

Anthraquinones A Probe to Enhance The Photovoltaic Properties of DSSCs

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ABSTRACT

Natural dye sensitized solar cells are a promising class of photovoltaic cells with the capacity of generating green energy at low production cost since no expensive equipment is required in their fabrication. Photovoltaics are a precious technology in the hasty world where energy prices are goes on increasing within seconds. Researchers are focusing to facilitate for producing eco-friendly, low cost and more efficient dye sensitized solar cells. In the present work we discuss the comparative photovoltaic studies of Lawsone, a natural dye from henna plant and Alizarin, a natural dye from the root of madder for fabricating the Dye sensitized solar cells (DSSCs). The absorption spectrum of Lawsone and Alizarin is found to be shifted to the longer wavelength region after the complex formation. As a result there is a significant increase in short circuit current density and conversion efficiency. This result is compared with the standard dye i.e. N719 dye.

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1. INTRODUCTION

Generation of electricity from different fuel sources and technologies is very important since we can not overly reliant on one type of power generation. Generation of Electrical Energy from Municipal Solid Waste (MSW) is a complex process since the waste has to undergo various unit processes before it is put in to the process of energy production. A mathematical model has been studied for MSWFPG in India, considering the type of waste collection process and the suitability of waste for incineration taking the heat value of MSW into account [1]. Also the modeling and simulation of PV arrays [2], are done for the better harvesting of solar energy. Dye sensitized solar cell (DSSC) [3] is stimulated by the energy and electron transfer mechanisms in natural photosynthesis. The major parts of a dye sensitized solar cell [4] are working electrode or photo anode, electrolyte and counter electrode. The sensitizer [5] is also plays an important role to harvest the photons and all the parts have relevance in the photovoltaic properties. Dye-sensitized solar cells [6] have attracted extensive academic and commercial interest during the last 20 years due to their potential for low cost solar energy conversion. When the light incident on the photo anode the dye molecules from the photo anode got excited from the HOMO layer to the LUMO layer (Figure 1). The counter electrode plays an important role of gathering electrons that are generated at the photo-anode [7] and delivered through the external circuit, back to the electrolyte. Since the electrolyte is corrosive the counter electrode requires a high reaction rate to reduce the iodine in the electrolyte to an iodide ion. The importance of counter electrode [8] to gather electrons that are generated at the photo-electrode is substantial. The natural

dyes like blue pea flower, pomegranate, rosella [9] etc are more eco-friendly but represents low conversion efficiency. So we modified them by preparing their metal complexes.

2. RESEARCH METHOD

2.1. Preparation of the dye

Lawsone [2 hydroxy [1,4] -naphthoquinone] dye and Alizarin dye is dissolved in methanol. Its corresponding Aluminium complex is prepared by adding AlCl_3 and FeCl_3 in methanol and then added to the dye solution. For the structural analysis of the dyes the absorption spectra of the dyes are taken.

2.2. Preparation of Dye sensitized Nanostructured TiO_2

Fluoride doped tin oxide-coated glass substrate (FTO) having resistance of $10\Omega/\text{cm}^2$ was purchased from Solaronix, Switzerland, with a size of $1\text{cm}\times 2\text{cm}$ is cleaned as reported in [8]. A photo electrode was prepared by using nanocrystalline TiO_2 (Degussa-P25) powder coating on FTO glass substrate by doctor blade technique. The coated films were dried at room temperature and then were sintered at 450°C for 1h. The thickness of the TiO_2 electrode was approximately $12\ \mu\text{m}$ as measured by a field emission scanning electron microscope (FESEM). Lawsone (2 hydroxy [1,4] -naphthoquinone) and Alizarin (1,2-dihydroxyanthraquinone) from Aldrich and its metal complex were used as the dye. Figure 1 shows the structure of the fabricated cell and Figure 2(a) shows the molecular structure of Lawsone dye and Figure 2(b) shows the molecular structure of Alizarin dye.

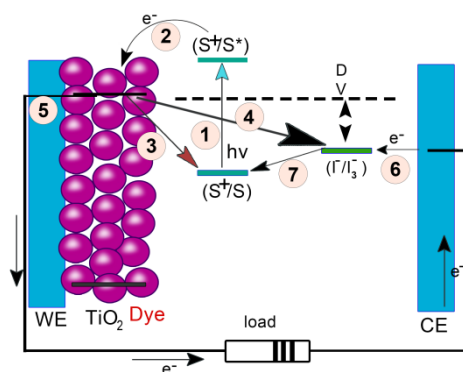


Figure 1. Structure of the fabricated cell

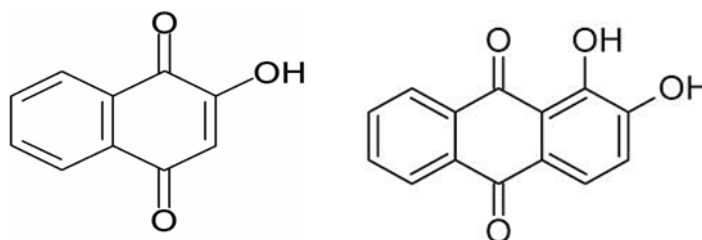


Figure 2(a). Structure of Lawsone (b). Structure of Alizarin

2.3. Preparation of counter electrode

In cleaned FTO glass substrates a few droplets of platinum solution consisting of $5\ \text{mmol}/\text{dm}^3$ PtCl_4 (98%, Aldrich) in isopropanol (99.7%, Merck) were spread and dried in the ambient temperature. Finally the substrate were fired in an oven at 385°C for 15 minutes and then cooled at room temperature [10].

2.4. Preparation of electrolyte

For electrolyte preparation, polyethylene glycol (PEG) (MW 400) potassium iodide, Acetonitrile and iodine from Aldrich were procured and used without further modification. Detailed procedure is given in our previous report [11].

2.5. Assembling of DSSC

For the fabrication of solar cells, the photoelectrodes were immersed in the dye solutions at room temperature for 12 h. Then, the dye-adsorbed electrode was assembled with the counter electrode to form a sandwich type DSSC. A drop of electrolyte solution is injected between the two electrodes of the cell. The electrolyte is injected into the space between the photoelectrode and the counter electrode. Now the device is ready for characterization.

3. RESULTS AND ANALYSIS

3.1. Absorption Spectra

The absorption spectra of Lawsone dye is shown in Figure 3(a). The spectrum ranges from 200 to 300 nm. The spectra of Aluminium and Iron metal complexes of Lawsone show shifting of the spectrum to 300nm- 500nm (Figure 3b and 3c). This the one of the reason for the better performance of the DSSC made from this coplexes.

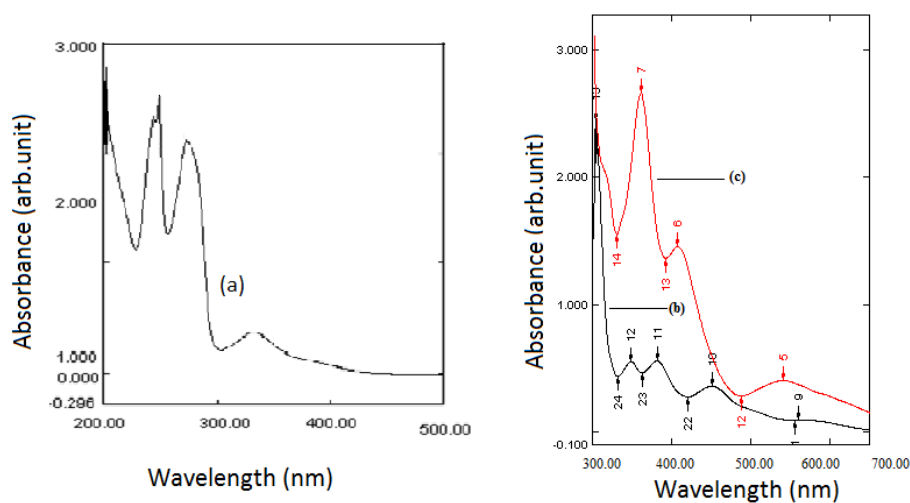


Figure 3(a). Absorption spectra of Lawsone dye in methanol (b & c) Absorption spectra of Lawsone dye and Al metal complex and Fe metal complex in methanol

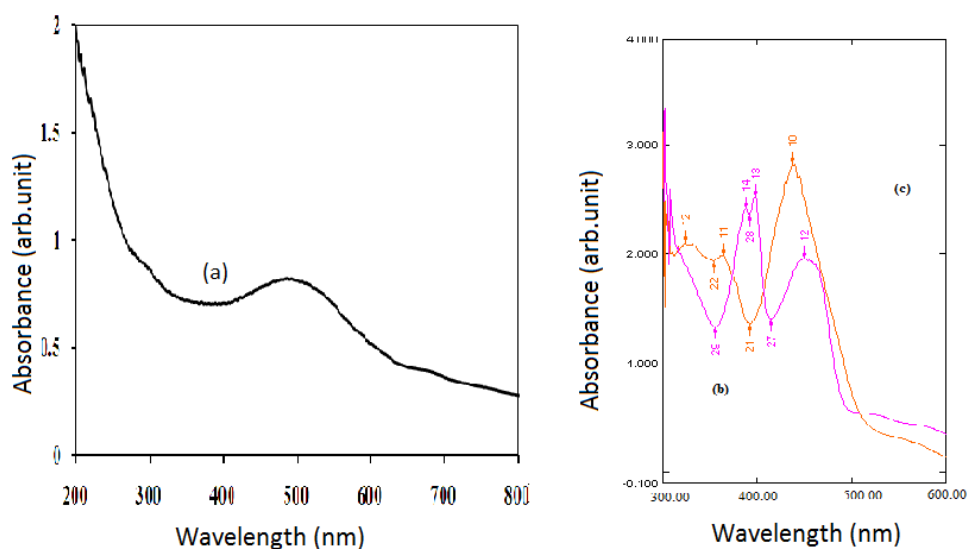


Figure 4(a). Absorption spectra of Alizarin dye in methanol (b & c) Absorption spectra of Alizarin dye and Al metal complex and Fe metal complex in methanol

Figure 4 shows the absorption spectra of Alizarin dye in methanol. Its spectrum ranges from 300-600 nm and the absorption spectra of its Al metal complex shows the absorption spectra from 200-500 nm. The absorption spectra of Aluminium and Iron metal complexes of Alizarine dye are shown in Figure 4(b) and (c).

3.2. Current- Voltage characteristics

Photocurrent–voltage curves of each sample were measured using a Keithley Electrometer 2420. A solar simulator with 300 W Xe lamp with an AM 1.5 spectrum and an output power of 100 mW/cm^2 was used to illuminate the active area, 1 cm^2 of the photo electrode.

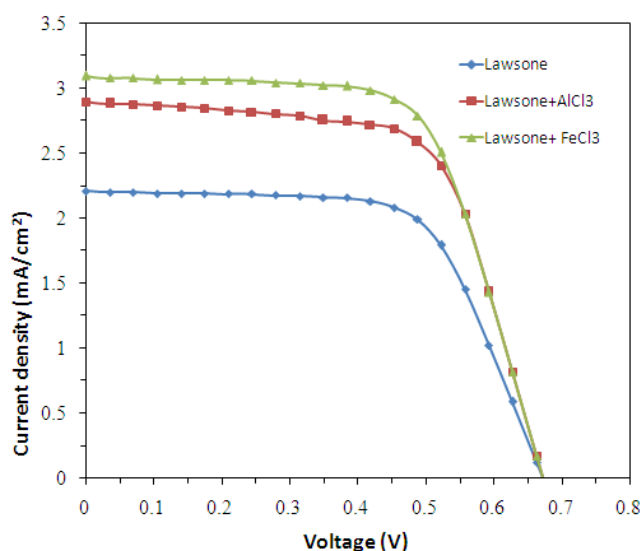


Figure 5. J-V characteristics of the fabricated device using Lawsone and its metal complexes

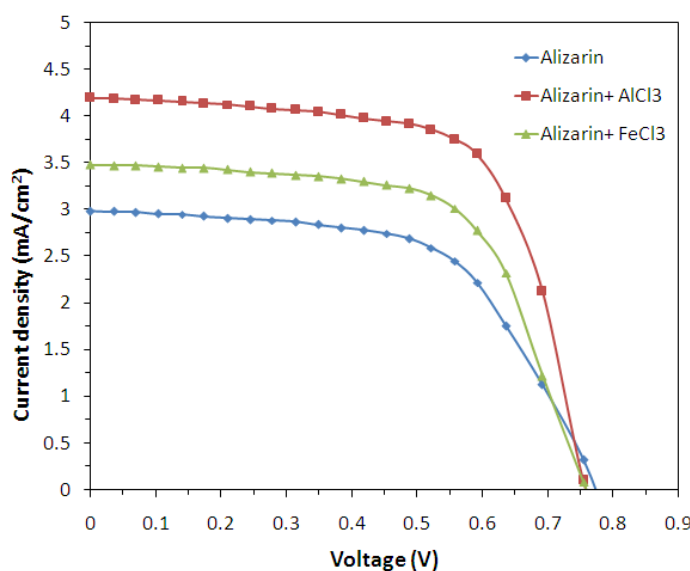


Figure 6. J-V characteristics of the fabricated device Alizarin and its metal complexes

Figure 5 compares the photocurrent-voltage curve of DSSCs using the photo electrode sensitized by lawsone and its metal complexes. It is seen that the Lawsone Iron metal complex is getting a current density of 3.09 mA/cm^2 and there by getting a conversion efficiency of 1.33%. Similarly Figure 6 compares the photocurrent-voltage curve of DSSCs using the photo electrode sensitized by Alizarin and its metal complexes. Figure 7 represents the photocurrent-voltage curve of DSSCs using the photo electrode sensitized

by N719 dye. Important photovoltaic parameters governing the efficiency of the DSSCs were determined from the photo-current-voltage curve, and the results are presented in Table 1.

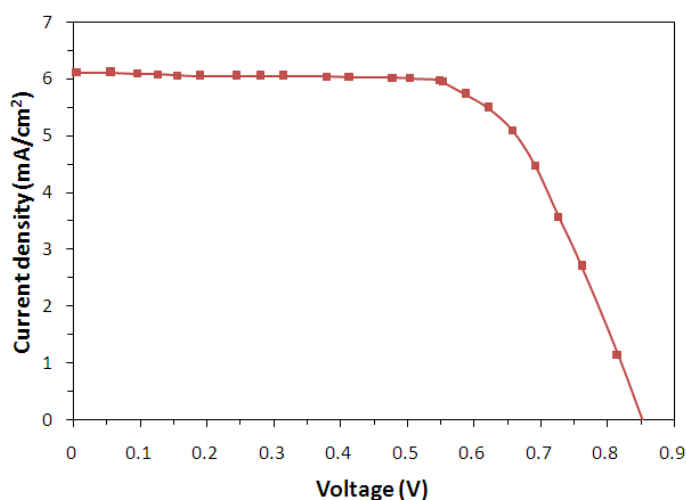


Figure 7. J-V characteristics of the fabricated device using N719 dye

Table 1. Photovoltaic parameters of the fabricated devices

Sample	J_{sc} (mA/cm ²)	V_{oc} (V)	FF	Efficiency (%)
Lawsone	2.21	0.66	0.65	0.95
Lawsone + Al metal complex	2.89	0.66	0.64	1.23
Lawsone +Fe metal complex	3.09	0.66	0.66	1.33
Alizarin	2.98	0.75	0.67	1.35
Alizarin +Al metal complex	3.47	0.75	0.63	1.66
Alizarin +Fe metal complex	4.19	0.75	0.60	2.11
N719	5.7	0.87	0.62	3.31

The overall conversion efficiency of the cell made from the dye is found to be increasing while attaching the metal complexes to it. All factors constituting the overall efficiency, that is, short-circuit current density (J_{sc}), and fill factor (FF), significantly increase when the metal complex of the natural dye is used for fabricating the device. This is because in Al complex and Fe complex with the natural dye the photoelectric charge transfer takes place at a much faster rate than the back reaction, in which the electron recombines with the oxidized dye molecule rather than flowing through the circuit and performing the work. The increase in J_{sc} for each device clearly shows the benefit of the complex formation of the natural dye in the current work for improving the performance of DSSC.

4. CONCLUSION

We made the metal complex of the natural dye, Lawsone, from Henna plant and Alizarin from the root of madder by adding Aluminium metal complex and Iron metal complex to it. It is found that after the complex formation more dye molecules are adsorbed on the TiO₂. The Pt coated counter electrode is used for making the sandwiched type cell and iodine based electrolyte. Photovoltaic characteristics are plotted and the photovoltaic parameters are measured. It is found that the photovoltaic parameters of DSSC with metal complex and dye in Pt as counter electrode increases when compared with the bare dye. Also the result is compared with that of the standard dye, N719.

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Ms. Jinchu I. is currently working as Faculty Associate in Department of Physics, Amrita School of Arts and Science, Amritapuri and also a part time Research Scholar in Dept.Physics. She obtained M.Sc, degree (Physics) from Mahathma Gandhi University in 2010. She was working as a Research Associate in CREATE@ Amrita, Amrita Vishwa Vidyapeetham in various DST projects for four years. She was also conferred B. Ed. in Physical Science, Kerala University in 2007



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