Basie concept for development of dye sensitized solar cells

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Abstract

The human life quality is greatly affected by the availability of energy. Renewable energy source such as solar energy is considered as a feasible alternative source for present day energy requirement. Among first and second generation silicon semiconductor cadmium telluride, copper and indium selenide/sulfide, these have been the subject of intensive research work for the last three decades. The present article deals about the advantages and future aspects of dye sensitized solar cells as new generation energy resources with cost, easy fabrication and environment friendly nature.

Key Words: Photovoltaic cells, Sensitizer, Semiconductor, Solar Energy

1. Introduction

With rising world population the demand of energy also increased day to day because the development and quality of human life is depended upon the energy resources. As we know increase in population and continuous use of fossil fuels in the form of wood, coal petroleum products in automobiles and electricity generation, leading to depletion of fossil fuels. Now, there is a need of renewable energy sources. Because, not only fossil fuels have finite life-time but they also have negative effect on the environment. With this trend without decisive action, the energy related emission of CO_2, will more than double by 2050 this is associated with the unsustainable consequence economically, environmentally socially.

Therefore, there is a pressing need to accelerate the discovery of advanced clean energy technologies (for renewable energy) in order to address the global challenges of energy security climate change and sustainable developments. The main source for renewable energy includes hydropower, wind power, wave power, solar energy and geothermal energy. When we will talk about the solar energy, we know that the sun on its own could supply the world's projected energy demand in a sustainable fashion. It never have negative environment footprint, it can be utilized from any where and utilizes existing techniques and manufacturing process making it cheap and efficient to implement. There only remains, the challenge of harvesting and storing this energy in a cost effective way. The solar technology is a solution of this challenge and solar cells are the tool of this technology.

Actually, solar cell is a device which permits the direct conversion of solar light in electricity through the photo electric effect.

There are three most common types of solar cells are available.

1. **Inorganic Solar Cells:** It consist of several layers of conducting materials, one type has mobile free electrons and second type has mobile free positive holes and the p-n junction (the connection formed between the two i.e. electron and hole pair move to opposite electrodes and generate current).
2. **Organic Solar Cells:** The cells consist of two layer of semiconductor material. They differ in their electron donating charge transfer occur between the two components. The energy of photons must fine exceed a certain threshhold to be absorbed, that it is the energy gap between LUMO to HOMO. In practice, the illumination of donor layer (in red) result in the photo excited state in which an electron is promoted from HOMO to LUMO of the donor. Subsequently the electron is transferred to the LUMO of the acceptor and resulting an extra electron in the acceptor and leaving a hole in donor. The photo generated charges are then transferred and collected at opposite electrodes.
3. **Hybrid organic-inorganic cell:** It consists of an organic dye(also called sensitizer or chromophore) absorbed at the surface of an inorganic wide band gap semiconductor.

On the basis of their functional use solar technology can be divided into three types:

i. PV: The Photovoltaic Cells' which directly convert solar energy into electricity.
ii. CSP: Concentrating solar power, system for use of concentrated solar radiation at high temperature energy source to produce electrical power and drive chemical reactions.
iii. SHC: Solar thermal collector for heating and cooling system, uses the thermal energy directly from sun to heat or cool domestic water or building spaces.

The Photovoltaic cells can further be dividedinto different categories:

a) First generation solar cells: This utilizes crystalline silicon technology and covers about 80% of the solar cells market. These cells involve both mono crystalline and multi-crystalline solar cells.

These cells involve costly raw materials and require high temperature fabrication processes.

b) Second generation solar cells: These cells may be constructed by depositing a thin film of photosensitive material on glass/plastic/stainless steel etc. These cells involve low consumption of raw materials, high automation and production efficiency, ease of processing, improved appearance and good performance at high temperature. These cells can further be divided into four categories:

i. Multi junction thin silicon films.

ii. Cd-Tl(Cadmium telluride) based cells

iii. Indium, galium, di-selinide/di -sulphide and copper, indium di -selenide/di-sulphide based cells.

iv.Amorphous silicon cells.

Limited life time and low efficiency are the draw backs of these cells.

c) Third generation photovoltaic: Purely organic solar cells and hybrid dye sensitized solar cells comes under this category. Low cost solar cells have been the subject of intensive research work for the last three decades.

Amorphous semiconductor has been announced as one of the most promising materials for low cost energy production. However, dye sensitized solar cells (DSSC)[1-3] emerged as a new class of low cost energy conversion devices with simple manufacturing procedure. In DSSC an attempt is focused to imitate photosynthesis, the natural processes in which plants converts sunlight into energy by sensitizing a nano crystalline wide band gap semiconductor mostly TiO_2 or ZnO or Na_2O_5 film using either by novel Ru-bi-pyridyl complex or other metal complex or organic chromophore.

In DSSC charge separation is accomplished by kinetic competition like in photosynthesis[4-6] leading to photovoltaic action. In the chromphore monolayer in the DSSC replaces light absorbing pigment (Chlorophyll), wide gap nano structured semiconductor layer replaces NADPH and CO_2act as electron donor.

Working and Construction: The device is comprises of two faced electrode a photo anode and a counter electrode with an electrolyte in between both electrodes. Both electrodes are usually made from a sheet of common float glass coated with a thin transparent conductive layer of fluorine doped tin oxide (FTO) or indium doped tin oxide(ITO). The cathode is a conductive glass covered with a few clusture of metallic platinum which has a catalytic effect in the reduction process of the electron transfer.

In the anode the transparent conductive electrode is covered with a thin film of meso porous semiconductor oxide normally, TiO_2 (anatase) although alternative wide band gap oxide such as ZnO and Na_2O_5 have also been investigated. Attached to the mono crystalline film is a mono layer of charge transfer dye. The performance i.e. efficiency of DSSC cell depends upon the dye / chromophore /sensitizer whose photon excitation initiated the whole mechanism.

Plenty of work is available for this including fabrication and most of them also involve nano technology ,various types of semiconductors, variety of improved applications, mono functional and bi functional devices, advanced electrolytes improved technique for thermal stability and flexibility for fabrication process.

Synthetic criteria for DSSC chromophores.

The first synthetic organic dye para Red was prepared by Meldola et al in 1885. The reactive dyes including developed later on & Specific the field of exploration Now, performance based dye synthesis became explored .Liquid crystal display imaging, CD, DVD, data recording, recording discs and many other fields are the multifacet applications of the chromophores or dyes.

In dye-sensitized solar cells, the dyes or sensitizersare the tool which play thechief role in solar energy harvesting process. The HOMO potential of the chromophores shouldbe sufficiently positive compared to the electrolyle redox potential for efficient dye regeneration. The LUMO potential of dye must be sufficiently negative to match the potential of conduction band of semiconductor. However by increase in the range of absorption spectra, HOMO and LUMO level of dye became close to each other if the HOMO and LOMO potential of the chromophore are too close, in that case the regeneration of dye as well as the electron injection from chromophore to semiconductor could be hindered.

Another important factor is that dye must have small reorganization energy for both excited and ground state redox process for the purpose of minimum loss of energy in primary and secondary electron transfer steps.

For DSSCpreparation[7-8] desired electron donor and electron acceptor materials are required to fulfill the energy requirements for generation of photo current. An electron get excited from the highest occupied molecular orbital (HOMO) to lowest unoccupied molecular orbital (LOMO) and a hole in HOMO, after illumination by light. During the generation of photo current, the band electrons and holes can be achieved to LUMO of the acceptor and be received by respective electrode provided that potential (I.P) of donor and the election affinity(E.A.) of the acceptor is larger than the exciton binding energy. Organic л-systems having their end capped with donor as well as accepter substituents can be used for molecular engineering. Donor accepter systems(D-л-A) systems of typical electronic property can be prepared with +M and +I effect substituent like OH, OR, NH_2 and NR_2, heterocyclic systems are required for donors and –M/-I effect substituent like NO_2, CHO and CN as well as various electron deficient heterocyclic systems are required for acceptors.

In push-pull electron density methods for property tuning of a D-π-A molecules(Fig. 1) require following procedures :

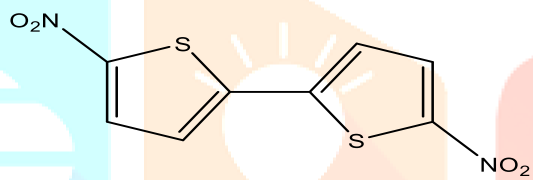
1. Tuning through the donors

2. Tuning through the π- system

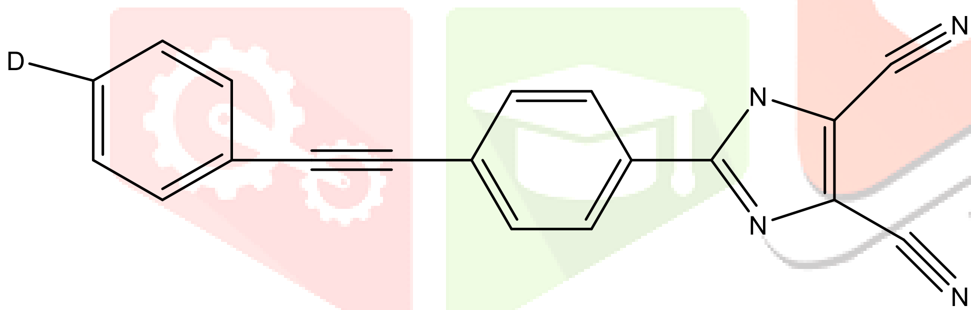
3. Use of hetero aromatic systems (Fig 2)

4. Use of pro aromatic systems

5. Tuning through the acceptor



(a)



(b)

Fig.1 (a) 2,2di- nitro bi-thiophene and (b) di phenyl acetylene derivative

D= a MeO , b MeO , c MeO , d MeHN , e Me_2N

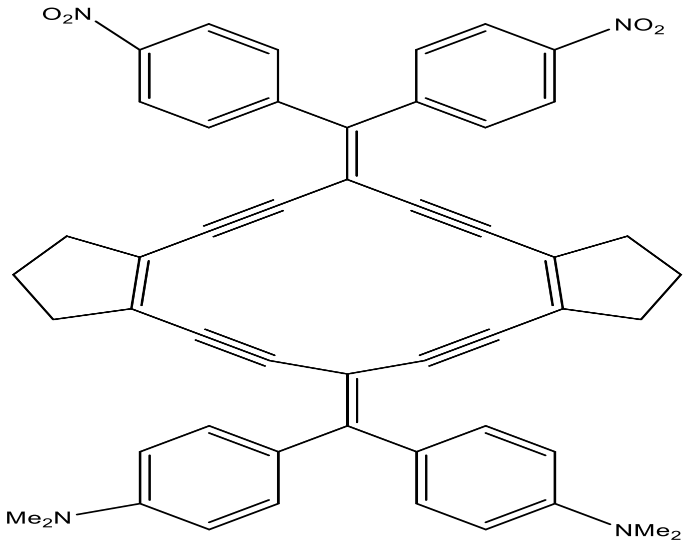


Fig.2 Proaromatic Compound

CONCLUSION:

Compared to silicon based solar cells dye sensitized solar cells are of low cost and easy tofabrication, their performance increases with temperature and bifacial configuration have advantage for diffuse light. These systems have a wide range advantage in terms of different combination of donors, linkers and acceptors of chromophores for dye sensitized solar cells provide a wide range of technical opportunity to improve the performance. Theyare proved to be better solar energy trapper for electricity.

Future objectives of DSSC research involve improved efficiency, more thermal stability, use of solid electrolyte with easy fabrication .

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