Investigation Of Properties Of Conjugated Polymers And Substrate Materials For Organic Solar Cell Applications

Abstract

A conventional organic solar cell consists of a plastic or glass substrate material coated with a conducting layer of Indium Tin Oxide (ITO). There is a layer of donor-acceptor material on the substrate, which serves as active layer. The donor materials are small organic semiconducting materials, synthesized as discrete molecules with well-defined structures. These materials include pentacene, perylene dimides and fullerene derivatives. Fullerene and its derivatives are used as acceptors. Non-fullerene materials have also gained interest, of late. The donor and acceptor materials still have certain limitations that need to be addressed. These have been already mentioned above (limited absorption range, low carrier mobility, energy losses and recombination, low stability and degradation).

An attempt has been made in this work to address some pertinent issues. Instead of glass or plastic substrate, a bio degradable cellulose substrate has been used. The cellulose has been extracted from agricultural waste, which is generally discarded or burnt, thus giving it another potential use.

The active material is TiO2, which is an efficient material for the purpose. It has good thermal stability and can be easily synthesized as well as coated on the substrate material, unlike the donor-acceptor materials used in conventional organic solar cells. A dye has to be used with this active material to harvest the light and create the exciton pair needed for conduction. These dyes are quite expensive and have a short absorption range. The current work envisages and attempts to use the naturally occurring Light Harvesting Complexes (LHC's) from plant leaf extracts, instead of dyes.

Light harvesting complexes (LHCs) are assemblies of molecules that play a crucial role in capturing and transferring energy from sunlight in photosynthetic organisms. These complexes are responsible for absorbing light and directing the energy to reaction centres where it is utilized for photosynthesis (Scholes et al., 2011). LHCs are found in various photosynthetic systems, including plants, algae and bacteria. They consist of pigments, such

as chlorophylls and carotenoids, which are responsible for absorbing light at different wavelengths. The absorbed light energy is then transferred through a process called energy transfer or resonance energy transfer, from one pigment molecule to another until it reaches the reaction centre. Whereas the dye is a pigment, the light harvesting complexes contain a series of sub protein molecules each possessing different valence and conduction bands.

One of the major reasons that have been understood from past studies and literature review for the fall of efficiency is the recombination effect. Recombination is an effect where the excited electron in the conduction band of the photoelectric active material, instead of getting collected at the ITO or FTO electrode, goes back to its own valance band.

LHCs are multi component in their constitution, with various protein molecules as the units. This gives them a wider range of absorption as well. Their incorporation in the system is expected to provide a number of levels in the matrix. These levels have been also supported by the UV-Vis analysis in the study.

It has been proposed in this work that due to the presence of multiple energy bands in the LHCs, the excited electron, instead of directly recombining to valance band of TiO2, goes to these intermediate levels of LHCs, thus providing an alternative path way to the electron to reach the electrode. This decreases the probability of recombination.

Polymers viz. Polypyrrole and Polyaniline have been used as counter electrodes. The interaction of functional groups in these polymers and the LHCs, called moieties, can also affect the performance of the device. This has been discussed in the thesis.

Some of the general observation from the results is as under.

- The highest efficiency of 7.7 % was obtained for the cell with LHC from Holy Basil and counter electrode of Polypyrrole sample 2 (PP2)
- The cell with same LHC (Holy Basil) and counter electrode of Polypyrrole sample 1 (PP1) gave an efficiency of 6.9 %.
- Efficiency of cells with Holy Basil LHC and Polyaniline electrodes PA1 and PA2 was found to be 6.1% and 5.7%, respectively.
- Interestingly, the efficiency of cells with Basil LHC and Polyaniline electrodes PA1 and PA2 was found to be 5.7% and 6.1 %, respectively.
- The maximum average efficiency for all the cells with counter electrode of one polymer sample having different LHCs was found to be 5.49% for Polypyrrole – sample 2 (PP2),

followed by 5.31% for Polyaniline – sample 2 (PA2), 4.66% for Polypyrrole – sample 1(PP1) and 4.48% for Polyaniline – sample 1 (PA1).

- The rise in efficiency of the cells with different LHCs varied from about 1.5 to 8 times in comparison to those without LHCs.
- The maximum gain in efficiency of a cell with LHC, in comparison with the same cell without LHC is about eight times for Amaranthus – PP1 combination
- For PPy 1 (Polypyrrole prepared using method 1) the combination with LHCs derived from Amaranthus gave a maximum efficiency of 7.4 %.
- For PPy 2 (Polypyrrole prepared using method 2) and LHC derived from Holy Basil, the maximum efficiency achieved was 7.6%.
- For PANI 1 (Polyaniline prepared using method 1) the combination with Holy Basil LHCs gave the maximum efficiency of 6%. PANI 1 with mint LHCs also gave the same efficiency.
- For PANI 2 (Polyaniline prepared using method 2) and Basil LHCs, the maximum efficiency achieved was 6.3%.
- The best results were found for the members of the plant family "lamiaciae" namely, Holy Basil (Tulsidhar), Basil (Tulsi) and Mint (Pudhina).
- Ficus religiosa (Peepal) and Banyan, which belong to the same family, also gave similar resuls.
- Spinach and Fenugreek (Methi) also yielded similar results.
- Giant Calotrope (Aakado) and Murraya Koenigii (Curry leaves) gave similar results.
- Some of the plant extracts like Coriander, Green Tea, Durrento, Longofolia, Aegle Marmelos and Dill leaves gave consistently poor results.

Thus, it can be observed that the variation in efficiencies happen for different polymer samples and are more pronounced from plant to plant. The combination of polymer-LHC also yields different efficiencies. Hence, the variation in frequency can be attributed to

- Polymer of the counter electrode
- Light Harvesting Complexes
- Polymer – LHC combination