The Efficiency of Dyes Sensitized Solar Cells Using Different Sensitized Dyes

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Abstract – *Manufacturing techniques of solar cell have been developed rapidly since their first appearance. Dyes sensitized solar cell (DSSC) is a modern technique of solar cell .It optimized by their low manufacturing cost and the high power conversion. In this paper three of DSSC were fabricated using three different sensitized dyes Cumarin 500, Alcian Blue 8GX and Bangal Ross B Sodium Salt. The absorbance of each DSSC was determined by ultraviolet- visible spectrometer. The open circuit voltage and current were measured for each sample to determine which of the dyes has the best efficiency of power conversion. The results also obtained the fill factor for each of DSSCs. The results showed the fill factor and the bandgap of each sample. The voltage and current results reflect that Bangal Ross has the highest efficient of the other dyes.*

Keywords: *Dyes, solar cell, efficiency, semiconductor*

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I. Introduction

The demand for renewable energy increased rapidly to cover the worldwide consumption of energy and replace the fossil fuel sources with clean energy such as solar energy. Therefore the main challenge is to use inexpensive materials such as organic materials and different methods to get high power conversion of the solar cell. The dye-sensitized solar cells (DSSC) which also sometimes recognized as dye sensitized cells (DSC_s) are a type of solar cells that used the principle of photoelectrochemical to convert light rays into electricity [1].The idea of DSSC was known in 1988 by Professor Michael Gratzel therefore it was referred as Gratzel solar cell [2]. The first version developed by scientists of a research institute and university in Lausanne, Switzerland [3] .The DSSC belongs to the third generation of manufacturing solar cell [4]. More precisely it classified as a thin film solar cell [5]. Dyes sensitized solar cell has the advantage which makes it more attractive than other photovoltaic solar cells such as their low cost manufacturing and the high efficiency of conversion [6]. $DSSC_s$ are also characterized by their low weight device and has the ability to operate in diffuse light and they can be used for indoor and outdoor systems [7].They have an attractive feature by operating in low-light and in cloudy weather where often there is only non direct sunlight available [8]. Moreover the $DSSC_s$ often have large potential scale compared with other PV cells. [9]. In general DSSC composed of mechanical support coated with transparent conductive oxides, semiconductor film often titanium dioxide is used widely, sensitizer on the surface of the semiconductor and an electrolyte containing a redox mediator [10]. This study aims to study the efficiency of solar cells by fabricating different dyes-sensitized using different dyes (Cumarin 500, Alcian Blue 8GX and Ross Bangal).The significant of this paper comes because it evaluates the performance of three different types of natural dyes by studying the optical properties and calculating the power conversion of each dye unlike other of the published works related fields which often focused in studying some of the optical properties of one dyes or two dyes.

II. Related Works

Dyes sensitized solar cell attracts a lot of scientific researchers due to its high efficiency. The most recent researches were described in Table I. Some of the published papers such as in Askari [16] distinguished the types of dyes, while some of the works such as in Sharma [17] which overview the history of the $DSSC_s$ and discussed the most of type of dyes that can be used in fabricating $DSSC_s$. There are several papers such as Takachi [14] which fabricated DSSC using two types of dyes with ethanol. Syafinara [12] studied only the absorption for different kinds of solvents. Sakina [13], presented fabricated DSSC using three types of dyes.

TABLE I
SUMMARY OF RELATED WORKS

Author	Year	Description
Sawsan [11]	2018	This paper studied three different Dyes sensitized solar cell using Ultraviolet-visible spectroscopy.
Syafinara et al [12]	2015	In this work the absorption has been studied in harvesting sunlight using different solvents and UV-V absorption spectrum.
Sakina et al [13]	2016	This work fabricated dye sensitized Solar cell from Erchrom Black T, DDTTC Rohadamin B, and Coumarin 500 with Al and ITO electrodes were fabricated.
k.Takechi et al [14]	2009	In this work Dye Sensitized Solar cell is fabricated using Eosin Y, Eosin B, Dyes with Ethanol and Titanium Oxide paste.
Arini et al [15]	2015	In this study the Effects of natural dyes is determined by comparing blueberry, gardenia blue and yellow and red yeast dye, and evaluating the effect of the multilayer of TiO_2
Askari [16]	2015	This paper review the types of DSC
Sharma [17]	2018	Discuss the efficiency of DSSC generations and presented a review of the new materials that used in fabricating $DSSC_s$.

III. Materials and Method

Three types of dyes were used to fabricate three DSSC and their efficiency was investigated by measuring the current and voltage. The dyes description was shown in Table II.

TABLE II
DYES SPECIFICATIONS

Scientific Name	*Constitution*	*Chemical formula*
Cumarin 500 (LC 5010).	7-Ethylamino-4-trifluormethylcoumarin	$C_{12}H_{10}NO_2F_3$ (Ulrich, 2000)
Alcian Blue 8GX	phthalocyanine methylenethio methylmethanaminiumato chloride	$C_{56}H_{68}Cl_4CuN_{16}S_4$ (Ram, 2010)
Bangal Ross B Sodium Salt	isobenzofuran xanthen tetrachloro dihydroxy tetraiodo sodium salt	$C_{20}H_2Cl_4I_4Na_2O_2$ (Ram, 2010).

The fabricating operation of each DSSC starts by depositing Titanium Oxide paste on FTO coated glass which used as electrode (either to be anode or cathode) as shown in Fig.1.

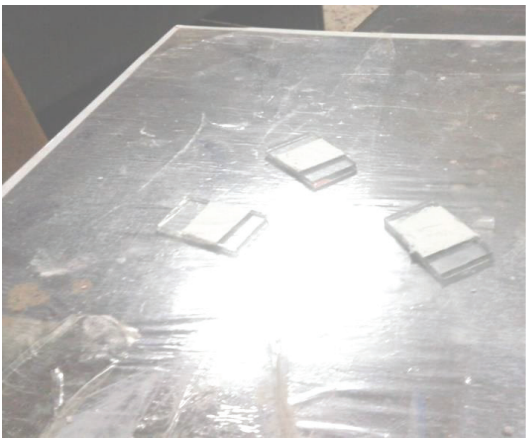

Fig. 1. Titanium Oxide paste on solar cell

The next step as shown in Fig.2 .is using a dye for each cell and each one has different color.

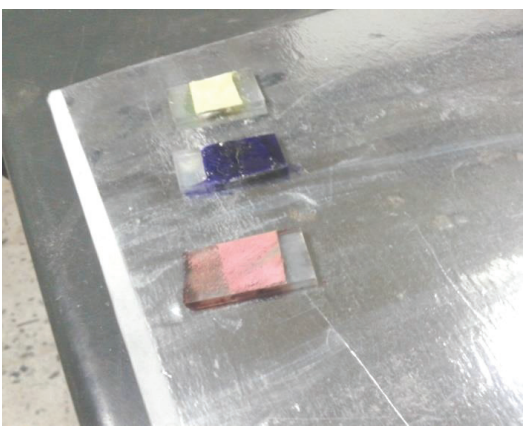

Fig. 2. Solar cells with dyes sensitized

Another clean glass plate of FTO glass needed to act like a counter electrode. Graphite from a pencil was used by sketching on the conducting glass (clean glass plate), then added the iodine electrolyte solution on the same surface. The optical properties of the formed cells were determined by ultraviolet- visible spectrometer. Electrical circuit was connected as shown in Fig.3. It consists of voltmeter, ammeter and light source lamp. This circuit was used to study the performance of each DSSC. The solar cells were exposed to light then the current and voltage of the each cell was recorded.

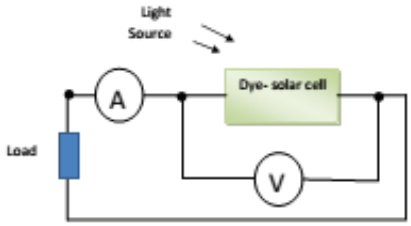

Fig. 3. Votage and Current

The band gap of the dye absorbed by titanium dioxide surface can be given by:

$$E = \frac{hc}{\lambda} \quad (1)$$

Where:

h is the Planck's constant,
v is the frequency
λ is the wavelength
c is the speed.

The absorption coefficient is given by:

$$\alpha = \frac{4\pi K}{\lambda} \quad (2)$$

Where:

α is the absorption coefficient

K is Boltzmann constant

The short circuit current I_{SC} and the open circuit voltage V_{OC} were determined from the I-V curve. The fill factor can be calculated by:

$$FF = \frac{I\max V\max}{I_{SC}\, V_{OC}} \quad (3)$$

The Power conversion efficiency (η) is given by:

$$PC = \left(\frac{I_{SC} \times V_{OC} \times FF}{\text{Light intensity}}\right) \times 100 \quad (4)$$

IV. Results and Discussion

This section of the paper illustrates the optical and electrical results obtained of each dye.

A. Results of Cumarin 500

The results of absorbance related to different wavelength are shown in Fig.4. The peak value of absorption for Cumarin 500 dye was approximately 299 nm as shown in Fig.4.

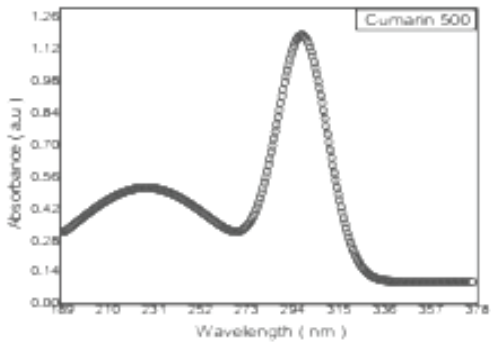

Fig. 4. Absorbance of Cumarin 500 DSSC

Also the Absorption Coefficient at different wavelength is shown in Fig.5.

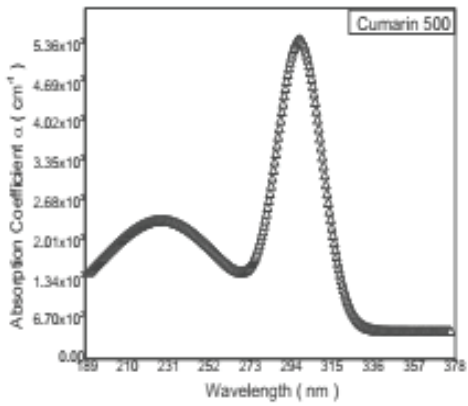

Fig. 5. Absorption Coefficient of Cumarin 500

The results of energy gap are shown in Fig.6. The results show that maximum value of Eg obtained for Cumarin 500 was 3.971 eV.

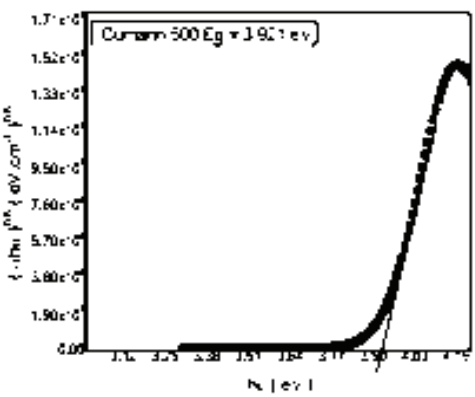

Fig. 6. Optical Energy gap of Cumarin 500

The fill factor results related to the voltage and current are shown in Fig.7.the maximum fill factor occurred when the maximum open voltage circuit was 0.0589 V and the short circuit current was 52.09 mA.

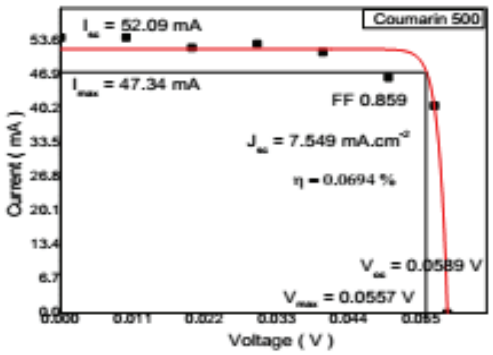

Fig. 7. Fill Factor of Cumarin 500

The measured results of the maximum voltage and current for Cumarin 500 DSSC were 0.057V and 52.93 mA respectively as shown in Table .III.

TABLE III
VOLTAGE AND CURRENT FOR CUMARIN 500

Voltage (V)	Current (mA)
0	54.2275
0.01	54.2275
0.02	52.2375
0.03	52.934
0.04	51.342
0.05	46.367
0.057	40.795
0.059	0

B. Results of Alcian Blue 8gx

Fig.8 shows the Ultraviolet – visible absorption spectra of Alcian Blue 8GX dye sensitized in the visible light spectrum. The peak value of absorption for this dye was approximately 330 nm.

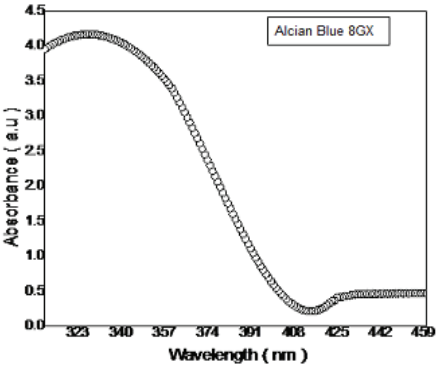

Fig. 8. Absorption for Alcian Blue

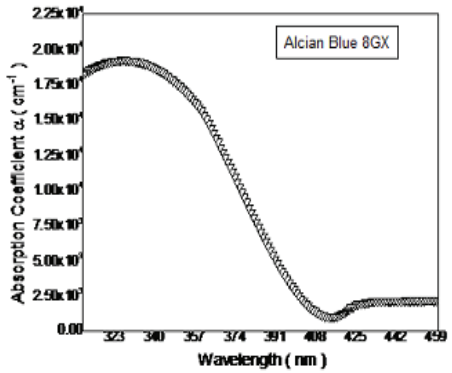

Fig. 9. Absoption coefficient of Alcian Blue

The results of energy gap for Alcian Blue 8gx are shown in Fig.10. The maximum value of Eg obtained for Alcian Blue was 3.095 eV.

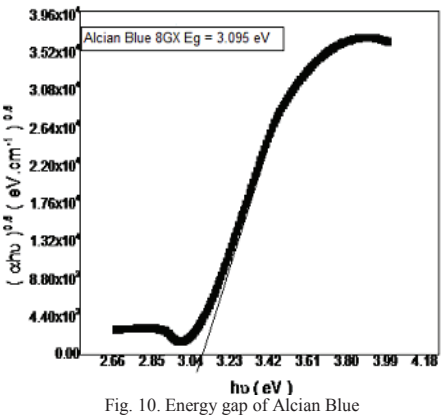

Fig. 10. Energy gap of Alcian Blue

The results of the measuring voltages and currents were reported in Table IV. The results

demonstrate that the maximum voltage and current which experienced by Alcian Blue were 0.058V and 44.73 mA respectively.

TABLE IV
VOLTAGE AND CURRENT FOR ALCIAN BLUE 8GX

Voltage (V)	Current (mA)
0	52.32
0.01	52.32
0.02	50.4
0.03	51.072
0.04	49.536
0.05	44.736
0.057	39.36
0.059	0

The results of the fill factor for Alcian Blue 8gx dye were measured using the calculation and UV. The obtained results were shown in Fig.11.the results show that the maximum fill factor is 0.864 when the maximum voltage and current were 0.0559 V and 45.6 mA respectivelly and the open circuit voltage was 0.0589V.

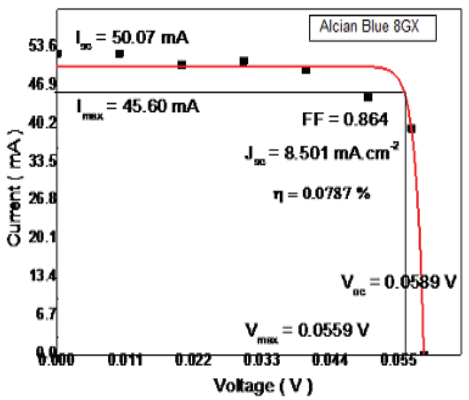

Fig. 11. Fill factor

C. Results of Bangal Ross

The peak value of absorption for this dye as shown in Fig.12 was approximately 580 nm.The results show that the Ross Bangal dye provided the highest absorption spectra among of the three dyes, Due to its absorption of the visible light in the wavelength region 450 – 650 nm which is in the visible and near Infrared region.

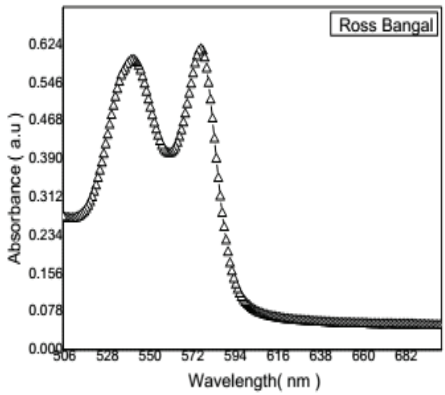

Fig. 12. Absorption for Ross Bangal

Similarly the wavelength of the peak value of absorption coefficient as shown in Fig.13. was approximately 572 nm.

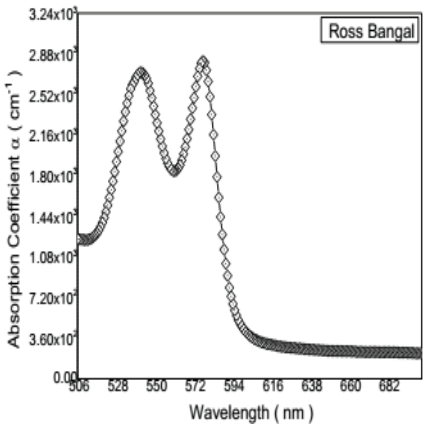

Fig. 13.Absorption Coeficient

The results of energy gap for Ross Bangal are shown in Fig.14. The maximum value of Eg obtained for Ross Bangal was 2.092 eV.

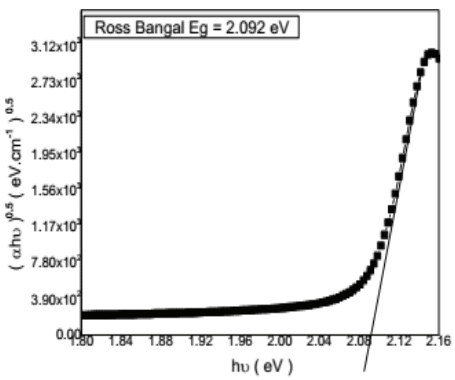

Fig. 14. Energy Gap

The obtained results of measuring the voltages and currents for Ross Bangal dye reported in Table V.

TABLE V
VOLTAGE AND CURRENT FOR BANGAL ROSS

Voltage (V)	Current (mA)
0	54.5
0.01	54.5
0.02	52.5
0.03	53.2
0.04	51.6
0.05	46.6
0.057	41
0.059	0

The results of the fill factor for ross bangal dye were measured using the UV and the results were shown in Fig.15. The results show that the maximum fill factor is 0.869 when the maximum voltage and current were 0.0588 V and 47.91 mA respectively.

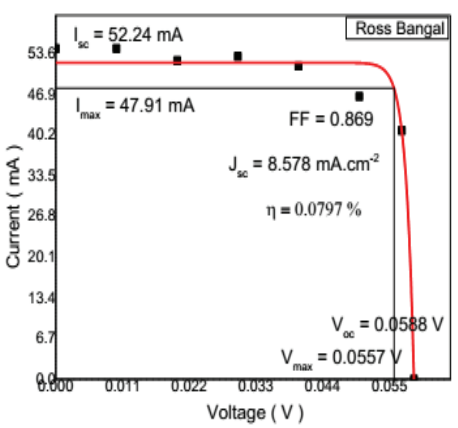

Fig .15. Fill factor of Ross Bangal

D. Performance Comparison

The overall results of each DSSC were summarized in Table.VI**.** This summary illustrates the measurement that has been taken from the solar cell of the each structure (Cumarin 500, Alcian Blue 8GX and Ross Bangal) Dyes.

The cell parameters obtained were I_{sc}, Voc, I_{max} and V_{max} for all samples. The parameters were used to calculate Power conversion Efficiency η for the fabricated Dyes – sensitized solar cells (Cumarin 500, Alcian Blue 8GX and Ross Bangal).

TABLE VI
SUMMARY OF PERFORMANCE

Dyes	*Eg (eV)*	*FF*	$J_{sc}\ (mAcm^{-2})$	$Voc(V)$	$\eta\%$
Alcian Blue 8GX	3.095	0.864	8.501	0.0589	0.0787
Cumarin 500	3.921	0.859	7.549	0.0589	0.0694
Ross Bangal	2.092	0.869	8.578	0.0588	0.0797

It was noted that the energy band gap effected on the efficiency of solar cells. While decreasing on the Eg leads to increase on the efficiency of the solar cell since the energy band gap decrease enables electrons having higher excitation energy to become free electron in a conduction band thus increasing the electric solar cell efficiency.

V. Conclusion

Dyes sensitized are the key in developing high performance and enhance the efficiency of solar cells. In this paper three samples of Dyes – sensitized solar cells of Cumarin 500, Alcian Blue 8gx and Ross Bangal dyes were used. Experiments described in the results section show that the efficiencies were 0.0694%, 0.0787% and 0.0797% respectively. This study revealed that there are many factors that influenced the performance and efficiency of a DSSC such as the chosen of the coloring of the Dyes sensitized used.

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