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Research article

The Effect of different Dyes on the Efficiency of Polymer Solar cell

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Abstract

Polymer solar cells are one of the promising alternative energies which can be easily manufactured with low coast. In this work polymer cells with different thicknesses and three different type of organic dyes (Rhodamine 6G, Coumarin 500 and Dibenzocyanin 45) are used in fabrication. The effect of the concentration of different organic dye on various electrical and optical properties of the samples produced has been studied. It was found that when the conjugate polymer layer deposition on the slides at low speeds by spin coating technique (increasing the thickness of the conjugate polymer layer), results gave a recognized higher efficiency in the tested cell. The use of the organic dye (DDTTCI) led to improve in efficiency and absorption coefficient of light in the samples used. In addition, the optical absorption spectra were recorded for those samples with a UV-VIS spectrophotometer (model: UV mini-1240) within the wavelength range of 200–800 nm, at room temperature. The samples show variations in absorption coefficient directly depending on the type of organic dye used as well as the concentration of conjugate polymer. The short-circuit current, open circuit voltage and the fill factor of each sample have been calculated. The efficiency was found in the range of 10.28-1.744% for designed samples.
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KEYWORDS: photovoltaic, spin coating, organic dye, UV-VIS spectrophotometer.

Introduction

Today's political considerations to move the world's energy consumption away from fossil fuels such as oil, coal and gas has increased the focus on renewable energies. This should be seen in relation to the environmental concerns, e.g. cutting carbon dioxide emissions and supply concerns, which can have a large economic and political impact. Renewable energy is perceived as a sustainable solution to ensure future energy supply as well as being carbon dioxide emissions free or neutral.

Solar energy is by far the renewable energy source with the greatest potential [1]. It has the ability to cover the world's energy demand several thousand times over and, unlike fossil fuels, solar energy is readily available world-wide[2].

Unfortunately, utilization of solar energy is very expensive; something that particularly goes for the conversion into electricity. Solar cells are therefore not widely used for commercial electricity production since they cannot compete with fossil fuels or other renewable energy sources [3]. For this reason, solar cells are commonly used in remote regions with no access to the power grid or in private homes as a green alternative to fossil fuels. As a result more than 0.04 % of the world's energy supply came from solar photovoltaic. [4] To understand why electricity using solar cells is so expensive one needs to look closer at the solar cells used to produce it. A typical solar cell is made out of silicon wafers similar to those used in the production of microchips [5].

A polymer solar cell (PSC) is one of the possible replacements. These solar cells add some very interesting properties to the solar cell as well as reducing the price considerably. Jacob Lund [6] have demonstrated that the production of large area PSC ($1m^2$) can be done at a cost 100 times lower than that of monocrystalline silicon solar cells in terms of material cost. Another area where the PSC has advantages over silicon cells is in flexibility. Whereas silicon crystal is rigid a polymer layer is very flexible yielding the possibility of a very flexible thin film solar cell. This is a property that can enable a variety of new applications, solar cell coated clothes has been demonstrated on (Jacob Lund, 2006) [6]. However there are still challenges to overcome. Firstly the service life of a PSC is very short, only a few hours for a simple metal/polymer/metal solar cell. Secondly the efficiency of the PSC is not high compared to the SSCs.

The Problem

Semiconductors which are used in solar cells are very expensive and have low efficiency which cannot meet the requirements for which are manufactured. The aim of this work is to search for highly efficient solar cells and reduce the cost of manufacturing solar cells. This can be done by manufacturing solar cells using conjugate Polymer coating by Solder (Sn/Pb).

Materials & Methods

The material utilized in this work:
1- Titanium Dioxide glass (ITO) and conjugate polymer Poly [2-methoxy-5-(2-ethylhexyloxy)-1,4 phenylenevinylene] (MEH-PPV) beside different organic dyes (Rhodamine 6G- Coumarin 500 – Dibenzocyanin 45).
2- The coating will done using the Spin Coating Machine.
3-The concentration of different organic dyes (Rhodamine 6G- Coumarin 500 – Dibenzocyanin 45) was changed and the corresponding output current voltage, power and efficiency were recorded.
4- The empirical relations are compared with previous studies and theoretical relations.

ITO

ITO (Indium Tin Oxide) is a transparent conductive material. It is a mixture of indium oxide (In_2O_3) and tin oxide (SnO_2). ITO is used as one of the electrodes in the solar cell.[6]

MEH-PPV

Poly[2-methoxy-5-(2-ethyl-hexyloxy)-1,4-phenylenevinylene] (MEH-PPV) seen in Figure 1 is the active material of the solar cell. It is a modification of PPV, modified by the MEH-group, which makes it more soluble in some liquids. It is appearance in dark brown or red granules [6].

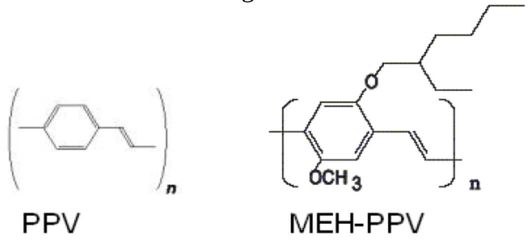

Figure 1: The two figures of the monomer of MEH-PPV(right) and the monomer of PPV(left).

Rhodamine 6G

Benzoic Acid, 2-[6-(ethylamino)-3-(ethylimino)-2,7-dimethyl-3H-xanthen-9-yl]- ethyl ester, monohydrochloride ($C_{28}H_{31}N_2O_3Cl$). It is appearance in red crystalline solid.[7]

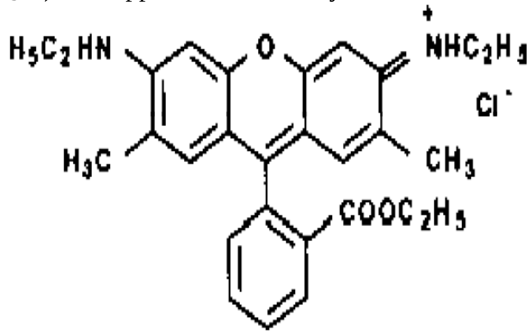

Figure 2: The structure of Rhodamine 6G.

Coumarin 500

7-Ethylamino-4-trifluormethylcoumarin ($C_{12}H_{10}NO_2F_3$).It is appearance in yellow crystalline solid. [7]

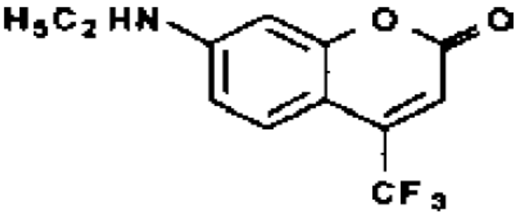

Figure 3: The structure of Coumarin 500.

Dibenzocyanin 45 (DDTTCI)

3,3'-Diethyl-4,4',5,5' dibenzothiatricarbocyanine Iodide Hexadibenzocyaini 45 ($C_{33}H_{29}N_2S_2I$). It is appearance in bronze crystalline solid.[7]

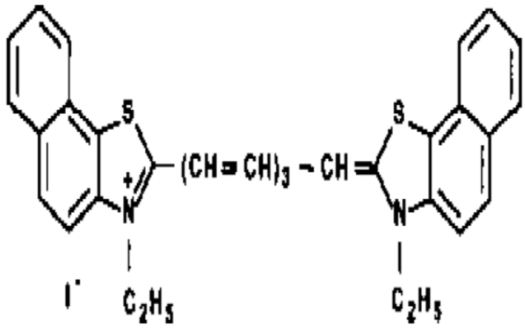

Figure 4: The structure of DDTTCI.

Solder (Sn/Pb)

Tin/lead solders, also called soft solders, are commercially available with tin concentrations between 5% and 70% by weight. The greater the tin concentration, the greater the solder's tensile and shear strengths. Alloys commonly used for electrical soldering are 60/40 Tin/lead (Sn/Pb) which melts at 370 °F or 188 °C and 63/37 Sn/Pb used principally in electrical/electronic work.

Fabrication of the Solar Cell

A clean glass plate with a thin layer of ITO (Indium Tin Oxide) is needed. The ITO acts as the first part of the solar cell, the first electrode. When a solar cell is made, it is important that the materials are clean. To clean the plate, it is first washed with soap; then with water and finally with ethanol and dried for 1 minute.

Solutions

Two solutions have been made, MEH-PPV solution, and dyes solution. The MEH-PPV solution has been treated carefully, the chemical MEH-PPV (PolyPhenylene Venylene) is very light sensitive so it has to be wrapped in silver paper to keep the MEH-PPV from reacting with sunlight. The dyes solutions are added in order to make

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the dissociation of excitons more efficient. The concentrations of the different chemicals solutions are described in table1.

Table1: The concentrations of different chemicals solutions for the solar cells.

Material	Solvent	Concentration
MEH-PPV	Ethanol	0.1 mg/ml
Rhodamine 6G	Ethanol	0.5 mg/ml
Coumarin 500	Ethanol	0.5 mg/ml
Dibenzocyanin 45 (DDTTCI)	Ethanol	1 mg/ml

Spin Coating

To deposit the polymer layers, a standard spin-coating technique was employed. Spin-coating implies either putting a droplet of a solution into the center of a rotating substrate, or first putting the solution onto the substrate and then spinning it up. In this work the first approach was used [(8)].
Two solutions have been coated over the plate. The first layer is the dye while the second layer is MEH-PPV which functions as the active layer in the solar cell. Then the plates were heated in oven at 80 ^{0}C for 30 minute in order to evaporate the water from the solution. Both layers MEH-PPV and the dye were coated for 1 minute. Table 2 shows the Parameters of spin coating machine for MEH-PPV and dyes.

Table 3: The Parameters of spin coating machine for MEH-PPV and dyes for the samples.

Samples	Dyes	Parameters of spin coating machine for Dyes	Parameters of spin coating machine for MEH-PPV	Groups
A3	Rhodamine 6G	V = 0.7 v , I = 500 mA	V = 0.9 v , I = 500 mA	A
A6	Rhodamine 6G			
A9	Coumarin 500			
A12	Dibenzocyanin-45			
A15	Dibenzocyanin-45			
B2	Rhodamine 6G		V = 1.1 v , I = 500 mA	B
B5	Rhodamine 6G			
B8	Coumarin 500			
B11	Dibenzocyanin-45			
B14	Dibenzocyanin-45			
C1	Rhodamine 6G		V = 1.3 v , I = 500 mA	C
C4	Rhodamine 6G			
C7	Coumarin 500			
C10	Dibenzocyanin-45			
C13	Dibenzocyanin-45			

The last layer is Solder Sn/Pb we spun it for 25 seconds as a second electrode. According to the parameters of spin coating machine in table 3 the thickness of samples will increase from Group C to Group A that means samples in Group A thicker than the others.

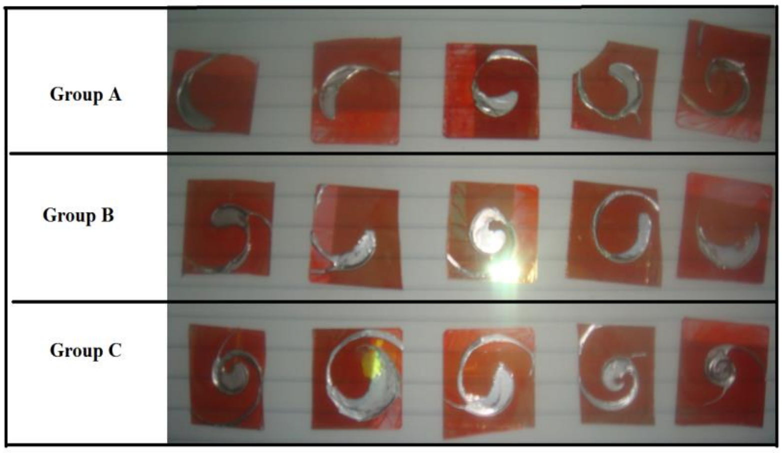

Figure 9: Actual conjugate polymers solar cells have been fabricated in this work

The measurement of absorption

The UV-VIS spectrophotometer (model: UV mini-1240) used in this work [9]. A glass slide that had been treated the same way as the slides with films but with no film on it was used as the reference slide. The wavelength was varied in units of 10 from 200 nm to 800 nm and the corresponding absorbance reading recorded.

Measuring the IV Characteristic

In order to compare various solar cells it is necessary to measure the characteristic values: V_{oc}, I_{sc}, the fill factor and the efficiency, η. All these factors can be determined from the IV characteristic of a solar cell and the power output from the lamp. For this reason an IV characteristic was performed under illumination for each solar cell in this project. The IV characteristic is a measurement of the current as a function of the applied voltage. In This work a simple circuit consist of electrical source, Rheostat, Ammeter, Voltmeter, solar cell and light source of output power 100 w was used (see figure 6). The measurement performs room at temperature.

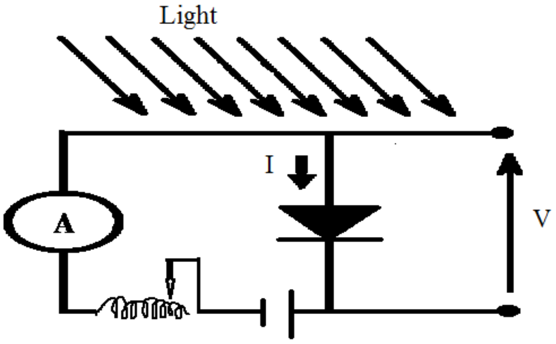

Figure 6: The setup for measuring the IV characteristics of solar cells.

Results

Fifteen solar cells sample have been fabricated in this work and it has been distributed in three groups A, B and C according to the spin coating machine parameters for (MEH-PPV) as show in table 3. The absorbance of the separate parts of the conjugate polymer solar cells has been measured, we choose three samples one from each group as models and their schemes are shows in figures bellow.

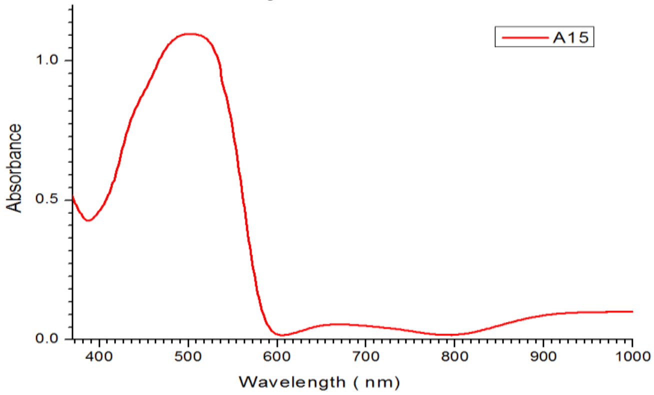

Figure 12: The graph shows the absorbance measured of sample A15.

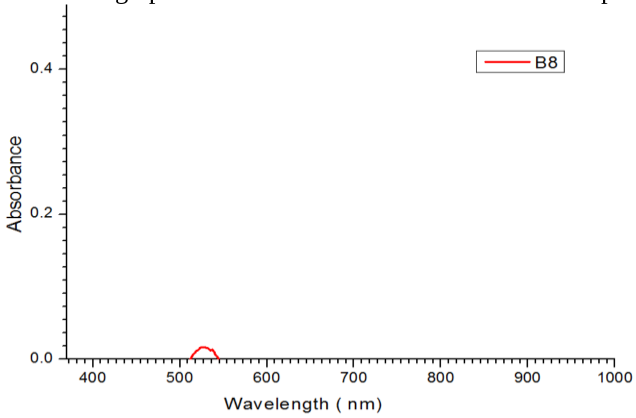

Figure 13: The graph shows the absorbance measured of sample B8.

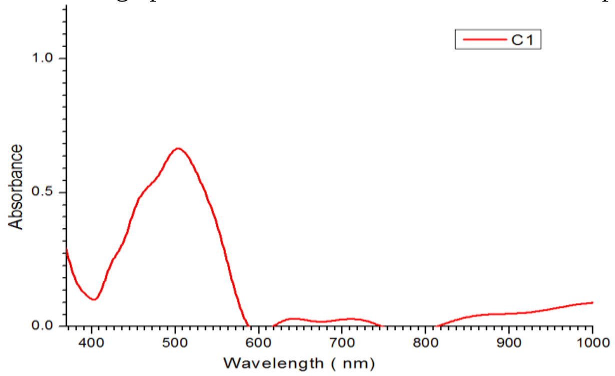

Figure 14: The graph shows the absorbance measured of sample C1.

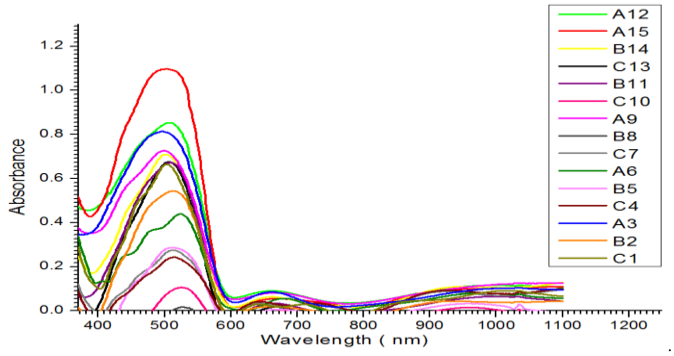

Figure 15: The absorbance measured for all samples

IV characterization

The IV-curve of the solar cells has been analyzed. Figures (16,17,18) show an IV-curve obtained from an ordinary conjugate polymer solar cell under illumination. I_{SC}, I_{mp}, V_{mp}, and V_{OC} are marked I_{SC}, I_{mp}, V_{mp}, and V_{OC} are marked on the curve.

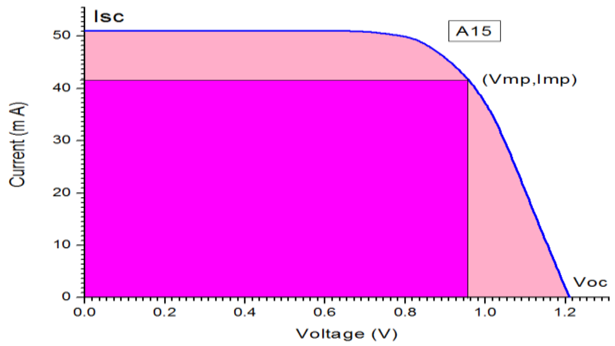

Figure 16: The graph shows the IV curve for sample A15.

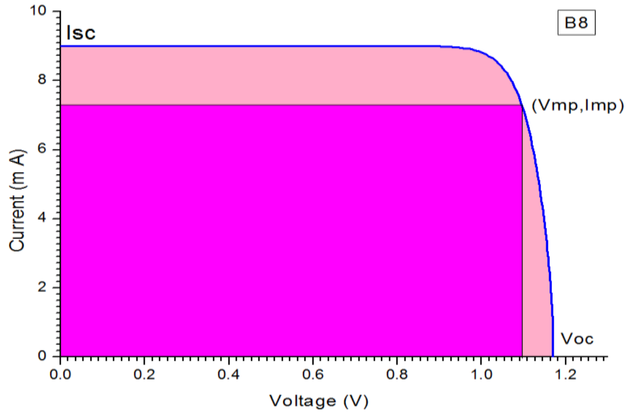

Figure 17: The graph shows the IV curve for sample B8.

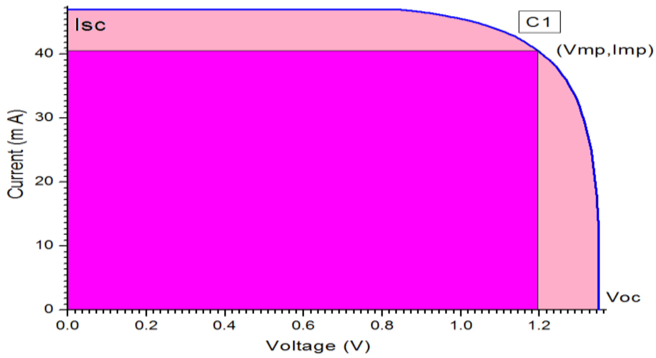

Figure 18: The IV curve for sample C1.

Discussion

The majority of the samples showed a wide range of absorption of the solar spectrum. For all samples the absorption peak shifts towards its maximum at a wavelength between 505-528 nm with decreasing of the thickness of the thin films as shown in figure 12. The highest absorbance recorded of the sample A5 it absorbs at most visible wavelengths with a maximum absorption at cyan wavelengths of the solar spectrum as shows in figure 11. The lowest absorbance recorded of the samples is sample A2 it absorbs at green wavelengths as shows in figure 8 and this may be caused by the thickness of the two layers of MEH-PPV and organic dye is not thick enough and the sample surface is not perfectly homogeneous.

IV Characterization

The IV-curve we obtained from the conjugate polymer solar cells a curve similar to the curve from the optimal model as described in (I. Montanari, 2002)[11]. Sample A4 recorded the highest value of the short-circuit current. Sample A2 recorded the highest values for each of the open circuit voltage and fill factor, as shown in figures 16, 14, respectively. All samples showed a variation in terms of obtained efficiency ranged between 10.28 % - 3.117 %. The highest efficiency of the solar cell has been obtained from sample A5, while the lowest efficiency was obtained from sample A2. This may be due to weak Absorption coefficient of light exhibited by the sample, which already discussed in the previous section. The samples produced in this work have shown good results in the efficiency compared to the results obtained in the previous studies in the same field [10]. Table 3 shows the short-circuit current, open circuit voltage, the fill factor, the current density and the efficiency obtained from all samples. The results of efficiency obtained from the samples are summarized in the histogram in Figure 18.

Table 4: The table shows Isc, Voc, Jsc, FF and the conversion efficiency for all the samples.

Samples	Isc (mA)	Voc (V)	Area (cm^2)	Jsc (mA/cm^2)	FF (%)	Efficiency (η) (%)
A15	51	1.21	4	12.75	0.66699	10.28
A9	52	1.3	6.25	8.32	0.8014	8.66
A12	55	1.24	5.25	10.47619	0.60527	7.862
C1	47	1.35	6.25	7.52	0.7509	7.62
B14	49	1.24	6.25	7.84	0.7827	7.609
A3	29	1.22	3.75	7.733	0.793668	7.487
C13	46	1.31	6	7.66	0.7441	7.466
B11	59	1.19	6.25	9.44	0.639	7.178
B2	23	1.25	3.75	6.133	0.5561	4.263
A6	10	1.32	3.5	2.857	0.8266	3.117
C10	15	1.21	5.25	2.857	0.6629	2.291
C4	12	1.26	4	3	0.5703	2.155
C7	10	1.25	4.24	2.352	0.68544	2.015
B5	9	1.25	4	2.25	0.7118	2.0019
B8	9	1.17	4.75	1.894	0.787	1.744

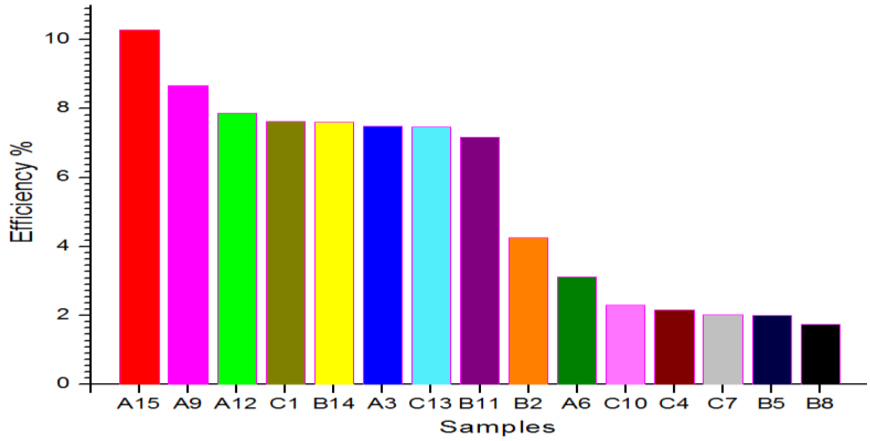

Figure 19: The graph shows the conversion efficiency for all samples.

Low-Cost

In order to reduce the cost of manufacturing solar cells conjugate polymer are used as the main materials in this work. The lower in cost was proved in several studies as reported in references (12) and (13). Polymer solar cells (PSC) are one of the possible replacements. These solar cells add some very interesting properties to the solar cell as well as reducing the price considerably. Jacob Lund [(6)] have demonstrated that the production of large area PSC ($1m^2$) can be done at a cost 100 times lower than that of monocrystalline silicon solar cells in terms of material cost. Recent developments in ink-jet printing, micro-contact printing, and other soft lithography techniques have further improved the potential of conjugated polymers for low-cost fabrication of large-area integrated devices on both rigid and flexible substrates.

Conclusion

In this work calculations of IV Characterization and absorbance spectra of conjugated polymers have been made and different types of polymer solar cells have been produced. Five samples of solar cells have been fabricated. The optical absorbance of these films was measured by UV-VIS spectrophotometer. The samples show a wide range of absorption of the solar spectrum. Sample A5 and sample A2 was recorded the highest absorbance and the lowest absorbance, respectively. For the IV-curve obtained for the conjugate polymer solar cells a curve similar to the curve from the optimal model as described in (I. Montanari, 2002)[(11)]. All samples showed a variation in terms of obtained efficiency ranged between 10.28 % - 3.117 %.

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