International Journal of Global Research Innovations & Technology (IJGRIT)
ISSN : 2583-8717, Impact Factor: 6.382, Volume 02, No. 02, April-June, 2024, pp 69-72

DIFFERENT ARCHITECTURES OF ORGANIC SOLAR CELLS

Dr. Hemant Kumar*

ABSTRACT

We note that both exciton and charge transport in organic materials usually require hopping from molecule to molecule. Thus, close packing of the molecules is assumed to decrease the width of the intermolecular barriers and a flat molecular structure should generally lead to better transport properties than bulky 3 dimensional molecules. We note that dense packing also favours a higher absorption coefficient. In order to meet these specific requirements for efficient photon to charge conversion different device architectures have been developed in the past. We give below a brief summary of the strengths and weak points of the three different architectures known today.

Keywords: *Organic Materials, Molecule, Intermolecular Barriers, 3 Dimensional Molecules.*

Introduction

Organic Photovoltaic cell or Organic Solar Cell (OPV or OSC's) are the term used to explain new era of technology. In short the when we try to understand the working of OSCs, a light photon is made incident on the PV devices, it is absorbed by the active layer, which is composed of the donor and acceptor. The absorbed light photon generates a bound electron-hole pair known as exciton. To generated electricity this exciton has to break into free electron and hole that are collected at different electrodes. Electrons are collected at cathode while holes are collected at anode. When the electrons at the cathode, and holes at anode, meet with each other through an external circuit, it constitutes an electric current through the circuit. When light is made incident on an OPV device, light photons are absorbed by the composed of the donar and acceptor materials. The absorbed photons generate excitons, which are bound electron and hole pairs. To generate electricity the excitons needs to break into free electron and holes. Exciton can be converted into free electron and hole due to the energy level differences of donar and acceptor materials. Interface area between donar and acceptor increase the population of free electron and holes. These free electron and holes ultimately increase the efficiency of OPV devices. To increase the numbers of free electron and holes we need to select suitable pair of donor and acceptor organic material. Different architectures of donar acceptor layes are design to increase the interface area between active layers of OPV devices.

Single Layer OSCs

The single layer OSC is comprised of a transparent electrode/organic photosensitive semiconductor/electrode (see Fig.1). Single layer structures consist of only one semiconductor material and are often referred to as *Schottky* type devices or *Schottky diodes* since charge separation occurs at the rectifying (Schottky) junction.

* Government Degree College, Kasganj, U.P., India.

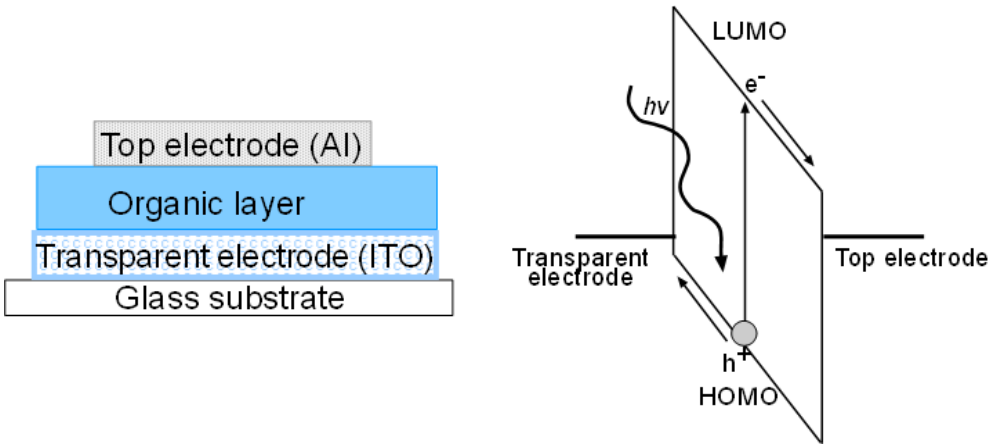

Fig.1: Single Layer OSCs Device Structure

The structure is simple but absorption covering the entire visible range is rare using a single type of molecule. The photoactive region is often very thin and since both positive and negative photo-excited charges travel through the same material recombination losses are generally high. In 1994, this structure was created by R. N. Marks *et al*. using 50-320 nm thickness of poly (*p*-phenylene vinylene) (PPV) sandwiched between an ITO and a low work function cathode. The reported quantum efficiencies for this device were around 0.1% under 0.1 mW/cm^2 intensity [1]. This low quantum efficiency resulted from intrinsically low mobility of charges through semiconducting organic material.

The carrier mobility of semiconducting organics remains around 10^{-3} cm^2/V·s, while the mobility of single crystalline silicon is about 10^3 cm^2/V·s order. This indicates that the photo generated charges in semiconducting organics require more time to be collected to the electrodes. The slow charge transport itself decreases the efficiency of the OSCs, as it increases the recombination possibilities of charges. The other problem that causes the low PCE in OSCs is the exciton formation rather than free charge carriers generation [2]. In single layer OSCs, only one place to dissociate excitons into free carriers is the organic-cathode interface. Later, it was known that the excitons are more efficiently dissociated at the interface between donor and acceptor, and a bilayer OSC was developed by inserting an acceptor layer between donor and the cathode.

Bilayer OSCs

The bilayer OSC structure includes an additional electron accepting and transporting layer than is found in the single layer OSCs. This structure benefits from the separated charge transport layers that ensure connectivity with correct electrode and give the separated charge carriers only little chance to recombine with its counterpart. The drawback is small interface that allows only excitons of a thin layer to reach it and get dissociated (see Fig.2).

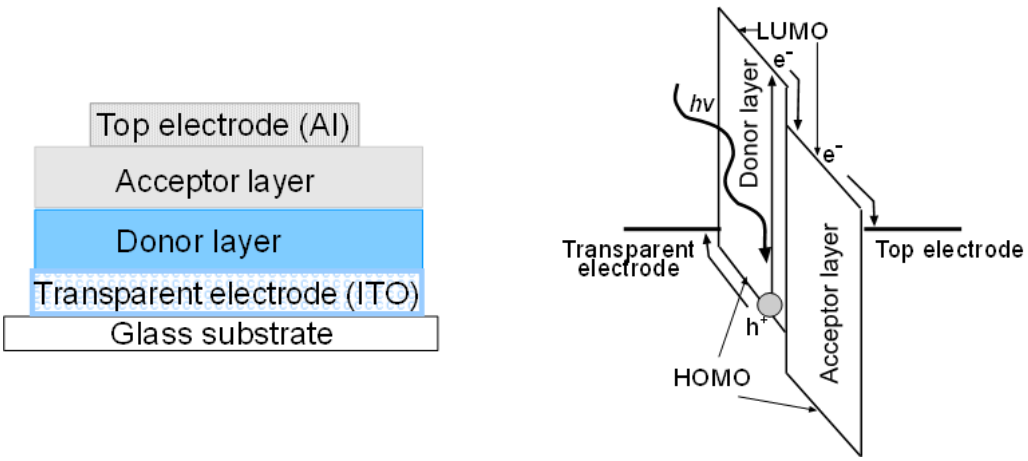

Fig. 2: Bi- Layer OSCs Device Structure

This structure was first realized by C. W. Tang in 1986 where device structure was comprised of indium tin oxide (ITO)/ Copper Phthalocyanine (CuPc)/ Perylene tetracarboxylic derivative (PV)/ silver (Ag) [3]. The reported PCE was 1% under simulated AM2 conditions. This ten-fold PCE increase resulted from improving exciton dissociation efficiency by adding electron transporting material that forms an offset energy band with hole transporting material. However, the reported PCE of bilayer OSCs was still significantly lower than that of inorganic based PV cells. One reason for this is the intrinsically short exciton diffusion length of excitons in organic semiconductors, which are typically around 10- 20 nm [4, 5].

Researchers attempted to overcome this limitation in the bilayer OSC by using buckminsterfullerene (C_{60}) in which the exciton diffusion length is around 20 nm. P. Peumans *et al.* replaced perylene tetracarboxylic derivative with C_{60} as an acceptor and the device showed 3.5% PCE [6]. This improvement of PCE is attributed to the longer travel distance of excitons in the triplet state of C_{60}. However, since donor and acceptor layers are around 40-60 nm thickness, most of the absorbed photon energy is not efficiently converted into free carriers and dissipates by recombination, which indicates that photogene rated excitons are dissociated only near the interface between donor and acceptor.

This dilemma was overcome by mixing the donor-acceptor materials together in single layer. This structure was terms as bulk heterojunctions and the cells were called bulk heterojunction solar cells.

Bulk Heterojunction OSCs

As discussed above bilayer OSCs harvest the excitons created near the donor-acceptor interface, whereas bulk heterojunction OSCs have an intermixed composite of donor and acceptor materials and that has an advantage of much larger interface area between donor and acceptor (see Fig.3). For the first time, Yu *et al.* prepared solar cell with a phase-separated polymer blend composite made of poly[2-methoxy-5-(2'-ethyl-hexyloxy)-l,4-phenylene vinylene] (MEH-PPV) as donor and cyano-PPV (CN-PPV) as acceptor [7].

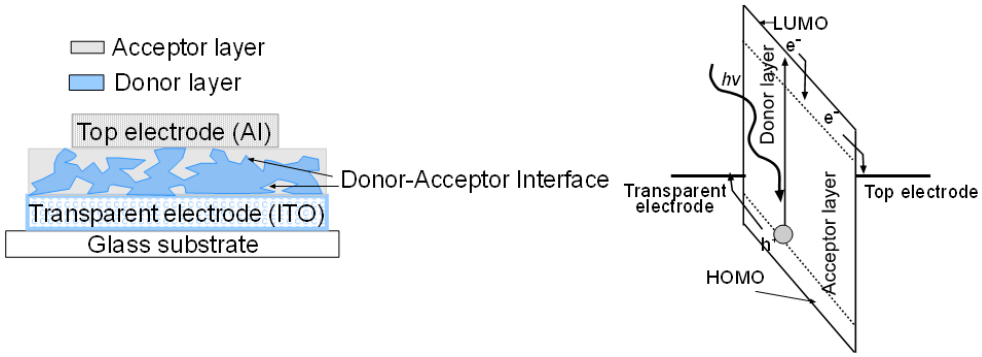

Fig. 3: Bulk Hetro-Junction OSCs Device Structure

The photoluminescence and electroluminescence of both component polymers was quenched in the blend, which is indicative of rapid and efficient separation of photo generated electron hole pairs with electrons on the acceptor and holes on the donor. This device showed promising photovoltaic characteristics with energy conversion efficiency of 0.9 %, which is 20 times larger than that of diodes made with pure MEH-PPV. Later on Yu *et al.* reported improved PCE from the conjugated polymer and C_{60}-based bulk heterojunction solar cells. Composite films of MEH-PPV and C_{60} exhibited PCE of about 2.9 %, which was much larger than that with pure MEH-PPV [8]. The efficient charge separation results from photo-induced electron transfer from MEH-PPV to C_{60} at the interface, and the high collection efficiency results from a bicontinuous network of internal donor acceptor heterojunctions.

Conclusion

When light is made incident on an OSCs, the photons are absorbed by the active layer, which is composed of the donar and acceptor materials. The absorbed photons generated excitons, the excitons diffuse to the donor-acceptor interface and dissociate into free electrons and holes. These free electrons and holes contribute into current driven inside the Cell. Another parameter which participates in determination of solar cell performance is the diffusion ability of free electros and holes at respective electrodes. To get maximum current we should design a special architecture in which exciton dissociation and collection of free electrons and holes on respective electrodes should be highest. This is an important fundamental issue to balance both parameters to get efficient solar cell.

References

1. R. N. Marks *et al. J. Phys.: Condens. Matter* **6**, 1379 (1994).
2. M. Knupfer, *Appl. Phys. A: Mater. Sci. & Proc.* **77**, 623 (2003).
3. C. W. Tang, *Appl. Phys. Lett.* **48**, 183 (1986).
4. J. M. Halls *et al. Appl. Phys. Lett.* **68**, 3120 (1996).
5. L. S. Roman, L.A.A. Patterson, O. J. Inganas, *J.Appl. Phys.* **86**, 487 (1999).
6. Y.P. Peumans, Stephen R. Forrest, *J. Appl. Phys.* **93**, 3693 (2003).
7. G. Yu, A. J. Heeger, *J. Appl. Phys.* **78**, 4510 (1995).
8. J. J. M. Halls *et al. Nature* **376,** 498 (1995).