Polymer Based Organic Solar Cells

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Abstract: **The non renewable sources of energy will deplete over time,alternative souces of energy are required for overcoming this problem.Solar energy is a form of renewable source of energy and it is converted to its useful form using solar(PV) cells.This paper discusses the working of organic solar cells based on polymers,it has been compared with Si solar cells and how the polymer based solar cells are preferred over other cells.These cells have been further classified into single layer solar cells,bilayer solar cells and bulk heterojunction solar cells.It has been concluded based upon the efficiency.**

Keywords: PV cells, polymer, single layer cells, bilayer solar cells, bulk heterojunction solar cells.

I. INTRODUCTION

One of the most important source of energy is solar energy (produced by the sun).It is used to provide electricity and it is best because it is free and does not compromise with the environment. The principle of the solar cells is : photo voltaic cells are composed of layers of semiconductors such as silicon. Energy is created when photons of light from the sun strike a solar cell and are absorbed within the semiconductor material. This excites the semiconductor's electrons, causing the electrons to flow, and creating a usable electric current.Various architectures for organic solar cells have been investigated in recent years. [1]

Organic photovoltaic (OPV) cells are a revolutionary technology for electrical energy production, being inexpensive to fabricate,lightweight, and mechanically flexible. Initial OPV devices based on a vapor-deposited donor–acceptor small-molecule heterojunction exhibited a power conversion efficiency (PCE) of 1%. However, during the last two decades dramatic performance increases have been achieved , the photoactive blend layer, comprising a conjugated polymer donor and a soluble molecular acceptor is sandwiched between an indium tin oxide (ITO) electrode (anode) and a metal electrode(cathode). The polymer donor serves as the main solar light absorber and as the hole transporting phase, whereas the small molecule transports electrons.Therefore a wide optical absorption range (to match the solar spectrum), large extinction coefficients, and large carrier mobilities are basic requirements toward the design of ideal photoactive blends. Furthermore, microstructural features favoring light-to-charge and charge transport in the out-of-plane direction are essential characteristics to enhance charge collection.

II. BASIC WORKING OF A SOLAR CELL

Solar energy is produced with the help of solar cells.A solar cell is an electronic device which directly converts sunlight into electricity. Light shining on the solar cell produces both a current and a voltage to generate electric power. This process requires firstly, a material in which the absorption of light raises an electron to a higher energy state, and secondly, the movement of this higher energy electron from the solar cell into an external circuit. The electron then dissipates its energy in the external circuit and returns to the solar cell. A variety of materials and processes can potentially satisfy the requirements for photovoltaic energy conversion, but in practice nearly all photovoltaic energy conversion uses semiconductor materials in the form of a *p-n* junction.

The basic steps in the operation of a solar cell are:

- the generation of light-generated carriers;
- the collection of the light-generated carries to generate a current;
- the generation of a large voltage across the solar cell;
- the dissipation of power in the load and in parasitic resistances.

In polymer based organic cell,for an efficient collection of photons, the absorption spectrum of the photoactive organic layer should match the solar emission spectrum and the layer should be sufficiently thick to absorb all incident light. A better overlap with the solar emission spectrum is obtained by lowering the band gap of the organic material, but this will ultimately have some bearing on the open-circuit voltage. Increasing the layer thickness is advantageous for light absorption,but burdens the charge transport.

Creation of charges is one of the key steps in photovoltaic devices in the conversion of solar light into electrical energy. In most organic solar cells, charges are created by photoinduced electron transfer. In this reaction an electron is transferred from an electron donor (D), a p-type semiconductor, to an electron acceptor (A), an n-type semiconductor, with the aid of the additional input energy of an absorbed photon (hν). In the photoinduced electron transfer reaction the first step is excition of the donor (D*) or the acceptor (A*), followed by creation of the charge-separated state consisting of the radical cation of the donor (D•+) and the radical anion of the acceptor (A•-).

$$D + A + h\nu \rightarrow D^* + A \text{ (or } D + A^*) \rightarrow D^{\bullet +} + A^{\bullet -}$$

For an efficient charge generation, it is important that the charge-separated state is the thermodynamically and kinetically most favorite pathway after photoexcitation. Therefore,it is important that the energy of the absorbed photon is used for generation of the charge separated state and is not lost via competitive processes like fluorescence or non-radiative decay.

In addition, it is of importance that the charge-separated state is stabilized, so that the photogenerated charges can migrate to one of the electrodes. Therefore, the back electron transfer should be slowed down as much as possible. To create a working photovoltaic cell, the photoactive material (D+A) is sandwiched between two dissimilar (metallic) electrodes (of which one is transparent), to collect the photogenerated charges. After the charge transfer reaction, the photogenerated charges have to migrate to these electrodes without recombination. Finally, it is important that the photogenerated charges can enter the external circuit at the electrodes without interface problems.[2]

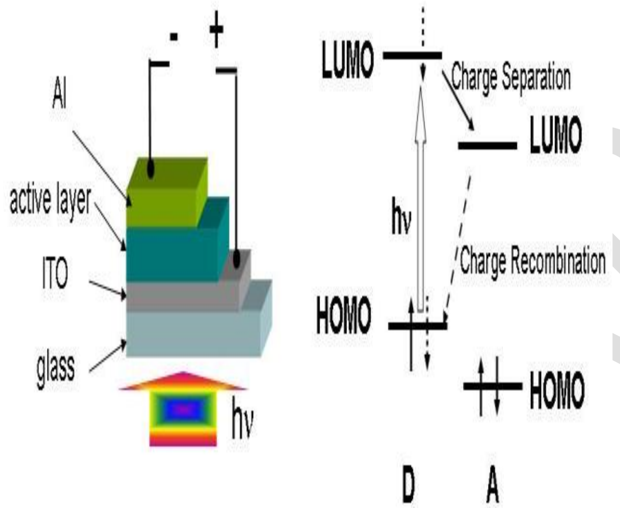

Figure showing basic solar cell

III. COMPARISION BETWEEN SI BASED PV'S AND ORGANIC PV'S

In the case of crystalline inorganic PV that almost exclusively employ a large thermal budget with prolonged heating steps and exist in a rigid or in flexible nature it is obvious that a thin flexible form that employ much less active material and lower thermal budgets are an advantage. In addition all the crystalline PV technologies employ relatively scarce components with low abundance except crystalline silicon which has been touted as the only environmentally friendly PV technology that is based on abundant elements that enable a scale comparable to the worlds energy needs. The polymer and organic solar cells in principle also enable this since carbon is highly abundant. Thus if the OPV was based entirely on carbon abundant elements this would be an example of a thin film technology that also fulfilled this requirement. In contrast many of the inorganic thin film technologies i.e. a-Si, CIGS, CdTe also have a lower thermal budget, use of less material and enables faster production, the OPV technology however does the same to a more extreme degree.[3]

IV. WHY ORGANIC PV'S ARE BEING DEVELOPED EVEN THOUGH THEY HAVE POOR PERFORMANCE?

In comparison a database search using Thompson Reuters Web-of-Science for respectively polymer solar cells(~12,000documents),amorphous silicon solar cells (6000documents), cadmium telluride solar cells (2500documents) and copper indium gallium diselenide solar cells (1500documents) reveals that the polymer solar cells are much more investigated than any of the other three inspite of the fact that polymer solar cells are not available in large volume whereas all other three are.

We ascribe this observation to two possible reasons and also describe some of the implications in the following section:

The first reason could be that polymer solar cells have an inherently large variation in materials because organic materials are molecular and in contrast to the other three subjects in this discussion where the number of elements are very limited and variation is mainly found in the deposition and processing methods. For polymer solar cells the variation is enormous and perhaps because of this a high performance has come along rather slowly in comparison with a-Si,CdTe and CIGS.

The second reason could thus be that a-Si, CdTe and CIGS quite rapidly reached industrially relevant performance with a limited choice of materials and variability. The spread in observed performance has thus been smaller and both academic and industrial agreement has been quickly reached. This is far from the truth when it comes to polymer and organic solar cells and this must ofcourse be rectified if polymer and organic solar cells are to be added to the list of industrially relevant thin film technologies.

The main advantage of organic materials is the ability to produce photovoltaic devices using solution phase techniques, such as ink jet printing or various roll to roll techniques, which could lead to very cheap, high throughput manufacturing [4,9]. The potential speed and simplicity of organic photovoltaics(OPV)processing is unmatched by other current technologies. Additionally, organic semiconductors have very high absorption coefficients [32], which allow very thin films to be used, whilst still absorbing as sufficient portion of the solar spectrum. This reduction in material used, coupled with low cost manufacturing techniques, implies that organic semiconductors have the potential to make as significant impact on the PV market.Extensive research over thelast 5 years has produced marked increases in the efficiency of

OPV devices, with the current record certified PCE being 10%. This efficiency has been seen as a landmark milestones since the beginning of research in organic based photovoltaics. Persistent, rapid improvement over the past 12 months would suggest that this 10% milestone is soon to be surpassed..[5]

V. TYPES OF POLYMER SOLAR CELLS

a) PV cells made from single layer of polymers

Single layer organic photovoltaic cells are the simplest form. These cells are made by sandwiching a layer of organic electronic materials between two metallic conductors, one is a layer of indium tin oxide (ITO) with high work function and other a layer of low work function metal such as Aluminum, Magnesium or Calcium.

The difference of work function between the two conductors sets up an electric field in the organic layer. When the organic layer absorbs light, electrons will be excited to the LUMO and leave holes in the HOMO, thereby forming excitons. The potential created by the different work functions helps to split the exciton pairs, pulling electrons to the positive electrode (an electrical conductor used to make contact with a non-metallic part of a circuit) and holes to the negative electrode.

Conjugated polymers were also used in this type of photovoltaic cell for example a cell used polyacetylene as the organic layer, with Al and graphite, producing an open circuit voltage of 0.3 V and a charge collection efficiency of 0.3; An Al/poly(3-nethyl-thiophene)/Pt cell had an external quantum yield of 0.17%, an open circuit voltage of 0.4 V; An ITO/PPV/Al cell showed an open circuit voltage of 1 V and a power conversion efficiency of 0.1% under white-light illumination.

Disadvantages of single layer cells:

Single layer do not work well,The problem experienced are they have low quantum efficiencies (<1%) and low power conversion efficiencies (<0.1%). A major problem with them is that the electric field resulting from the difference between the two conductive electrodes is seldom sufficient to split the excitons. Often the electrons recombine with the holes without reaching the electrode.[6]

b) Bilayer solar cells

Bilayer cells contain two layers in between the conductive electrodes.The two layers have different electron affinity and ionization energies, therefore electrostatic forces are generated at the interface between the two layers. The materials are chosen to make the differences large enough that these local electric fields are strong, which splits excitons much more efficiently than single layer photovoltaic cells. The layer with higher electron affinity and ionization potential is the electron acceptor, and the other layer is the electron donor. This structure is also called a planar donor-acceptor hetero junction.[7,8]

c) Bulk HeteroJunction solar cells

It is a solar cell where organic polymer material is used for the semiconductors.For the combination of electron donating (*p*-type) and electron accepting (*n*-type) materials in the active layer of a solar cell, care must be taken that excitons created in either material can diffuse to the interface for charge separation. , the diffusion length of excitons in organic semiconductors is limited to about ~10 nm only due to their short lifetime and low mobility, It is an important condition to efficient charge generation. Anywhere in the active layer, the distance to the interface should be on the order of the exciton diffusion length. Despite their high absorption coefficients, exceeding 10^5 cm-1, a 20 nm double layer of donor and acceptor materials would not be optical dense, allowing most photons to pass freely.

The solution is simply mixing the *p* and *n* type materials and relying on the intrinsic tendency of polymer materials to phase separate on a nanometer dimension, Quantitative dissociation of photo generated excitons is obtained at the junctions throughout the bulk of the material irrespective of the thickness.

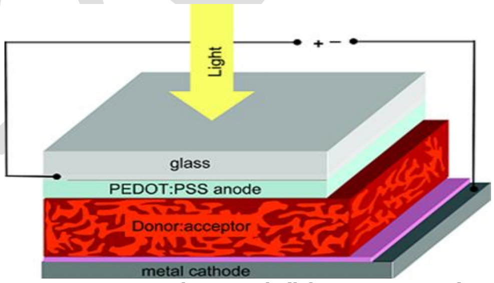

Figure showing a bulk heterojunction solar cell

Polymer-fullerene solar cells were among the first to utilize this bulk-heterohunction principle. Photogenerated charges should be able to migrate to the collecting electrodes through this intimately mixed blend. Because holes are transported by the *p*-type semiconductor and electrons by the *n*type material, these materials should be preferably mixed into a bicontinuous, interpenetrating network.

The bulk heterojunction is presently the most widely used photoactive layer The name Bulk heterojunction solar cell has been chosen, because the interface (heterojunction) between both components is all over the bulk.

The exciton, created after the absorption of light diffuses towards this charge-transfer interface for charge generation to occur. The diffusion length of the exciton in organic materials, however is 10 nm or less. This means that for efficient charge generation after absorption of light, each exciton has to find a donor acceptor interface within a few nm, otherwise it will be lost without charge generation. An intimate bicontinuous network of donor and acceptor materials in the nanometer range should suppress exciton loss prior to charge generation.

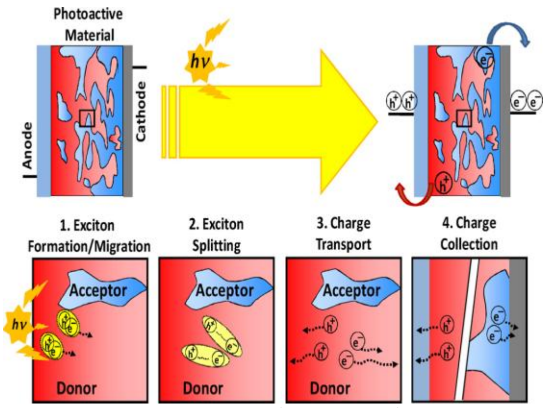

Figure showing the process of charge transfer in bulk hetrojunction

Various combinations of donor and acceptor materials have been used to build bulk heterojunction solar cells in which the composite active layer is inserted between two electrodes. One of the most promising combinations of materials is a blend of a semiconducting polymer as a donor and a fullerene, C60 derivative as acceptor.

In BHJ OPV cells a glass or plastic substrate is coated with a thin layer of high work function ITO functioning as the transparent anode. The photoactive layer is sandwiched between the anode and the top low work function cathode, typically Al or Ca. Interfacial layers can be inserted between the anode-photoactive and cathode-photoactive layers to improve device performance and stabilize operation.For efficient operation the photoactive blend should produce an interpenetrating network of donor and acceptor domains, with considerable interfacial area and effective percolation pathways connecting the acceptor regions to the cathode and donor regions to the anode

Different combinations of donor and acceptor materials have been used to build bulk heterojunction solar cells in which the composite active layer is inserted between two electrodes. One of the most promising combinations of materials is a blend of a semiconducting polymer as a donor and a fullerene, C60 derivative as acceptor.[2,9]

VI. CONCLUSION

Organic photovoltaic (OPV) cells are a revolutionary technology for electrical energy production, being inexpensive to fabricate, lightweight, and mechanically flexible .Single layer solar cells have efficiency less than 0.1% while bilayer solar cells have efficiency upto 4.54% and bulk hetero junction upto 10-15%.Scientists are trying to develop more and more solar cells and trying to increase the efficiency of the cells, Moreover they are developing such solar cells such that they can sustain for atleast 10 years and can tolerate all ambient conditions.

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