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Organic Solar Cell - The Photovoltaic System

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Abstract—*The ultimate goal of energy production is that it should be environment friendly, cost effective and user responsive. The organic solar cell can fulfill all these three requirements.*

Organic photovoltaic is the technology to convert sunlight into electricity by using conductive organic polymers or small organic molecules. These organic materials absorb the light and transport the charge to produce the electricity from sunlight by the photovoltaic effect.

Organic solar cells are mostly thin flexible and light weight. These cells are made of thin layers of organic materials with thickness in the 100 nm range, which is about 1000 times thinner than for crystalline silicon solar cells and still 10 times thinner than for current inorganic thin film cells. It can be used in large areas and also for small ranges because of its flexible quality. Today, the power conversion efficiency of organic solar cell has reached more than 10%. However, the optimum efficiency has to be improved as yet. It can be a good solution for low cost energy production in comparison to inorganic solar cell materials.

This paper provides an overview of organic solar cell and suggests some measure for improving the efficiency.

Introduction:-

In recent years, the growing demand for clean energy resources has made the new way for research and development in field of renewable energy. The energy generated by solar cells is a good solution to the problem of maintaining our energy supply. Organic solar cells have the potential to be a part of the next generation of low cost solar cells.

Organic photovoltaic is a rapidly increasing new solar technology to convert sunlight into electricity by employing thin films of organic semiconductors. Organic solar cells use carbon compound based materials mostly in the form of small molecules and polymers to convert solar energy into electrical energy. These organic molecules have the ability to absorb the light and induce the transport of electrical charges between the conduction bands of the absorber to the conduction band of the acceptor molecules. There are various types of organic photovoltaic cells like Single layered, Bi-layered, Hetero junction and Bulk hetero junction organic solar cell. Whereas the single layer comprises of only one active material the other devices are based on respectively two kinds of materials such as electron donor (D) and electron acceptor (A).

According to recent record the power conversion efficiency of organic solar cell has been improved to beyond 12% but it is still relatively low compared with the inorganic solar cell.

Basic Structure and Working Principle of Organic Solar Cells:-

Various architectures for organic solar cells have been investigated in recent years. The process of converting sunlight into electric current in an organic solar cell is accomplished by following four steps: -

- Absorption of light
- Charge transfer and separation of the opposite charges
- Charge transport
- Charge collection

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 rays. 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 beneficial for light absorption, but burdens for 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 organic solar cells, charges are created by photo induced 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 help of additional input energy of an absorbed photon (hν). In the photo induced electron transfer reaction, the first step is exciton of the donor (D*) or the acceptor (A*), followed by creation of the charge-separated state consisting of the radical cation of the donor ($D^{\bullet+}$) and the radical anion of the acceptor ($A^{\bullet-}$).

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

For an efficient charge transfer, it is important that the charge-separated state is the thermodynamically and kinetically most favorite route after photo-excitation. 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-radioactive decay. It is important that the charge-separated state is stabilized, so that the photo-generated charges can migrate to one of the electrodes. Therefore, the back electron transfer should be slowed down as much as possible.

Illumination of donor through a transparent electrode (ITO) gives the photo-excited state of the donor, in which an electron is promoted from the highest occupied molecular orbital (HOMO) to the lowest unoccupied molecular orbital (LUMO) of the donor.

Subsequently, the excited electron is transferred to the LUMO of the acceptor. This gives an extra electron on the acceptor (A•-) and leaves a hole at the donor (D•+). The photo-generated charges are then transported and collected at opposite electrodes. A similar charge generation process can occur, when the acceptor is photo-excited instead of the donor.

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 photo-generated charges. After the charge transfer reaction, the photo-generated charges have to migrate to these electrodes without recombination. Finally, it is important that the photo-generated charges can enter the external circuit at the electrodes without interface problems.

Comparison of Organic and Inorganic Solar cell:-

The most obvious difference is that in an inorganic semiconductor the free charge carriers, electrons and holes are created directly upon light absorption, while electrostatically bound charge carriers, excitons are formed in organic semiconductor.

The dielectric constant of organic semiconductors is low as compared to inorganic semiconductors.

The other primary difference is the small Bohr radius of carriers in organic semiconductors as compared to inorganic semiconductors.

An organic semiconductor has simpler processing at lower temperatures (20-200*C) than an inorganic cell, like Si (400-1400*C).

The advantage of organic solar cells over electrochemical cells is the absence of a liquid electrolyte.

The thickness of the active layer of organic solar cells is only 100 nm thin, which is 1000 times thinner than Si-solar cells and 10 times thinner than inorganic thin film solar cell.

So, organic solar cells have potential for low cost and large area application. These can be deposited on a flexible substrate and the material can be tailored according to the demand.

Scope of efficiency improvement Organic Solar Cell:-

OPV cells are cheaper to produce, light weight and flexible bur they provide much lower efficiencies than IPV cells.

New combinations of materials that are being developed in various laboratories focus on improving the three parameters that determine the energy conversion efficiency of a solar cell, *i.e.* the open-circuit voltage, the short-circuit current, and the fill factor that represents the curvature of the current density-voltage characteristic

The open-circuit voltage of bulk-hetero junction polymer photovoltaic cells is governed by the energy levels of the highest occupied molecular orbital (HOMO) and the lowest unoccupied molecular orbital (LUMO) of donor and acceptor, respectively.

One of the crucial parameters for increasing the photo current is the absorption of more photons. This may be achieved by increasing the layer thickness and by shifting the absorption spectrum of the active layer to longer wavelengths. Hence, a gain in efficiency can be expected when using low-band gap polymers.

A high fill factor is advantageous and indicates that fairly strong photocurrents can be extracted close to the open-circuit voltage. In this range, the internal field in the device that assists in charge separation and transport is fairly small. Consequently a high fill factor can be obtained when the charge mobility of both charges is high.

Conclusions:-

Organic solar cells proves to be very promising technology for providing low cost photovoltaic energy. Although the current situation is the technology requires lots of optimization and research for improving conversion efficiency and stability of organic solar cell. Donor-acceptor based organic solar cells are currently showing the efficiencies of 12%. Recent improvement in efficiency and life time shows that organic solar cells will enter the market quickly.

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