

Optical Properties Of Blend Polymers Of Polyvinyl Alcohol/Poly (O-Toluidine) And Their Solar Cells Application

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ABSTRACT: The chemical polymerization method was used to prepare poly(o-toluidine) (POT) which is characterized by (FTIR, XRD, and SEM) and then the blend polymers of PVA/POT were investigated by mix different volume ratios of polymers as (1:1, 1:2, 2:1 PVA:POT). The optical properties of the blend polymers were studied after deposited it on the glass substrate by a spin coating method and this study appeared the energy gaps of blend polymers increased with increasing the amount of POT. The J-V curves of prepared photovoltaic devices (PVA:POT/n-Si) which were measured under dark and illumination ($100\text{mW}/\text{cm}^2$) gave information about prepared devices performance, whereas the better power conversion efficiency was recorded at the ratio (1:2 PVA:POT) to be 1.567 with J_{sc} , V_{oc} , and FF equal to 13.3647, 0.32, 0.36634 respectively

Keywords : Polyvinyl alcohol; Poly (o-Toluidine); optical properties; photovoltaic devices.

1 INTRODUCTION

Conductive polymers have become an attractive components in solar cell devices based on facile tuning of materials parameters, fabrication it by using printing technique, mechanically flexible properties [1-6] in addition to have important characteristics and excellent properties like, the optical and electrical properties, inexpensiveness and environmental stability as well as easy of synthesis and preparation as thin films on a large area [7,8]. Polyaniline and its derivative (Poly(o-Toluidine)) were used as active layer in different applications such as schottky diodes, LED, FET, sensors and inhibitor for carbon steel [9-13]. While the polyvinyl alcohol (PVA) consider as important material due to a water soluble polymer with a low electrical conductivity, excellent film forming capacity, good transparency and compatibility with additives [14-16] in addition to other properties like, a cheap, non-toxic and biocompatible polymer[15,16]. Physical properties of PVA make it important material to use it as cross link material by mix it with other material to get material with unique properties [14-15, 17-22]. According to above polymers, the blend polymers of PVA/POT were investigated to prepare organic/inorganic solar cell (PVA:POT/n-Si) in this work. The conversion process of light to electricity includes four steps: (a) light absorption and exciton formation, (b) exciton dissociation, (c) charge transport and (d) charge collection. These steps are affected by the chemical structure of active materials, that is, the donor and acceptor, and the morphology of the active polymer film [23-27].

2 EXPERIMENTAL

2.1 Preparation of blend polymer

The chemical polymerization was used as method for synthesis of the poly (o-toluidine) (POT) by dissolving 0.27M of o-Toluidine monomer(provided by Fisher scientific) in 0.25M HCL by using constant stirrer at (0-5) °C for 30 min., while 10 gm of ammonium per sulphate{ $(\text{NH}_4)_2\text{S}_2\text{O}_8$ }(provided by sigma-Aldrich) was dissolved in distilled water which was added to the dissolved monomer as drop by drop for ~ 20 min. to keep a ratio of the monomer to

oxidizing agent as (1:2).After completing dropping ammonium per sulphate, the mixture continued in stirrer for 24hr's more to obtain a greenish-black precipitate of the polymer which was filtered and washed three times by distilled water, methanol and acetone respectively to remove unreacted material and oligomers and then dried in vacuum oven at 60°C for 24h's[28]. While the blend polymer of polyvinyl alcohol (PVA) ($[\text{CH}_2\text{CH}(\text{OH})]_n$) (Purchased from sigma-Aldrich) and poly (o-toluidine) were prepared by separately dissolving 10mg of both POT and PVA in tow tubes by use of 1 ml of formic acid as solvent for each one under condition of magnetic stirrer for 3hr's until completing dissolving, then different volume ratios (1:1, 1:2, 2:1 V/V) of both POT and PVA were mixed together by using magnetic stirrer for 5hr 's to obtain completing mixture [29].

2.2 Preparation of samples

The final mixture (obtained in section 2.1) was filtered and deposited on the glass substrate(for optical properties) through use of spin coating method, then carried out on a digital hot plate to be heated up to 90°C for 15 min. to remove the solvent. Three thicknesses of the prepared thin films were measured by Ellipsometry spectroscopic to be presented as (45.5, 44.5, 50.35nm) for PVA:POT of volume ratio (1:1), (1:2) and (2:1) respectively. Whereas the same prepared blend polymers were deposited on the silicon substrate (n-type) to prepare solar cells device. The photovoltaic devices structure(see figure(1)) consist a single layer of blend polymers with thickness of (45.5, 44.5, and 50.35nm) for PVA:POT of volume ratio (1:1), (1:2) and (2:1) respectively deposited on the silicon wafer has thickness of 310-330 μm and two electrodes used in present devices are gold(Au) (used as top electrode and deposited by the EMS150R rotary pumped coating) with thickness of 20nm (to be high transparent for incident light) and aluminium(Al) (used as back electrode and deposited by the EDWARD Auto 306 vacuum coater) with thickness of 100nm. The two types of substrates used in this work were cleaned in different ways, the first substrate (glass substrate) was washed in ultrasonic by distilling water, methanol and acetone and the second substrate (silicon substrate) was etching by Hydrofluoric acid (HF) to remove silicon dioxide layer.

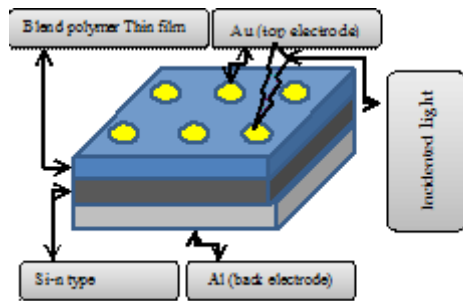


Fig. 1. The solar cells structure used in this study.

2.3 Measurement circuit

The circuit used to test photovoltaic device performance including on the Keithley electrometer (Model 65174) can be measure a current as a function of the applied voltage and it can be supply voltage in range (-0.1 to 0.7)V in step of 0.01V and its was interfacing with computer for save and display the data measured by it. The light source (Bentham Lust. Ltd) operated by Bentham 605 current stabilised power supply of xenon pyranometer conjunction with a cc10 kip and xenon solar integrator was used as equivalent of the sunlight which is setup to provide light with intensity of $100\text{mW}/\text{cm}^2$.

2.4 UV-visible

The UV-Vis spectra of the polymers were recorded by using Cary 50 spectrophotometer in the range of 250-1200 nm.

2.5 Fourier Transform Infrared (FT-IR)

The FTIR spectra were used to characterize the poly (o-toluidine) with a wave number range of $500\text{--}4000\text{cm}^{-1}$. This technique provided information about structure and chemical bonding of material.

2.6 X-Ray diffraction

X-ray diffraction was considered as important technique to give information about nature and structure of the materials which is used to illustrate the crystallinity case for poly (o-toluidine).

3 RESULTS AND DISCUSSION

3.1 FTIR Spectra

The structure of POT was characterized by FTIR as shown in figure (2), where the absorption band at 1112.82cm^{-1} corresponding to C-C methyl-substituted SQ and Q rings. The band around 1170.71cm^{-1} indicated to C-H in SQ ring while other two bands ($1280, 1324\text{cm}^{-1}$) due to benzenoid and quinoid ring asymmetric stretching vibrations. The bands at about $1485.09, 1596.95\text{cm}^{-1}$ were assigned to the C-N stretching of benzenoid and Quinoid ring respectively. The characteristic of band at 2923.88cm^{-1} was referred to C-H stretching as result as substituted methyl group [30, 31].

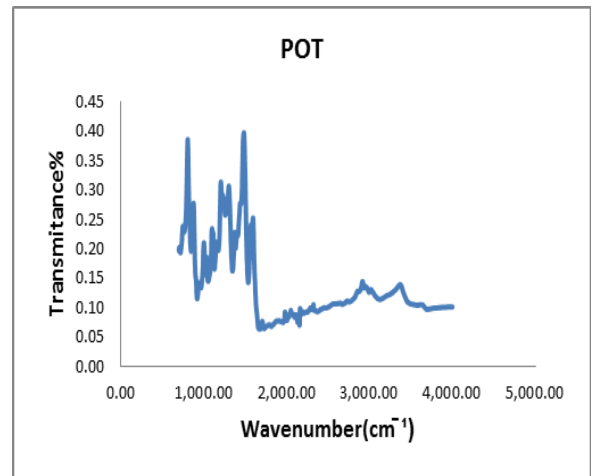


Fig. 2. FT-IR absorption spectra of POT.

3.2 XRD characterization

The XRD pattern of the POT as illustrated in figure (3).exhibited an amorphous structure with small peaks at 16.87° and 25.5° which were interplanar distance of o-toluidine-o-toluidine [32].This result was agreed with previous study which showed that the conducting polymers have semicrystalline or amorphous structure [33].

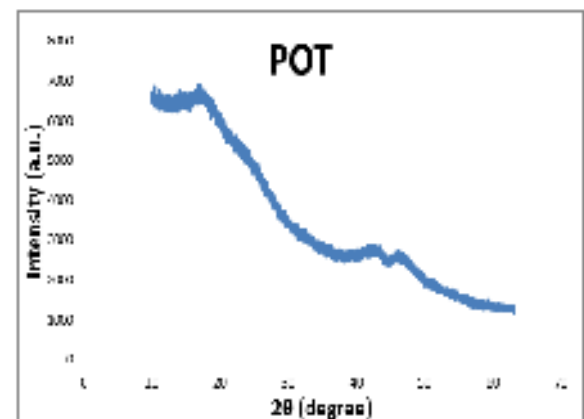


Fig. (3): XRD scattering pattern of POT.

3.3 Morphology

The morphology of prepared devices from blend polymers (as illustrated in figure (4)) shows surface morphology without pinhole or porosity according to SEM images. The surface morphology of ratio PVA2:POT1 can be seen and explained that POT incorporated in PVA matrix. While the thin film surface of the ratio PVA1:POT2 exhibit good film with low deformity and explain that, the PVA nanofibers were completely formed inside POT. The ratio PVA1:POT1 display low roughness and completely mixed in this ratio.

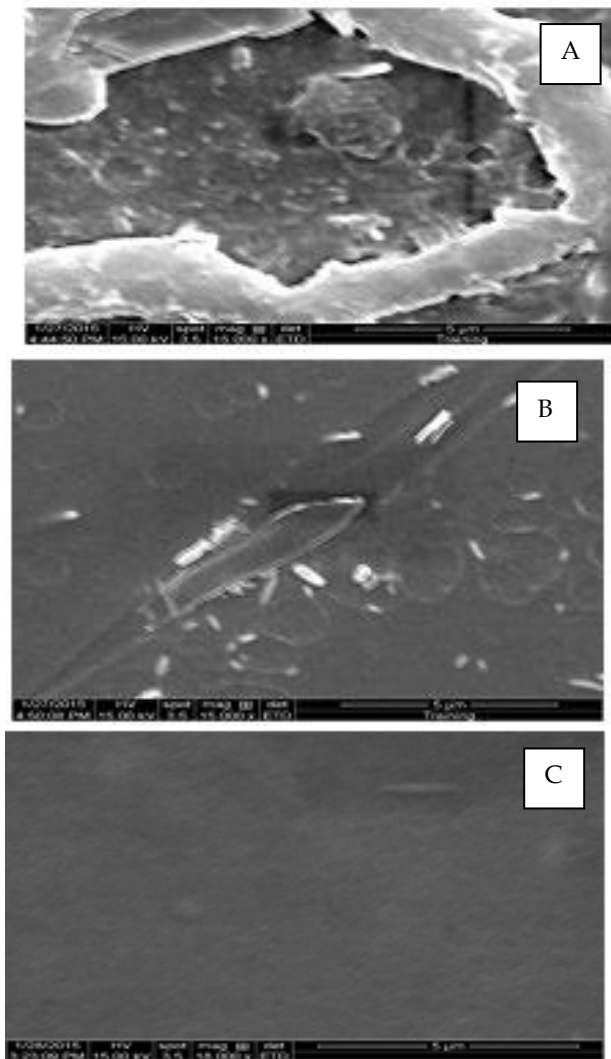


Fig. (4): SEM image of the blend polymers: (A) PVA2:POT1, (B) PVA1:POT1, (C) PVA1:POT2.

3.4 Optical properties

The UV absorption process is the electron transition from the top of the valence band to the bottom of the conduction band. Absorption spectra of the POT, PVA, and blend polymer of POT:PVA thin films (represented as shown in figure (5)) are recorded at room temperature in the wavelength range (250-1000) nm.

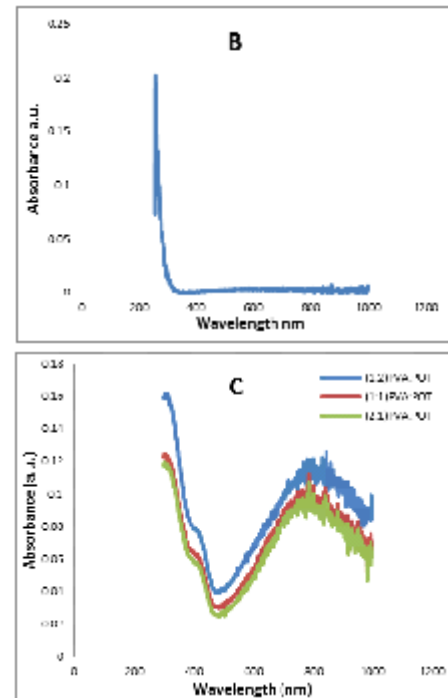
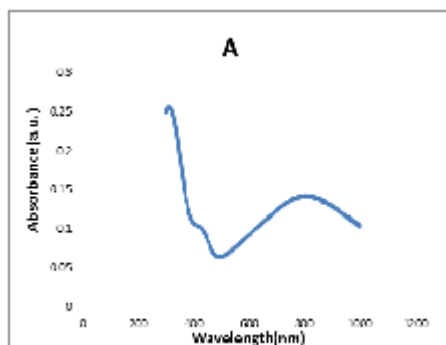


Fig. 5. UV-Vis absorption spectra of polymers: (A) POT, (B) PVA, (c) blend polymers of PVA/ POT.

increases the degree of polymerization which leads to increase in molecular weight of the polymer when synthesis it in low temperature degree which was (0-5) $^{\circ}\text{C}$. While the PVA is high transparent material that means it has low absorbance after dissolve it because of the surface morphology became has low roughness which reduce the light scattering process and its spectrum exhibits a shoulder-like band at 316 nm assigned to the carbonyl groups associated with ethylene unsaturation of the type $-(\text{CH}=\text{CH})_2\text{CO}-$, and is indicative of the presence of conjugated polyene double bonds [34,35]. The absorption peaks of the blend polymers at about (304, 415, and 791) are refer to the $\pi-\pi^*$, polaron- π^* and π -polaron transition respectively for ratios of (1:2, 1:1, 2:1 PVA:POT) and the band intensity of blend polymers were increased with increase amount of POT [36,37].

The optical transition of a blend polymers determined according to depend the absorption coefficient (α) on photon energy ($h\nu$) and the absorption coefficient (α) was calculated from the absorbance (A) using Lambert Beer's law [38]

$$I = I_0 \exp(-\alpha d) \quad (1)$$

$$\alpha = (2.303/d) \exp(I_0/I) = (2.303/d) A \quad (2)$$

Where I_0 and I are the intensities of incident and transmitted radiation respectively, d is the thickness of the sample. Moreover the energy band gaps of the polymers were calculated according to Tauc's relation by extrapolation of the straight line portion of the $(\alpha h\nu)^{1/n}$ against $h\nu$ to $\alpha=0$. [39].

$$\alpha h\nu = A(h\nu - E_g)^{1/n} \quad (3)$$

Where $h\nu$ is the energy photon, α is absorption coefficient, A is a proportional constant and the value of n equal to (1/2) for direct transition. The direct band gaps of blend polymers were obtained from by plotting $(\alpha h\nu)^2$ versus $h\nu$ curves, to be (3.23, 3.31, 3.21, 3.2, 4.62) for (1:1, 2:1, 1:2)PVA:POT, POT, and PVA respectively.

3.2 Characteristics of the solar cell devices

The parameters of prepared photovoltaic devices (tabulated in table (1)) which determined from the J-V characteristics as illustrated in figure (6) are open voltage circuit (V_{oc}) is the voltage that should be applied to the cell, short circuit current (J_{sc}) is the photocurrent generated by the radiation, fill factor (FF) is the ratio of output maximum power to the ideal power (as given in equation (5)), and power conversion efficiency (η) is the ratio of generated power to the incident radiation power (P_{in}) as given in the following equation[35]:

$$\eta = (FF V_{oc} J_{sc} / P_{in}) \quad (4)$$

$$FF = (I_{max} \cdot V_{max}) / (I_{sc} \cdot V_{oc}) \quad (5)$$

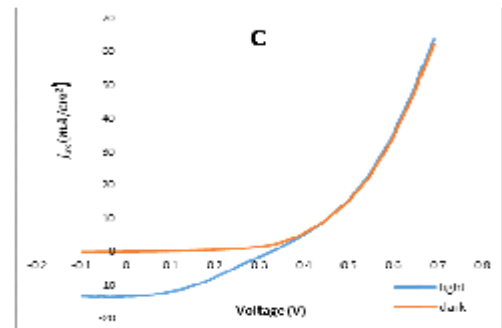
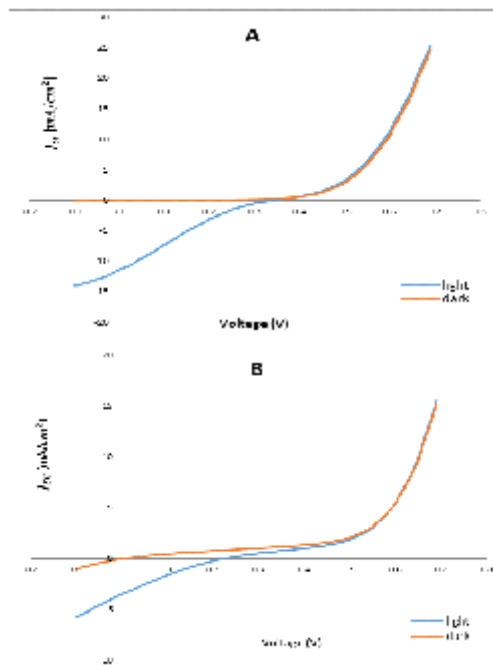


Fig. 6. Current-voltage characteristics of the solar cell devices for the blend polymer ratios.

(A) 1:1 PVA:POT, (B) 2:1 PVA:POT, (C) 1:2 PVA:POT

The performance of the solar cell depended on the many factors like amount of absorbed incident light, crystallinity of material, morphology of thin film surface and influence of dopants on the material [40-41]. Three devices of the blend polymers were prepared in this work showed power conversion efficiency (0.778, 0.161, and 1.567) for the (1:1), (2:1), (1:2) PVA:POT ratios respectively. The performance of the prepared cells were determined according to parameters of devices, whereas J_{sc} was increased with increasing the ratio of POT to be 13.364 mA/cm^2 at (1:2)PVA:POT, also the V_{oc} associated with series resistance, so that its decrease with high series resistance and FF calculated according to device parameters to be 36.6% at the ratio of (1:2)PVA:POT. The absorption intensity of prepared cells shows that, the high absorbance was at device of ratio (1:2 PVA:POT) compared with other devices which is explain high power conversion efficiency and amount of absorption related with surface morphology of thin film; a poor absorber morphology limiting the electron hopping transport[42-43].

TABLE 1
CHARACTERISTICS OF THE SOLAR CELLS

Material	V_{oc} (V)	J_{sc} (mA/cm^2)	V_p (V)	J_p (mA/cm^2)	P_{max} (mW/cm^2)	FF (a.u)	η (%)
(1:1) PVA:POT	0.35	11.343	0.13	5.99	778.7	0.19616	0.7788
(2:1) PVA:POT	0.22	3.465	0.1	1.6114	161.14	0.211387	0.16114
(1:2) PVA:POT	0.32	13.3647	0.18	8.70533	1566.959	0.36634	1.567

4 CONCLUSION

The Poly(o-Toluidine) was synthesis by chemical polymerization method and characterized by (FTIR, XRD, and SEM) techniques then the blend polymers of PVA/POT was made which were deposited on the glass substrate and silicon wafer (n-type) for study the optical properties and solar cell fabrication. The absorption peaks of the prepared samples

were refer to $\pi-\pi^*$, polaron- π^* and π -polaron and have optical energy gaps (3.23, 3.31, 3.21, 3.2, 4.62) for (1:1, 2:1, 1:2)PVA:POT, POT, and PVA respectively. The solar cells of a blend polymers were investigated and showed power conversion efficiency to be (0.778, 0.161, and 1.567) for the (1:1), (2:1), (1:2) PVA:POT ratios respectively.

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