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A Review on Donor Material of Bulk Heterojunction Organic Solar Cells

VIKAS PRASAD[1], MD. ASIF IQBAL[2] (ASST. PROGF), DR. DEEPIKA CHAUHAN[3], MR. GAURAV SRIVASTAVA[4]

[1,2] *Department of Electrical Engineering, Poornima College of Engineering, India*

[3] *Associate. Professor, Department of Electrical Engineering, Poornima College of Engineering, India*

[4] *Assistant Professor, Department of Electrical Engineering, Poornima College of Engineering, India*

Abstract - The aim of the paper is to get the brief idea about the materials used in organic solar cells. In this paper there is a brief comparison between donor materials MDMO-PPV/ P3HT/PSBTBT/PBDTTT-C of bulk heterojunction organic solar cells were studied and characterized. It is found that PBDTTT-C:PCBM is the most efficient material among the group. The maximum efficiency.

I. INTRODUCTION

Photovoltaic Cell is a device that converts solar energy into electricity through the photovoltaic effect [1]. In organic photovoltaic (OPV) technology, polymer solar cells (PSC) have attained attraction in recent years. Polymer-based solar cells have reached power conversion efficiencies of 5% in recent reports. Deposition of organics by screen printing, inkjet printing, and spray deposition is possible because these materials can be made soluble [2]. The active material is usually a blend composed of a conjugated polymer (donor) and small molecule acceptor. Bulk heterojunction structure is one of the most promising combination of donor and acceptor materials where the blend is formed with bicontinual phase separation. The simple homo-polymer poly (3-hexylthiophene) (P3HT), one of the most prominently used and best understood polymers in organic PV cells [2].

In this paper, there is a discussion about donor materials of four different groups (PPV,PT, BT and BDT) keeping the acceptor material fixed for every donor material for a comparative study and evaluating their performance.

II. DONOR MATERIALS

The donor materials used in this paper is basically of four different groups (PPV, PT, BT and BDT). These donor materials are common for the same acceptor material PCBM ([6,6]-phenyl-C61-butyric acid methyl ester). It is a more practical choice for an electron acceptor when compared with fullerenes because of its solubility in chlorobenzene. This allows for solution processable donor/acceptor mixes, a necessary property for “printable” solar cells.

1. MDMO-PPV

Poly [2-methoxy-5-(3,7dimethyloctyloxy) - 1,4 phenylenevinylene] -is a p- type semiconductor polymer(electron donor) which is the subject of researches in particular with the aim of forming p - n junctions , with the PCBM or the PCNEPV as n- type materials (electron acceptors), making it possible to produce photovoltaic cells made of polymers having a good energy efficiency.

2. P3HT

Poly (3-hexylthiophene) (P3HT) is a polymer with chemical formula $(C_{10}H_{14}S)_n$. It is a polythiophene with a short alkyl group on each repeat unit. It is noteworthy since it is a semi conducting polymer; it can conduct positive charges (holes). It is a common material for studies of organic electronics (e.g. FETs) and for organic photovoltaics (OPV).

3. PSBTBT

Poly[(4,4’-bis(2-ethylhexyl) dithienol[3,2-b:2’,3’-d] silole)-2,6-diyl-alt-(2,1,3-benzothiadiazole)-4,7-diyl])

4. PBDTTT-C
(Poly [4,8-bis-(2-ethylhexyloxy)-benzo(1,2-b:4,5-b’dithiophene)-2,6-diyl-alt-(4-(2-ethlyhexanoyl)-thieno[3,4-b] thiophene-)-2-6-diyl)])

III. PROPERTIES OF DONOR MATERIAL

1. P3HT Poly(3-hexylthiophene)

- Density: ~1.33 g/cm^3
- Neutron SLD: 0.817×10^{-6} Å^{-2}

Material	density (g/cm^3)	X-ray energy (keV)	X-ray wavelength (Å)	critical angle (°)	q_c (Å^{-1})	SLD (10^{-6}Å^{-2})
P3HT	1.33	2.0	6.20	0.700	0.0248	12.20
		4.0	3.10	0.352	0.0249	12.33
		8.0	1.55	0.176	0.0249	12.29
		12.0	1.03	0.117	0.0248	12.25
		16.0	0.77	0.088	0.0248	12.24
		24.0	0.52	0.058	0.0248	12.2

Table 1: Properties of P3HT

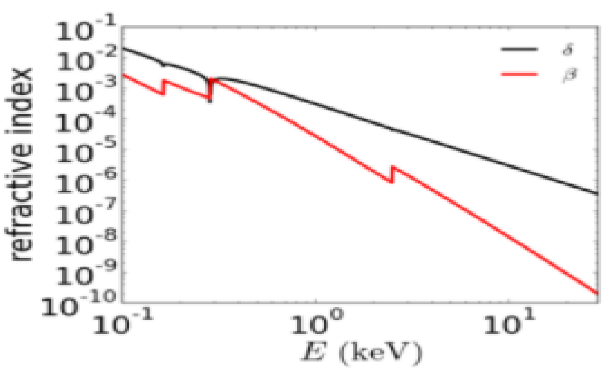

Fig. 1: Graph for the P3HT refractive index vs E.

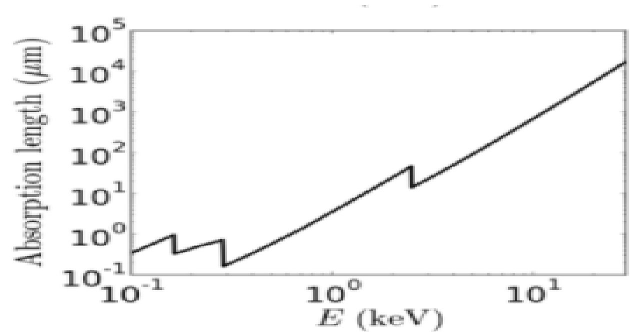

Fig. 2: Graph for the P3HT Absorption Length VS E.

2. PBDTTT-C (Poly[4,8-bis-(2-ethylhexyloxy)-benzo(1,2-b:4,5-b’dithiophene)-2,6-diyl-alt-(4-(2-ethlyhexanoyl)-thieno[3,4-b] thiophene-)-2-6-diyl)])

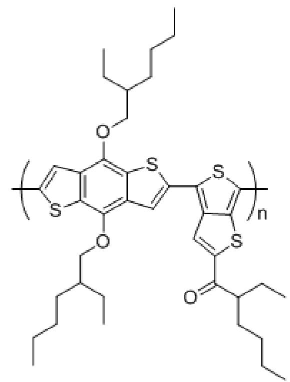

Fig.3: Structure of PBDTTT-C

HOMO = -5.12 eV
LUMO = -3.35 eV
Mn> 23,000
PDI: 1.8~2.5

3. MDMO-PPV poly [2-methoxy-5- (3,7-dimethyloctyloxy) -1,4-phenylenevinylene] being investigated in particular for the purpose of forming pn junctions, with PCBM or PCNEPV, as n-type materials (electron acceptors), making it possible to produce photovoltaic cells polymers with good energy efficiency.

IV. RESULTS AND DISCUSSIONS

1. MDMO-PPV: PCBM
The optimum blend thickness for MDMO-PPV: PCBM has been found to be 70 nm where the efficiency is enhanced up to 3.45%. In our

simulation environment, the PCE for 100 nm thickness has been found to be 2.89% with Voc = 0.82 V, Jsc = 5.83 mA/cm2 and FF=59.2%. Experimentally, at this thickness, the recorded efficiency is 2.5% where Voc = 0.82 V, Jsc = 5.25 mA/cm2 and FF=61%. [2]

2. P3HT: PCBM

For P3HT: PCBM solar cell, the maximum efficiency has been noted as 4.72% at thickness of 90 nm. For benchmarking, we have compared our results with the analytical model proposed by Chowdhury results from their model suggest that the efficiency of a 100 nm thick cell is 4.31% whereas our results show 4.39% with Voc = 0.66 V, Jsc = 10.02 mA/cm2 and FF=65.8 %. [2]

3. PSBTBT: PCBM

The maximum efficiency for PSBTBT: PCBM cell too, has been found at lower thickness. In this case, the optimum efficiency and thickness values are 4.64% and 80 nm respectively. A temperature dependent simulation study performed by Yang estimates a reduced efficiency of 4.24% at 80 nm thickness and 30oC temperature. [2]

4. D. PBDTTT-C: PCBM

For PBDTTT-C: PCBM based solar cell with standard architecture, efficiency has been found to be in higher range than other active materials studied in this work. The optimum blend thickness, here too, has been noted as 80 nm where the efficiency reaches up to 6.55% with Voc = 0.72 V, Jsc = 13.48 mA/cm2 and FF=67.2%. Experimental analysis at this thickness gives a reduced efficiency of 6.3% with Voc = 0.711 V, Jsc = 14.1 mA/cm2 and FF=63%. [2]

V. CONCLUSION

Table 2: Photovoltaic properties of active materials

Active Material	PCE (%)	V_{oc} (V)	J_{sc} (mA/cm^2)	FF (%)
MDMO-PPV:PCBM	3.45	0.851	7.071	59.5
P3HT:PCBM	4.71	0.673	10.079	66.3
PSBTBT:PCBM	4.64	0.721	10.613	60.5
PBDTTT-C:PCBM	6.55	0.724	13.478	67.2

In this paper we have compared the donor materials used in the Bulk Heterojunction Organic Solar Cells where this is used as fixed acceptor base. The donors used was MDMO-PPV: PCBM, P3HT:PCBM, PSBTBT:PCBM and PBDTTT-C:PCBM among these the best material found was PBDTTT-C:PCBM as in the table we can see that PBDTTT-C:PCBM has the FF of 67.2% which has led to the best recorded efficiency of 6.55%.[2]

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