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Luminescent Concentrators Based on Organic Dyes for Improving Solar Cell Efficiency

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Abstract— Erythrosine dye is fluorine organic and sensitive to light, so it is used to fabricate (LSC) thick layer from epoxy risen additive by the Erythrosine dye. The efficiency of silicon solar cell was measured before and after using the (LSC), the increment of efficiency occurred from (9.03) to (11.19). Also, the (absorption & fluorescence) stokes shift, radiated lifetime, fluorescence lifetime, and quantum efficiency was calculated.

Index Terms—Conversion efficiency Solar cell, Dye concentrator, Organic Dyes.

1 Introduction

THE sun is the principal source of energy on earth. So the current studies are on using this energy and converting it to other forms of energy like the electric energy. It is considered. One of the purest means used to generate electricity is the solar cell. It is considered eco-friendly. The solar cell is a device that directly converts the solar cell into electricity. The current study aims at improving the efficiency Solar cell using concentrators which are optical parts that increase the radioactivity on the solar cell. The concentrators used here are based on organic dyes. They are simply made, inexpensive, and used in all types solar cell [1]

Organic pigments are considered organic chemical substances that have the ability to absorb and converse wavelengths of light transition in the visible electromagnetic spectrum, and often these dyes in the form of powder would need to be fluid to melt it and become a solution [2].

The organic pigment source is from either plants or animals or metallic materials. These must be plenty and cheap, and most of them have high fluoridation. Therefore, in this research, we used organic pigments instead of inorganic pigments that are expensive and unavailable, and most of them are low-lying with fluoridation [3].

The objection of this work was to increase the efficiency of solar cells by using luminescence solar concentrators panels of organic dyes, determination of the best concentration and thickness for (LSC) panels.

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2 Experimental Erythrosine dye

This dye used in this research was of analytical grade. Also known as Red No. 3 is an organ iodine compound, specifically a derivative of fluorine. It is cherry-pink synthetic, printing ink, biological stain[4] primarily used for food coloring.[5] It is maximum absorbance is at 530 nm in an aqueous solution.

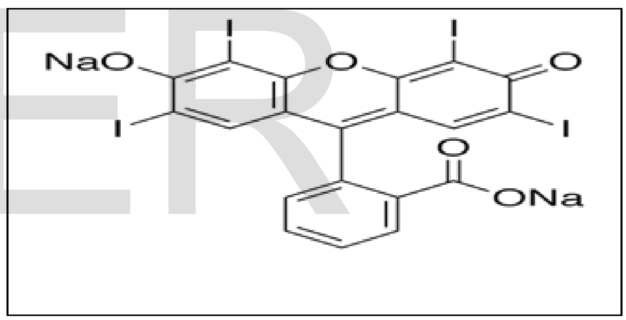

Fig. 1. The structure of Erthrosine dye [6]

TABLE 1

The properties of Erthrosine dye [7]

Properties	
Mulcarole formula	C20H6I4Na2O5
Molar mass	879.86 g/mol
Form	Powder
Melting point	142 to 144 °C
Fluorescence	λ_{max} 527
Absorption	λ_{max} 530 nm

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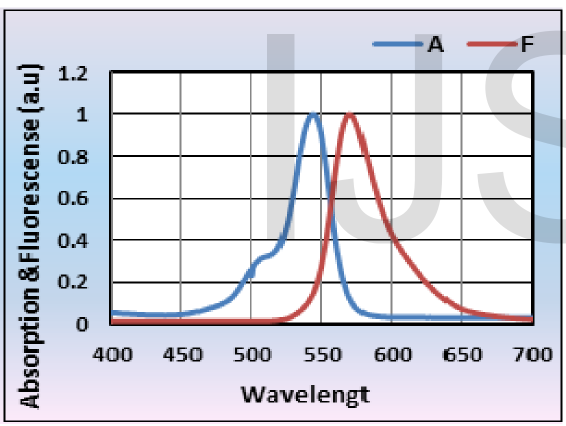
3 The Absorption and Fluorescence Spectrum of Erthrosine in Aceton

The Absorption and fluorescence spectra have been studied for four concentrations (1×10^{-5}, 2×10^{-5}, 5×10^{-5}, 1×10^{-4}) mol/L as shown in figure (2) from these figures the Erthrosine dye has large absorption spectrum(from 547 to 531) nm .At the lowest concentration (1×10^{-5}) mol/L the peak of absorption spectrum was at (547)nm and at the high concentration (1×10^{-4}) mol/L the peak of the absorption spectrum at (531)nm. Also the fluorescence spectrum from (568-527)nm. While at the lowest concentration (1×10^{-5})mol/L the peak of fluorescence spectra was at (568) nm and for a high concentration (1×10^{-4}) mol/L the peak of fluorescence spectrum at (527) nm. Erthrosine dye has a high fluorescence and sorption and it has big disunion between fluorescence and absorption curves.



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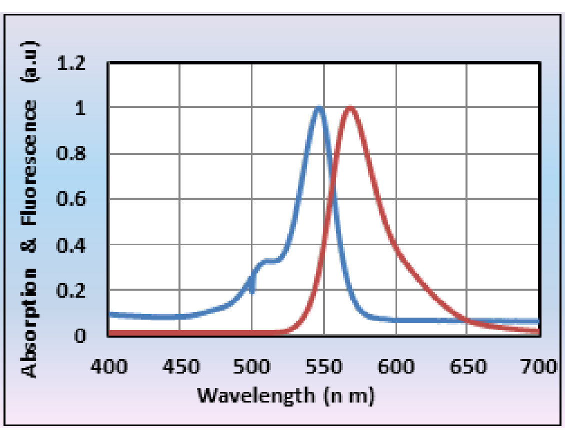

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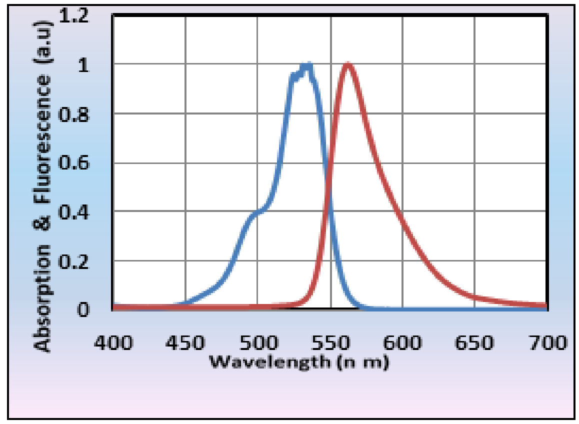

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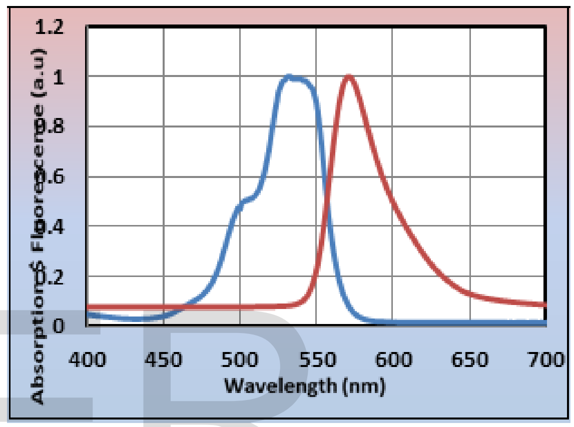

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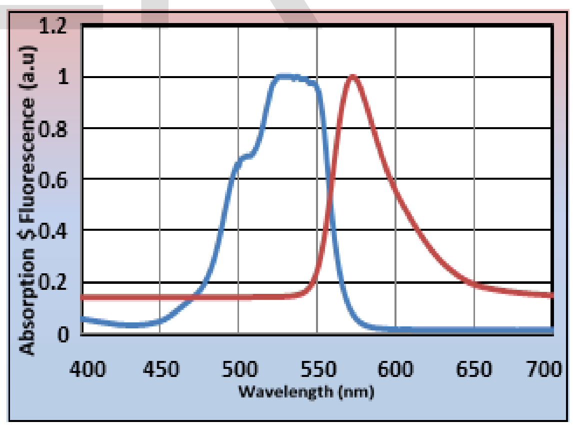
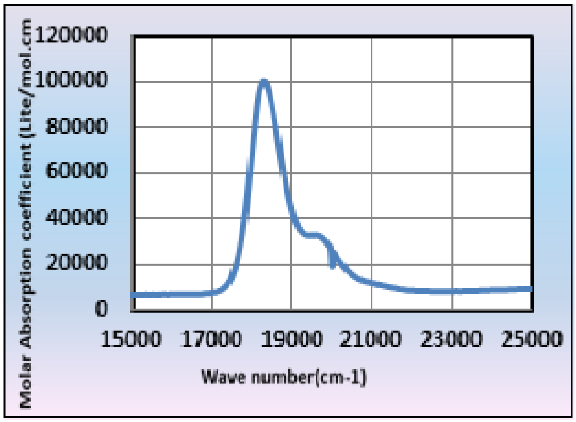


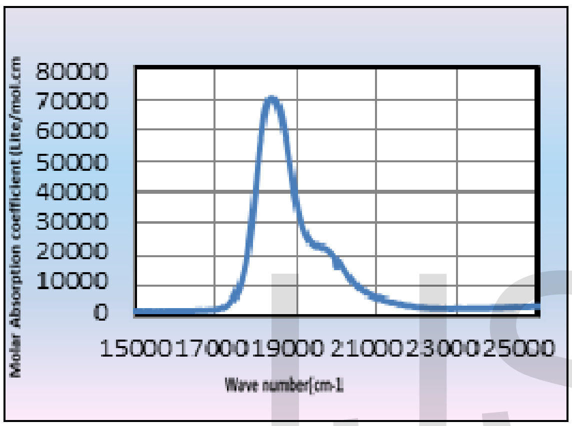
(e)

Fig. 2. Spectra of absorption and fluorescence of Erthrosine at different concentration (a)1×10-5,(b)2×10-5,(c)5×10-5(d)7×10-5 (e) 1×10-5 mol/L.

The relationship between Molar absorption coefficient ($L/mol^{-1}.cm^{-1}$) and wave number (cm^{-1}) has been illustrated also, in figure (3), these are to calculate the area under the curve as well as nonradiative life time (τ_{fm}) and fluorescence life time(τ_f) .



(a)



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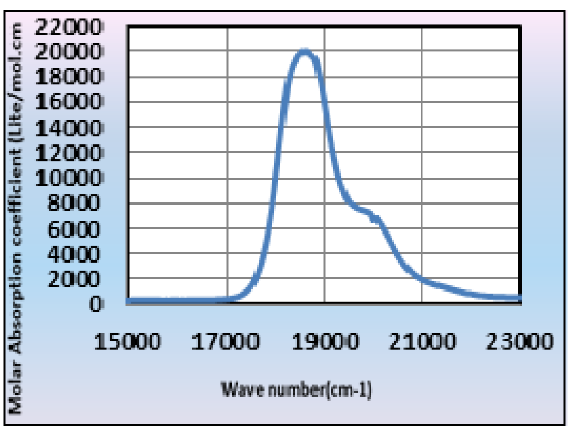

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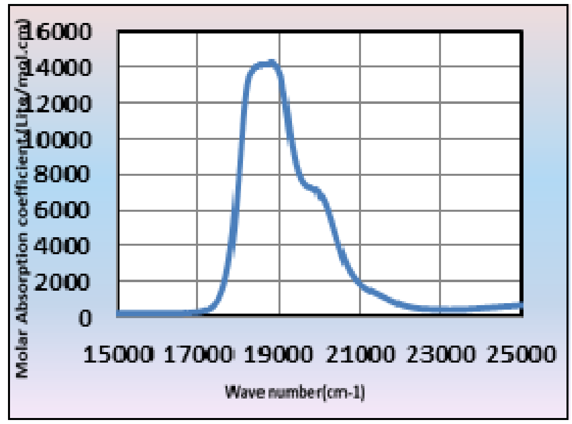

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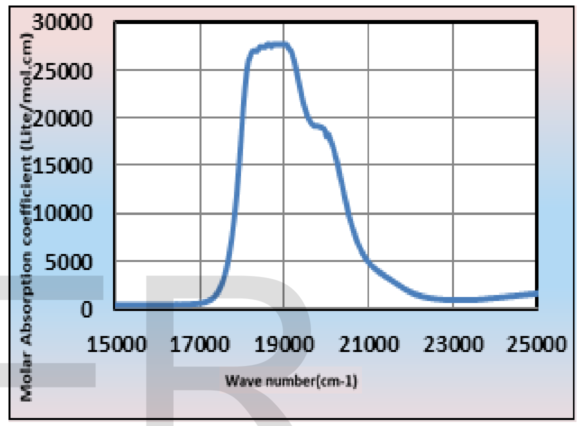

(e)

Fig. 3. Spectra of molar coefficient (L/mol.cm) versus Wave number (cm-1) Erthrosine at different concentration (a)1×10-5,(b)2×10-5,(c)5×10-5(d)7×10-5 (e) 1×10-5 mol/L

The values of the stock shift between absorption and fluorescence spectra are given in table (2), were calculated by taking the different between maximum fluorescence and absorption which are measures by UV-Visible spectrophotometer, and the values quantum efficiency measures by an equation:

Q_{fm}=∫F (v-) dv-)/ (∫ε (v-) dv-) ……………….(1) [8]

Where; $\int F(\bar{v})d\bar{v}$: is the total area under the curve of the fluorescence and $\int \varepsilon(\bar{v})d\bar{v}$: is the area under the curve of the molar absorption coefficient which is a function of the wave number ($\bar{v}$) also, the radiative lifetime is calculated according to the equation as follows:

$\tau_{fm} = 1/K_{fm}$ ………………………..………..(2) [8]

Where:

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τ_{fm} : is the radiative lifetime and its unit (s)

K_{fm} : is the rate of disappearance of the unit (s^{-1}).

$\tau_f = Q_{fm} \times \tau_{fm}$ ....(3) [8]

where:

τ_f : is fluorescence lifetime and its unit (s)

TABLE 2

THE VALUES OF STOCKS SHIFT, RADIATED LIFETIME, FLUORESCENCE LIFETIME AND QUANTUM EFFECT OF FLUORESCENCEOF ERTHROSINE AT DIFFERENT CONCENTRATION.

Concentration mol/L	A_{max}	F_{max}	Stokes Shift ? $\lambda=\lambda_{flo}-\lambda_{abs}$	The radiated Life time τ_{fm} (ns)	The fluorescence Life time τ_f (ns)	The quantum efficiency% Φfm
1×10^{-5}	547	568	21	3.751669	3.676636	98%
2×10^{-5}	544	570	26	8.05	7.76E+00	96%
5×10^{-5}	536	570	34	16.215	14.9178	92%
7×10^{-5}	532	571	39	18.4312	16.2184	88%
1×10^{-4}	531	572	41	21.3	16.827	79%

In the table (2) general for all the quantum efficiencies are mostly less than unity (<100%) that dependent on the radiative and non-radiative processes, where as a radiative process overcome on a non-radiative process, the quantum efficiency will be near of unity. For our samples, at low concentrations the fluorescence quantum efficiency increases. As the the quantum efficiency of Erthrosine dye has become 98% for concentrate $1\times10^{\wedge}-5$ after that less and less until it became about 79% for concentrate $1\times10^{\wedge}-4$ as it noted in the previous table (2).

Upper limits of cell parameters

Short-Circuit Current, Isc

Open circuit voltage (Voc)

Fil factor (FF) [9]

(LSC) panels of Erthrosine dye

We proper (LSC) panels by using Epoxy resin doping with dye solution in acetone and the dimension of this panels is corresponding with the dimension of silicon solar cell. When the Luminescent Solar Concentrator(LSC) panels of Erthrosine dye putting on the solar cell, the module analyzer appearance measures the efficiency (η), fill factor (FF) and current – voltage relationship curves. The values of these are shown in the table (3), as follows with increasing efficiency ratio.

TABLE 3

EFFICIENCY OF THE SOLAR CELL USING (LSC) PANELS OF ERTHROSINE DYE AT DIFFERENT CONCENTRATION

SAMPLES	Concentration (Mol/L)	Thickness (mm)	Imax mA	Vmax volt	FF	η%	Δ η%
(LSC) panel Erythrosine dye	1×10-5	0.5	80.30	4.122	0.783	11.03	0.224
		1	79.80	4.210	0.866	11.19	0.243
	2×10-5	0.5	80.60	4.032	0.758	10.83	0.203
		1	80.20	4.108	0.841	10.98	0.22
	5×10-5	0.5	72.50	4.452	0.88	10.75	0.194
		1	74.10	4.333	0.774	10.84	0.204

From table(3) we observed that the maximum increase in efficiency is ($\Delta\eta = 0.24\%$) for the concentration (1×10^{-5}) mol/L and the thickness (1mm),the minimum ($\Delta\eta = 0.194$) for the concentration (5×10^{-5})mol/L and the thickness (0.5) mm. Figures(4,5 and 6) shows of the current – Voltage curves for the solar cell by using (LSC) panels for Erthrosine dye. Through our findings in this study, we noted the extent of convergence or agreement with the rest of the previous studies in terms of results (12).

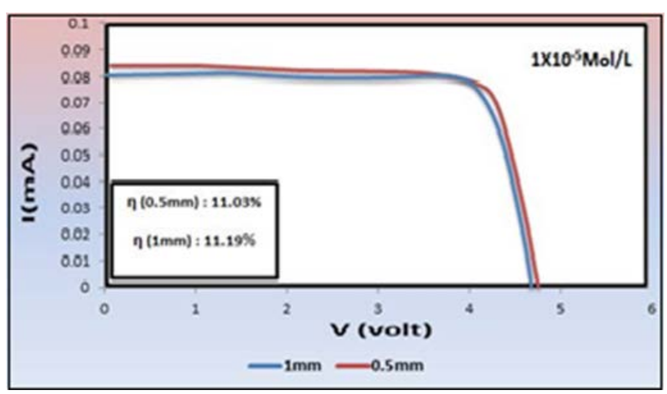

Fig. 4. current – voltage curve of the solar cell using Erthrosine dye(1×10^{-5}) mol/L of (1,0.5)mm thickness.

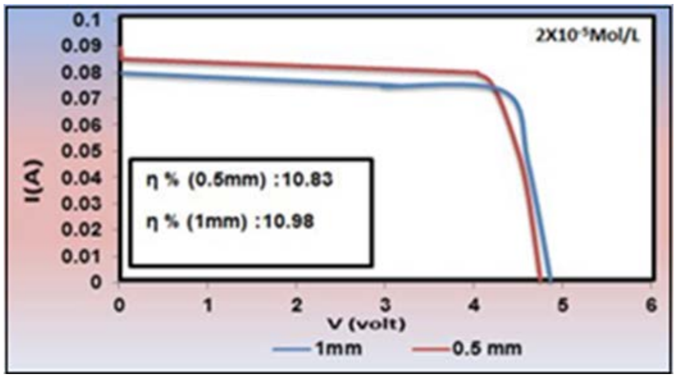

Fig.5. Current -Voltage curve of solar cell using Erthrosine dye(2×10-5)mol/L of thickness(1,0.5)mm.

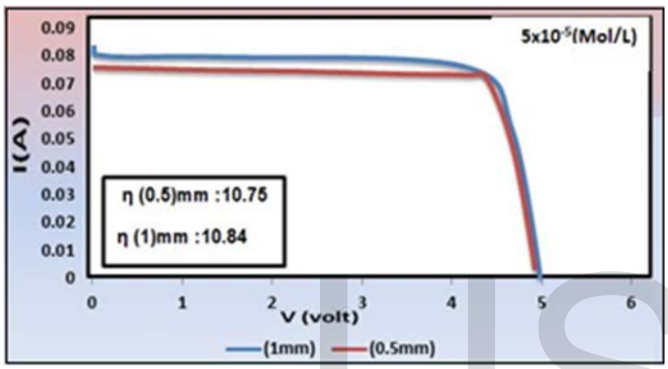

Fig. 6. Current-Voltage curve of solar cell using Erthrosine dye (5×10-5) mol/L of(1,0.5)mm thickness

The efficiency of solar cell records increases with low concentrations. This is because in low concentrations a reduce of the number of collisions between molecules, while for the increase of concentration cause of increase the number of molecules. This leads to increase the like hood of collisions between molecules. Thus, they lose energy non-radioactively as heat causes a loss in the fluorescence process.

Increase thickness, this will increase efficiency solar cell because more thickness leads to increase the number of dye molecules in the plate thus increase of fluorescence intensity.

In increasing values in the conversion efficiency (Δη %) is shown in tables (3) of Erthosine.

4 Conclusion

All (LSC) panels for (Erthrosine,) dye succeeded to increase the efficiency of the solar cell, of certain degrees and depend on concentration and thickness as well as an effect of panels. Erthrosine dye with concentration(1x10-5) mol/L, gave the highest quantum efficiency (98%), and it has a large extent of absorption and high fluorescence. Low concentrations are preferable to use in improving the efficiency of the solar cell.

The increase in the concentration of all samples used in the research leads to shifting peaks of the absorption and fluorescence spectra to long wavelengths, within ranges have been studied (300-700 nm).

The increase in the value of quantum efficiency (qFM) with the decrease in concentration also increases Radiative life time (τFM) and fluorescence life time (τF) where τFM >τF for all samples.

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