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Introduction and Processing of Different Organic Solar Cell (OPVC)

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Abstract - The scope of this paper to investigate the theoretical study of different types of organic solar cells as introduction and characterization of single layer, bulk hetero-junction, laminated devices. In this analysis we take operation of organic photovoltaic as Absorption of light and generation of excitons, Diffusion of excitons to active interface, Charge separation, Charge transport, and Charge collection.

The objective of this work is to understand the above characteristics of organic solar cell.

Keywords - ***Acceptor, Donor, Exciton, Fabrication, Heterojunction, Indium Tin Oxide, Organic solar cell , opv(organic photo voltaic), Single Layer.***

I. Introduction

A solar cell is an electrical device that converts energy of light into electricity. In current years, research and development in the field of organic solar cells has advanced tremendously, driven by potential for a selection of low cost, large area devices. Organic solar cells have emerged as new promising photovoltaic devices due to their potential applications in large area, printable and flexible solar panels. Organic solar cell is a class of photo voltaic that uses organic polymers for absorption of light and transporting the charge. This type of cell fabricated easily and processed on flexible substrates. Poly(3-hexylthiophene) P3HT AND [6,6]-Phenyel-C61-butric acid methyl ester PCBM are organic materials used in organic photo voltaic cell as simultaneously electron donor and electron acceptor) : Poly(3,4-ethylenedioxythiophene) Polystyrene sulfonate (PEDOT:PSS) –as hole transport layer[1]

II. Single Layer Device

An organic photovoltaic having fabricating layer of indium tin oxide (ITO) as a electrode is a thin transport layer. Back electrode is a metal like Al, Ca, and Mg.

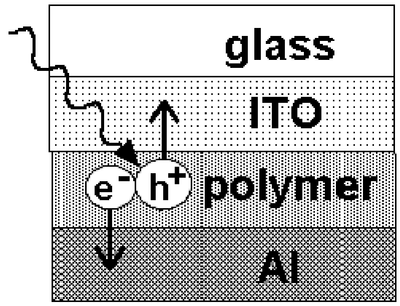

Fig. 1 Device Architecture of Single Layer Organic Solar cell

- By connecting two electrodes with a conductor an electric field occurred in organic layer due to difference in work function.
- By absorption of light electrons excited to LUMO and leaving hole in HOMO[2]-[3], forming excitons, the electric field in organic layer breaking the exciton pairs, due to this processing electrons go to positive electrode and holes going to negative electrode.
- This single layer solar cell referred to as Schottky diodes.
- This type of solar cell is simple to fabricate has low quantum efficiency and conversion efficiency.
- In this type of cell value of electric field is not sufficient for separation of exciton pairs.
- In single layer organic cell electrons and holes travel in same material and recombination losses are generally high.

III. Double Layer Device

- The double layer organic solar cell improves functionality of single layer solar cell by including a distinct organic donor layer and distinct acceptor layer between two electrodes [8].
- These two layers of materials have differences in electron affinity and ionization energy, so electrostatic force occurs at common boundary of layers. The materials are chosen as to make differences very large so electric field occurs strong to breakup excitons large efficiently than single layer photo voltaic.
- Electron acceptor layer take the high electron affinity and ionization .Electron donor layer take low electron affinity and ionization [4].

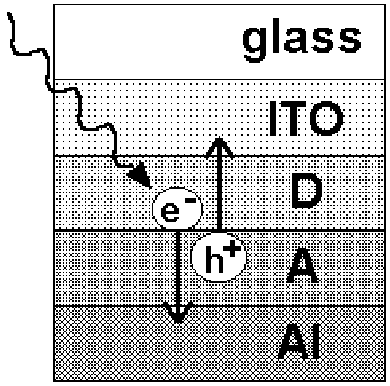

Fig. 2 Device Architecture of Bilayer Organic Solar cell

- It is also called as planar donor acceptor heterojunction solar cell.
- Drawback of this type of solar cell is small interface that allows only excitons of thin layer to reach it and get associated.
- A little fraction of exciton reach heterojunction interface due to 100nanometer thickness of polymer, but diffusion length of excitons is of order 4-10nanometer.

IV. Bulk Hetero-junction Device

In this type of device electron donor and acceptor are mixed together forming a polymer blend.

- If exciton diffusion length is same to blend length than most generated excitons reach to interface break efficiently. Electrons move to acceptor domains then carried through device and collected by one electrode and holes pulled into opposite direction collected by other side.
- This type of cell contain large interface area if the molecular mixing produced on a scale that allows good contact between alike molecules and most excitons to reach donor/acceptor interface.
- This type of cell is also called as dispersed heterojunction opv [8]-[9].

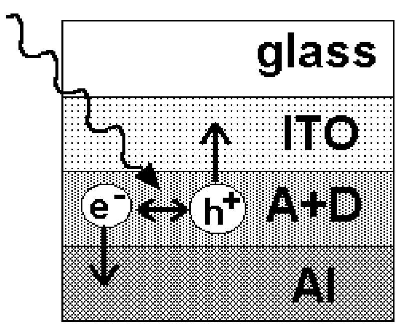

Fig. 3 Device Architecture of Bulk Heterojunction Organic Solar cell

V. Laminated Layer Device

- This type of solar cell device advantage over above opv. It contain laminated polymer donor-acceptor device considered as intermediate of bilayer and bulk heterojunction device.
- In blend layer charge separation produced in middle that is obtained after laminating two separate layers together and charge transport can only occur through correct transport layer [3].
- This type of structure has options to treat each layer separately before forming the blend layer and instant encapsulation between the two substrates.
- It required low glass transition temperature to form intermixed layer.

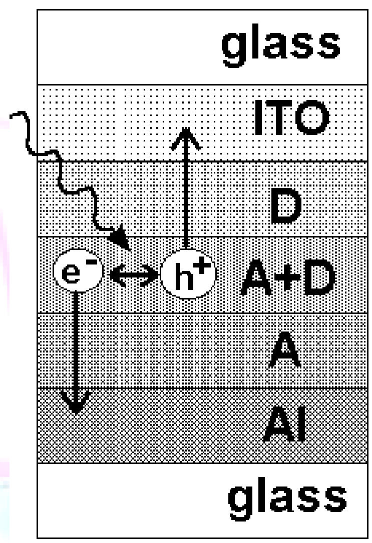

Fig. 4 Device Architecture of Laminated Layer Organic Solar cell

VI. Operations of Organic Solar Cell

Five important processes can be optimized in opv for conversion solar energy into electrical energy.

1. **LIGHT ABSORPTION AND PRODUCTION OF EXCITONS**

Absorption spectrum of photoactive organic layer match the solar emission spectrum and layer should be sufficiently thick to absorb incident light.

2. **DIFFUSION OF EXCITONS TO ACTIVE INTERFACE**

Excitons reach photoactive interface with in exciton lifetime, since excitons diffusion length is approx. 10nanometer, only those excitons formed in 10nanometer from interface will contribute charge separation.

3. **CHARGE SEPARATIONS**

An electron is transformed from electron donor to electron acceptor material by absorption energy h**ʊ**.

4. **CHARGE TRANSPORT**

After charge transfer electrons and holes are in closeness and therefore there is a large chemical potential gradient that drive charge carriers away from exciton disjoint interface.

5. **CHARGE COLLECTIONS**

This is complete by a transparent conduction oxide such as ITO on one side and a metal contact such as Al on other side [5]-[6].

VII. CURRENT-VOLTAGE CHARACTERISTICS

I-V characteristics of solar cell are similar to a diode. In light I-V curve is obtained for typical PV cell [7].

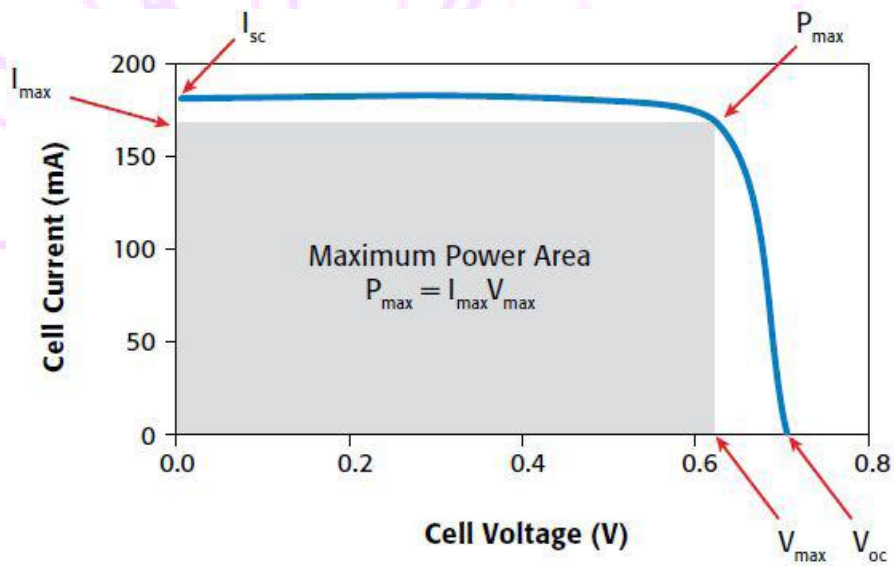

Fig. 5 Forward bias I-V characteristics of a solar cell

The important parameters of the cells under illumination are:

- short circuit current I_{sc}
- open circuit voltage V_{0C}
- max power point P_{max}.

Fill factor (FF) is $FF = P_{MAX.} / I_{SC} V_{OC} = I_{MAX} V_{MAX} / I_{SC} V_{OC}$

The conversion efficiency of the cell is given as

$$\eta = P_{max} / P_{min}$$

P_{max} is max. Power extracted from cell
P_{in} is total radiant energy incident on surface of cell

DEGRADATION OF OPVC

Unluckily OPVs presently have very short lifetimes. There are some promises for mechanism of degradation:

- Environmental and intrinsic factors
- Light (photo degradation)
- Temperature, moisture, presence of oxygen
- Chemical composition, morphology
- Can be physical or chemical degradation

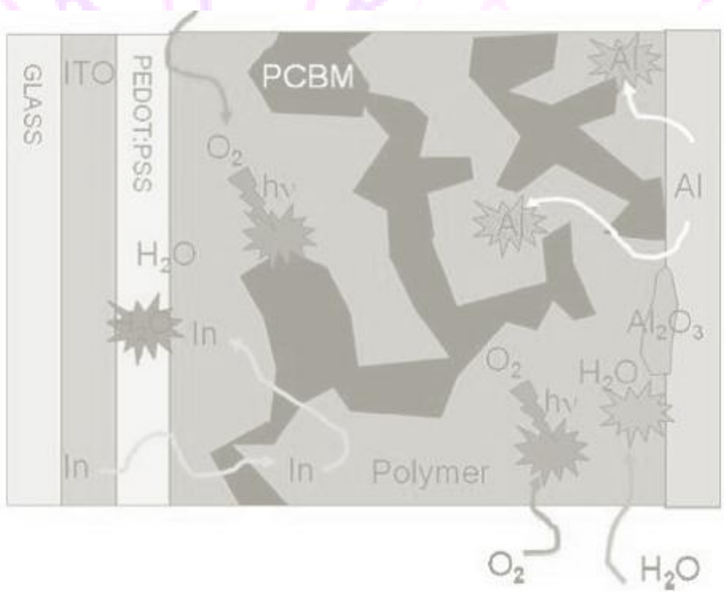

Fig. 6 Degradation mechanisms in OPVC

FABRICATION

The organic solar cell device is basically a multi-layer system, the layers essential are generally**:**

- A transparent conducting oxide (TCO) such as Indium Tin Oxide (ITO), normally deposited by sputtering

- Organic layers deposited furthermore by spin coating or thermal vacuum evaporation [10]
- Metal electrode for example Al deposited by thermal vacuum evaporation

Sputtering of Transparent Conducting Layer (TCO)

- Sputtering is a physical process whereby atoms in a solid target material are expelled into the gas phase due to bombardment of the material by energetic ions [11].
- The sputtered atoms even as they are not in their thermodynamic equilibrium state, are tending to condense back into the solid phase in front colliding with the substrate, kept back a few cm above the target.
- Argon is usually used to create Are+ plasma.

The steps involved in the sputtering process are:

- The substrates are cleaned and mount in vacuum chamber [11].
- The vacuum chamber is firstly evacuated to a relatively high-vacuum level (< 2X10-5 Torr), making use of a vacuum rotary pump and a high vacuum pump such as diffusion pump or turbo-molecular pump.
- The sputtering gas such as Argon is admit in the chamber in restricted manner creation use of a mass flow controller; this bring the chamber pressure to about 10-3 Torr.
- An Rf generator (13.56MHz) supplies the most wanted Rf power to the system (across the target and the substrates). A plasma is therefore formed and the sputtering process begins.
- A pre-sputtering phase of about 10min is normally recommended to clean the target previous to opening the shutter, thus exposing the substrate.
- The thickness is monitored using a thickness monitor. Once the desired thickness is reach, the shutter is closed, the Rf generator is turned OFF, and the sputtering gas supply is also stopped up.
- The chamber is vented to Nitrogen gas and the samples detached from the chamber.
- For some materials, there is require to moreover heat up the substrate throughout the sputtering process or carry out a post annealing step at a preferred temperature.

Typical process parameters for ITO sputtering are:

- Rf power: 50W
- Ar flow rate: 2 sccm
- Substrate temperature: 250^{o}C

Organic layer deposition: Spin coating

There are four different stages in the spin coating process**:**

- Deposition of the coating fluid on the wafer or substrate**:** This can be complete by using a nozzle and pouring the coating solution or by spraying it on the surface. Spin coaters usually have 2 modes of dispense:
- Static dispense (solution dispensed on a steady substrate) (ii) dynamic dispense (solution dispensed even as the substrate is rotating at a slow speed).
- Acceleration of the substrate up to its absolute, preferred, rotation speed.
- Spinning of the substrate at a constant rate; fluid viscous forces control the fluid thinning behavior.
- Spinning of the substrate at a constant rate; solvent evaporation dominates the coating thinning behavior [12]-[13]-[14].

Back Electrode Deposition: Thermal Vacuum Evaporation

- In a thermal vacuum evaporation system, the material is heated up to its boiling point by apply the preferred electric current to a resistive heater.
- The material thus evaporates and condenses on the surface of the substrate.
- Thermal vacuum evaporation is fundamentally used for metallization.
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VIII. Conclusion

A theoretical study of different organic solar cell has been presented. Operations of opv as absorption of light, generation and diffusion of excitons, separation, transport, collection of charge can be studied. Laminated layer device has advantage over above studied opvs. I-V characteristics and I_{sc} (short circuit current), V_{oc} (open circuit voltage),$P_{max.}$(max.power point) can be studied for typical solar cell. Here it also considered factors about degradation of Opv. Fabrication of organic solar cell can be processed as Sputtering of TCO, spin coating, thermal vacuum evaporation. To conclude we can say that Opv devices are easy to fabricate, can also processed on flexible substrates, however they have relatively low conversion efficiencies and offer low stability.

IX. References

[1]Deboisblanc J 2010 Synthesis and characterization of P3HT: PCBM organic solar cells, Thesis department of physics and astronomy Pomona College

[2] Scharber MC and Sariciftci NS 2013 efficiency of Bulkheterojunction organic solar cells Progress Polymer Science

[3] M.G. Zebaze Kana lecture notes participants of the Pan African school of materials research, held at African university of Science & technology (AUST) ,Abuja

[4] Dennler N, Sariciftci S and Brabec CJ 2006 Conjugated polymer Based organic solar cells in Semiconducting Polymers: Chemistry, Physics & Enginnering,Vol I Second Edition Edited by G Hadziioannou & GG Malliaras,Weinheim (Wiley-VCH verlag GmbH&CoKga) P511-512

[5] Barry P.Rand, Henning Richter “organic solar cells fundamentals, devices and up scaling” PANSTANFORD PUBLISHING CRC Press Taylor and Francis GroupBocaRaton, FL 33487-2742 T Markvart, Practical handbook of photovoltaic’s-Ⅲa

[7] “Solar I-V Characteristics “Alternative energy tutorials Website (Home of Alternative and Renewable Energy Tutorials) Wallace C.HO Choy, organic solar cells materials and device physics DOI: 10.1007/978-1-4471-4823-4_1 SPRINGER-VERLAG LONDON 2013, Richter C.(Ed),Linwt,D.(Ed),Gueymard, solar energy , C.A (ED) 2013

[9] Dixon D.S. fung, organic solar cells materials and device physics, Dept. of Electrical and Electronical Engineering, The University of Hongkong JeF Pourtinans (editor),Vladimir Arkhipov(editor) “Thin film solar cells Fabrication,Charaacterization&Applications” Wiley ISBN-10;0470091266

[11]T.J. Coutts,J.D. Perkins,D.S. Ginley,T.O. Mason, conference paper presented at 195^{th} meeting of electro chemical society Seattle,Washington

[12] Long bin Qiu,Luis K.Ono,Yabing Qi,Advances and challenges to the commercialization of organic inorganic halide perovskite solar cell technology

[13] Scriven, LEC (1988) “physics and applications of dip coating and spin coating”,MRS proceedings.121.

[14] Lukas wengeler , Coating and drying process for functional films in polymer solar cells.