

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ABSTRACT

Organic solar cell of Al/ZnO/a-SiH/polymer was fabricated by using the sputtering technique. The efficiency of hydrogenated amorphous silicon combined with different types of polymers was studied. The results of I-V characteristics show that the annealing has high affected on the open circuit voltage and it enhances their short circuit current. The current–voltage characteristics curves indicate that the efficiency for solar cell heterojunction increases from 2% to 3.4% for the first type of polymer, ZnO/a-SiH/poly(3-hexylthiophene), as the annealing temperature increases. For the other type of polymer when the cell was fabricated using ZnO/a-SiH/polyvinyl chloride and ZnO/a-SiH/paraphenylene vinylene, the efficiencies increase from 2.1% to 4.1% and from 3% to 5%, respectively, as the annealing temperature increases. These types of polymers are good for organic solar cells but the third type is the best.
Keywords: Organic solar cell, Electrical properties of polymers, Heterojunction structure, Solar cell efficiency, fabrication ZnO/SiH/polymer, Thin films

I. INTRODUCTION

The fabrication of hydrogenated amorphous silicon/polymer heterojunction solar cell is one of the greatest challenges facing the industry to show high power conservation efficiencies at low cost. A lot of research to overcome this problem by trying to raise efficiency through amendments and changes in the fabrication of the cells, are concerned on the role of polymers in this direction. Production of different types of polymers to obtain higher efficiency as well as other physical polymer properties has been considered. One of these researches, published by Professor Alan Breeze (2001) in chemistry, has worked with conductive polymers for the development of efficient plastic solar cells [1]. Due to a high absorption coefficient of *a*-Si:H in the visible range of the solar spectrum, 1µm thickness of *a*-Si:H layers is sufficient to absorb 90% of usable solar light energy. Low processing temperature allows using a wide range of low-cost substrates such as glass sheet, metal or polymer foil. These features has made *a*-Si:H a promising candidate for low-cost thin-film solar cells. Low-cost thin-film solar cells are regarded as the second-generation solar cells for terrestrial application. Although solar cells made of silicon are still the best in function, they are somewhat expensive and cumbersome. It is typically half the cost of solar system construction costs. Organic photovoltaic have been extensively investigated over the past few years due to their potential low cost nature and envisaged simplicity in fabrication [2]. Interest in organic/inorganic heterojunction has grown simultaneously with most of the work concentrated on titanium based photovoltaic. A small number of pertaining reports on hydrogenated amorphous silicon a-Si: H / polymer heterojunction solar cells have been reported [3, 4]. However, active participation of the polymer in photocurrent generation has been confirmed only recently [4]. The efficiency of these hybrid devices has been low, and for a-Si:H /polymer cell, the best reported efficiency is 0.01%.4. The less studied n-i-p structure offers the possibility to use non-transparent materials as substrates (stainless steel or plastic films). In this case the cell is directly exposed to the light and the substrate must be very reflective and show , if possible, a light trapping effect as shown in Fig.1 [4]. In this work, starting from a technology developed on glass substrates, the device performance of solar cells on polymer substrates is optimized step by step. One parameter of interest for solar cell is the fill factor (FF) given by the relation [5]:

$$FF = V_m I_m / V_{oc} I_{sc} \quad (1)$$

where V_m, I_m, V_{oc}, and I_{oc} are the maximum voltage, maximum current, open circuit voltage, and short cicuit current. The optimum I-V characteristics for solar cell are shown in Fig.2.

The photovoltaic conversion efficiency is another important parameter. It is a measure of the amount of light energy that is converted into electrical energy and is given by.

$$\eta = P_m/P_{in} = FF x \, I_{sc} \, x \, V_{oc} / P_{in} \quad (2)$$

where P_m is the maximum output power , and P_{in} the incident power [6].

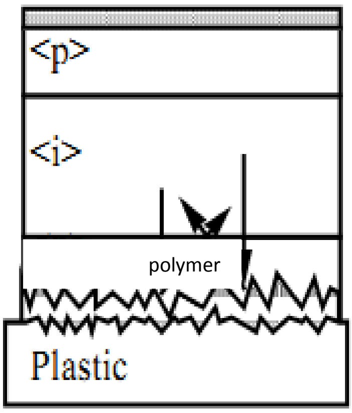


Fig.1: The "standard" p-i-n structure

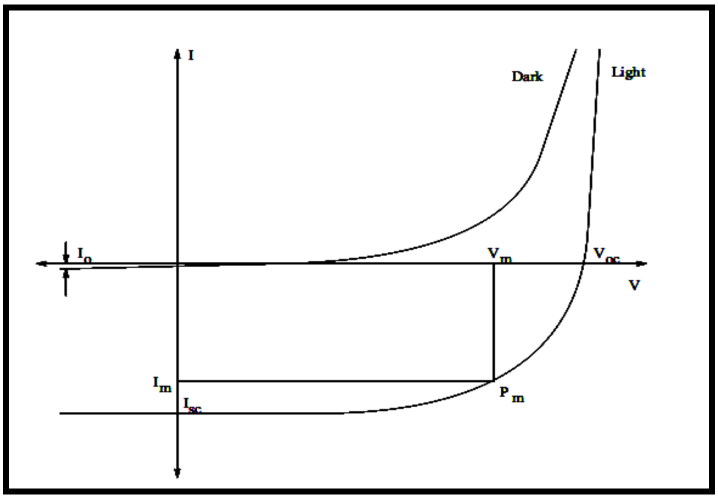


Fig.2: I-V Curve of the solar cell in dark and under illumination

II. EXPERIMENTAL WORKS

The solar cells were deposited by sputtering coating technique with speed 5000 rmp. The two coplanar electrodes have a surface of 105 cm^2, the substrate is fixed face down to the upper electrode. The effective temperature was performed heating between 170 ºC and 240 ºC depending on the layer thickness when the substrate allowed it and slow cooling in inert atmosphere Argon mixed with Hydrogen by a ratio 1/2. For plastic films with a lower temperature resistance, the cells were deposited with an appropriated temperature 150ºC. The metallization of the back contacts was deposited by Joule effect or sputtering. The ZnO layers were reactive sputtered and to complete the device fabrication, 100nm of Al top metal electrode was evaporated with vacuum 10^{-4} bar. The devices were characterized by the illuminated I-V curves to determine the device efficiency. Microstructure examination of samples with scanning electron microscope was made.

III. RESULTS AND DISCUSSIONS

Figures.(3, 4 and 5) show a typical current-voltage (I-V) characteristic for forward and reverse bias of ZnO/a-SiH/Polymer heterojunction deposited at room temperature and after annealing (T_a) at 323 K and 343 K for 30 min for three types of polymer. These measurements show in the forward bias, the current increases exponentially with voltage as expected but in reverse bias as we annealed the samples, the current was found to increase slowly with voltage (soft breakdown) and no any trend of saturation or sharp breakdown. This is due to the domination of edge leakage current which is caused by the sharp edge at the periphery of the contact and also due to the generation of excess carriers in the depletion region at higher fields [6].

I_{sc} and V_{oc} increase as the annealing temperature increases, and the efficiency of the cell improves with the annealing because of the increase of J_{sc} as shown in Tables 1. ZnO is transparent in the visible region of the solar spectrum, whereas a-Si:H is strongly absorbing in this region. Under illumination, the electron-hole pairs are created. 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 [7]. The generation in the a-Si is not a significant contributor to the photocurrent, and most of the photocurrent arises from the extractions generated in the polymer.

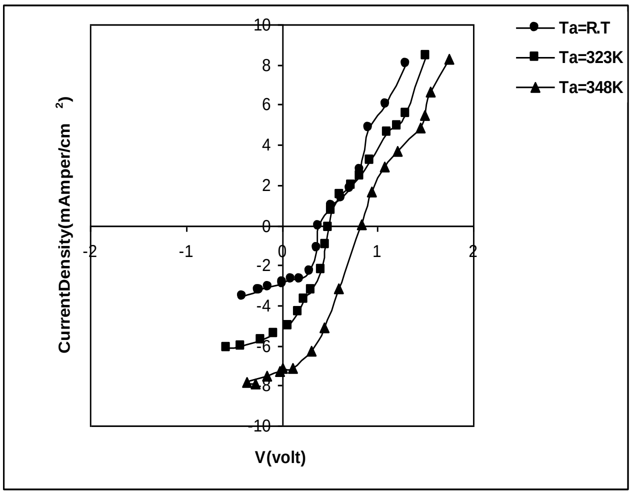


Fig.3: Current-Voltage curves of the ZnO/a-Si:H/P3HT cell.

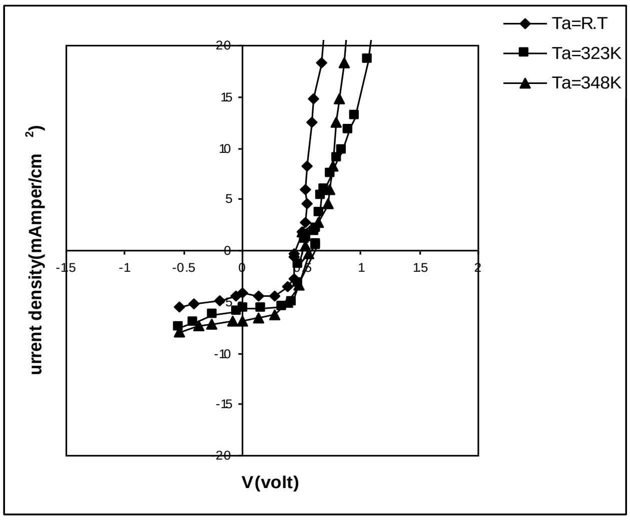


Fig.4: Current-Voltage curves of the ZnO/a-Si:H/PVC cell.

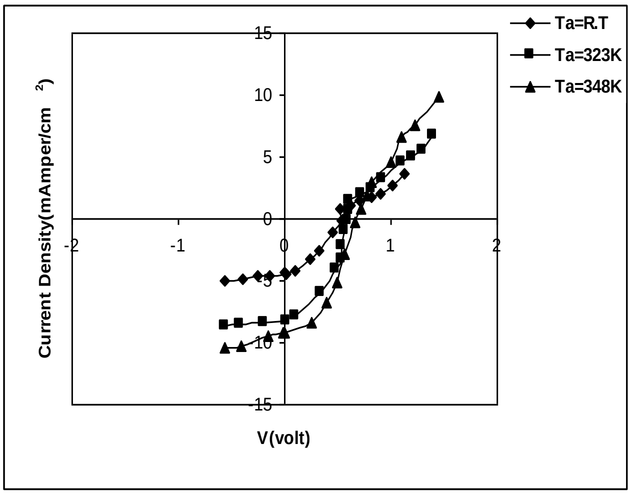
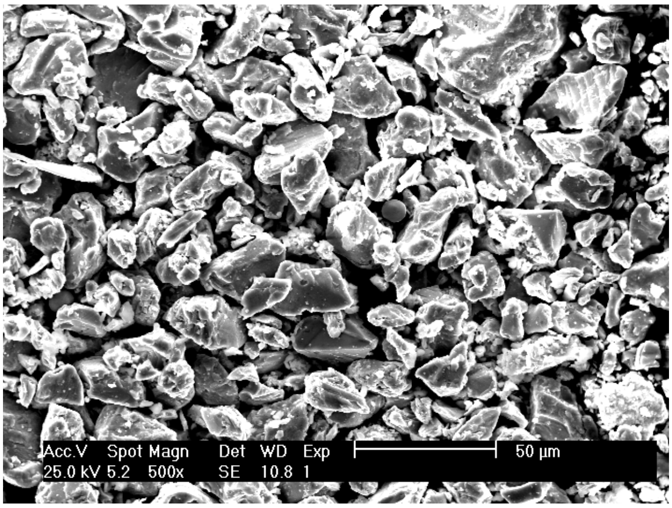


Fig.5: Current-Voltage curves of the ZnO/a-Si:H/PPV cell.

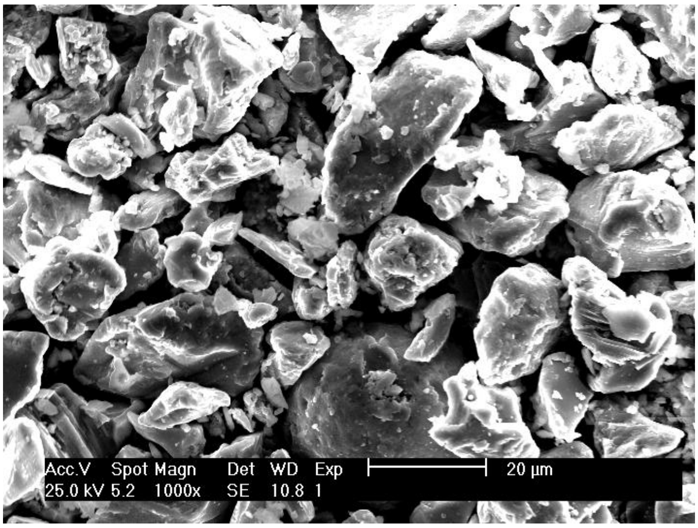
Table 1: Values efficiency (η%), saturation , V_{oc} ,J_{sc} ,V_{max}, J_{max} for different types of polymers as a function of different annealing temperature

Type of polymer	T_a (K)	V_{oc} (Volt)	J_{sc} (mA/cm^2)	Vmax (Volt)	J_s max (mA/cm^2)	η %
ZnO/a-Si:H/P3HT	R.T	0.46	4.3	0.4	3.8	2
	323	0.58	5.8	0.45	5	3.1
	348	0.6	7	0.47	5.22	3.4
ZnO/a-Si:H/PVC	R.T	0.4	5.8	0.46	4	2.1
	323	0.5	6.7	0.47	5	3.3
	348	0.6	7.4	0.49	5.3	4.1
ZnO/a-Si:H/PPV	R.T	0.5	6	0.4	4.4	3
	323	0.57	11	0.47	6.175	4.5
	348	0.61	11.4	0.5	6.44	5

The micrographs of ZnO powder as shown in Fig.6 (a and b) are taken by scanning electron microscopy image (SEM) with magnifications 500 and 1000 X respectively with particle diameters in the range of (50-12) µm by using image data program.



(a)



(b)

Fig.6: scanning electron microscopy image of ZnO powder of magnification (a) 500 X (b) 1000 X

IV. CONCLUSIONS

Open circuit voltage V_{oc} and short circuit current J_{sc} were increased with increasing of the annealing temperature. The efficiency of the cell increases with the increase of annealing temperature. In organic solar cell most illumination of the photocurrent arises from exciton generated in the polymer.

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