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RESEARCH ARTICLE

Comparison the Electrical Characteristics of PEDOT: PSS Tandem Solar Cell and P3HT Tandem Solar Cell by Varying Thickness

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ABSTRACT

Aim: This project aims to improve the electrical characteristics in the polymer tandem solar cell by changing polymers with thickness to increase the efficiency.

Methods and Materials: The PEDOT: PSS and P3HT Polymer was chosen as a group having 20 samples in each respectively. The electrical characteristics are stimulated by varying the polymer with thickness. Changing the polymer material leads to improved efficiency in the tandem solar cell. **Results:** The Independent T test was done which reveals that the P3HT (P = 0.553) was found to be statistically significantly compared with PEDOT: PSS polymer material. **Conclusion:** The analysis we found P3HT appeared to have better efficiency than PEDOT: PSS polymer tandem solar cell from Green energy. While P3HT(p=0.583) having the better significance compared with PEDOT: PSS (p=0.883).

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Introduction

Tandem solar cells are layer by layer structure with different elements, basically called organic solar cells, are engaging wealth of attention due to their great potential ("Graphene-Based Polymer and Organic Solar Cells" 2017) to produce the power conversion in a sufficient manner absorbing from the Green Energy resource. However, the wide usage power consumption and lack of efficiency need to add polymers in the tandem solar cells continues to be extremely restricted by their poor device performance (Prabaharan, Rosen, and Campana 2019). To fulfil this goal, various methods are introduced, together with active materials modification (polymers) and device structures (blenders) and nano materials. Due to the inevitable match between the spectrum of active materials energy is going to be lost in organic photovoltaics (Temple et al. 2010).. The shortage of superior low-bandgap polymers was the key limiting issue for achieving superior multi-junction photovoltaic cells.

Here we tend to report the event of a superior low bandgap of polymers. The PEDOT: PSS is a polymer material (poly(3,4-ethylenedioxythiophene): (poly (styrene sulfonate)) with P3HT (poly(3-hexylthiophene)) (bandgap o1.4 eV), with a bandgap of 1.38 eV, high mobility, deep highest occupied molecular orbital. As a result, PEDOT: PSS power conversion efficiency is 7.62%. The polymer enables P3HT tandem solar cell certified 10.60% power conversion efficiency under standard reporting. One of the best applications of tandem solar cells is the Perovskite tandem solar cell. This cell has already proved to be quite efficient based on materials used in the formation. In the combination layer formation having strong optical absorption and optical diffusion length based on this ability to be printed by spiral technology ("Tandem Perovskite Solar Cells" 2018). Another one is DSSC - dye synthesized solar cells. These cells are being used for semi transparent and flexible modules. Use them in tandem architecture due to its big potential to reduce the price of solar industry. Efficiency range can be improved from 8 to

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more than 17% ((“Tandem Perovskite Solar Cells” 2018; Langmar et al. 2019).

Based on this survey from the last five years nearly 200+ projects and researches are done in that some of most cited sites is(Rana, Islam, and Abdullah-Al-Rabbi 2018) Proposed: A tool is designed for extremely efficient perovskite star cells that use P3HT as a hole-transport material without any dopants. stretch out the platform to wide modules (24.97 sq. centimetres) that area unit created utilizing a flexible bar-coating technique for the deposition of P3HT and deliver the goods a PCE of 16.0 percent. (Teale et al. 2020).Proposed Tandem photovoltaic cell is basically dependent on transparent and semiconductive intermediate layers. The PCE of homo- tandem device with poly(3-hexylthiophene): phenyl-C61- butyric acid methyl group organic compound nanomaterials as a vigorous layer and poly (3,4 ethylenedioxythiophene): poly (styrene sulfonate)/ poly (ethylenimine) as achieve IML initially 3.40%. More improvement of the cell potency was accomplished utilizing silver nanoparticles (Ag-NPs) of assorted sizes and graphene quantum dot embedded IML. (Sidahmed and Kitai 2016) Proposed: Demonstrate the performance of single layer devices supported on carrier continuity equation in MATLAB. Polymers P3HT: PCBM, offer power conversion potency of 3.0% therefore series connected in Tandem cell pBBTDPP2: PCBM as front cell and P3HT: PCBM as rear cell is meant to attain higher potency wherever the planned model offers the ability conversion potency of 6%. Front cell P3HT photovoltaic cell within the device configuration that provides the ability conversion potency of 8.8%, until currently the atmost potency for organic photovoltaic cell.](Zhou, Zimmermann, and Jungemann 2016) (Zhou, Zimmermann, and Jungemann 2016) Proposed: Organic solar Cells (OSC) still suffer from lower efficiencies than their inorganic counterparts because of their narrow absorption band in optical phenomenon of single cell OSC. Considering current matching, the thickness of each and every cell has been observed and designed to get higher performing multi and triple-cell Organic solar cells. An efficiency of 8.29% has been obtained from a double-cell (junction) OSC by series connecting P3HT: PCBM (front cell) and pBBTDPP2: PCBM (back cell)(Z. Shao et al. 2016). A new low-bandgap material with 1.59ev energy has been introduced in the middle layer to design a triple-junction tandem Organic solar cell which provides a Power conversion efficiency of about 14%, which is a great enhancement in PCE(Hayase 2019). High Performance polymer tandem solar cells in this project explains the uses of tandem solar cells, importance’s and their drawbacks (lack of efficiency and high bandgap energy) help me to do this project(da Silva et al. 2015).

Previously our team has a rich experience in working on various research projects across multiple disciplines (Sathish and Karthick 2020; Varghese, Ramesh, and Veeraiyan 2019; S. R. Samuel, Acharya, and Rao 2020; Venu, Raju, and Subramani 2019; M. S. Samuel et al. 2019; Venu, Subramani, and Raju 2019; Mehta et al. 2019; Sharma et al. 2019; Malli Suresh Babu et al. 2019; Krishnaswamy et al. 2020; Muthukrishnan et al. 2020; Gheena and Ezhilarasan 2019; Vignesh et al. 2019; Ke et al. 2019; Vijayakumar Jain et al. 2019; Jose, Ajitha, and Subbaiyan 2020). Now the growing trend in this area motivated us to pursue this project.

Here the un-answered problem is lack of power conversion efficiency and high bandgap energy between the polymers PEDOT: PSS and P3HT in the tandem solar cell. While doing this research gained a knowledge about polymers and importance of the tandem solar in future. This project aims to improve the electrical characteristics in the polymer tandem solar cell by changing polymers PEDOT: PSS with P3HTand vary with thickness to increase the efficiency.

Methods and Materials

This study was performed in Saveetha University. This project was done in GPVDM (General-Purpose Photovoltaic Device Model) software. Total sample size of group 1 and group 2 is 32. The required samples for this analysis is done using statistical parameters. Minimum power of the analysis is fixed as 0.8 and maximum accepted error is fixed alpha is 0.05 and beta is 0.2.

For the PEDOT: PSS having the highest band gap energy with (1e-07) thickness was stimulated by using the GPVDM software tool. The electrical charge drain density is obtained for various applied voltages. Collected 20 samples from this polymer and the electrical characteristics of drain density and applied voltages are obtained.

P3HT polymer having the low bandgap energy as compared to the PEDOT: PSS. Similarly collect the 20 samples from the P3HT polymer in the GPVDM software and obtain the electrical characteristics between the applied voltage and charge dat drain density obtained from the GPVDM software.

In the GPVDM software a new simulation Tandem structure was selected at first. Create a new name for that and make some changes in the layer edition. PEDOT: PSS is the existing polymer tandem solar structure in GPVDM software change with polymer material Fig. 3 We need to change that polymer as an active layer in the layer edition with (1e-07) m^{-3} thickness after that run the simulator and take the electrical characteristics in the plot file. The data will be imported in an Excel sheet and saved. Similarly taken the same process to P3HT polymer material that polymer can be changed in the material database. Run the simulator, import the data in excel sheet and save it (Hima and abdelkader Hima 2018).In this above having different layers in the layer edition P3HT: PCBM(Malti, Chiali, and Sari 2016) with (2e-07) thickness ITO metal oxides with (1e-07) thickness nanomaterials- Al, Au metals with (1e-09), (5e-09) thickness a PEDOT: PSS with (1e-07) thickness and P3HT polymer with (1e-07) thickness. After completion of both simulations. 40 samples were collected from both the polymers by changing PEDOT: PSS with P3HT and compared the thickness in origin software to plot the graphs between applied voltage and data density.

Data sets are collected from the two sample groups. Group 1 consists of PEDOT: PSS polymer and Group 2 consists of P3HTpolymer. In each group taken 20 samples to obtain the electrical characteristics applied voltage and charge dat applied voltage

Table 1 Applied voltage with charge density in both groups applied voltage and charge dat density in PEDOT:PSS and P3HT.Here the collection of the data from the dataset calculates the efficiency with the help of applied voltage and charge dat density with the product of fill factor. fill factor=65 to calculate the efficiency. Efficiency is the product of voltage and charge dat density with fill factor (ff=65). Tabulate the all values obtained from the statistical analysis. independent variables such as P3HT: PCBM with (2e-07) thickness ITO metal oxides with (1e-07) thickness nanomaterials Al, Au metals with (1e-09), (5e-09) thickness and dependent variables PEDOT: PSS with (1e-07) thickness and P3HT polymer with (1e-07) thickness. After completion of both simulations Analysis Collect the 40 values from both polymers by changing PEDOT: PSS with P3HT and compare the thickness in origin software to plot the graphs between applied voltage and data density.

Table 1. Applied voltage with charge density in both groups PEDOT:PSS and P3HT

S.No	group (PEDOT: PSS)	charge. applied voltage(v)	charge dat density(m^-3)	group (P3HT)	charge. applied voltage(v)	charge dat density(m^-3
1	1	-3.65E-03	1.77E+21	2	-4.93E-03	2.78E+21
2	1	3.64E-02	1.92E+21	2	5.51E-02	3.02E+21
3	1	7.64E-02	2.08E+21	2	9.51E-02	3.61E+21
4	1	1.16E-01	2.44E+21	2	1.35E-01	3.85E+21
5	1	1.96E-01	2.89E+21	2	1.75E-01	4.48E+21
6	1	2.36E-01	3.17E+21	2	2.55E-01	4.92E+21
7	1	3.16E-01	3.52E+21	2	3.35E-01	5.52E+21
8	1	3.57E-01	3.98E+21	2	3.75E-01	6.40E+21
9	1	3.97E-01	4.64E+21	2	4.56E-01	7.79E+21
10	1	4.37E-01	5.63E+21	2	4.96E-01	1.01E+22
11	1	5.18E-01	6.73E+21	2	5.38E-01	1.41E+22
12	1	5.60E-01	7.28E+21	2	5.80E-01	2.14E+22
13	1	6.51E-01	1.02E+22	2	6.26E-01	3.42E+22
14	1	7.06E-01	2.48E+22	2	6.77E-01	5.58E+22
15	1	7.73E-01	4.16E+22	2	7.38E-01	6.57E+22
16	1	8.16E-01	6.83E+22	2	7.75E-01	8.92E+22
17	1	8.56E-01	1.08E+23	2	8.13E-01	1.35E+23
18	1	9.16E-01	1.60E+23	2	9.06E-01	1.94E+23
19	1	9.56E-01	2.04E+23	2	9.75E-01	2.16E+23
20	1	9.61E-01	2.24E+23	2	1.02E+00	2.63E+23

Results

Total sample size of group 1 and group 2 is 32. The required samples for this analysis is done using statistical parameters. Minimum power of the analysis is fixed as 0.8 and maximum accepted error is fixed alpha is 0.05 and beta is 0.2. Optimization method is used in this simulation to fix parameters PEDOT:PSS with P3HT and polymers in the tandem solar cells to obtain the maximal power conversion efficiency. PEDOT:PSS polymer the basic structure of PEDOT:PSS elements act as active interlayers to obtain the drain density characteristics. Layer thickness can be edited in layer edition with initially (1e-07)m3 were shown in Fig. 1. P3HT Polymer basic structure in GPVDM. P3HT elements act as an interlayer to obtain the drain density characteristics Layer thickness can be edited in layer edition initially(1e-07) m3 were shown in Fig. 2 Layer edition in GPVDM having different elements which are needed for structure to make Tandem solar cells. Consist with P3HT: PCBM (2e-07),ITO metal oxides (1e-07),and some nanomaterials. Al (1e-09), Au (5e-09) thickness a PEDOT: PSS with (1e-07) thickness and P3HT polymer with (1e-07) thickness. This algorithm works on optical stimulation as shown in Fig. 3. Electrical characteristics of applied voltage and drain density in PEDOT:PSS The blue line indicates the efficiency of the tandem solar cell in between the two electrical characteristics voltage with charge density were shown in Fig. 4. Compare the electrical characteristics of PEDOT:PSS and P3HT polymer in Origin In this structure current density and applied voltage is changed with respect to the polymer material with different thickness Fig. 5. Efficiency is changed with respect to the materials band gap energy from 1.6 to 1.3ev. Whenever the bandgap energy is minimized automatically the power conversion efficiency is increased with the help of the collection database (Santhosh, Bangera, and Shivakumar 2017) Table 2. The performance of P3Ht polymer and P3HT:ICBA polymer in origin. In this structure the PCE is varied with respect to voltage and density in P3HT and P3HT:ICBA polymer tandem solar cells based on the Table 2. P3HT polymer having better efficiency than P3HT:ICBA in Fig. 6. Group statistics based on PEDOT:PSS and P3HT Structures showed that PEDOT:PSS,P3HT appeared to be of lesser standard error mean value Table 3. Independence sample test based on Levene's Test for Equality of variances appeared to better significance for PEDOT:PSS and P3HT P3HT Tandem solar cells having the improved efficiency compared with PEDOT: PSS polymer tandem solar cell with [P=0.53] significance in independent sample tests in the SPSS tool Fig. 7. Simple Bar graph means of charged applied voltage, drain density in both groups. With respect to changes in the input values (independent variables) the corresponding output values (dependent variables) also changes Fig. 3. Independent t-test was used to compare the electrical characteristics of two algorithms and a statistically P3HT: ICBA tandem solar cell having PCE is (8.9%)(You et al. 2013). When compared with the other algorithms performance of the proposed P3HT polymer achieved better (10.6%) performance than PEDOT:

PSS (7.62%) were shown in Table 2. Tandem solar cells having the improved efficiency compared with PEDOT: PSS polymer tandem solar cell with [P=0.53] significance in independent sample tests in the SPSS tool Table 4.

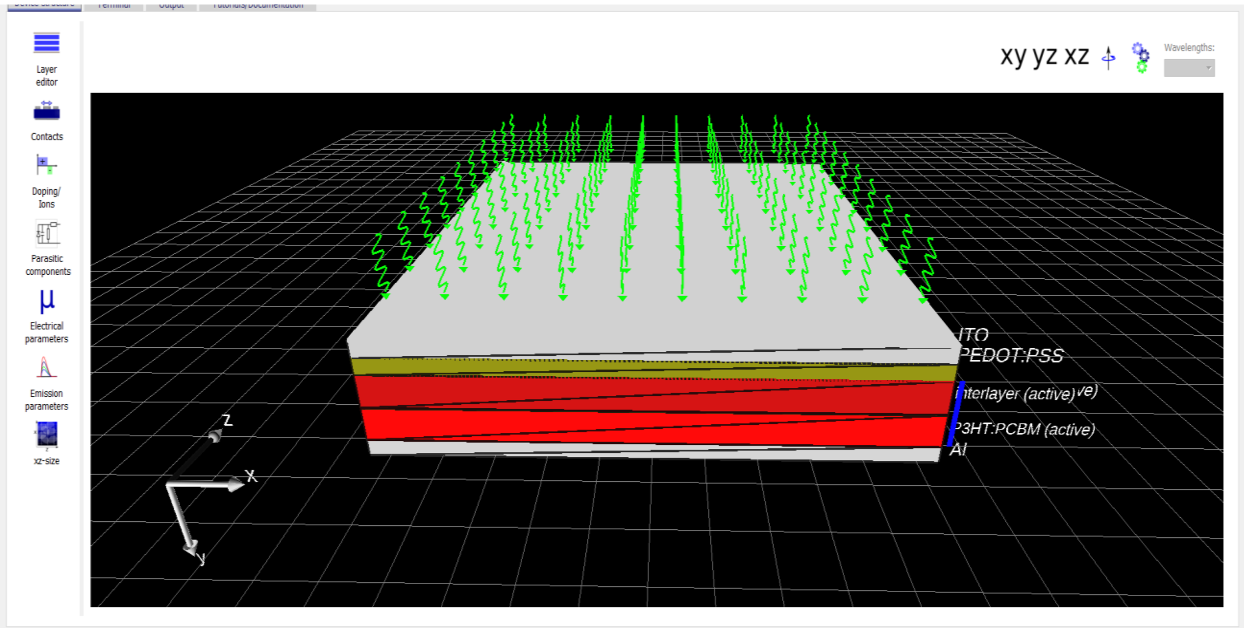

Fig. 1. PEDOT:PSS polymer the basic structure of PEDOT:PSS elements act as active interlayers to obtain the drain density characteristics. Layer thickness can be edited in layer edition with initially(1e-07)m3

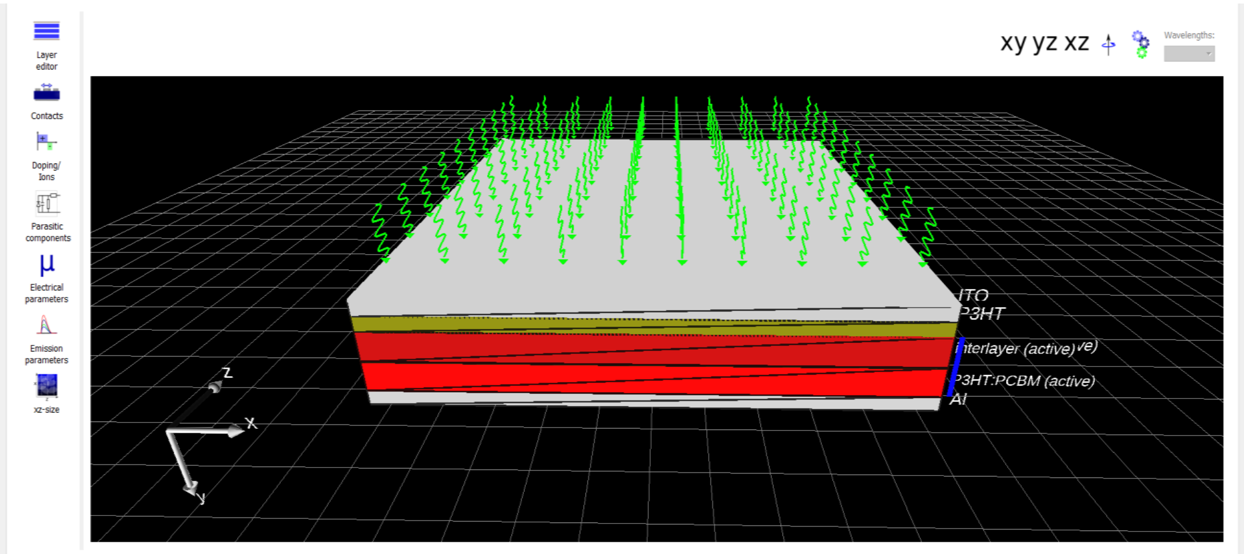

Fig. 2. P3HT Polymer basic structure in GPVDM. P3HT elements act as an interlayer to obtain the drain density characteristics Layer thickness can be edited in layer edition initially(1e-07) m3

Layer name	Thicknes	Optical material	Layer type	Solve optical problem	Solve thermal problem
ITO	1e-07	oxides/zno	other	Yes	Yes
P3HT	1e-07	polymers/p3ht	active layer	Yes	Yes
P3HT:PCBM	2e-07	blends/p3htpcbm	active layer	Yes	Yes
interlayer	5e-09	metal/au	active layer	Yes	Yes
P3HT:PCBM	2e-07	blends/p3htpcbm	active layer	Yes	Yes
Al	1e-07	metal/al	other	Yes	Yes

Fig. 3. Layer edition in GPVDM having different elements which are needed for structure to make Tandem solar cells. Consist with P3HT: PCBM (2e-07), ITO metal oxides(1e-07), Al (1e-09), Au (5e-09) thickness a PEDOT: PSS with (1e-07) thickness and P3HT polymer with (1e-07) thickness. This algorithm works on optical stimulation.

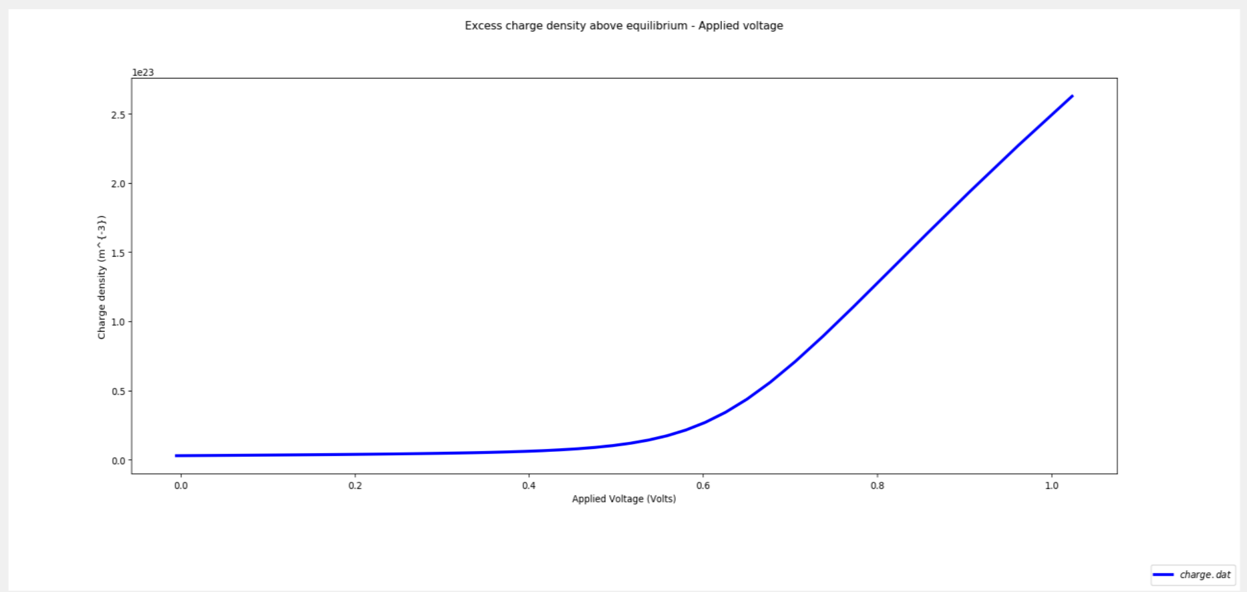

Fig. 4. Electrical characteristics of applied voltage and drain density in PEDOT:PSS The blue line indicates the efficiency of the tandem solar cell in between the two electrical characteristics voltage with charge density

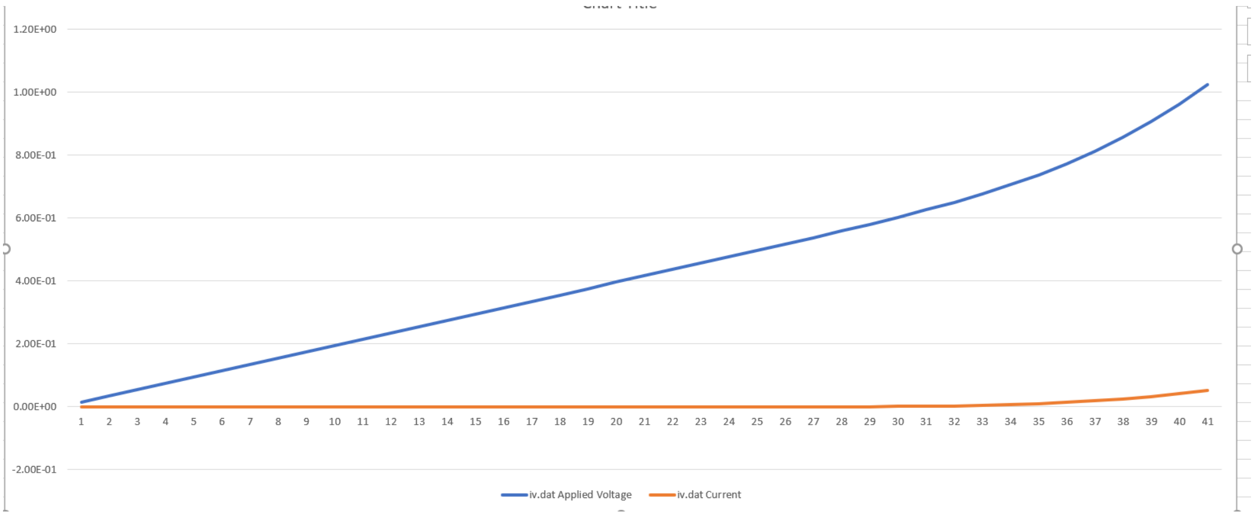

Fig. 5. Compare the electrical characteristics of PEDOT:PSS and P3HT polymer in Origin. In this structure current density and applied voltage is changed with respect to the polymer material with different thickness. Efficiency is changed with respect to the materials band gap energy from 1.6 to 1.3ev

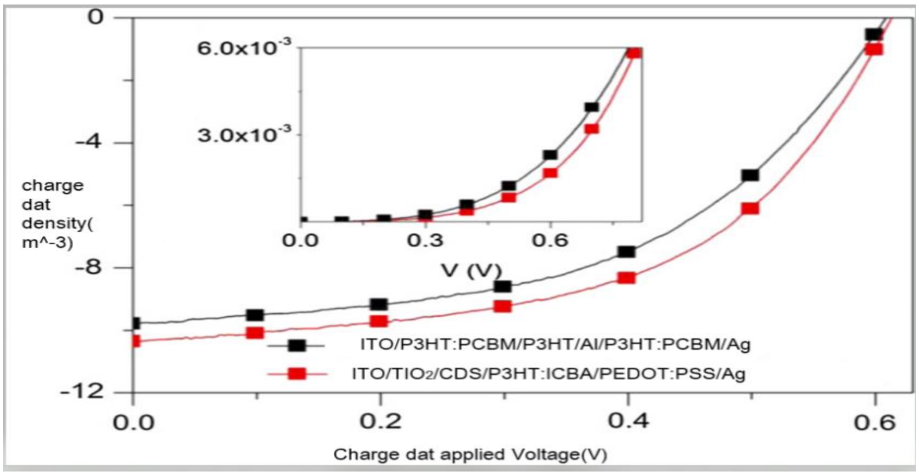

Fig. 6. Comparing the performance of P3Ht polymer and P3HT:ICBA polymer in origin. In this structure the PCE is varied with respect to voltage and density in P3HT and P3HT:ICBA polymer tandem solar cells based on the Table 2. P3HT polymer having better efficiency than P3HT:ICBA

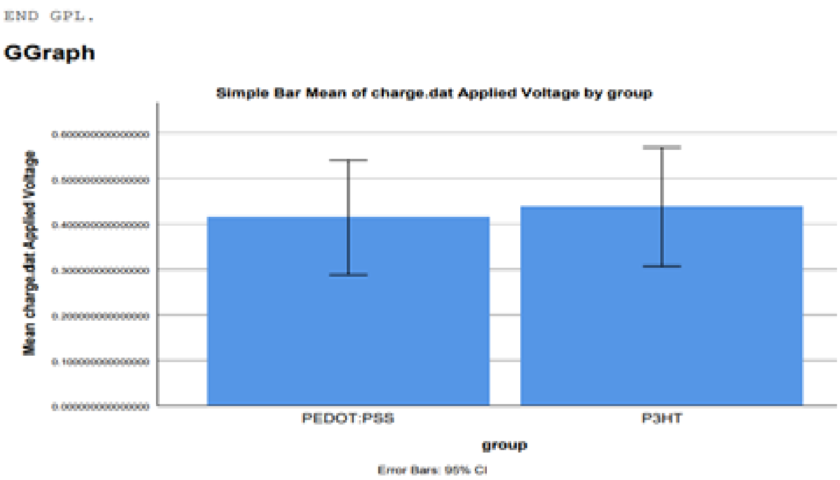

Fig. 7. Comparison of PEDOT:PSS and P3HT polymer tandem solar cell in terms of electrical characteristics. The mean charge applied voltage of P3HT is better than the PEDOT:PSS and the standard deviation of P3HT is slightly better than PEDOT:PSS X Axis: PEDOT:PSS vs P3HT Algorithm Y Axis: Mean applied voltage ± 1 SD.

Table 2. New Low Bandgap Polymer designed for polymer Tandem solar cell

polymer	bandgap(ev)	voltage	density	Fill factor	PCE
PEDOT: PSS	1.56	0.76	15.2	66.9	7.62
P3HT: ICBA	1.30	0.60	17.8	66	8.9
P3HT	1.38	0.68	17.8	65	10.6

Table 3. Group statistics based on PEDOT: PSS and P3HT Structures showed that PEDOT: PSS, P3HT appeared to be of lesser standard error mean value

	Groups	N	mean	Std. Deviation	Std. Error Mean
Charge applied voltage	PEDOT: PSS	20	.4144219168	0.2769793251	0.0604418440
	P3HT	20	.2876435870	0.2876435870	0.62768967
Charge dat charge density	PEDOT: PSS	20	3.31691E+22	6.00051E+22	1.30942E+22
	P3HT	20	4.14243E+22	7.15209E+22	1.56032E+22

Table 4. Independence sample test based on Levene's Test for Equality of variances appeared to better significance for PEDOT:PSS and P3HT P3HT Tandem solar cells having the improved efficiency compared with PEDOT: PSS polymer tandem solar cell with [P=0.53] significance in independent sample tests in the SPSS tool

		f	significance	t
PEDOT: PSS	Equal variances assumed	0.22	0.883	-270
	Equal variances not assumed			-270
P3HT	Equal variances assumed	0.395	0.533	-405
	Equal variances not assumed			-405

Discussion

P3HT polymer tandem structures appeared to be better accuracy than PEDOT:PSS polymer tandem solar cells. The efficiency of homo- tandem device P3HT intermediate layer has initially 3.40% for the further enhancement of the cell efficiency using nanomaterials Au, Al of different sizes then the structure got maximum efficiency 4.03% achieved(Sidahmed and Kitai 2016). A Single junction solar cell thermodynamically predicted optimal bandgap energy in the GaAs solar cells is 1.59eV by changing that element with polymer P3HT having a strong photoluminescence efficiency with 1.3eV bandgap energy in the tandem structure leads to produce more PCE (A. Shao and Zhang 2016). Electrical characteristics were analyzed in GPVDM software by changing the tandem structure. In the layer edition, all elements were arranged in a sequence manner based on thickness. Comparison was done in Origin software which is shown in Fig. 5. Standard Deviation Charge density of PEDOT:PSS is 0.2769793251 and P3HT is 0.2876435870. Standard Error rate of applied voltage is, 6.00051E+22 for PEDOT:PSS and for P3HT, 7.15209E+22. Standard error mean of PEDOT:PSS is 1.30942E+22 and P3HT is 1.56032E+22 which is shown in table 1 and table 2. Here the collection of the data from the dataset the efficiency was calculated with the help of product of applied voltage and charge dat density which also multiplied by fill factor. Fill factor =65 then efficiency was calculated with help of voltage and density. From the statistical analysis, all the obtained values were tabulated. Mean efficiency was calculated and compared with the help of SPSS tools.

By consolidating the performance, the following changes were noted. i) Drain density is varied along with the applied voltage ii) Bandgap energy is minimized by changing the polymer. iii) Solubility is increased with polymer thickness. Initially, the power conversion energy is below 300hrs in solar cells. Since Bandgap energy affects the Power conversion efficiency (PCE)., doping polymer in layer edition to make it an active layer to produce the efficiency in a sufficient manner.

The tandem solar cell could be implemented to produce the maximum efficiency without the help of non-fullerene acceptors which minimize the size of the tandem solar panel and also speed up the initial power conversion energy below 300hr in the solar cells.

Conclusion

This methodology described in this study will be of great utility to other researchers to aid in the rational design and efficient optimization of tandem solar cell devices from Green energy. While comparing both the materials P3HT appeared to have better efficiency than PEDOT: PSS polymer tandem solar cell while P3HT (p=0.583) having the better significance compared with PEDOT: PSS (p=0.883).

Declaration

Conflict of Interest

No conflict of interest in this manuscript.

Author Contributions

Author KS was involved in sampleset preparation, statistical analysis and paleograph. Author AS was involved in idealization, data declaration, concrete-suggestion, structuring report.

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