ORIGINAL PAPER

EFFECT OF DILUTE MIXING CONCENTRATIONS OF ORGANIC DYES IN INCREASING THE EFFICIENCY OF THE SOLAR CELL

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Abstract. *In this research the impact of concentration dilution for a mixture of two dyes (Erythrosine, Eosin y) on the efficiency of solar cell was investigated. This was conducted via the fabrication of transparent panels that are placed on solar cell surface. The latter panels were made of the above dyes mixture with epoxy resin with different concentration (variable dilution ratios). The results demonstrate that increasing concentration dilution would lead to increase the solar cell efficiency, Also, the open circuit voltage (V_{oc}), short circuit current (I_{sc}), Fill Factor (FF), fluorescence lifetime (t_f) radiation lifetime (t_{fm}), maximum voltage (v_{max}), maximum current (I_{max}) and solar cell efficiency was calculated.*

Keywords: *luminescent solar concentrator, dye, Erythrosine, Eosin y, solar cell.*

1. INTRODUCTION

The main source of most of the energies that is currently available in the ground is the sun, so we aim to exploit this energy and convert it in to other form of energies, such as electric power. Cleanest way to generating electricity which is considered to be environmentally friendly is the solar cell. It is a device that converts solar energy directly in to electrical energy [1]. This research aims at raise the efficiency of the solar cell using concentrators which are an optical element to increase the amount of radiation falling on the solar cell. Using the Luminescent Solar Concentrator (LSC) in concentration with solar cell in an option to make solar power most effective Duo to the concentrated sun light, the concentrator has several potential advantages, which include the possibility of lower cost and higher efficiency potential than one sun solar cell. Recently solar concentrators in space have received growing attention in view of reduced solar array cost [2]. Photovoltaic technology is improving rapidly [3-9] and methods of creating more efficient solar cells are being developed every year, but the industry is still being held back by cost [10].

The best way to reduce the costs of solar cell is simply to use less material by concentrating light on to a smaller area. The standard way of concentration involves using lenses or mirrors to refract or reflect light on to a smaller area [11]. A LSC is made up of luminescent dye in a transparent substrate with photovoltaic cells such as polymethyl methacrylate (PMMA) or polycarbonate, glass or even liquid solutions. Several matrix materials with similar refractive index can be used to markup the collector dividing the roles

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of light absorption and photon transport [3, 9, 12]. Light enters the face of the substrate, where it is absorbed by the dye. The dye reemits another photon at a longer wavelength, in the normal case of stokes fluorescence; the emitted wavelength will be shifted to a longer wavelength. If the probability of emission is equal in all direction part of the light will leave the transparent medium while another part will be reflected back because it intersects the surface at an angle leading to total internal reflection [13]. Luminescent dyes emit most of their light at longer wavelengths than they absorb, so the light that the solar cells absorb is closer to the peak of the responsively. This mean the solar cell absorb light more efficiently, and the LSC_s do not heat up the solar cell [14].

Stokes shift can be defined as the difference in wavelength or frequency units in the position of the large absorbance and emission spectra of the same electronic transitions. Stokes shift is the result of oscillatory relaxation or attenuation in the solvent rearrangement [15]. The ratio of the total amount of energy emitted to the total amount of energy absorbed called quantum efficiency (q_{FM}). It is also possible to calculate from the ratio between the area of the fluorescence spectrum and the area of the absorbance spectrum as shown in equation (1) [16].

$$q_{fm} = \frac{\int F(v^{-})dv^{-}}{\int \varepsilon\,(v^{-})dv^{-}} \tag{1}$$

Matlab program was used to calculate $Q_{FM.}$

2. EXPERIMENTAL PART

In the present paper we chose two organic dyes, Erythrosine, (called the second Red no 3) and Eosin y (called the second red acid as red 87) as illustrated in the Table 1.

Table 1. The properties of Erythrosine & Eosin y dyes. [10, 11]

Dye	Erythrosine	Eosin y
Molecular formula	$C_{20}H_6I_4Na_2O_5$	
λ_{max} of Absorbance [nm]	530	518
λ_{max} of fluorescence [nm]	572	544

It was used an organic solvent known as propanone, with a molecular formula C_3H_6O, to solve the two dyes. The letter solvent would not impact the amount of absorption of the two dyes since its absorption is almost negligible in the visible range taken as illustrated in Fig. 1.

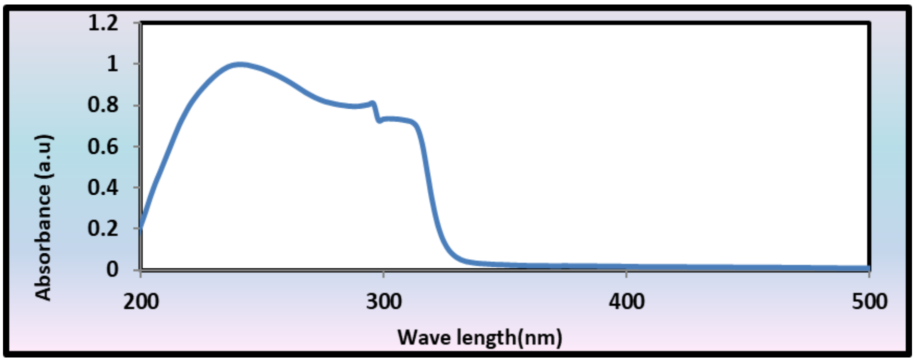

Figure 1. Absorbance as function of wavelength.

The polymer epoxy resin was used in the manufacture of panels which is consisting of two parts; one of them will be solidified after adding the second part (e.g. ratio 1:2). It should be noted that the epoxy resin is one of the materials that is suitable for the manufacturing of panels concentrators where its absorbance is existed in the ultraviolet verge, 288 nm and contributes to the reduction of heat and has high permeability, which is ranging from 87 to 98% in the visible spectrum.

2.1. ABSORBANCE AND FLUORESCENCE SPECTRUM OF MIXING DYES

The absorbance and fluorescence spectra was studied for five concentrations 4.9095×10^{-6}, 9.9826×10^{-6}, 2.4547×10^{-5}, 3.4912×10^{-5}, and 4.9913×10^{-5} mol/L as shown in Figs. 2, 3, 4, 5, and 6. In these figures it can be seen that the mixing dye has a large absorbance spectrum in 542 nm. At the lowest concentration (i.e. 4.9095×10^{-6} mol/L) the peak of absorbance spectrum was 542 nm, and at high concentration (i.e. 4.9913×10^{-5} mol/L) the peak of absorbance spectrum was 542 nm. Also, the fluorescence spectrum in the range of 568-572 nm at the lowest concentration (4.9095×10^{-6}) mol/L the peak of fluorescence spectrum was at 565 nm, and for a high concentration (i.e. 4.9913×10^{-5} mol/L) the peak of fluorescence spectrum was 571 nm. Thus, it can concluded that when the concentration increase, the absorbance increases hence it agree with Beer – Lambert Law**.**

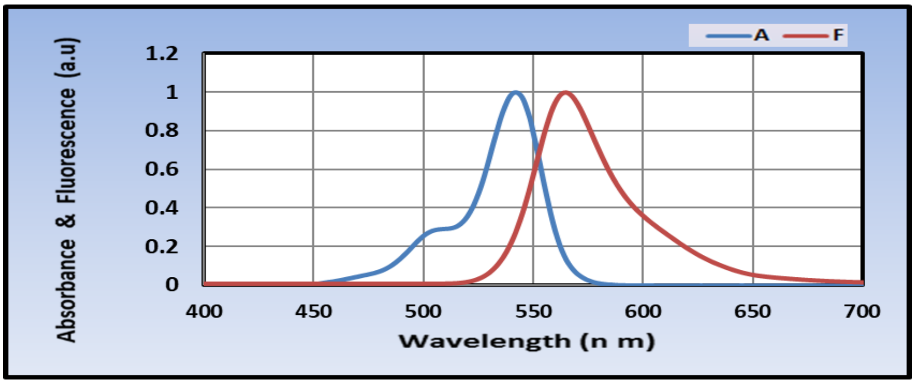

Figure 2. Absorbance and fluorescence spectra for mixing dyes of 4.9095×10^{-6} mol/L.

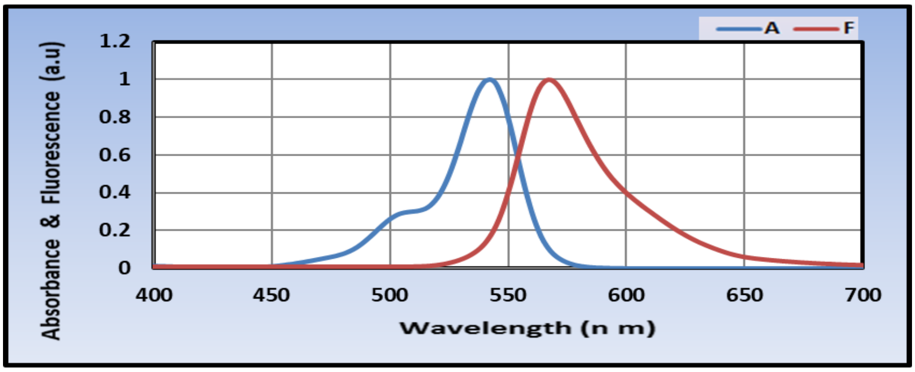

Figure 3. Absorbance and fluorescence spectra for mixing dyes of 9.9826×10^{-6} mol/L.

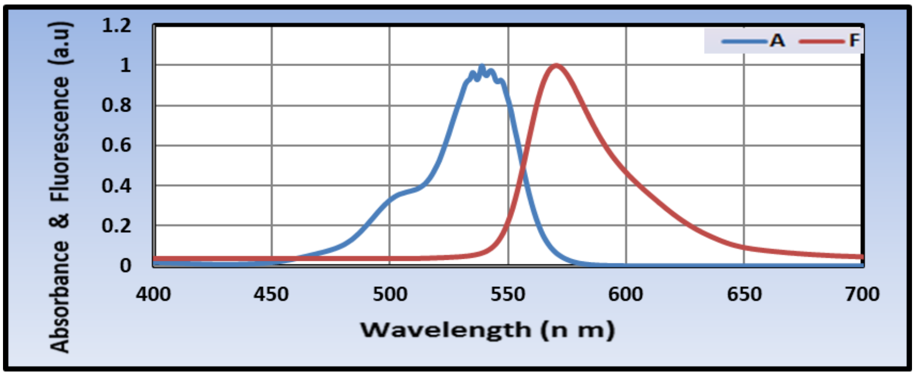

Figure 4. Absorbance and fluorescence spectra for mixing dyes of 2.4547×10^{-5} mol/L.

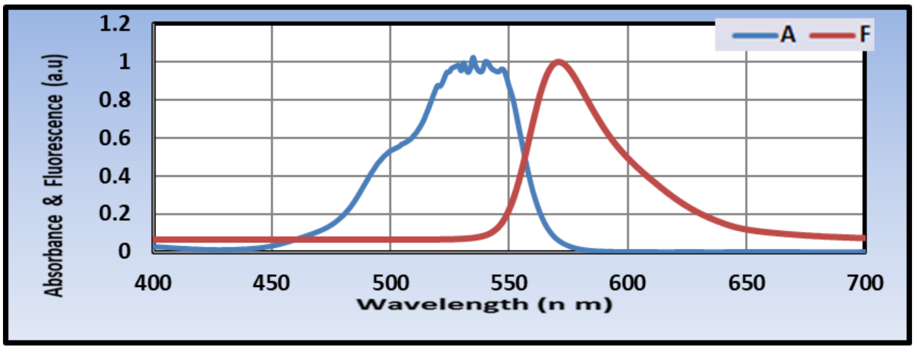

Figure 5. Absorbance and fluorescence spectra for mixing dyes of 3.4912×10^{-5} mol/L.

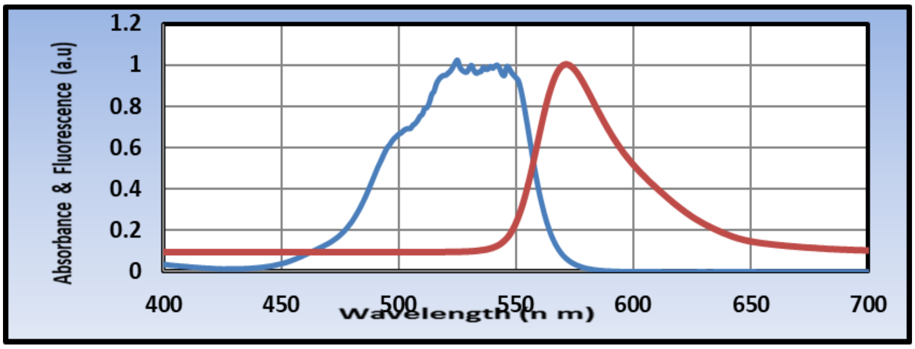

Figure 6. Absorbance and fluorescence spectra for mixing dyes of 4.9913×10^{-5} mol/L.

From the above figures the wavelengths for higher absorbance, as well as wavelengths for higher fluorescence, stokes shift, radiation lifetime, (tfm), fluoridation lifetime (tf), and quantum efficiency (Φfm) of mixing dye were calculated as shown in Table 2.

Table 2. The values of stocks shift, radiated lifetime, fluorescence lifetime and quantum efficiency of fluoresecence of mixing dyes at different concentration

Concentration [mol/L]	λ_A max [nm]	$\lambda_F$max [nm]	Stokes Shift $\Delta\lambda=\lambda_{flo}-\lambda_{abs}$	Radiated life time τ_{fm} [n sec]	Fluorescence life time τ_f [n sec]	Quantum efficiency, Φ_{fm} [%]
4.9095×10-6	542	565	23	3.959777	3.789506	95%
9.9826 ×10-6	542	567	25	7.662611	7.219712	94%
2.4547×10-5	539	570	31	16.60244	15.00694	90%
3.4912×10-5	541	571	30	17.69492	13.84628	78%
4.9913×10-5	542	571	29	22.32886	15.9763	71%

The quantum efficiency for mixing dyes in Table 2 is 95% for the concentration 4.9095×10^{-6} mol/L. It started to decrease to 71 % for the concentration 4.9913×10^{-5} mol/L due to the radiation/non-radiation processes.

Table 3. Maximum wavelength and fluorescence intensity for dilute concentrations.

Concentration [mol/L]	λ_F max [nm]	Fluorescence intensity
4.9095×10^{-6}	565	261
9.9826×10^{-6}	567	213
2.4547×10^{-5}	570	60.03
3.4912×10^{-5}	571	32.99
4.9913×10^{-5}	571	21.45

The Table 3 shows the highest fluorescence intensity at value 261 for a wavelength at 565 nm in 4.9095×10^{-6} mol/L concentration and the fluorescence starts to decrease when increasing the concentration until the fluorescence value become 21.45 at 571 nm wavelength, with a value of concentration at 4.9913×10^{-5} mol/L. This is due to the high concentration which leads to decreases the fluorescence. This aspect is due to inner filter effect which can be attributed to the non-fluorinated molecules in the solution, which will absorb the spectrum of fluorescence from the fluoridated particles, this process being called self-absorption [17].

2.2. SOLAR CELL EFFICIENCY MEASUREMENTS

In this part of the work the epoxy panels were made containing a mixture of two dyes with one thickness, (1mm), then these panels were placed above the solar cell to measure the efficiency of the solar cell and the table below shows the calculations before and after using the panel concentration.

Table 4. Improve efficiency solar cell by using (LSC) of mixing dyes

Concentration [mol/L]	FF	V_{open}	I_{short}	V_{max} [volt]	I_{max} [mA]		$\Delta\eta$ %
Pure Cell	0.857	4.905	63.50	4.359	61.30	8.906	
4.9095×10^{-6}	0.837	4.832	77.50	4.106	76.39	10.45	0.17336
2.4547×10^{-5}	0.871	4.822	73.40	4.230	72.89	10.27	0.1531
3.4912×10^{-5}	0.845	4.730	76.20	4.196	72.60	10.15	0.1396

In Table 4 it was calculated the maximum value of current (I_{max}), Short-Circuit Current, (I_{SC}), maximum value of voltages (V_{max}), Open Circuit Voltage (V_{OC}), Fill Factor (FF), the efficiency of solar cells (η) and increment in the efficiency of solar cells($\Delta\eta$) % of the mixing dyes panels. The highest efficiency recorded was 0.1733 for the high diluted concentration (i.e. 4.9095×10^{-6} mol/L). It should be noted that when the dye concentration has increased, width of fluorescence and emission spectrum becomes narrower. This can be explained by that increasing the number of molecules of the dyes would result in preventing excited photon from being penetrated deeply which would reduce the amount of interactions with molecules [16-19].

3. CONCLUSIONS

1. High diluted concentrations are preferable to use in increase the efficiency of the solar cell.
2. Luminescent Solar Concentrators (LSC) for mixing two dyes panels succeeded in increase the efficiency of the solar cell.
3. The Acetone succeeded to solve the two dyes.
4. The increase in the value of quantum efficiency (Φ_{fm}) with the decrease in concentration also increases radiative lifetime (τ_{FM}) and fluorescence life time (τ_F) where $\tau_{FM} > \tau_F$ for all samples.

REFERENCES

[1] Ellabban, O., Abu-Rub, H., Blaabjerg, F., *Renewable and Sustainable Energy Reviews*, **39**, 748, 2014.
[2] Jeong, D.G., Song, D.S., Lee, Y.H., *Output Current-Voltage Characteristic of a Solar Concentrator.* In Communication and Networking (pp. 223-226), Springer, Berlin, Heidelberg, 2010.
[3] Lungu, J., Oprea, C.I., Dumbrava, A., Enache, I., Georgescu, A., Radulescu, C, Ionita, I., Cimpoca, G.V., Gartu, M.A., *Journal of Optoelectronics and Advanced Materials*, **12**(9), 1969, 2010.
[4] Radulescu, C, Hossu, A.M., Ionita, I., *Dyes and Pigments*, **71**(2), 123, 2006.
[5] Radulescu, C, Tarabasanu-Mihaila, C., *Revista de Chimie*, **57**(10), 1034, 2006.
[6] Radulescu, C, Hossu, A.M., *Revista de Chimie*, **56**(7), 742, 2005.
[7] Radulescu, C, Tarabasanu-Mihaila, C., Hossu, A.M., Ionita, I., *Revista de Chimie*, **55**(12), 1006, 2004.
[8] Radulescu, C, Tarabasanu-Mihaila, C., *Revista de Chimie*, **55**(1), 25, 2004.
[9] Radulescu, C., *Revista de Chimie*, **56**(2), 151, 2005.
[10] Olson, J.D., *Novel photovoltaics: An introduction to basic characterization*, University of California, Santa Cruz, 2009.
[11] Green, M.A., *Progress in Photovoltaics: Research and Applications*, **11**(5), 333, 2003.
[12] Kittidachachan, P., Danos, L., Meyer, T.J., Alderman, N., Markvart, T., *CHIMIA International Journal for Chemistry*, **61**(12), 780, 2007.
[13] Goetzberger, A., *Fluorescent solar energy concentrators: Principle and present state of development.* In High-Efficient Low-Cost Photovoltaics (pp. 159-176), Springer, Berlin, Heidelberg, 2009.
[14] Mansour, A.F., Killa, H.M.A., El-Wanees, S.A., El-Sayed, M.Y., *Polymer Testing*, **24**(4), 519, 2005.
[15] Albani, J.R., *Structure and dynamics of macromolecules: absorption and fluorescence studies*, Elsevier, 2011.
[16] Speiser, S., *Chemical Reviews*, **96**(6), 1953, 1996.
[17] Fukuda, M., Mito, K., *Japanese Journal of Applied Physics*, **39**(10R), 5859, 2000.
[18] Lyday, P.A., *Iodine and iodine compounds*, Ullmann's Encyclopedia of Industrial Chemistry, 2005.
[19] Pecoraro, E., García-Revilla, S., Ferreira, R.A., Balda, R., Carlos, L.D., Fernández, J., *Optics express*, **18**(7), 7470, 2010.