Comparison of electrolyte used in the synthesis of natural dye based dye sensitized solar cells

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Abstract*: As the impact of fossil fuels is evident with the climate changes, world is now fast moving onto realizing renewable energy sources for their regular life where solar energy plays a vital role. In this paper three electrolytes are compared which are used to prepare dye sensitized solar cells (DSSCs) with a polymer polyaniline (PANI). The three electrolytes are used with a photosensitizing agent-a natural dye extracted from spinach with indium tin oxide (ITO) coated glass substrate. A mixture of iodide and triiodide (conventional electrolyte) and polyaniline is explored. The resulting efficiencies of the compared electrolytes were: 0.8076%-conventional electrolyte, 0.617%-polyaniline electrolyte, and 0.5723%-mixture of the two electrolytes.*

Keywords: *Natural dye, polymer solar cells, organic solar cells, polyaniline.*

1. Introduction

In the recent era where the entire world is shifting from perishable source of fuel to sustainable it is necessary that we should venture in the field of electricity production with the same focus, and to do so world is more and more focusing in electricity production utilizing solar energy in the most clean, organic and efficient manner. There had been a tremendous growth in the field of solar cells, and heavy research work is being enforced in the branches like organic solar cells, polymer solar cells, perovskite solar cells, and in dye sensitized solar cells. In the recent coverage, it has been noted that dye sensitized solar cells have started to make their first break through in the market, where their efficiency has been maximized with that of general second-gen silicone based solar cells (13-15% and theoretical maximum 33%) [1]. It has also been noticed that European union is inputting specific interest in further improvement of this one of the most efficient source of energy generation[2]. Michael Gratzel first produced a proper dye sensitized solar cell (DSSC) in 1988[3], and from then on these cells are also known as Gratzel cells in the name of their developer. In, 1991 the first high efficiency dye sensitized solar cell was produced[4]. Michael Gratzel was awarded with the 2010 Millennium Technology Prize[5], for his contribution in the field of solar cells. Currently, 11% is the peak efficiency for manufactural DSSC[6-7]. But recently, 15% solar cell efficiency as a prototype was introduced in 2015[8]. European Union have authorized a consensus which states by 2020, 20% of the energy production should be via renewable energy resource and it will mark the advent of beginning of a new era where solar cells like DSSCs would be competing with 2nd gen. solar cells and also with the several other types of 3rd gen solar cells[2]. Although in 2003, world's first 400 modules of DSSCs were manufactured but they lacked competence (due to chemical instability) and thus were called back for further improvements[9]. The benefits of dye-sensitized solar cells ranges from low cost to easy manufacturing, the cells basic requirements are two substrates to lay anode and cathode layers, where in between them is sandwiched electrolyte and the sensitizing dye. In the recent development major research has been ventured upon choosing a proper dye, and a proper electrolyte. Generally inorganic dyes which resulted in staunch efficiency would be preferred as the first choice but they come with an adverse environmental effect which is usage of rare earth elements. Thus to counter this effect we delved to another level and thus schemed organic dyes in the picture.

Currently, numerous organic dyes have been used to produce output as perfect as the inorganic dyes but the result seem to falter and wouldn't achieve the maximum laid down by the inorganic dyes. Thence, a fair amount of research work is being inputted in the determining the perfect environment for the lasting and efficient functioning of the solar cells. The best results with natural organic dyes come from spinach with 4% efficiency[10-14], red beetroot 2.71%[15-16], red cabbage 2.9%[17-18], wakame (Japanese tree bark) with 4.6 % [19]. These natural entities are rich in anthocyanin, betalains and chlorophyll or any such strong light sensitizers. Another major region for research in these cells are the electrolyte being used in the cells, conventional electrolyte seem to the degenerate the dyes and liquid electrolyte tend to dry up and reduce the current generation within just 3 to 4 weeks.

Thus, a blend of gel based electrolyte and quasi-solid/liquid electrolyte[20-23] has been implemented to route a different approach for the stated cells. Considering the ease of attaining the required material for their production makes their demand in market superior, as these cells can be formed within the lab by using the most basic chemical at hand and further sophistications can be implemented to improve the results. And so with the break-through within this field of solar cells, we have chosen to work upon the listed two layers within the solar cells. Also to treat the UV radiation degradation we can use UV absorbing luminescent chromophores and antioxidants[24-25].

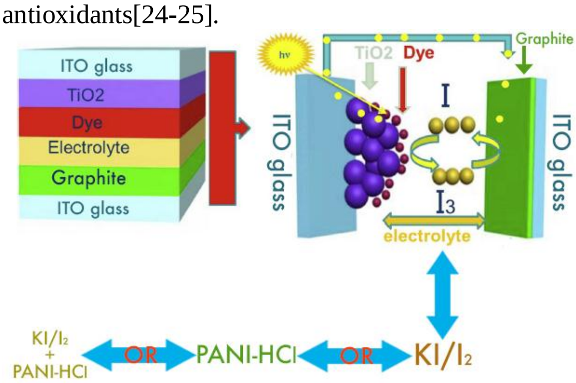

Figure 1. Layer stack structure of DSSC with different electrolytes.

Three types of electrolytes are compared in this paper. A polymer is used named as Polyaniline doped with HCL (PANI/HCL) which is used as a separate electrolyte as well as with tri-iodide/iodine electrolyte as well.

2. Methods and Materials used

2.1 Chemicals used

Laboratory chemicals were preferred so as to make the availability of chemicals sufficient namely: Amorphous TiO_2 for electrode, iso-propyl (IPA) alcohol as a solvent medium to extract photosensitizing element from spinach leaves, glycol, and graphite to be used as the counter electrode[26].

2.2 Preparation of natural dye sensitizers

The process of extracting photosensitizing element (chlorophyll) from the spinach leaves is a very basic step, in this a few leaves of spinach are crushed in a mortar with the pestle and with that iso-propyl alcohol (IPA) is added to extract chlorophyll from the leaves which crushing the fresh leaves.

2.3 Electrode preparation

ITO coated glass sheet substrates were used, where a layer of electrode was deposited over the conductive surface for the area-1.5 x 2.5 cm^2. The layer constitutes of 1gm of amorphous TiO_2 mixed with 0.7-0.8 mg of poly-ethylene glycol in presence of 3 mL of distilled water and further grinded extensively which is then coated over the glass substrate. The counter electrode was prepared by rubbing pencil lead (graphite) onto the ITO conductive side of the glass sheet. The coating of these two layers is done via screen printing, wherein a rather constant force is utilized to make the layer of the desired material of varied thickness[26-28].

2.4 Electrolyte(s) preparation

Three different types of electrolyte were prepared, wherein a conventional electrolyte of I_2/I^{-3} was one of them, for this about 2.07 gm of KI and 0.19 gm of I_2 were dissolved in 10 mL of ethylene glycol which resulted in a dirty yellow electrolyte[26-29]. The second electrolyte was made using the polymer Polyaniline, which was weighed 1gm and was then immersed into 10 mL of ethylene glycol to obtain a suspended electrolyte. And the third electrolyte was

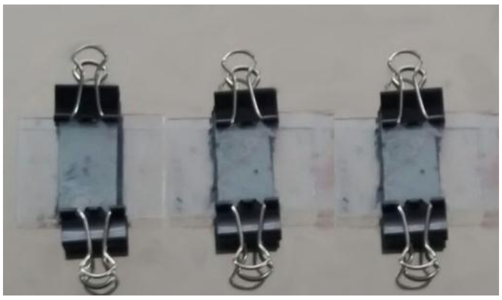

Figure 2. Three arranged DSSCs

2.5 DSSC Assembling

Firstly, the three cells were arranged in the layer stack structure as indicated in the Figure 1, where in all three cells have the electrode layer dye-sensitized with natural dye extracted from the spinach leaves, made as a mixture of these two, with 1:1 proportion once the cells are structured the three electrolytes are filled dropwise in the crevices of the glass substrates which spreads upon capillary action. Thereafter the cells are bounded using the binding clips.

3. Result and Discussion

It is evident from the UV spectroscopy of the spinach extract that chlorophyll pigment (the photosensitising

Table 1. Table representing 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	0.245	0.0108	0.595	0.8076	120
2.	PANI/HCl	0.182	0.0154	0.472	0.617	120
3.	KI/I_2 + PANI/HCl	0.132	0.0179	0.429	0.5723	120

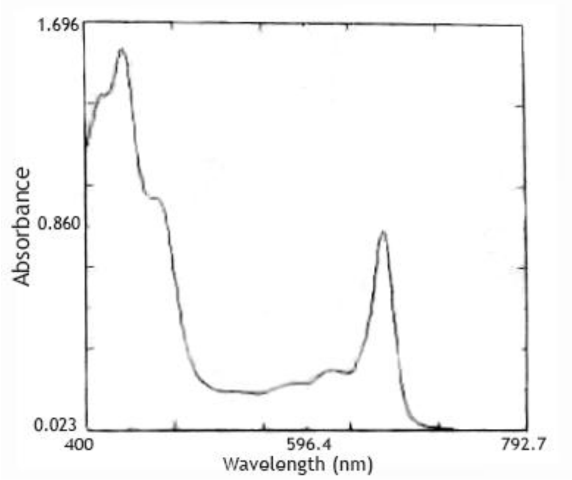

Figure 3. UV Absorption curve of Spinach extract

pigment) shows two peaks one at 494 nm and other one at 619 nm, the absorption spectrum shows a broad range of photo sensitization.

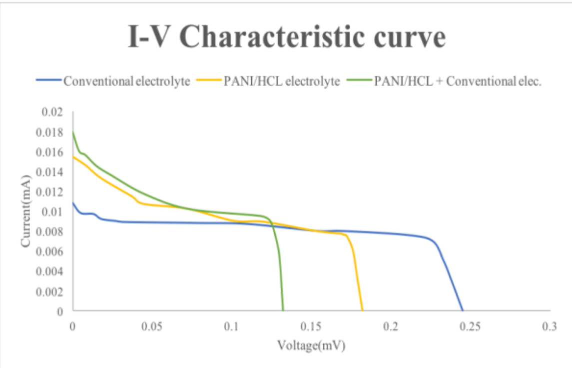

Figure 4. I-V Characteristic curve of the three cell

A rather interesting finding is that the PANI/HCL suspension electrolyte shows promising behavior which is slightly behind the conventional electrolyte. The data of all three cells can be observed from the table 1.

As its evident that the PANI/HCL and the KI/I_2 mixture electrolyte don't produce optimum results and the PANI/HCL has performed quite better we may associate this with the ability of polymer suspension where the charge transfer is hinder due to inappropriate solvent, moreover if the solvent for the polymer suspension might have been water-the charge transfer could have increased making the polymer electrolyte compete the conventional electrolyte. The conventional electrolyte ranges the with the highest efficiency although the short circuit current attained by the mixture electrolyte is the highest. It should be noted that polymer polyaniline shows strong semi-conductor properties in near future with optimum research, parameters and technology it will play a major role in harness of solar energy.

4. Conclusion

In the conclusion, it should be stated that oil derived electrolytes still offer a stable and high efficiency for the solar cells, but since these are liquid electrolytes they tend to dry and increase the charge transfer barriers. Thus, to resolve this issue polymer electrolytes are being extensively studied which are brought in quasi-solid state of existence and thus embarking a more stable, strong and optimum grade for the solar energy produced by dye-sensitized-solar cells. Polymer electrolytes play a major role in revolutionizing the field of solar with the extensive research for their growth.

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