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Progress on Mangiferaindica As Dye Sensitized Solar Cell

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Abstract

The efficiency of *Mangifera Indica* was improved upon by utilizing three known sensitizers- inherent in its leave and peel. The results obtained in this experiment may vary due to the versed mango germplasm collection which is about 150. The experimental technique adopted was in line with objective of furthering the efficiency of *Mangifera Indica*. The natural dye sensitized solar cell (DSSCs) obtained was tested via solar simulator and UV spectrophotometer. When the DSSCs was analyzed in the dark, it resulted in a low negative value of short circuit current $I_{sc} = -1.00 \times 10^{-7}$ mA and a low short circuit voltage $V_{oc} = 0.06V$ due to the absence of light. When the DSSCs was analyzed in light, its short circuit current $(I_{sc}) = 1.22 \times 10^{-2}$ mA, an open circuit voltage $(V_{oc}) = 0.53v, V_{max} = 0.35v$, $I_{max} = 1.00 \times 10^{-2}$ mA. The *Mangifera indica* dye have peak transmittance at 220nm and good transmittance level between 400nm to 800nm. There were no transmittances between 240nm to 420nm. This shows that the range of the expected photoelectric conversion effect is between 240nm to 420nm. Though the overall conversion efficiency (Eff) =0.345%, the range of its photoelectric conversion effect gives more room for better results.

Keywords: *mangifera indica*, dye sensitized solar cell, UV-analysis, efficiency

Introduction

Anthocyanins are flavonoid pigments which occur naturally to often give a bright red, blue, or violet color to plant petals, fruits, and stems (Młodzinska, 2009). Natural pigments extracted from fruits e.g. mango (*Mangifera Indica*), orange (citrus), guava leaf and the likes have been extensively investigated and can be used as sensitizer for dye-sensitized solar cells (DSSCs). This kind of solar cell was originally referred to as dye sensitized nanostructure solar cell. (Gratzel 1998). Recent comparative study(which includes *Mangifera Indica*) between thirty five species of leaves, root and stems showed that *Melastoma malabathricum*, *Hibiscus rosa-sinensis*, and *Codiaeum variegatum* are potential candidates for DSSCs (Aiman et al., 2014). This findings did not consider other parts of the *Mangifera Indica*. The Mangiferaindica (Mango) fruit peels are rich source of carotenoids and they provide diverse photosynthesizing effect which convert sunlight into electricity. The use of natural dyes extracted from leaves and fruit peels as photosensitizer is because they have advantages over synthetic dye i.e. they are easily available, they considerably reduce the cost of devices and they are abundant in supply. Another salient point for opting for *Mangifera Indica* is its optical absorption and charge separation processes. The third reason why *Mangifera Indica* was considered in this study is because it exhibits three salient sensitizer i.e. tanin (Nicolai et al.,2004), anthocynanins (Aiman et al., 2014) and carotenoids (Yamazaki et al., 2007). Hence, the optimization of the structure of natural dyes of *Mangifera Indica* (see figure 1) to improve its efficiency would be very effective than species having single sensitizers (Wang et al., 2008). However, the efficiency of *Mangifera Indica* is dependent on the mango germplasm collection which had been discussed in Ribero et al.,(2013) and shown in table 1 below. Thus, genetic breeding programs for *Mangifera Indica* may yield more efficient sensitizers for DSSCs.

The operating techniques of DSSCs are not complex like the fabrication of solar sensitized metallic oxides (Uno et al., 2014a,b). Hence, much of the theoretical background of the DSSCs has not been explored like other solar sensitized metallic oxides (Emetere, 2013; 2014). The DSSCs fabrication techniques are somehow flexible and important for the efficient maximization of the functionality of the *Mangifera Indica*. For example, the DSSCs have a mesoporous oxide layer composed of nanometer-sized particles which allow for electronic conduction to take place.

Table 1: The mango germplasm collection (Ribero et al., 2013)

Genotype	Origin	Genotype	Origin	Genotype	Origin
Bonita	Brazil	**Mallika**	India	**Bourbon**	Brazil
Mallindi	India	**Black Java**	Australia	**Maçã**	Brazil
Ataulfo	Mexico	**M-13269**	USA	**Beta**	Brazil
Kent	EUA	**Aplle DCG 406**	Thailand	**Langra**	India
Ametista	Brazil	**Kensington**	Australia	**Amrapali**	India
Lita	Embrapa	**Amarelinha**	Brazil	**Keitt**	USA
Alfa	Brazil	**Juazeiro VI**	Brazil	**Alphonso**	India
Mangadágua	Brazil	**Manguito**	Brazil	**Manila**	Philippines
Calmon	Brazil	**Carabao**	Philippines	**Manzanillo**	Mexico
Carlotão	Brazil	**Mastruz**	Brazil	**Caxangá**	Brazil
Maya	Mexico	**Chené**	South Africa	**Momi-K**	USA
Comprida Roxa	Brazil	**Amon**	Thailand	**Morais**	Brazil
Da Porta	Brazil	**Ômega**	Brazil	**Néldica**	South Africa
CPR	Brazil	**Heidi**	South Africa	**Simmonds**	USA
Hilda	Brazil	**Smith**	USA	**Espada Ouro**	Brazil
Recife	Brazil	**Itamaracá**	Brazil	**Tyler Premier**	USA

Titanium dioxide ($T1O_2$) is preferred to Zinc oxide as mesoporous oxide layer because it raised the efficiency of DSSCs from 1% to 7%. (Archer *et al* 2008). The mesoporous oxide layer is important because the sensitizer is grafted onto the TiO2 surface through suitable anchoring groups (e.g. carboxylate, phosphonate or hydroxamate) to allow the light excitations. The electron injection from the adsorbed dye into the nanocrystallites renders the TiO2 conductive. Hence, the preparation of the mesoporous oxide layer contributes to the research objective i.e. furthering the efficiency of *Mangifera Indica.*

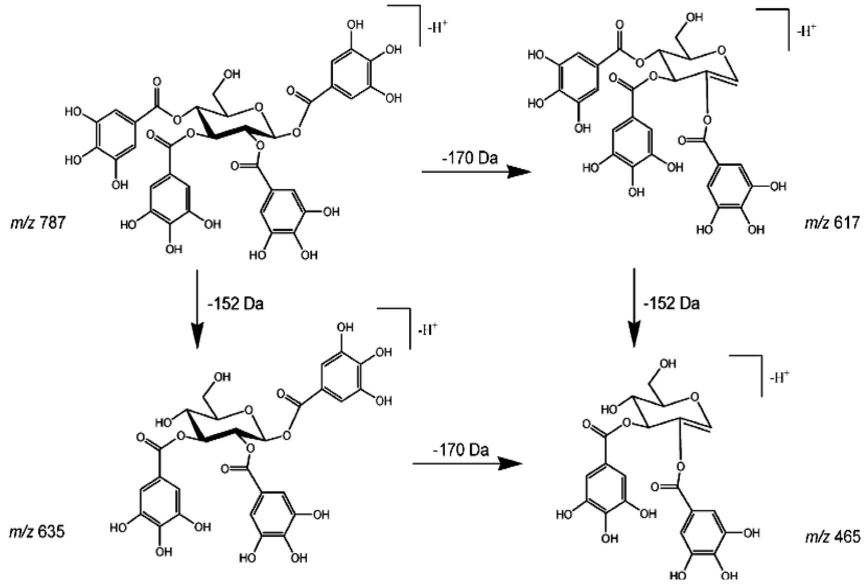

Figure 1: Fragmentation pathways of *Mangifera Indica* structures (Nicolai et al., 2004)

In this paper, the preparation technique was discussed in section two. The type of analysis was discussed in section three. The results of the study were discussed in section four. Vital conclusions were made in section four.

Preparation of Dye Solution From Unriped Mango Peel

The mango fruits were plucked from trees and then rinsed with fresh water and peeled off from the fruits. 5g of this peeled was weighed on weighing device and soaked in 15ml of ethanol. The mixture was blended using electric blender. The solution was poured into a glass tube and separated within 20 seconds using centrifuge. The filtrate settled at the top of the glass. The filtrate was separated and covered with aluminum foil for about 12 hours to prevent it from sunlight. This filtrate is the sensitizer. As discussed earlier, the preparation of the mesoporous oxide layer is also paramount as the sensitizer. Fluorine Tin Oxide glass was cut into size 2.0 by 2.0cm with a diamond cutter. Both sides of the FTO glass were rinsed using ethanol absolute in order to remove liquid on the surface of the glass. The FTO glass was then dried using a hot air blower for 2 minutes and placed in a Petri dish. TiO2 was mixed with tapenol (which serve as the solvent) using glass stirring rod to form a homogeneous paste. The glass rod was used to apply a portion of the paste at the centre of conducting side of fluorine Tin Oxide (FTO) glass using screen printable mesh. A hot air blower (120^oC) was used to temporarily dry the deposited paste. The dye solution from mango fruit (*Mangifera Indica*) peel was poured into a petri dish and a pair of tweezer was used to immerse sintered Titania electrode into the already prepared sensitizer.

The paste Titania was facing up in order to prevent it from scratches. The petri was covered (to prevent sunlight) while the titania electrode was kept in the solution for about 12 hours. The titania electrode was stained and kept in another separate petri dish. The sintering of the titania electrode was done with the use of programmable heater. After the TiO_2 is screen printed on the FTO, it was then taken to the programmable heater where it was heated up to 500^oC for 1hour. This process allowed the TiO_2 to melt properly on the glass. A programmable heater is used here so that the TiO_2 stayed firmly on the cover slip since the material used was FTO glass substrate. After completing the sintering process, cover glass was left for 1 hour to cool down in order to avoid delaminating. The impregnation process i.e. the process of suspending FTO glass substrate into the dye solutions that was extracted from unripe mango fruit peel. This substrate was suspended for 24 hours and the FTO glass was brought `out in some few hours and rinsed properly with propanol. The negative part of the dye sensitized solar cell is the electrode. Hence, the FTO glass was cut to the size 2.0cm by 2.0cm and the conducting side was verified with the use of a multimeter. The conducting side can also be known physically due to its rough surface but the use of multimeter is preferable to avoid mistakes. The FTO glass substrate was rinsed with ethanol 99% and allowed to dry. The preparation of the counter electrode like the negative part of the DSSCs requires that the FTO glass be cut into size 2cm by 2cm and the conducting side verified with the use of multimeter. The glass was cut from the un-conducting side to prevent its discontinuity on the FTO region. The FTO was rinsed with ethanol and dried. A platinum catalyst was screen printed on FTO conducting part using a squeeze technique. This platinum catalyst was allowed to settle on FTO glass for some minutes and taken to programmable heater to decompose and sintered at 450^0 for 40 minutes. The FTO glass was allowed to cool below 100^0C say 60^0 to avoid the platinum been delaminated on the FTO glass substrate. The sealing of electrodes was carried-out by the formation of space between the electrode and counter electrode (negative & positive part) to allow for the injection of electrolyte. This is done by placing the deposited area of the electrodes on each other and then sealed together by using a gum (Epoxyl glue) or seal. The cell was then heated to haste quick sealing of the gum on the electrode. The seal was done to prevent moisture from entering. The masked area was then sealed out using ethanol & cotton wool and this serves as negative terminal. The Iodide electrolyte solution was then injected and the electrolyte was then absorbed between the spaces of the electrode until the space was fully filled and the space of Injection was sealed and this finalized the assembly of DSSC. The filling of the electrolyte is paramount to the research. To achieved this feat, a droplet of Iodine electrolyte was put between the region of the cell. The size of the gap determines the amount of liquid electrode been injected. This Iodine electrolyte brings about the flow of charges as well as conductivity and when this is done the process of dye sensitized solar sell is completed and is ready for testing. The fluorine tin oxide glasses with substrate TiO_2 impregnated with *Mangifera indica* peel and henna leaf sensitizers were separately glued together with the platinum counter electrodes using Epoxide glue (with both part A & B (Resin and Hardener) were mixed together). The gum was pasted on the working parts of the electrodes (using a squeezee and a printable mesh), so that both the platinum counter and the dye covered TiO_2 electrodes were placed on each other in a sandwich type and were allowed to seal together for 24 hours.

Solar Simulator And Uv- Spectrophotometer Analysis

The natural dye extracted from *Mangifera Indica (*as sensitizer) was performed by measuring the I-V (the current voltage) curve under light. The test was performed with the use of equipment called Solar Simulator connected to the source. The interpretation was done quantitatively by a computer with a lab trace software .The performance of the natural dye is evaluated by j_{sc} (short circuit current),V_{oc}(open circuit voltage), Fill Factor (FF) as well as the conversion efficiency. UV spectrometer was used to perform absorption spectrometry. The diagram below shows the transmittance and absorption spectrum for mangiferaindica peel. Figures below show the absorption spectra of ethanol extract of mangiferaindica and this natural extract absorbed in the visible region of light spectrum and fulfilled the criterion for the use of photosensitizer in the dry sensitized solar cell.

Results and Discussion

I-V Characterisation

The graph of I-V characterisation was then plotted by using the values obtained for both current and voltage (as shown in figure 2). The values of the current and voltage as obtained are illustrated in both figure 2&3.

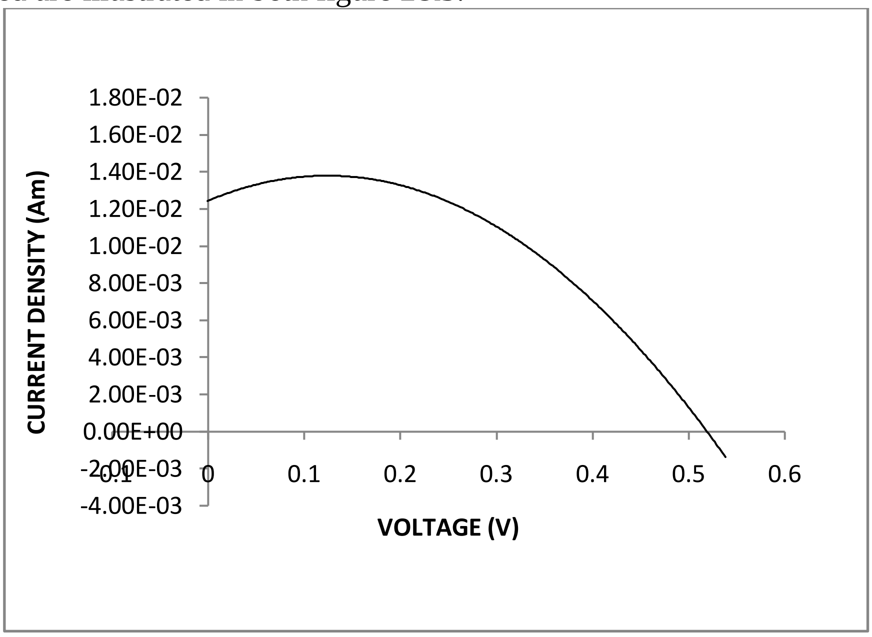

Figure 2: Light I-V curve for *Mangifera indica* dye

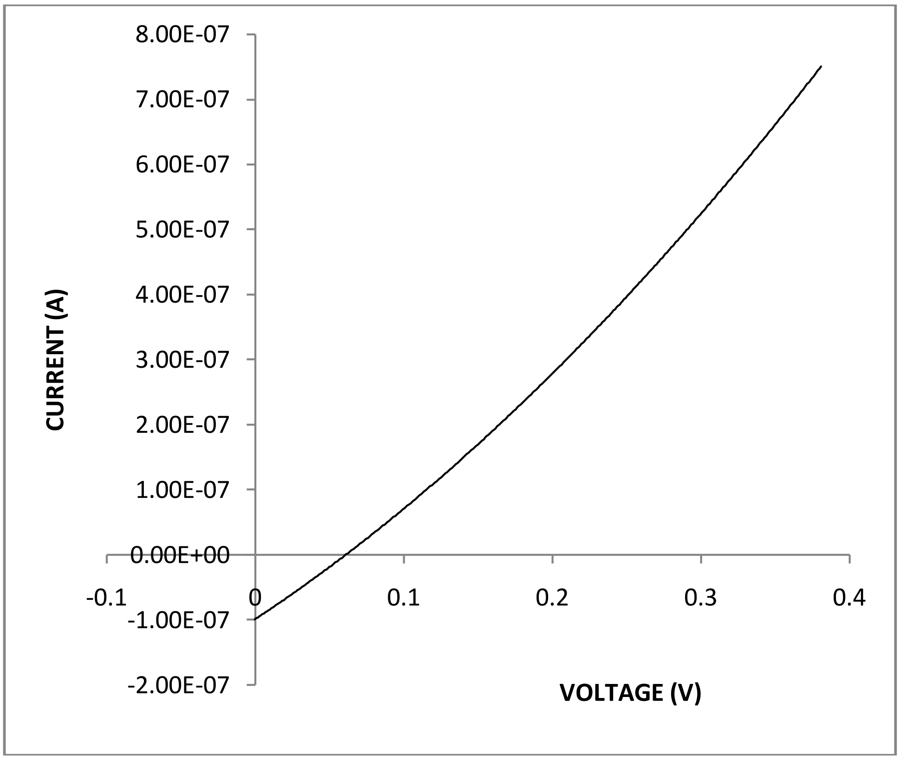

Figure 3: Dark I-V curve for *Mangifera Indica* dye

Figure 2, the experiment was performed in the dark and the graph of current against voltage was plotted and this resulted in the low negative value of short circuit current I_{sc} = -1.00 × 10^{-7} mA and a low short circuit voltage V_{oc} = 0.06V due to the absence of light. In Fig 3, the current decreases as the voltage increases. This experiment was performed in the presence of light where rays fall on the sample which resulted in the parameters obtained i.e. short circuit current (I_{sc}) = 1.22 × 10^{-2} mA, an open circuit voltage (V_{oc}) = 0.53v,V_{max} = 0.35v, I_{max} = 1.00 × 10^{-2} mA. The Light IV-characteristic of the DSSC was used to determine value of the Open circuit voltage (Voc), Short circuit Current (Isc), Short circuit voltage, Open circuit voltage, Maximum current density (I_{max}), Maximum voltage(V_{max}), Maximum power $P_{max}$and to calculate the Fill factor(FF) and the Cell Efficiency. From theory, the Fill factor (FF) data is acquired from measuring the photoelectric conversion efficiency of the DSSCs. the conversion efficiency of the DSSC prepared from the dye extracted from Mango peels is 0.345136% with open circuit voltageVoc 0.53V, short circuit current density (Isc) of 1.22E-2(mA/cm²), Fill Factor (FF) 0.16 and light intensity (P_{in}) 1000(watt/m^2).The power conversion efficiency (η) of the solar cells was calculated and gotten as η = 0.345136%.The efficiency of the *Mangifera Indica* is summarized in table 2 below

Table 2: Efficiency of the *Mangifera indica*

Power input (mW)	Maximum Power (W)	Maximum Current (mA)	Short Circuit Current (mA)	Maximum Voltage (V)	Open Circuit Voltage (V)	Short Circuit Current Density (mA)	Filling Factor	Efficiency (ɳ) %
1000	3.5×10^{-3}	1.00×10^{-2}	1.22×10^{-3}	0.35	0.53	4.07×10^{-2}	0.16	0.345

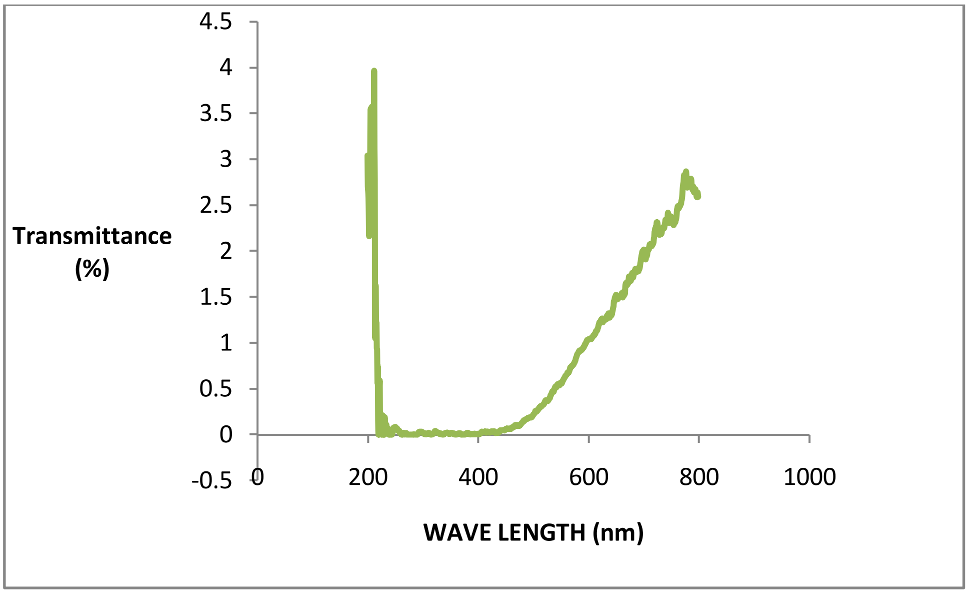

Figure 4: Transmittance Spectrum for *Mangifera indica* dye

The wavelength range of spectrum lays between 200nm and 800nm. It found that, the *Mangifera indica* dye have peak transmittance at 220nm and good transmittance level between 425nm to 800nm. This shows that the three inherent sensitizers of *Mangifera indica* (i.e. anthocyanin, carotene and thanin) are advantageous to its efficiency. There were no transmittances between 240nm to 420nm. This shows the range of the expected photoelectric conversion effect. The peak absorption is at 265nm with three visible bands at 255nm, 265nm and 370nm. The figure above shows the absorption spectrum for extracted dye in which the incident is absorbed by dye sensitizer and exploits the light energy by dye to induce the reaction of electron transfer. The efficiency 0.345% is a good one compared to the past work carried out on DSSC (Moustafa *et al.*, 2012;Xue et al.,2012), the efficiency was 0.05% using khella leaf as sensitizer.

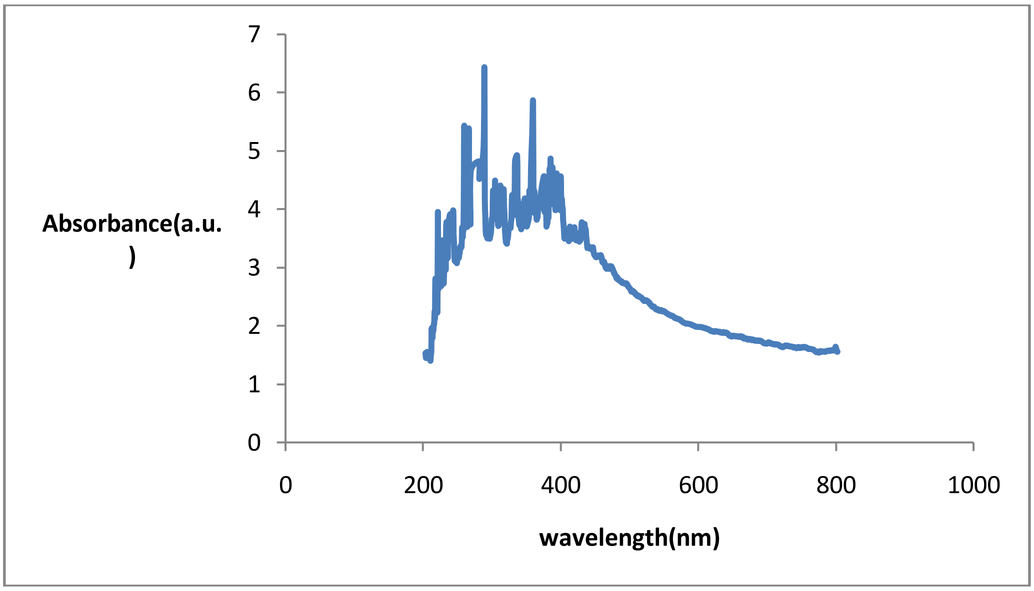

Figure 5: Absorbance spectrum for *Mangifera Indica*

Fig 4 and 5 shows the Transmittance curve of the MangiferaIndica dye on TiO_2 and absorbance spectra. The absorption spectra provide the necessary information on the absorption transition between the dye ground state and excited state and the solar energy range absorbed by the dye and the absorbance values were calculated from

$$A=[\text{Log}_{10}(1/T\%)] \quad (1)$$

where A is known as absorbance, T is Transmittance and Log_{10} is the common logarithm. The absorption wave length of the dye on TiO_2 is from (200-800) nm.

Conclusion

The natural dye used as sensitizer was the natural dye extracted from mango fruit (Mangiferaindica) leave and peel. The DSSC fabricated consist of 2.25cm^2 active area of titanium dioxide coated on FTO glass (fluorine tin oxide) immersed in ethanol solution of natural dye extracted as an anode (electrode) and counter electrode. These two electrodes were coupled together and the space between them was filled with the Iodolyte AN-50 as solid electrolyte or redox mediator. The photo electrochemical parameters of the dye extracted (Mango fruit Peel) from the results obtained are short circuit current (Isc)= 1.22x10^{-2} ,current density (Jsc)=4.07x10^{-2}, open circuit voltage (voc) =0.53V, fill factor (FF) of 0.16 and the overall conversion efficiency (Eff) =0.345%. The natural dye which was used as sensitizer for DSSCS was the alternative to organic dye. Since they are widely available, have low cost of production, they are environmental friendly and they are simple to construct or build. Although from the result obtained it has low efficiency, yet from the results obtained, the continuous used of natural dye as an alternative for electricity generation can enhance the additional studies and further research for new natural sensitizers. Though the overall conversion efficiency (Eff) =0.345%, the range of its photoelectric conversion effect gives more room for better results.

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