Improving solar cell energy conversion efficiency by using illuminous dyes concentrators

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Abstract

AuramineO is fluorinated organic and sensitive for light, has been chosen in this work dissolved in ethanol liquid. The ethanol did not effect on AuramineO absorption because the absorption of ethanol drop and approaches to zero in the visible spectrum region. After studying the spectroscopic properties of AuramineO dye, it showed that it has wide range of absorption spectra and high fluorsensation. So the relative intensity of both absorption and fluorescence spectra were increased by increasing concentration to a certain extent and thus compatible with Beer-Lambert law. Accordingly we could determine the highest absorption and fluorescence of each concentration and calculated molar absorption coefficients, quantum efficiency, radiated lifetime, fluorescence lifetime and stokes shift. These panels of AuramineO dye were used as concentrators for solar cell and all their panels are infallible improving and raises the efficiency of solar cell at ratio spotty. Measures of the thickness for the panels showed they effect on the efficiency solar cell that the thickness of panels if increase the solar cell efficiency decrease, therefore it is preferred using little thickness.

Keyword: Solar cell, Dye concentrator, Conversion efficiency.

تحسين كفاءة تحويل الطاقة للخلايا الشمسية باستخدام مركبات الأصباغ الأيضانية

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الخلاصة

الأورامين (O) هي صبغة عضوية متظورة وحساسة للضوء تم اختيارها في عملنا وأداتها في كحول الأيثانول. إن سائل الأيثانول لم يؤثر على امتصاصية الصبغة لأن امتصاصية الأيثانول تتبجي وتقترب من الصفر في منطقة الطيف المرئي. بعد دراسة الخصائص الطيفية للصبغة تبين انة طيف امتصاص واسع المدى وفوق درجة عالية من الشدة النسبية لطيفية الامتصاص والفلورة يزداد مع زيادة التركيز لحد معين وهذا يتفق مع قانون بيرلايمبرت، وفطنذلك تم تحديد اعلى امتصاصية وفوقرة لكل تركيز مستخدم لصبغة الأورامين وكذلك حسب معدل الامتصاص المولاري والكفاءة الكمية و زمن الإشعاعي و زمن عمر الفلوورة و ازاحة ستوكس. إن الولوا صبغة الأورامين استخدمت كمركزات للخلايا الشمسية، وكل هذه الالوا حسنت في تحسين ورفع كفاءة الخلايا الشمسية وبنسب متتفاوتة أما قياسات السمك للالوا جل ظهرت تأثيرها على كفاءة الخلايا الشمسية ذلك كان سمك الالوا إذا زاد كفاءة الخلايا الشمسية تقل لذا يفضل استخدام السمك القليل.

كلمات مفتاحية: خلايا الشمسية، مركبات الأصباغ، كفاءة تحويل.
1- Introduction:
Solar energy is the most available renewable energy on Earth and it is becoming more widely used to generate electrical power all around the world due to its environmental, economical and strategic benefits. Photovoltaics (PV) is the main technologies used to convert solar energy into electricity. Most of solar energy studies aim to increase the conversion efficiency of solar cell by using the luminescent concentrators of panels or films of the epoxy which are created from organic dye materials.\(^{(1)}\)

Luminescent solar concentrators: are interesting devices for use in combination with photovoltaic (PV) cells. A luminescent solar concentrator (LSC) is a glass or plastic plate containing or coated with luminescent materials phosphors or dyes that absorb sunlight and emit light at longer wavelengths.\(^{(2)}\)

Organic dyes pigments are organic chemicals capable of absorbing and reverse light wavelengths transition within the visible spectrum of the electromagnetic spectrum, and often these dyes in the form of powder would need to be fluid in order to melt it and become a solution. The source of organic pigments from either plants or animals or metallic materials. These must be abundant and inexpensive, and most have high fluoridation. For these reasons we used in our research organic pigments instead of inorganic pigments that are expensive and do not exist in abundance, and most of them are low-lying with fluoridation\(^{(4)}\). In this present work was Auramine O dye were used and it has a large overlap between absorption and emission spectra. It is used in LSC as Luminescent materials.

2- Aim of the work:
1) To improve the performance efficiency of solar cells by using luminescence solar concentrators panels of organic dyes, to get a high efficiency of solar cell.

2) Determining of the best concentration and thickness for (LSC) panels.

2) Auramine (O) dye:
Auramine O is a diaeaylmethane dye used as a fluorescent stain. In its pure form, Auramine O appears as yellow needle crystals. It is very soluble in water and soluble in ethanol and can be used to stain acid – fast bacteria. Also it can be used as an antiseptic agent\(^{(5)}\). Only AuramineO displays an amplification of the fluorescence signal with increasing concentration, while the fluorescence of the other dyes is quenched by interaction with the polymer – stabilized metal nanoparticles\(^{(6)}\). AuramineO is strong brilliant yellow dyes stuff, deconlourizes immediately on contact with strong alkali\(^{(7)}\).

Figure below is shows the structure of AuramineO dye.
Figure(2) The structure of AuramineO dye

Table(1) The properties of AuramineO dye

<table>
<thead>
<tr>
<th>Properties</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mulcarole formula</td>
<td>$C_{17}H_{22}ClN_3$</td>
</tr>
<tr>
<td>Molar mass</td>
<td>303.83 gm/mol</td>
</tr>
<tr>
<td>Form</td>
<td>Powder</td>
</tr>
<tr>
<td>Melting point</td>
<td>267 °C</td>
</tr>
<tr>
<td>Fluorescence</td>
<td>$\lambda_{max}$ 542 nm</td>
</tr>
<tr>
<td>Absorption</td>
<td>$\lambda_{max}$ 370 nm</td>
</tr>
<tr>
<td>Composition</td>
<td>Dye content 85%</td>
</tr>
</tbody>
</table>

2) The Absorption and fluorescence spectrum of AuramineO in Ethanol:
The absorption and fluorescence spectra has been studied for four concentrations $(1 \times 10^{-5}, 3 \times 10^{-5}, 5 \times 10^{-5}, 3 \times 10^{-4})$ mol/L as shown in figures (3),(4),(5),(6) from these figures the Auramine O dye has large absorption spectrum from (430-470)nm. At the lowest concentration $(1 \times 10^{-5})$ mol/L the peak of absorption spectrum was at (434)nm, and at the high concentration $(3 \times 10^{-4})$ mol/L the peak of the absorption spectrum at (466)nm. Also the fluorescence spectrum from (535-545)nm. While at the lowest concentration $(1 \times 10^{-5})$ mol/L the peak of fluorescence spectra was at (542)nm and for a high concentration $(3 \times 10^{-4})$ mol/L the peak of fluorescence spectrum at (540)nm. AuramineO dye has a high fluorescence and absorption and it has big disunion between fluorescence and absorption curves.
The relationship between Molar absorption coefficient \( (L/mol^{-1}.cm^{-1}) \) and wave number \( (cm^{-1}) \) has been illustrated also, in figure (7), these are to calculate the area under the curve as well as non radiative life time \( (\tau_{fr}) \) and fluorescence life time \( (\tau_f) \).
Figure (7) Spectrum of Molar coefficient (L/mol.cm) and Wave number(cm⁻¹) of AuramineO for (a) 1×10⁻⁵, (b) 3×10⁻⁵, (c) 5×10⁻⁵, (d) 3×10⁻⁴ mol/L.

And the radiative lifetime is calculated by the equation as follows:

\[ \tau_f = \frac{1}{K_f} \quad \ldots \quad \ldots \quad \ldots \quad (2) \]

\( \tau_f \): the radiative lifetime and its unit (s)

\( K_f \): the rate of disappearance of the fluorescence lifetime and its unit (s⁻¹).

\[ \tau_f = Q_{fm} \times \tau_f \quad \ldots \quad \ldots \quad \ldots \quad (3) \]

\( \tau_f \): fluorescence lifetime and its unit (s)

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

\[ Q_{fm} = \frac{\int F(v^-) dv^-}{\int \varepsilon (v^-) dv^-} \quad \ldots \quad \ldots \quad \ldots \quad (1) \]

\[ \int F(v^-) dv^- \quad \text{The total area under the curve of the fluorescence} \]

\[ \int \varepsilon (v^-) dv^- \quad \text{The area under the curve of the molar absorption coefficient which is a function for the wave number (v^-)} \]
Table (2) the stock shift between the Abs. and fluor. Spectra, the radiated lifetime, fluorescence lifetime and quantum efficiency of fluorescence for AuramineO.

<table>
<thead>
<tr>
<th>Concentration Mol/L</th>
<th>$A_{max}$ nm</th>
<th>$F_{max}$ nm</th>
<th>$\Delta\lambda$=2flo-2abo</th>
<th>$\tau_{fm}$ n sec</th>
<th>$\tau_f$ n sec</th>
<th>$Q_{fm}$ %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1×10^{-5}</td>
<td>434</td>
<td>542</td>
<td>108</td>
<td>1.1E+06</td>
<td>9.1E+07</td>
<td>0.83</td>
</tr>
<tr>
<td>3×10^{-5}</td>
<td>436</td>
<td>540</td>
<td>104</td>
<td>3.2E+02</td>
<td>3.2E+02</td>
<td>0.99</td>
</tr>
<tr>
<td>5×10^{-5}</td>
<td>438</td>
<td>542</td>
<td>104</td>
<td>5.1E+02</td>
<td>4.8E+02</td>
<td>0.94</td>
</tr>
<tr>
<td>3×10^{-4}</td>
<td>466</td>
<td>540</td>
<td>74</td>
<td>2.9E+01</td>
<td>2.2E+01</td>
<td>0.93</td>
</tr>
</tbody>
</table>

4- (LSC) panels of Auramine O dye:
When the Luminescent Solar Concentrator panels of Auramine O dye putting on the solar cell, the module analyzer appearance measures the efficiency ($\eta$), fill factor (FF) and current – voltage relationship curves. The values of these are shown in table (3), as follows with increasing efficiency ratio.

Table (3) efficiency solar cell using (LSC) panels of AuramineO dye

<table>
<thead>
<tr>
<th>Samples</th>
<th>concentration mol/L</th>
<th>$I_{max}$ (mA)</th>
<th>$V_{max}$ (volt)</th>
<th>FF</th>
<th>Thickness (mm)</th>
<th>$\eta$ %</th>
<th>$\Delta\eta$ %</th>
</tr>
</thead>
<tbody>
<tr>
<td>(LSC) pnels</td>
<td>1 $\times$ 10^{-5}</td>
<td>62.10</td>
<td>3.916</td>
<td>0.751</td>
<td>0.21</td>
<td>8.843</td>
<td>0.503</td>
</tr>
<tr>
<td>AuramineO dye</td>
<td>2 $\times$ 10^{-5}</td>
<td>55.60</td>
<td>3.989</td>
<td>0.87</td>
<td>0.32</td>
<td>8.065</td>
<td>0.371</td>
</tr>
<tr>
<td></td>
<td>3 $\times$ 10^{-5}</td>
<td>52.90</td>
<td>4.020</td>
<td>0.841</td>
<td>0.38</td>
<td>7.733</td>
<td>0.314</td>
</tr>
</tbody>
</table>

From table (3) we observed that the maximum increase in efficiency is ($\Delta\eta$ = 0.503%) for the concentration (1 $\times$ 10^{-5}) mol/L and the thickness (0.21) mm, the minimum ($\Delta\eta$ = 0.314) for the concentration (3 $\times$ 10^{-5}) mol/L and the thickness (0.38) mm.

Figures (9, 10 and 11) show the current – Voltage curves for solar cell by using (LSC) panels for AuramineO dye.
Figure (9) current – voltage curve solar cell using Auramine O dye ($1 \times 10^{-5}$) mol/L of (0.21)mm thickness.

Figure (10) Current - Voltage curve solar cell using Auramine O dye ($3 \times 10^{-5}$) mol/L of thickness (0.38) mm.

Figure (11) Current-Voltage curve solar cell using Auramine O dye ($2 \times 10^{-5}$) mol/L of (0.32) mm thickness.

Table (2), it shows dislodgment in Stokes shift, highest efficiency accrued at concentration ($3 \times 10^{-5}$) mol/L while it decreases when the concentration increases, and the results were not true at high concentration because Beer-
Lambert law doesn't work at these concentrations. Current-Voltage curves of the AuramineO dye which used as concentrator panels concentrations shows that the increasing of the concentration led to increase the circuit current at the same values of the voltage. The overlapping between the absorption and fluorescence spectra of AuramineO dye in table(2) decreased while we notice the values of the stock shift increase this in agreement with Beer-Lambert law.

5-Conclusion:
AuramineO dye with concentration \((3 \times 10^{-5})\) mol/L, gave the highest quantum efficiency (0.99%), and it has a large extent for absorption and a high fluorescence. All (LSC) panels for AuramineO infallible to raise the efficiency of the solar cell of certain degrees and depend on concentration and for thickness also affect the panels. The AuramineO dye when increased the concentration, radiated lifetime and fluorescence lifetime decreased. Best results were obtained for Luminescent Solar Concentrator panels with AuramineO dye of \((1 \times 10^{-5})\)mol/L and thickness (0.21)mm at which the efficiency reached \((\eta = 8.84\%)\) and the ratio of increase in efficiency was \((\Delta \eta = 0.503\%)\).

References:
1- Bojana Vasic, M.Sc. (the solar cell efficiency improvement with the organic concentrator), Universitat politecnical decatalunya, spain, 2011.
6- مطراق و تقنيات حديثة في التحليل الكيميائي الآلي ، الدكتور جميل ضياء , الجامعة المستنصرية / كلية العلوم ، 2013.