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COMPARISON OF OPTICAL AND STRUCTURAL CHARACTERS OF DIFFERENT NATURE BASED DYES FOR EFFICIENT DYE-SENSITIZED SOLAR CELLS

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ABSTRACT

Dye-sensitized solar cells are well known for their flexibility and low cost production. Artificial photosynthesis carried out in natural DSSC is efficient in converting solar radiation into chemical energy. A wide band gap semiconductor TiO_2 is used for charge separation and transport. Extracts from hibiscus, marigold and henna are characterized using photo fluorescence and FTIR spectroscopy. The cells made of these extracts are tested for its efficiency by analyzing the I-V characteristics. The annealing of TiO_2 to the FTO coated glass plate as well as the sensitization of the dyes is studied by analyzing its photo fluorescence. Natural compounds present in these extracts are anthocyanins, carotenoids and lawsone.

Keywords: Dye-sensitised solar cell (DSSC), FTO coated glass plate, Fill Factor, Anthocyanin, Carotenoids and Lawsone

I. INTRODUCTION

A dye sensitized solar cell, based on the principles of photo-electrochemical solar cells, is a low-cost solar cell belonging to the group of thin film solar cells. A DSSC is composed of a porous layer of titanium dioxide powder, covered with a molecular dye that absorbs sunlight. Sunlight passes through the transparent electrode into the dye layer where it can excite electrons that then flow into the titanium dioxide. Ruthenium is commonly used sensitizer with efficiency 11%. In theory, the maximum voltage generated by such a

cell is simply the difference between the (*quasi*-) Fermi level of the TiO_2 and the redox potential of the electrolyte, about 0.7 V under solar illumination conditions (V_{oc}). Being environment friendly (non toxic and completely degradable) DSSCs with natural dye sensitizers are preferred. The work is focused on the characterization of different types of natural dyes using various spectroscopic methods and studying its response to light by varying its parameters. Natural dyes extracted from (i) hibiscus flower, (ii) marigold flower and (iii) henna leaf are used.

II.MATERIALS AND CHARACTERIZATION

Preparation of DSSCs

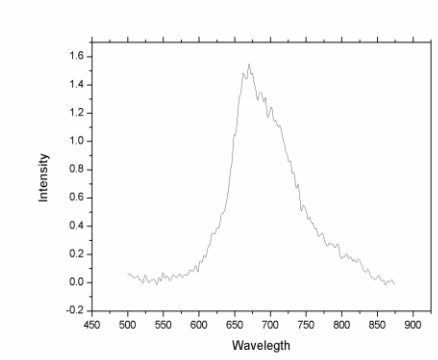
Cells are constructed using FTO glass. TiO_2 paste is annealed on FTO glass at approximately 400°C for 60 min. Dyes of samples ((i), (ii), and (iii)) are

extracted using ethanol and cells are dipped into the concentrated extract. Counter electrode is made by coating graphite on another FTO plate. The electrodes are combined and electrolyte is added. Measurements are made using multimeter, standard resistances etc.

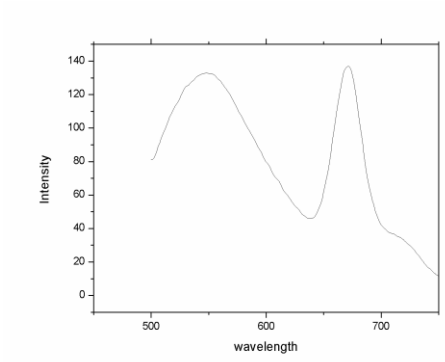
Characterization

1. Optical characterization

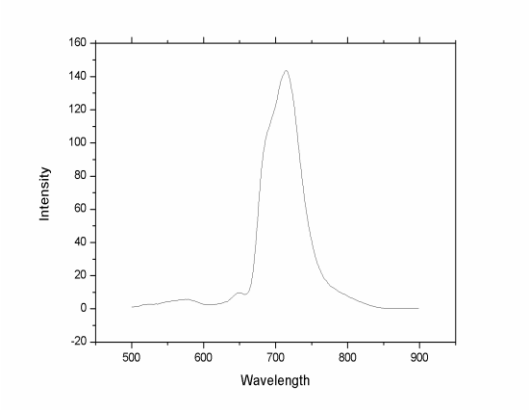
The absorbances of different dyes are analyzed using PL spectroscopy.



1(a)



1(b)

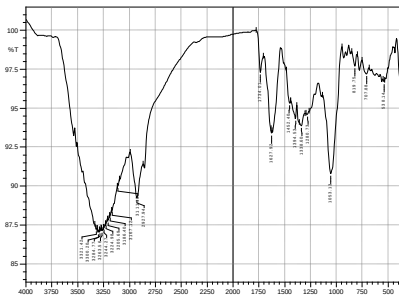


1(c)

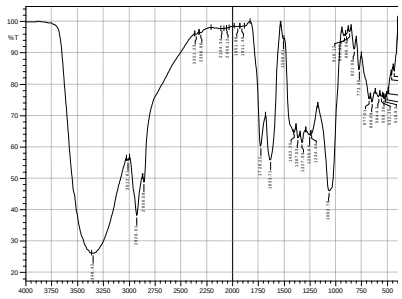
Graph 1: PL spectra of extracts of Hibiscus (a), marigold (b) and carotene (c).

2. Structural characterization

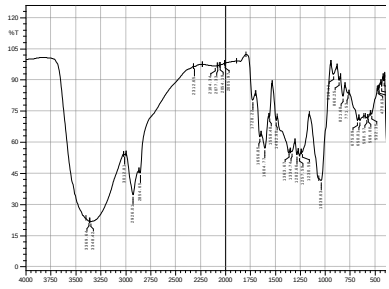
Functional components of dyes are characterized by analyzing FTIR spectra of the extracts.



2 (a)



2 (b)



2 (c)

Graph 2: FT-IR spectra of Hibiscus (a), Henna (b) and marigold (c).

III. MEASUREMENTS

The efficiency (η), short circuit current (J_{sc}), open circuit voltage (V_{oc}), fill factor (FF), maximum power (P_{max}) of the DSSCs are measured by analyzing the I-V characteristics [1] and their EMFs when exposed to maximum sunlight are measured. For comparison, efficiency has also been measured under a 60W incandescent lamp also. The change in EMF with intensity of sunlight is also measured.

IV. RESULT AND DISCUSSION

1) Natural dyes are optically characterized by analyzing their PL spectra. Hibiscus extract shows numerous excitation bands with some prominent bands at a range 650-700nm. Marigold extract shows two excitation bands at 548nm and 671.5nm. Carotene has one excitation at 741.5nm. (**Graph 1**)
2) Structural characterization is done by FT-IR spectroscopy. (**Graph 2**)

- H.rosa-sinensis has Anthocyanin derivatives-Quercrtin and Cyanidin. From FT-IR result of Hibiscus (Graph 2(a)), the presence of O-H, benzene, C-O and alkane C-H represents the existence of Quercetin and Cyanidin.[2]
- Lawsonia Inermis has the molecule Lawson in its leaves which is responsible for its dye colour. The presence of O-H, benzene, C-O and C=O in FT-IR result (Graph 2(b)) represents the existence of Lawson.
- Calendula officinalis (variety Bonbon Abricot) contains 10% β-Carotene, 35% Flavoxanthin and 15% Luteoxanthi+Auro[3]. The presence of ether in FT-IR result (Graph 2(c)) represents the existence of flavoxanthin, C-O stretch confirms Luteoxanthin and alkane C-H, =C-H, C=C and O-H confirms β-Carotene.[3]

3) The EMF of different DSSCs is measured. Anthocyanins give the highest at 0.54V; Carotenoids gives 0.018V and 0.0138V by Lawson.

- It is observed that even in dark the DSSCs give a very feeble voltage (of the order of mV). This confirms that radiations other than visible also contribute to the EMF of the cell.
- It is observed that in sunlight voltage increases with increase in the intensity and it is maximum between 2:00 pm and 2:45 pm (~1050 W/m^2 intensity).
- It is also observed that the EMF of the cell decreases with time (on an average 0.0025mV/min when exposed to light and 0.09mV/day in dark).

4) Comparing the efficiencies of DSSCs

- The efficiencies of DSSCs made of three dyes are found using diode model. From **Table 1**, Anthocyanins has the highest efficiency with 0.13% at sunlight and 1.14% with incandescent lamp. Carotenoids have 0.23E-03% efficiency at sunlight and1.35E-03% at incandescent lamp. Lawson shows least efficiency, 0.203E-04% at sunlight and 3.08E-04% with incandescent lamp.
- It is also observed that the efficiency increases with the intensity of light. The DSSCs shows greater efficiency with incandescent lamp (5052.5 lx) than in sunlight (1050 W/m^2).
- When irradiance of source increased by 79.2% efficiency increased by 88.4% on an average.
- Fill factors of DSSCs shows that cells made of anthocyanins and carotenoids are Grade A cells and that made of lawsome is Grade B cell.

Plant name (common name)	Part	Dye	J_{sc} (A/m^2)	V_{oc} (V)	η	FF	P_{max} (W)
Hibiscus rosa-sinensis (Hibiscus)	Flower	Anthocyanin (Quercetin and cyanidin)	3.678	0.52	0.1283529%	0.71	0.0006317
Calendula officinalis (marigold)	Flower	Carotenoids (Luteoxanthin+Auro, Flavoxanthin, β-carotene)	0.257	0.0133	2.28337E-04%	0.73	0.0000012
Lawsonia Inermis (Henna)	Leaf	Lawsone	0.0235	0.013	2.0318E-05%	0.7	0.0000001

Table 1: Table comparing different parameters of DSSCs [4]

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