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ScienceDirect
Energy Procedia 6 (2011) 85–91
Energy Procedia

MEDGREEN 2011-LB

Synthesis and characterization of (Pani/n-si)solar cell

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Abstract

Polyaniline(PAni) doped with formic acid was synthesis by chemical polymerization method using ammonium persulphate as oxidizing agent . Polyaniline /n-silicon hetrojunction have been fabricated by spin coating of polyaniline onto n-type silicon substrates. I-V characteristic of these junction diode show rectifying behavior with rectifying ratio of about 100. The I-V characteristics of PAni/n-Si junction were measured at room temperature (303K) and after annulling at 363K. They are found to exhibit quality factors of 1.83 and 1.32, saturation current of $5x10^{-6}$A and $5x10^{-4}$A, and barrier heights of 0.73eV and 0.61eV respectively. The photovoltaic properties of this hybrid solar cell were studied in the dark and under illumination investigated hybrid and was found to deliver short circuit current density J_{sc} =45μA/cm^2, open circuit voltage V_{oc} = 400mV, and solar cell efficiency η =0.3% under AM 1.5 simulated solar light with the intensity of 100mW/cm^2.

Selection and/or peer-review under responsibility of [name organizer]

Keywords: PbS thin films,Chemical bath deposition,Optical properties.

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doi:10.1016/j.egypro.2011.05.010

1. Introduction

Conducting polymers have an immense advantage of being simple to synthesis, with their chemical structure tailored to alter their physical properties, such as their band gap. They exhibit an extensive range of electrical conductivity and can exhibit metallic to insulator property (10^5 - 10^{-9} S/cm). Further to their ease of synthesis and with lower cost, they are known to have low poisoning effects. They possess a large variety and versatility in their chemical structure and are therefore extensively used in devices for the detection of environmentally hazardous chemicals [1-3]. Organic semiconductors have attracted great attention in the field of active materials for solar cell applications such as in organic light emitting diodes (OLEDs) [4], field-effect transistors (OFETs) [5] and solar cells [6-10]. Polyaniline (PAni) is one of the most promising conducting polymers [11-13]. The most important feature that makes PAni so interesting as sensitive p-n junction layer for the solar cell is the variation of its electrical and optical properties at room temperature [14]. Solar cell fabrication from semiconductor materials such as silicon, amorphous silicon and gallium arsenide is expensive (requiring very clean processes) so savings associated with using solar energy rather than fossil fuel sources for electricity could take more than a decade. Within the first many years of use, solar energy currently costs the equivalent of 20-25 cents per kWh, compared with 8 cents per kWh for conventional electricity. Thus, a key research area is to look for materials that are cheaper to fabricate and that require less energy to produce. In recent years, the development of thin film plastic solar cells, using polymer-fullerene [15,16] or polymer-polymer [17] bulk heterojunctions as an absorber (and transport layer at the same time), has made significant progress. Efficiencies between 1% and 2.5% for laboratory cells under AM1.5 illumination conditions have been reported [18-19]. The typical structure of these devices consists of a composite of two materials with donor and acceptor properties, respectively, sandwiched between two electrodes. One advantage of this type of devices is their ease of processability.The active layer is solution processed by using spin-coating technique.

In this research we have investigated the diode junction and the photovoltaic properties of conducting polymer/n-Si hybrid solar cell structure. The current density-voltage (J-V) characteristics have been measured for solar cell devices prepared from the organic polymer polyaniline doped with formic acid and deposited onto n-type silicon substrates. The studied J-V characteristics were used to determine solar cell parameters such as (V_{oc}), (J_{sc}), (P_{max}), (FF), (η), **series** resistance (R_s) and shunt resistance (R_{sh}).

2. Experimental procedures

N-type silicon wafers with <100> orientation and resistively of (1-20 Ω. cm) have been used as substrates for the deposition of the conducting polymer thin films. Prior to film deposition the silicon substrates were ultrasonically cleaned in acetone and then de-ionised water; this was followed by hydrofluoric acid (HF) etch in order to remove any native silicon dioxide (SiO_2) layer. The etched wafers were then stored in methanol until they are used for film deposition. Polyaniline was synthesized by the oxidation polymerization of aniline in acidic media. This polymer was prepared following chemical methods described in the literature [20] and then dried in an oven at 50 ^oC for a period of 48 hrs. Powder of the polymer was dissolved in formic acid (HCOOH) in the concentration of 10 mg.ml^{-1}. Single layer heterojunction solar cells were then prepared by spin casting solutions of PAni-HCOOH onto the silicon substrates using spin speeds in the range 1000-5000 rpm and spinning time of 60 sec. thin films were then placed on a hotplate with temperature of 363K for a period of 60 min for annealing. Aluminum (Al) contact of about 90 nm in thickness was thermally evaporated onto the back (the unpolished side) of the Si substrate. This was carried out under vacuum of 10^{-5} -10 $^{-6}$ mbar and evaporation rate of 5 nm.sec^{-1}. Similar procedure was followed for the deposition of gold (Au) contacts onto the polymer film, with the thickness of about 20 nm evaporated through a suitable mask which provides device area of about $3x10^{-6}$ m^2. For DC electrical measurements of diode junction a Keithley electrometer (Model 6517A) was used to measure current density (J) as a function of applied voltage in range ±1V and in steps of 0.05V. The photovoltaic properties of the solar cells were measured under illumination using a Bentham 605 solar simulator fitted with a xenon lamp.

3. Results and discussion

I-V characteristics of PAni/n-Si diode junction at room temperature and after being heated at 363 K are shown in Figs. (1 and 2). In this work we have examined six samples in order to check experimental reproducibility .All tested samples of PAni/n-Si show rectifying behavior, with rectifying ratio (forward to reverse current ratio) of about 100. Assuming the thermionic emission theory, the ion of applied voltage (V) is given by [21]:

$$J=J_s\,(e^{\,qV/nkT} -1) \qquad (1)$$

where J_s is the reverse saturation current density, q electron charge, n ideality factor, k Boltzmann's constant and T is the temperature measured in Kelvin. J_s is given by the following relation:

$$J_s= A^*T^2\, e^{-\,Ø/kT} \qquad (2)$$

where A* is Richardson constant, and Ø is the barrier height.

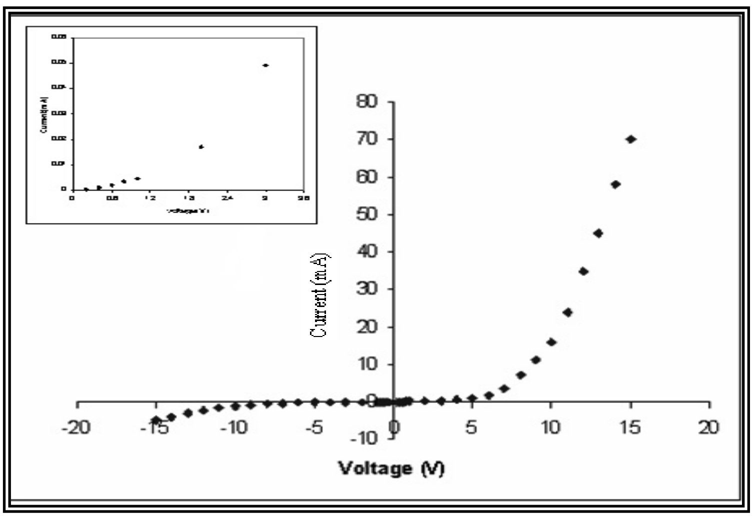

Fig.1: I-V Characteristics of PAni/n-Si at room temperate (303K)

Fig. (3) shows the relationship between Ln I and applied voltage at room temperature (303 K) and at 363 K. The extrapolation of the linear portion of the two curves give saturation current I_s of about $5x10^{-6}$A and $5x10^{-4}$A respectively. The ideality factor n obtained from the slop of linear parts is 1.83 and 1.32 respectively. The barrier heights as estimated from eq. 2 are of 0.733eV and 0.61eV respectively.

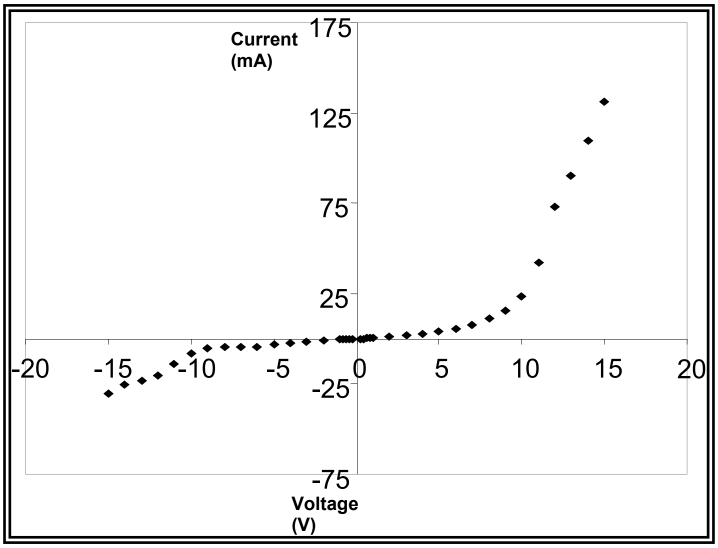

Fig. 2: I-V Characteristics of PAni/n-Si at 363K.

Table 1 shows junction parameters of PAni/Si. These results clearly indicate that annealing at 363K have the effect of improving junction parameters.

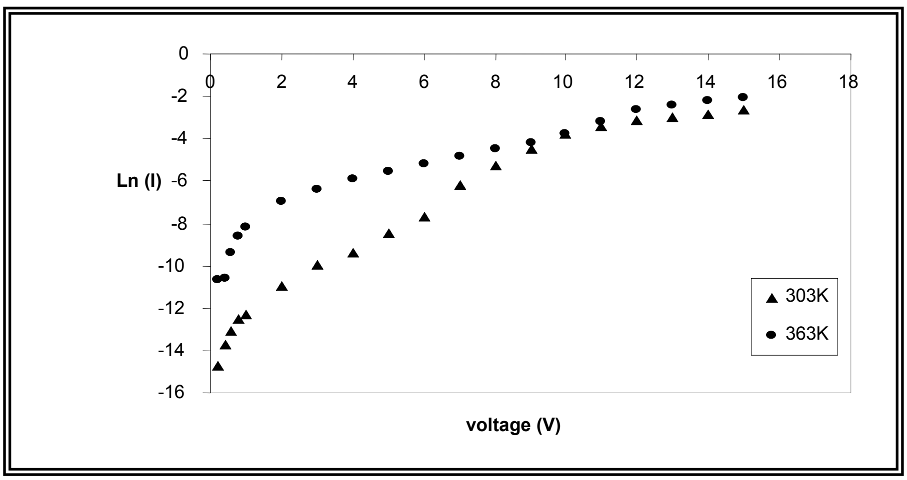

Fig. 3: Ln (I) as a function of applied voltage for PAni/n-S at room temperature 303K and 363K.

Table 1

Values of PAni/Si junction parameter

Temp .treatment (K)	barrier heights Ø (eV)	saturation current Is (A)	ideality factor n
303	0.73	5x10-^{6}	1.83
363	0.61	5x10^{-4}	1.32

Fig. (4) shows the J-V characteristics of the fabricated PAni/n-Si solar cell structures, measured both in dark and under illumination. The polymer film thickness for this particular result is 30nm as determined by spectroscopic ellipsometry measurements and the illumination intensity is of 100 mW/cm^2. The rectifying junction is expected to exist at the interface between the silicon substrate and the polymer film. This can be further justified by the fact that the silicon substrate used in this work is of n-type while the PAni-HCOOH films are considered as the hole transporting layer [6]. Solar cell parameters, i.e., open-circuit voltage (V_{oc}), short circuit current density (Jsc), maximum current (I_{max}), maximum voltage (V_{max}) and fill factor (FF) have been determined. The solar conversion efficiency η is given by the formula:

$$\eta = (FF\, V_{oc}\, J_{sc} \,/\, P_{in}) \qquad (3)$$

where P_{in} is the power of the incident light.

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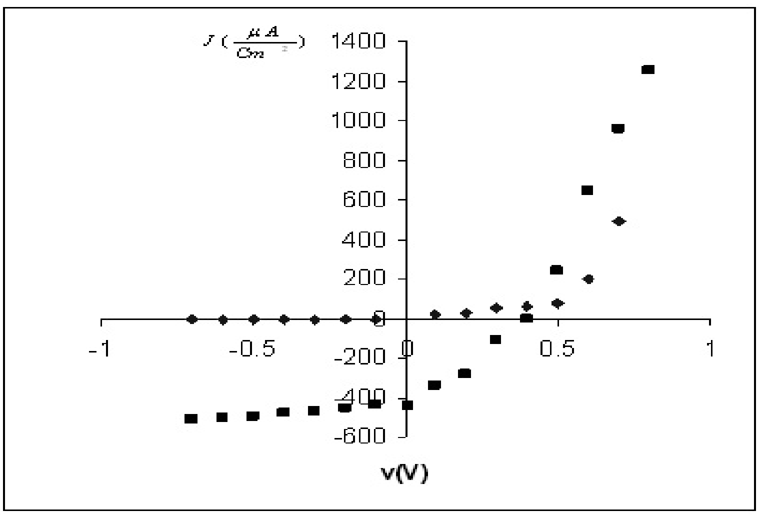

Fig. 4: Current density as function of voltage for Au/PAni/n-Si/Al solar cell. The white light illumination intensity is 100 mW/cm^2.

The open-circuit voltage of these solar cells is V_{oc} =0.4V, short circuit density current J_{sc} =0.445 mA/cm2, and fill factor FF=0.24. Atypical solar conversion efficiency of 0.3% has been obtained, which is of small value as compared with aluminium/polyaniline/GaAs metal-insulator semiconductor solar cell which was found to give efficiencies in the region of 5% [17].The series resistance and shunt resistance determined from the Figure 3 have values of about 311.4 $M\Omega/cm^2$ and $10G\Omega/cm^2$ respectively. The value of 0.4 V for the open circuit voltage obtained in this work compares well with the value 0.51V obtained for Pani/n-Si solar cell devices [22]. The low value of FF is associated with a high series resistance and a high shunt resistance. High values for R_S may originate from electrode contact resistance and high R_{sh} is related to morphology of the film; a poor absorber morphology limiting the electron hopping transport [23,24].

4. Conclusion

Thin films of Polyaniline doped with formic acide (HCOOH) prepared on n-Si substrates by spin-coating method. The result of I-V characteristic show (i) PAni/Si junction show rectifying behavior, the value of parameter improvement by annealing at 363K, Is increases about two order (10^{-6} to10^{-4}A), n became 1.32 and Ø about 0.61eV (ii). The Solar cell efficiency under AM 1.5 simulated solar light with the intensity of $100mW/cm^2$ found about 0.3% is obtained for films with PAni thickness of 30 nm. The low efficiency obtained in this work was caused by the morphology of the polymer film.

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