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Synthesis of dye-sensitized solar cells using polyaniline and natural dye extracted from beetroot

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Abstract

In today's world where fossil fuels are on the verge of depletion, solar energy offers a much valuable path to harness its abundance, which has led to the discovery of third gen organic solar cells. The paper reports a detailed methodology for the preparation of polymer based dye sensitized solar cell (DSSC) using polyaniline (PANI). The cells were made using natural dye extracted from beetroot and indium tin oxide (ITO) coated glass. Three solar cells having different electrolytes were prepared and their efficiencies were determined. A mixture of conventional electrolyte (iodide and triiodide mixture) and HCl doped PANI have also been used and the results obtained from all the three cells were observed, compared and discussed. Ultraviolet spectroscopic results confirm the presence of dye extracted from beetroot and by the I-V curves, efficiencies of the cells calculated was 0.04694% (conventional electrolyte), 0.03170% (HCl doped PANI as electrolyte) and 0.02699% (conventional and PANI mixture as electrolyte).

Keywords: Natural Dyes, Organic Solar Cells, Polymer Solar Cells, Polyaniline**.**

Introduction

In the twenty first century the most eminent need, which has risen many folds within just a few decades is energy. Today, energy can directly be related to environmental impact considering the indiscriminate use of fossil fuelsand its subsequent depletion. Hence, their usage has been reduced and work upon production of energy via other means has begun[1]. There is an increment in the greenhouse gases in the environment due to the use of fossil fuels and thathas led to Global warming, which is adversely affecting the Earth currently.

Due to rise in global warming, infectious diseases which develop in warmer climates tend to show collateral effects on human life (malaria, dengue and chikungunya), Also a critical rise in global pollution has been observedin the last few decades, due to extensive usage of fossil fuels[2]. Now, to counter these effects and to limit their usage, other sustainable modes of energy production are taken into consideration.

Renewable resources offer an abundance of energy exploitation opportunity with ample of energy being provided to earth daily. The attention to the most developed technologies is focused which are hydro, wind and solar energy; out of which-solar energy stands out to be the most effective one.

Photovoltaics, has offered the most opportunities for exploitation considering that whatever energy we consume on earth in a year, which is much less than what the earth receives in the form of solar energy in a single hour[3].

In the past six decades, several different photovoltaic devices have shown up and recently in the last decade a large scale production of solar panels has begun considering the rise in awareness amongst the individuals with respect to the environmental deterioration.

The main aim which needs to be worked upon is to attain a balance between: efficiency, environmental impact, cost factor and stability of the photovoltaic device, and many scientific researches are already going on to acquire this aim-effectively[4]. A diverse spectrum of individuals from various fields like material science, electrical and electronics, environmental science and chemistry are working consciously for the betterment of this field[4]. Its major applications in industrial sectors are solar homes systems, solar lighting, solar power plants, solar lights for traffic signals, parking lots, bus stop shelters etc.

Dye-sensitized-solar-cells (DSSC) is a photo-electro-chemical device which has attained special attention from all around the world, due to its simple manufacturing and usage of easily available materials[5]. It is a highly versatile device, w.r.t its composition, structure and methods of manufacturing. It is more efficient in low irradiation as compared to other solar cells and is highly adaptive when clubbed with different substrates due to its versatile nature as indicated above. DSSC is a device, whose critical points are an active layer, electrodes, electrolyte and substrates. The photosensitization layer which is the dye, over which extensive research is going on, to improve its basic function and improve efficiency directly. The Figure-1 illustrates the basic structure of a DSSC.

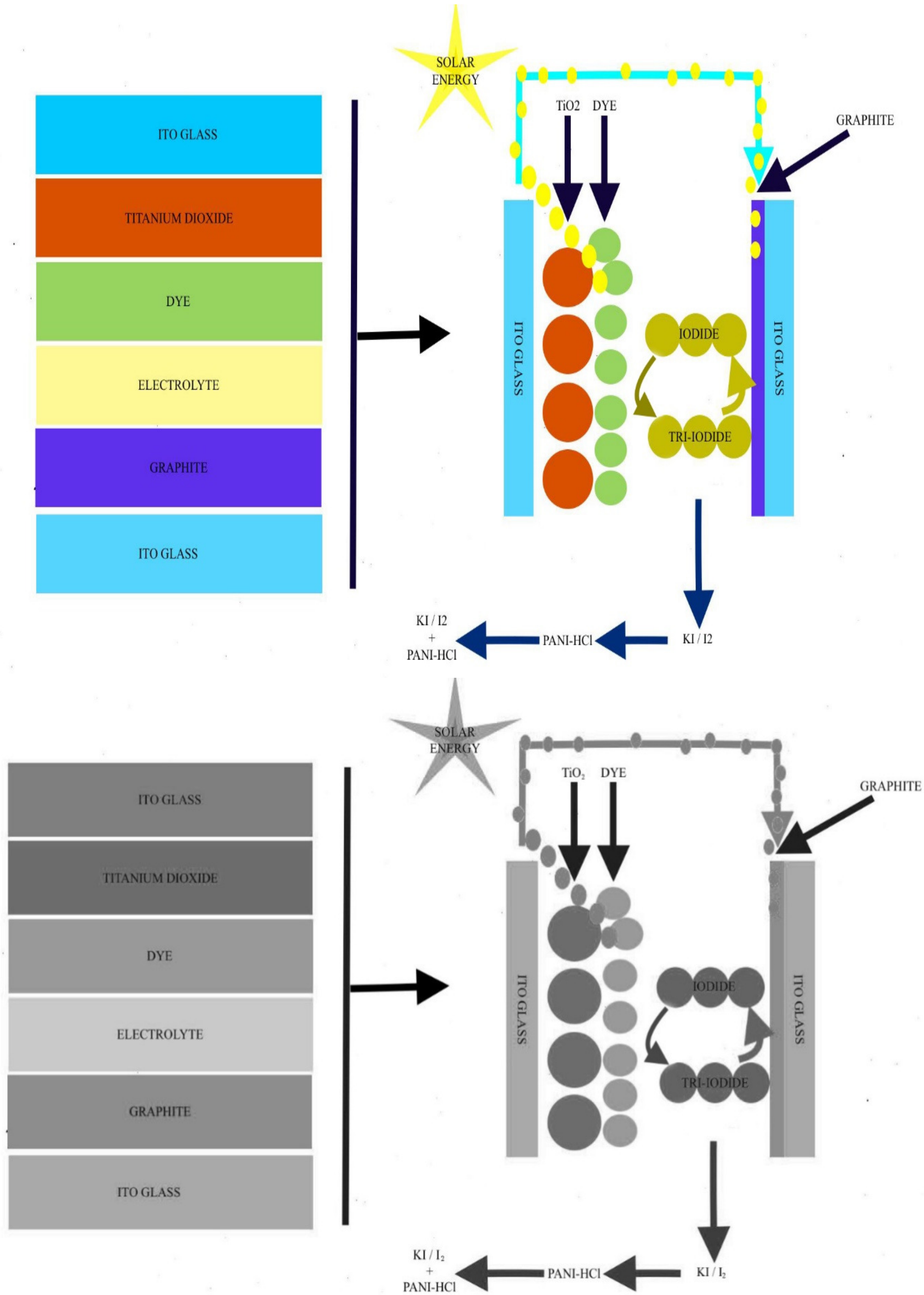

Figure-1: Illustration of Structure and working of a DSSC-with changes in electrolytes.

In this paper, different electrolytes are proposed which can be used instead of the conventional electrolyte. A specific polymer named as polyaniline doped with hydrochloric acid (PANI-HCl) offers a good conductance and thus can be used as a replacement to conventional electrolytes. Three different electrolytes namely: KI/I_2, PANI-HCl and a mixture of PANI-HCl and KI/I_2 are used.

Material and methods

Chemicals used: Iso-propyl alcohol and ethylene glycolas solvents, amorphous TiO_2 and graphite for electrode preparation and liquid extract of beetroot for photosensitizing layer. Analytical reagents like iso-propyl alcohol, ethylene glycol, amorphous TiO_2 were purchased from Piyush Chemicals, India. Graphite was extracted from the pencil.

Preparation of natural dye sensitizers: In this process, fresh beetroot was converted into small pieces and then crushed in a mortar using a pestle while addition of iso-propyl alcohol (IPA) as a solvent. The colored extract which was then obtained within the mortar was filtered twice and the final solution was used for photo-sensitization. The figure-2 illustrates making of beetroot dye.

Figure-2: Preparation of Beetroot Dye.

Electrode preparation: Substrates of ITO coated glass sheets were used, on which an area of 1.5 cm by 2.5 cm was coated with electrode compositions. The cathode was made by using amorphous TiO_2 which was obtained in a form of paste[6,7]. In the mortar about one gram of titanium oxide was added and with it 0.7-0.8 mg of poly-ethylene glycol was added, after this 3 mL of water was added in increments of 1 mL while being crushed by pestle in the mortar. In the end a thick viscous paste was obtained which was used for application. The anode was prepared of graphite, by rubbing a pencil over the conductive area of the ITO glass substrate[7].

Electrolyte(s) preparation: Three electrolytes were prepared, one was conventional KI/I_2 which was made by adding 2.07 gm KI and 0.19 gm I_2 in 10 mL ethylene glycol and stirred for approximately ten mins[7,8]. Second was a polymer based electrolyte in which PANI doped HCl was made using the conventional method[9], and then 1 gm of the polymer was added to 10 mL of ethylene glycol to obtain a suspended electrolyte. Finally, the third electrolyte was made as a mixture of first and second electrolyte (Elec.) in a proportion of 1:1.

DSSC assembling: Three DSSCs were prepared each with a different electrolyte as described above. Firstly, the layers of the DSSCs were arranged in the illustrative stack like structure as in figure 1.1 and then clipped using the binder clips. Finally, electrolytes were added via capillary action in between the layers. Figure-3 presents three prepared DSSCs.

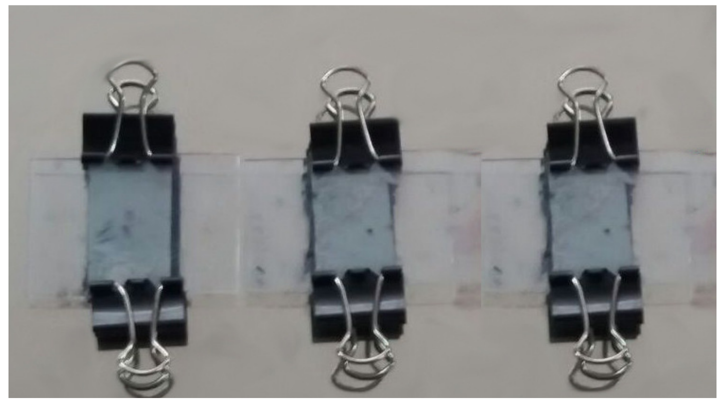

Figure-3: Three assembled solar cells.

Results and discussion

The three cells showed a typical solar cell behavior though the current generation was low whilst the voltage generation was similar to any other DSSC. The photosensitization dye of Beetroot shows maximum absorbance in the range of 480 nm to 555 nm (Figure-4), beetroot dye consists of Betalains which is responsible of producing a response when irradiation-stimulus is provided. The typical UV-spectroscopy curve for PANI-HCl has also been indicated (Figure-5).

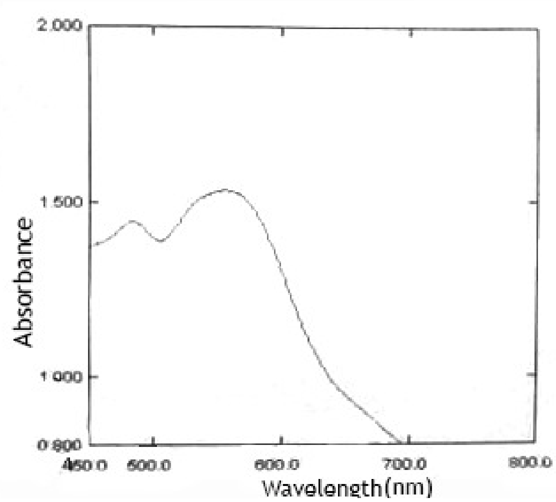

Figure-4: UV-Spectroscopy curve of Beetroot based natural dye.

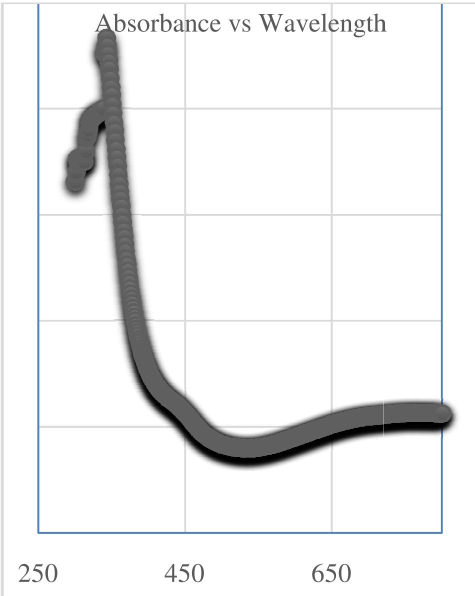

Figure-5: UV-Spectroscopy curve of PANI-HCl in water solvent.

On observing the UV-spectroscopy curves of PANI-HCl dissolved in water (Figure-5), it can be noticed that constant curves are obtained even after 5-minutes lapse, which suggest that PANI-HCl is readily soluble in water.In general, the UV-spectroscopy curve of PANI-HCl shows two typical absorption peaks in its emeraldine base form. The first one is indicated at 323 nm (narrow peak) while the another one at 620 nm (broad peak)[10-12]. These peaks correspond to the $\pi \rightarrow \pi^*$ transition on the centre of benzenoid unit and the quinonoid excitation band, respectively[10-12]. The initial peak is at 3.75 eV, which suggests the p-p* transition in the benzenoid rings, which is nearlyunharmed due to doping. This excitation band also corresponds to the extent of conjugation between the conjoining phenyl rings in the polymeric chain[10-12]. The next peak at 2.0 eV is due to the exciton absorption of the quinonoid rings and this is directly associated with the interchain or intrachain charge transport. The doping process brings in blue and red shift. The blue shift indicates the increment in the oxidation state, and so improved conductivity while the red shift suggests the enhancement in the emeraldine base structure-which is consequent due to further improvement in the extent of doping[10-12].

The current-voltage (I-V) characteristics of the three DSSCs are illustrated in the figure-6. It can be clearly seen that the conventional electrolyte offers the result which is similar to that of a typical solar cell while the characteristic curves of other two vary slightly.

The major aspect, which can be observed from these curves is that PANI-HCl can be used as suspension electrolyte, though it is a little behind the traditional electrolyte. The Table-1 indicates the details of the three DSSCs.

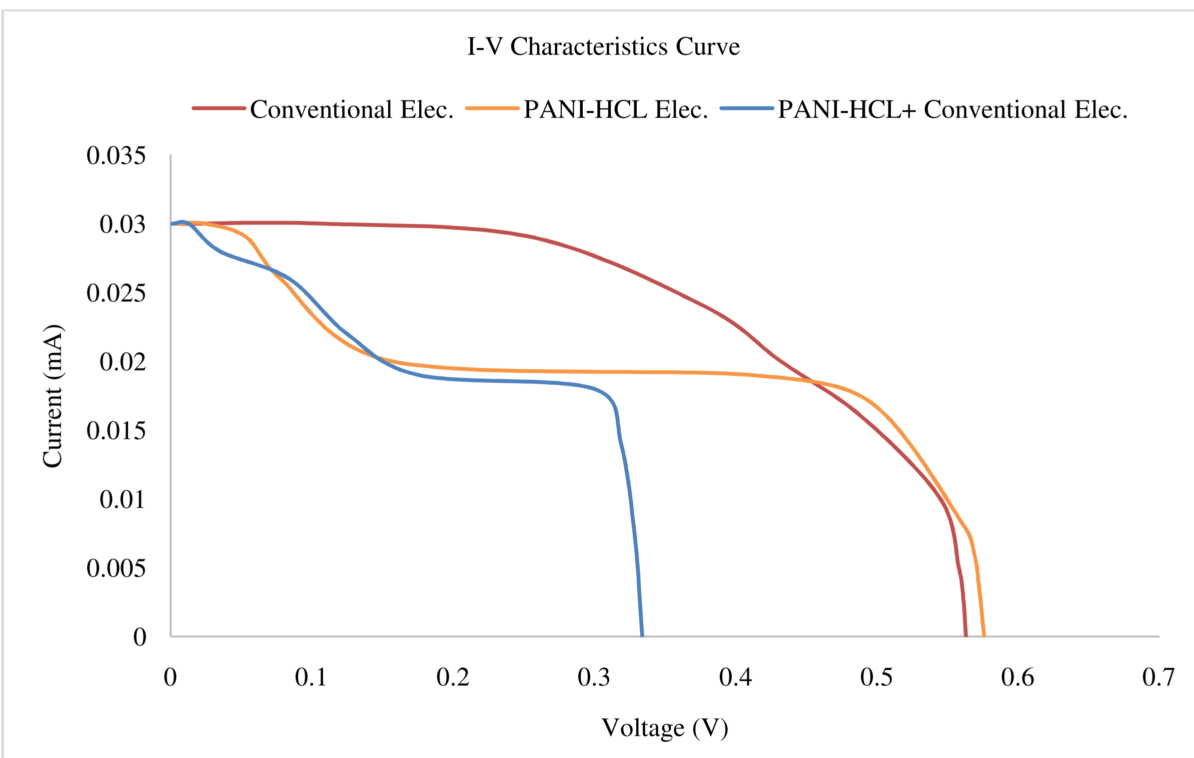

Figure-6: I-V Characteristics curve of the three solar cells.

Table-1: Representation of the characteristic data of the three DSSCs.

S.No.	Electrolyte	V_{OC} (V)	I_{SC} (mA)	F.F.	n%	P_{in} (W/m^2)
1.	KI/I_2	0.563	0.128	0.127	0.04694	60
2.	PANI	0.576	0.089	0.120	0.03170	60
3.	PANI+KI/I_2	0.334	0.229	0.068	0.02699	60

It can be noted that the mixture electrolyte fails to perform better, though the short-circuit current obtained from it is the highest-its power generation is quite poor. The reason for slight faltering of PANI-HCl against traditional electrolyte can be attributed to the solvent used to make the suspension-if water would have been used it could have performed slightly better, this is due to its higher stability within water as solvent. Also, the reason for appropriate DSSC behavior of the PANI-HCl based electrolyte can be due to the greater similarity between the polymer and semi-conductors. Also, it may be possible that the solar cell with mixture of electrolytes might have cause some hindrance to the charge transfer due to improper amalgamation of two electrolyte.

Conclusion

On a concluding note it can stated that polymers can be used as electrolytes which can provide better efficiency as compared to oil-derived electrolytes. Polymers as electrolyte options are considered as they have strong conductive property and would aid to the better transfer of charge carriers if utilized with proper solvents and proper amalgamation. In the experiments carried out in this paper, conventional electrolyte performs far better as compared to the polymeric electrolyte. The dye-sensitized-solar-cellsfield is undergoing extensive research currently in all parts of the world and work over its overall efficiency improvement is going on—as it provides better options as compared to silicon based solar cells, yet the former presents better efficiency than DSSCs.

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