ISSN No:-2456 – 2165

Comparison of Optical and Structural Characters of Different Nature Based Dyes for Efficient Dye-Sensitized Solar Cells

Rejeena R Sebastian, Dr Xavier T S, Athulya S, Aswathy J S
Post Graduate Department of Physics, Government College for Women, Trivandrum, Kerala 695014, India
Sebastianrejeena@Gmail.Com

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. Efficiency of DSSCs depends on photo-excitation efficiency of the dye and its dye-anchoring capability. 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. Natural compounds present in these extracts are anthocyanins, carotenoids and lawsone.

Keywords: Dye-Sensitised Solar Cell (DSSC), FTO Coated Glass Plate, Photo-luminescence (PL), 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. In a DSSC, a dye capable of exiting photoelectrons is made to adsorb on mesoporous TiO_2 layer. Ruthenium is commonly used sensitizer with efficiency 11%. Natural dyes, being environment friendly (non toxic and completely degradable) DSSCs with natural dye sensitizers are preferred. Some of the parameters which determine the efficiency of DSSCs are photo-excitation capacity of the dye and its adsorption on TiO_2 layer. The work is focused on the characterization of different types of natural dyes using various PL and FTIR spectroscopic methods. Photoluminescence spectroscopy gives the photo-excitation capability of the dye. FTIR spectroscopy helps in finding the dye-anchoring functional groups which promotes adsorption of dye on TiO_2 layer. Cells are constructed and tested for efficiency to verify spectroscopic results. Natural dyes extracted from (i) hibiscus flower, (ii) marigold flower and (iii) henna leaves are used.

II. MATERIALS AND CHARACTERIZATION

A. *Characterization*

1. *Optical Characterization*

The photo-excitation capability of different dyes is analyzed using PL spectroscopy.

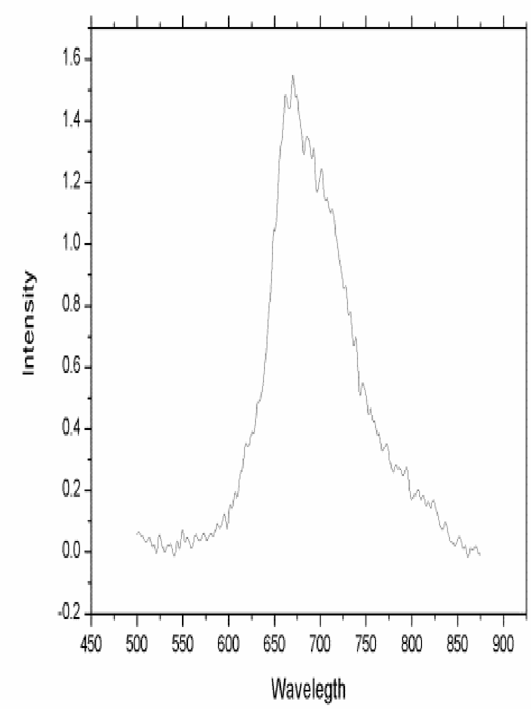

Fig. 1: PL Spectra of Extracts of Hibiscus

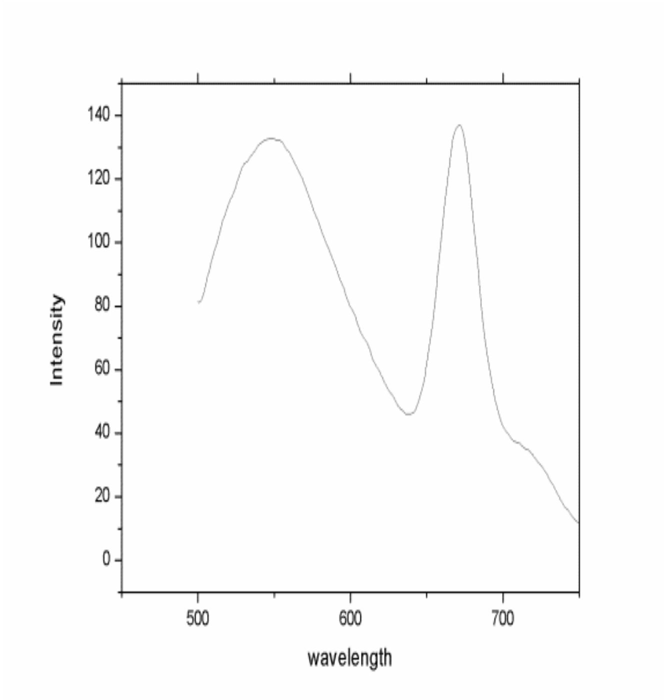

Fig. 2: Marigold

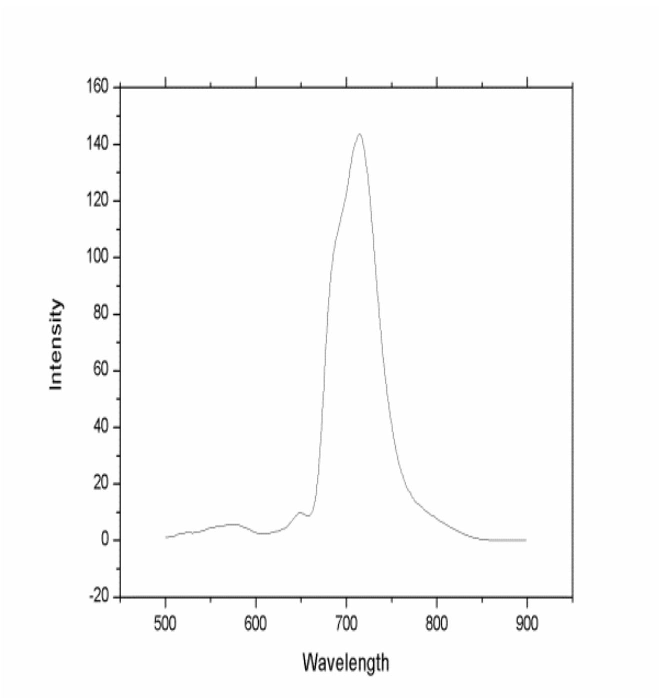

Fig.3: Carotene

Graph 1: PL Spectra of Extracts of Hibiscus (A), Marigold (B) and Carotene (C).

B. Structural Characterization

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

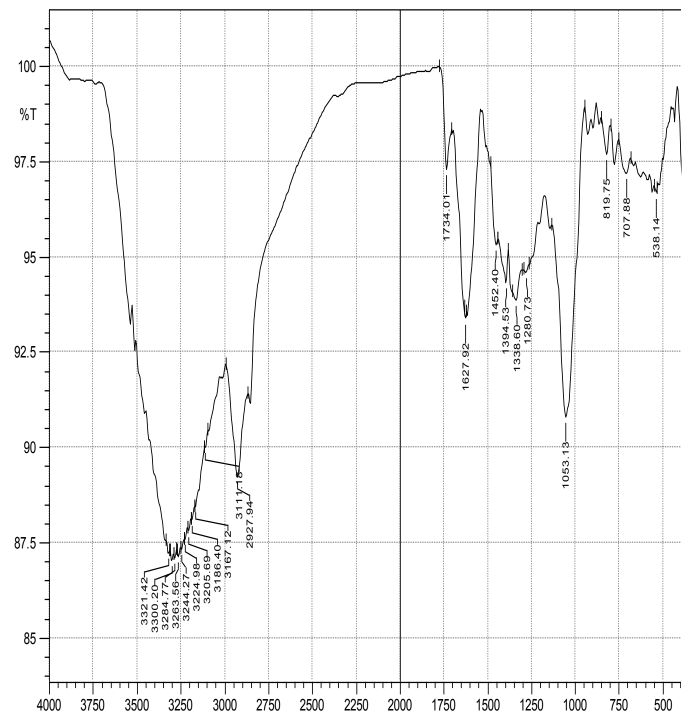

Fig.4: FT-IR Spectra of Hibiscus

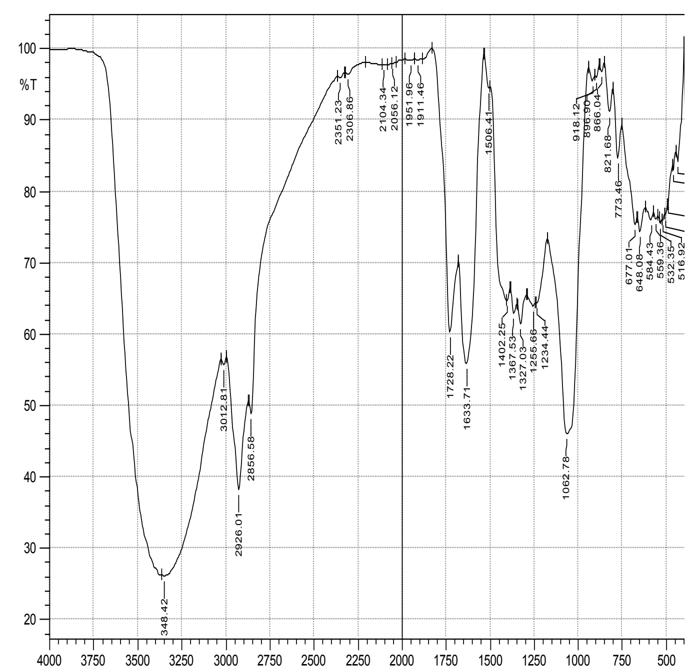

Fig. 5: Henna

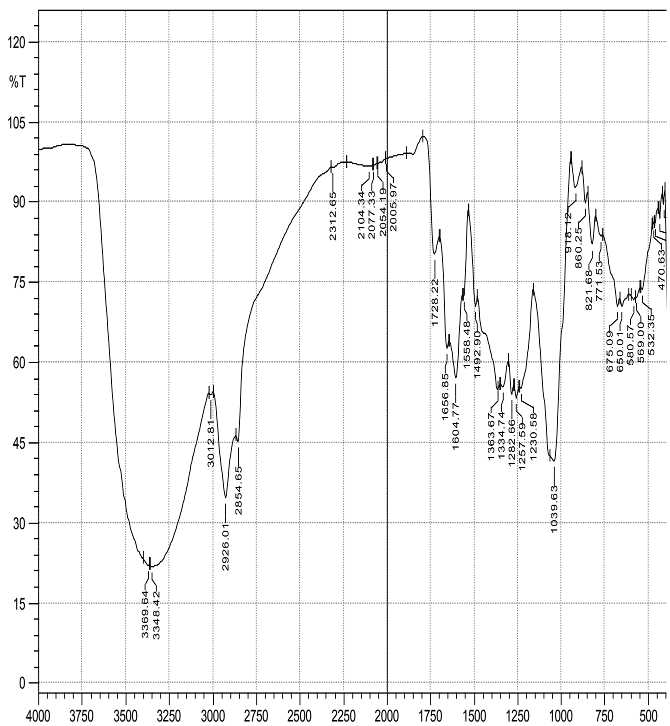

Fig.6: Marigold

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

C. *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 are extracted using ethanol and cells are dipped into the concentrated extract. Annealing of TiO_2 on to the FTO surface and adsorption of dye is confirmed using PL spectra. 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.

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

- 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. Henna has one excitation at 741.5nm. (Graph 1)

- Structural characterization is done by FT-IR spectroscopy. (Graph 2) H.rosa-sinensis (Anthocyanin), has dye-anchoring groups such as amide, ester, carboxylic acid and hydroxyl groups. Lawsonia Inermis (Lawson) has carboxylic acid and hydroxyl groups for dye-anchoring. Calendula officinalis (Carotenoids) contains carboxylic and hydroxyl groups for dye anchoring.

- 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 can excite electrons from the photo-sensitizer.
  - 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).

- Comparing the efficiencies of DSSCs

  - The experimental efficiencies are in agreement with the PL and FTIR spectra results. The efficiencies of DSSCs made of three dyes are found using diode model [2]. Anthocyanin has the highest efficiency with 0.13%, carotenoids have 0.23E-03% efficiency and lawson shows the least efficiency 0.203E-04%.
  - 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 source irradiance is increased by 79.2% efficiency also got 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 (variety Bonbon Abricot) (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 [3]

V. CONCLUSION

Efficiency of dye sensitized solar cells depends on the dye-anchoring capacity and photo-excitation capacity of the dye used. From PL and FTIR spectra analysis it is found that Hibiscus extract (Anthocyanin) should have the highest efficiency as it has the more dye-anchoring groups and excitation peaks. The same is confirmed by the experimental results.

REFERENCE

[1] K Kalyanasundaram (2010 October 3), Dye-Sensitized Solar Cells, CRC press
[2] K. Takechi, R.Muszynski and P.V.Kamat, Fabrication procedure of dye-sensitized solar cells, February 2016, http://www3.nd.edu/~pkamat/pdf/solarcell.pdf.
[3] Hubert Hug, Michael Bader, Peter Mair, Thilo Glatzel, Biophotovoltaics: Natural pigments in dye-sensitized solar cells, DSM Nutritional Products, University of Applied Sciences Northwestern Switzerland, Department of Physics, University of Basel, Switzerland.