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Anthraquinones A Probe to Enhance The Photovoltaic Properties of DSSCs

Jinchu I[1], Jyothi R[2], N. Pandurangan[2], K. S. Sreelatha[3], K. Achuthan[1], C. O. Sreekala[1]
[1]Department of Physics, Amrita School of Arts and sciences, Amrita Vishwa Vidyapeetham, Kollam-690525, Kerala
[2]Amrita School of Biotechnology, Amrita Vishwa Vidyapeetham, Kollam-690525, Kerala, India
[3]Department of Physics, Govt.College, Kottayam- 686013, Kerala, India

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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.

Corresponding Author:

C. O. Sreekala,
Asst. Professor, Amrita School of Biotechnology,
Amrita Viswa Vidyapeetham,
Clappana, P.O- 690525, Kollam, Kerala, India.
Email: sreekalaco@am.amrita.edu

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 10Ω/cm^2 was purchased from Solaronix, Switzerland, with a size of 1cm×2cm 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 450^0 C for 1h. The thickness of the TiO_2 electrode was approximately 12 μm 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.

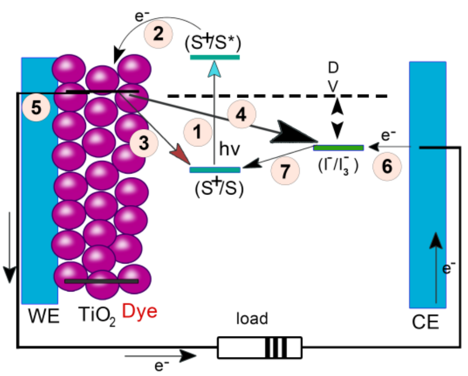

Figure 1. Structure of the fabricated cell

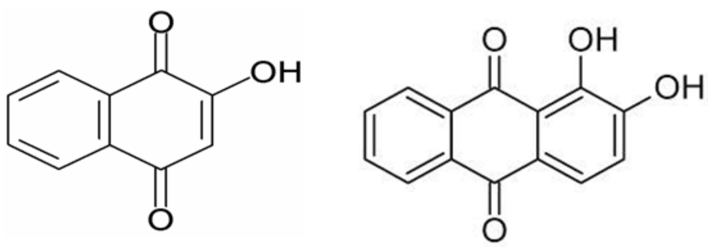

Figure 2(a). Structure of Lawsone (b). Structure of Alizarin

2.3. Preparation of counter electrode

In cleaned FTO glass substrates a few droplets of platinum solution consisting of 5 mmol/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^{0}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.

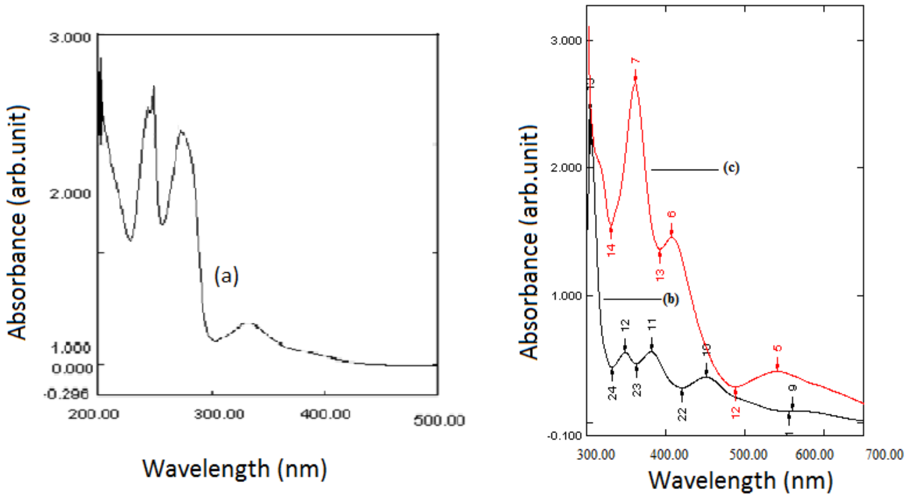

Figure 3(a). Absorption spectra of Lawsone dye in methanol (b & c) Absorption spectra of Lawsone dye and Al metal complex and Fe metal complex in methanol

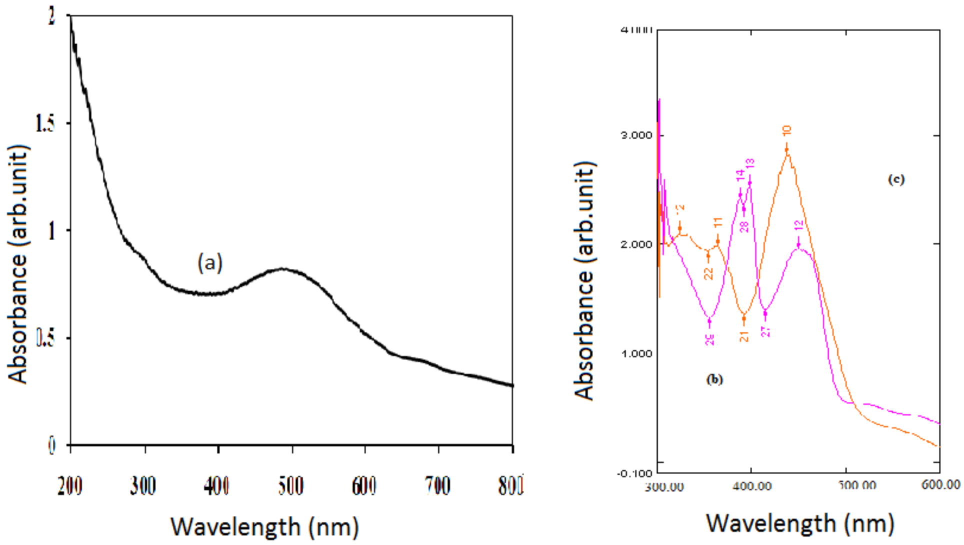

Figure 4(a). Absorption spectra of Alizarin dye in methanol (b & c) Absorption spectra of Alizarin dye and Al metal complex and Fe metal complex in methanol

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.

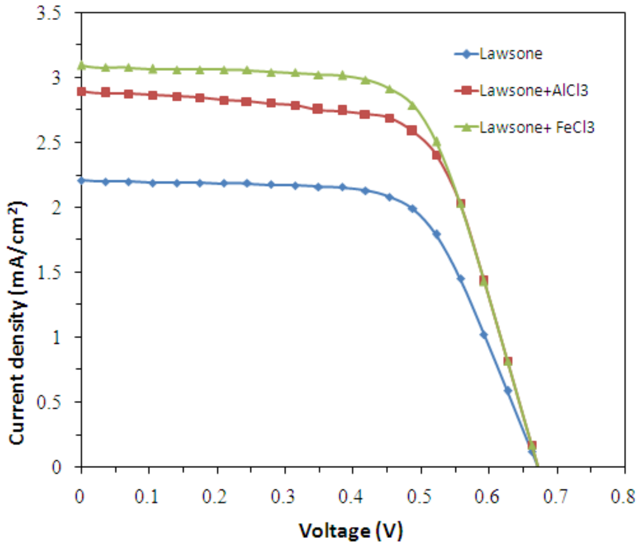

Figure 5. J-V characteristics of the fabricated device using Lawsone and its metal complexes

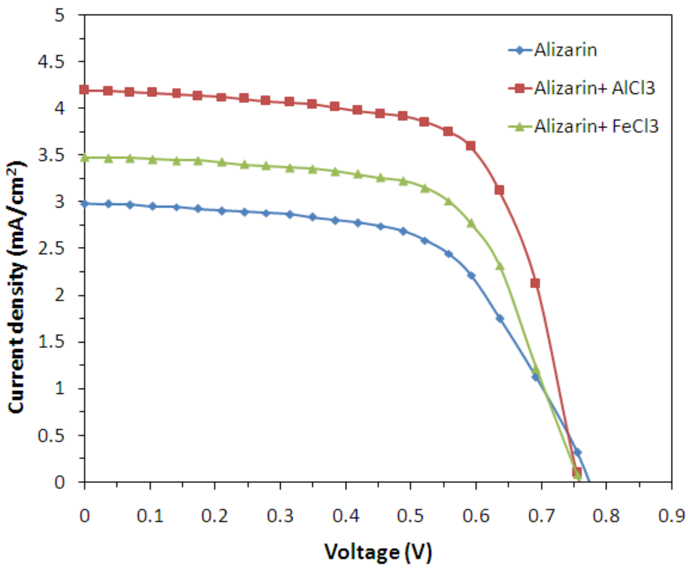

Figure 6. J-V characteristics of the fabricated device Alizarin and its metal complexes

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 Lawosone Iron metal complex is getting a currentdensity 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 Table1.

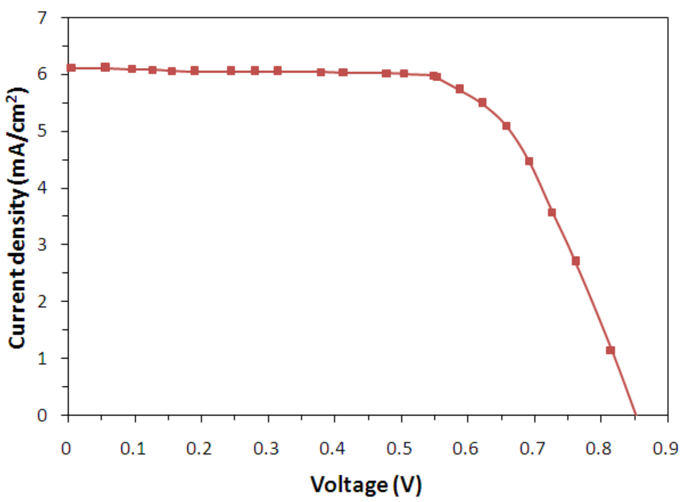

Figure 7. J-V characteristics of the fabricated device using N719 dye

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 TiO_2. 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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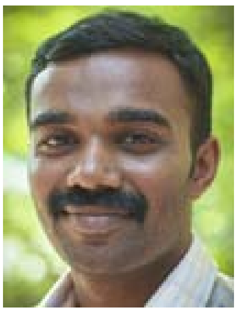
BIOGRAPHIES OF AUTHORS

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

Ms. Jyothi R. currently serves as Senior Lecturer at the Amrita School of Biotechnology, Amrita Vishwa Vidyapeetham, Amritapuri campus, Kollam. She received her M.Sc in Chemistry from Mahatma Gandhi University, in 2002. She was also conferred B. Ed. in Physical Science, Mahatma Gandhi University, in 2003. She is working as a Subject Matter Expert in Chemistry in different DST projects,VALUE@ Amrita and for the Online labs at CREATE @ Amrita.



Mr. N. Pandurangan is working as Senior Research Fellow (CSIR-SRF) in Department of Phytochemistry, Amrita School of Biotechnology, Amritapuri from 2009 August. He obtained M.Sc., degree (Chemistry) from Periyar University in 2006. He was working as a Research Associate in R & D, Merchem Limited, Cochin for 3 years on heterocyclic compounds and their applications to rubber industries also dealing with synthesis of specialty chemicals. After joining this school, he worked on extraction of medicinal plants and isolated the products. He was awarded CSIR-SRF fellowship in 2013 after starting his research. He is also working on synthesis of organic compounds. He is well-versed with the modern techniques of isolation and characterization of natural and synthetic products. He is also studying the bioactivies includes computational chemistry of various natural and synthetic flavonoids. Presently he is developing a diversity oriented synthesis for various biological studies.

Dr.K.S.Sreelatha currently working as Assistant Professor, Department of Physics, Govt.College Kottayam. She received her PhD in Non linear dynamics from CUSAT, Kerala in 2000. She has more than 15 yearas of teaching and research experience. She has produced two PhDs and supervising two more, in the areas of photovoltaics and nonlinear dynamics. She had more than 30 international publications in her credit. Her Areas of Interest includes Nonlinear dynamics, Optical solitons and wave guide modelling, Photovoltaics & DSSC, nanomaterials and their applications etc. She is also working as a faculty consultant in Value@Amrita virtual lab project @Amrita University.

Dr. Krishnashree Achuthan received the MS degree in Chemical Engineering from Clarkson University, USA and PhD degree in Semiconductor Fabrication from Sandia National Labs, New Mexico, in 1994 and 1998 respectively. She is the Principal Institute Coordinator for the project on virtual labs by MHRD under the National Mission on Education through ICT scheme at Amrita University. She is currently the Dean of PGP programs in Amrita Vishwa Vidyapeetham University, India and also the Principal Investigator of VALUE Virtual labs, International EU Programs and the CEO of Amrita Technology Business Incubator. She has over 15 years of worldwide industry experience and teaching. She is the author of over 50 International Journal and Conference Publications as well as more than 29 US Patents. Dr. Achuthan was a recipient of the World Education Awards 2013 for Best Innovation in Open and Distance Education (Virtual lab Project).

Dr. C.O. Sreekala currently serves as Assistant Professor in Department of Physics, Amrita School of Arts and Sciences. She was conferred with a PhD in Physics from Amrita University in 2011. She plays a key role as Principal Investigators in some of the significant DST projects. She also makes her presence as a Subject Matter Expert in Physics of VALUE @Amrita Nov 10, 2008 to Present. She has more than fifteen years of teaching experience and research experience. Her area of interest includes Photovoltaics, Biosensors, Microfluidics and Micro contact printing.