Spectroscopic properties of different concentration xanthene›s dye mixture (6G, 3GO, B and C) solution in chloroform

*** Ali H. Al-Hamdani, ** Slafa I. Ibrahim and *** Hussein Ali Hadi Al-Hamdani**
*** Laser and Optoelectronics Engineering Department, University of Technology, Iraq**
**** Energy and Fuel Research Center, University of Technology, Iraq.**
***** Electrical and Electronic Engineering Department, College of Engineering, University of Kerbala, Iraq**
Received Date: 13/Jul/2015
Accepted Date: 20/Jul/2015

الخلاصة

تم في هذا البحث دراسة طيف الامتصاص والفلورة ضمن المدى (700 – 400) نانومتر لمزيج من (رودامين 6G، رودامين 3GO، رودامين B، رودامين C) والتي تعود إلى عائلة الزانثين بنسبة (1:1:1:1)، حيث تمت إذابتها في الكلوروفورم لتحضير محاليل بتركيز ($1*10^{-4}$، و$7*10^{-5}$، $5*10^{-5}$، $3*10^{-5}$، $1*10^{-5}$، $5*10^{-6}$) مول\لتر بدرجة حرارة الغرفة.

نلاحظ إن شدة الامتصاص وعرض حزمة طيف الامتصاص، وحيود الحزمة تزداد بزيادة التركيز والتي تتوافق مع قانون بيير–لامبرت. الكفاءة الكمية لمزيج الرودامين المذاب في الكلوروفورم تم حسابه باستعمال التراكيز أعلاه وكانت كما يلي (58%, 68%, 76%, 94%, 71%, 70%) على التوالي. تم حساب زمن العمر الإشعاعي وكما يلي (1.44, 1.25, 0.99, 0.65, 0.18, 0. 08) نانوثانية على التوالي. كما تم حساب زمن عمر التألق وكما يلي (0.84, 0.86, 0.75, 0.61, 0.12, 0.05) نانوثانية على التوالي.

الكلمات المفتاحية

صبغات الزانثين، رودامين 6G، رودامين 3GO، رودامين B، رودامين C.

Abstract

In this research the absorption and fluorescence spectrum in the range (400-700) nm for (Rhodamine 6G, Rhodamine 3GO, Rhodamine B and Rhodamine C) mixture which belong to Xanthene family were studied in the ratio (1:1:1:1), it has dissolved in chloroform to prepare different concentration ($5*10^{-6}$, $1*10^{-5}$, $3*10^{-5}$, $5*10^{-5}$, $7*10^{-5}$, and $1*10^{-4}$) mole/L at room temperature.

We notice that the absorption intensity, bandwidth of absorption spectrum and stock shift are increased with increasing concentration, and this agree with Beer-Lambert law. The quantum efficiency of the dissolved Rhodamine mixture in chloroform has been calculated by using the

same above concentration and their results are as follows (70%, 71%, 94%, 76%, 68% and 58%) respectively. The radiative life time have been computed as given (0. 08, 0. 18, 0. 65, 0. 99, 1. 25, and 1. 44) nanosecond respectively. Fluorescent life time have been also computed as given (0. 05, 0. 12, 0. 61, 0. 75, 0. 86 and 0. 84) nanosecond respectively.

Keywords

Xanthene's dye, Rhodamine 6G, Rhodamine 3GO, Rhodamine B, Rhodamine C, Laser dye.

1. Introduction

Lasing dyes are generally defined as substances capable of emitting light when stimulated and typically have, as their lasing media, dye compounds composed of conjugated double bonds [1].

Xanthene dyes are those containing the xanthylium as chromophore with amino or hydroxy groups meta to the oxygen as the usual auxochromes. Rhodamines are commercially the most important amino xanthenes. The organic dye laser has found many applications in scientific research because of its unusual flexibility [2]. Many experimental and theoretical works concerning the spectral properties of xanthene dyes were done because of their great promising results in solar concentration and nonlinear optics device applications.

There are large amount of data about laser dyes from many authors, Alaverdyan1 R. B. and co-workers studied Luminescence spectrum thermal properties of Rhodamine 6G doped polymethyl metacrylate film sandwiched between cholesteric liquid crystal layers [3]. Kailasnath M. and co-workers studied the energy transfer and optical gain studies of FDS: Rh B dye mixture investigated under CW laser excitation [4]. Bahattab M. A. and co-workers studied Photostability of Liquid Mixture Based on Rhodamine 590 Dye in Vinyl Acetate Polymer Solution [5]. Ali B. R. studied the energy transfer in dye laser mixture (1-Fluorescien+1-Rh 6G) [6], Ali H. Al-Hamdani study the spectroscopic properties for Rodamine 3GO [7], Rodamine B [8] dissolved in chloroform, Fluorescein Sodium dye in Ethanol [9], mixture of R6g and Rc dissolved in chroform [10] and R6G doped PMMA [11].

In the present work we study spectral properties of (R6G, R3GO, RB and RC) which is efficient laser dye and covers the wavelength region from 500 to 700 nm.

2. Materials and methods:

Solutions of different concentrations of four dyes (R6G, R3GO, RB and RC) in chloroform solvent were prepared from given weight of dye powder, according to the following equation:

$$w = \frac{Mw \times V \times C}{1000} \ldots (1)$$

Where: W weight of the dissolved dye (gm), *Mw* molecular weight of the dye (gm/mol),

V the volume of the solvent (ml), C the dye concentration (mol/l).

The prepared solutions were diluted according to the following equation:

$$C_1 \chi V_1 = C_2 \chi V_2 \ldots (2)$$

Where: C_1 primary concentration, C_2 new concentration, V_1 the volume before dilution, V_2 the volume after dilution.

The spectrum of the molecular fluorescence F (ύ) gives the relative fluorescence intensity at wave-number (ύ), this is related to the quantum efficiency by the following equation [4].

$$q_{fm} = \int_0^\infty F(\acute{\upsilon})\, d\acute{\upsilon} \ldots (3)$$

In order to evaluate absolute quantum efficiency, we have to consider both the radiative and non-radiative processes taking place in the medium, therefore

$$q_{fm} = \frac{K_{fm}}{K_{fm} + \Sigma K_d} = \frac{K_{fm}}{K_{fm} + K_{IC} + K_{ISC}} \ldots (4)$$

Also Since $K_{fm} = 1/\tau_{fm}$ and $\tau_f = 1/(K_{fm} + \Sigma K_d)$

Therefore,

$$q_{fm} = \frac{\tau_f}{\tau_{fm}} = \int_0^{\infty} F(\acute{\nu})\, d\acute{\nu} \ldots (5)$$

Where, τ_{fm} is the radiation life time can be calculated using relation as follow,

$$\frac{1}{\tau_{fm}} = 2.88 \times 10^{-9}\, n^2\, (\nu'^2) \int \varepsilon(\nu)\, d\nu \ldots (6)$$

Where, **n** is refractive index of a medium, **ύ** is wave number at the maximum absorption, and **∫ε(ύ) d ύ** is the area under the absorption spectrum curve as a function of the wave number [4].

The measurements of the absorption spectra of the samples are taken by using a spectrophotometer (Metertech, SP8001, UV/VIS spectrophotometer), and the emission spectra taken by using (Spectrofluorometer-model SL174, Elico). Refractive index is taken by using Refractometer (Bellingham and Stanley Ltd, Tunbridgewells, ABBE60, England).

Xanthenes derivative dyes used in this work are:

1. Rhodamine 6G which also called Rhodamine 590, Basic Rhodamine Yellow, molecular formula $C_{28}\ H_{31}\ N_2\ O_3\ Cl$, molar mass (479. 02 g/mole).
2. Rhodamine B which also called Rhodamine 610, Basic Violet 10, molecular formula $C_{28}\ H_{31}\ N_2\ O_3\ Cl$, molar mass (479. 02 g/mole).
3. Rhodamine 3GO chloride; molecular formula $C_{26}\ H_{27}\ N_2\ O_3\ Cl$, molar mass (451. 02 g/mole).
4. Rhodamine C, molecular formula $C_{28}\ H_{31}\ N_2\ O_3\ Cl$, molar mass (479. 02 g/mole).

3. Results and discussion

The absorption and fluorescence spectral of dye mixtures at different concentrations in the ratio of (1R6G: 1R3GO:1RB:1RC) are shown in Table(1) and Fig. (2), (3), (4), (5), (6), (7), (8) and (9) respectively.

From these Figs. we can observed that absorption intensity at maximum wavelength is increased with increasing concentration of dye mixture and this is in agreement with Beer – Lambert law. Also it is noticed from Fig. (1) that the bandwidth of the absorption spectrum are increased with increasing concentration of dye mixture and these behaviors are due to the increase in concentration which produces an increase in number of molecules in volumetric unit which effect in the energy state.

From Table (2) one can observe that the radiative life time and fluorescence life time increase with increase in the concentration. The fluorescence life

Table (1): The wavelength at relative maximum intensity for absorption and Fluorescence of dye mixtures at different concentration in the ratio of (1R6G: 1R3GO: 1RB: 1RC).

Dye ratio	Conc. (mole/L)	Wavelength (ABSmax) nm	Absorption Intensity	Wavelength (Fmax) nm	Fluorescence Intensity
1:1:1:1	5*10-6	535. 76	0. 3069	547. 5	154
1:1:1:1	1*10-5	537. 12	0. 4912	549. 5	3371
1:1:1:1	3*10-5	535. 76	1. 1816	555. 5	3570
1:1:1:1	5*10-5	541. 55	2. 3673	575	1145
1:1:1:1	7*10-5	538. 66	2. 5044	577. 5	918
1:1:1:1	1*10-4	528. 42	2. 6157	583	531

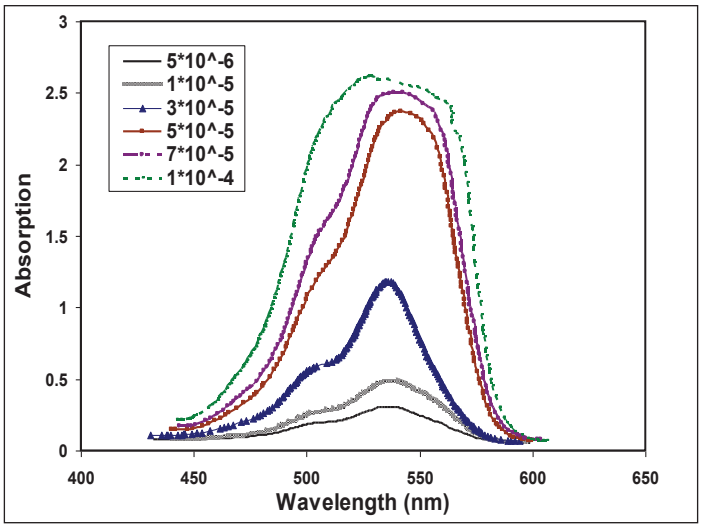

Fig. (1): Absorption spectrum for mixture of (1R6G: 1R3GO: 1RB: 1RC) at different concentration

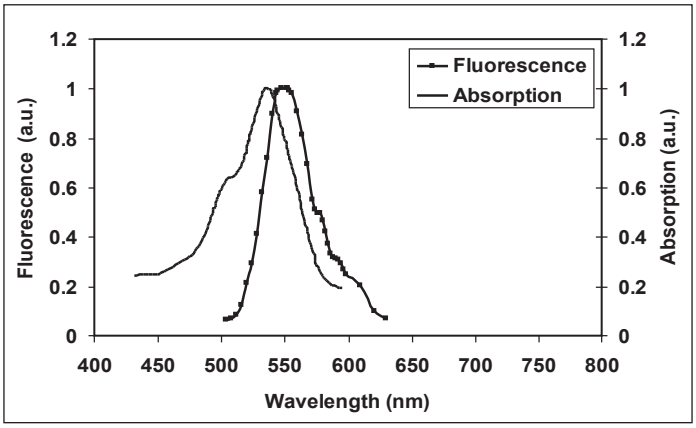

Fig. (2): Absorption and fluorescence spectrum for mixture of (1R6G: 1R3GO: 1RB: 1RC) at concentration ($5*10^{-6}$mole/L).

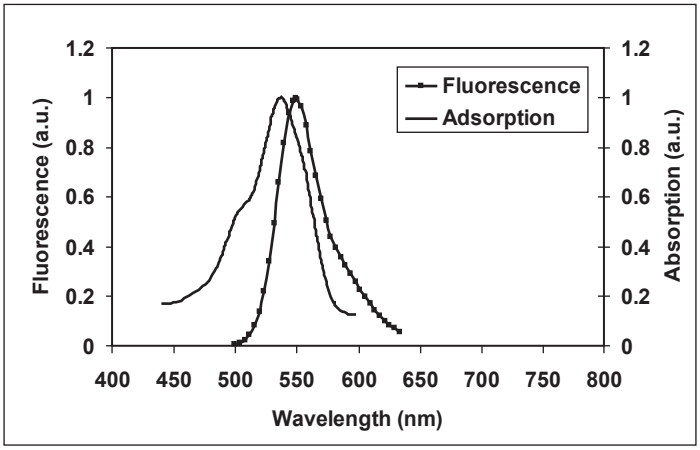

Fig. (3): Absorption and fluorescence spectrum for mixture of (1R6G: 1R3GO: 1RB: 1RC)at concentration ($1*10^{-5}$mole/L).

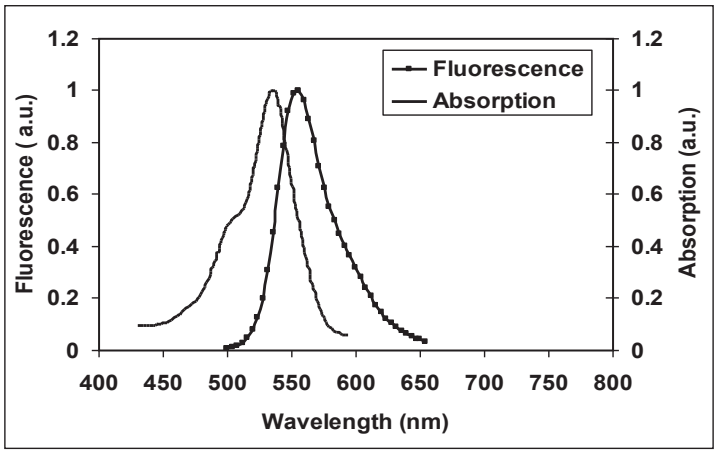

Fig. (4): Absorption and fluorescence spectrum for mixture of (1R6G: 1R3GO: 1RB: 1RC) at concentration ($3*10^{-5}$mole/L).

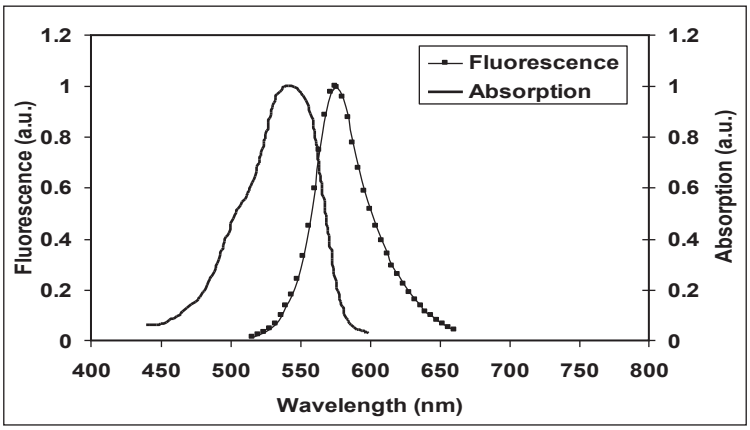

Fig. (5): Absorption and fluorescence spectrum for mixture of (1R6G: 1R3GO: 1RB: 1RC) at concentration ($5*10^{-5}$mole/L).

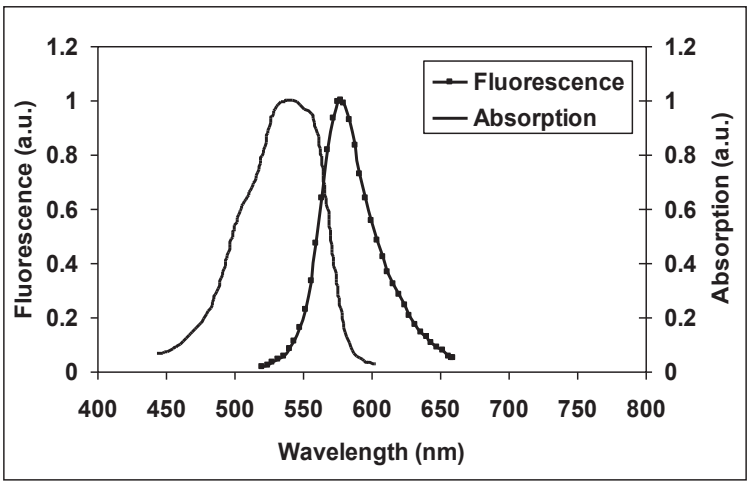

Fig. (6): Absorption and fluorescence spectrum for mixture of (1R6G: 1R3GO: 1RB: 1RC) at concentration ($7*10^{-5}$mole/L).

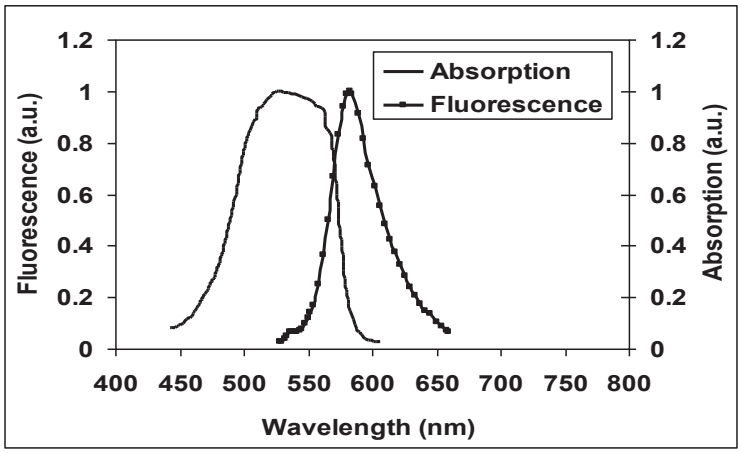

Fig. (7): Absorption and fluorescence spectrum for mixture of (1R6G: 1R3GO: 1RB: 1RC) at concentration ($1*10^{-4}$mole/L).

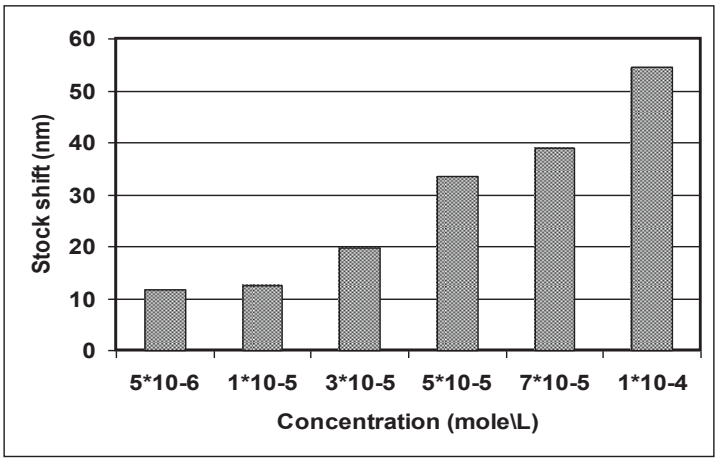

Fig. (8): The stock shift between absorption and fluorescence spectrum of samples.

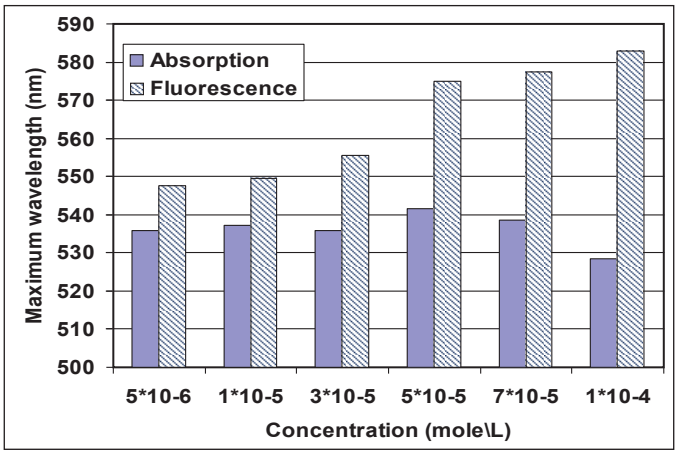

Fig. (9): The maximum wavelength of absorption and fluorescence spectrum of samples.

time was less than radiative life time because of non radiative processes. The results indicate that the best concentration was the lower one (3*10-5 mol/l) which quantum efficiency equal 94. 41% so this dyes concentration can be used to improve solar cell conversion efficiency. But since the other important parameter (stock shift) was small (only 19. 7 nm) which offer a small matching between the solar spectrum and silicon solar cell responsively. So one conclude that there is a large leakages in the collected data about dye properties and there is a great interest must focus on this filed.

Table (2): The stock shift, quantum efficiency yield, radiative emission probability, radiative life time, and fluorescence life time of dye mixtures at different concentration in the ratio of (1R6G: 1R3GO:1RB:1RC).

Conc. (mole/L)	Stock shift (nm)	Quantum efficiency %	Kfm	τfm (nsec)	τf(nsec)
5*10-6	11. 74	70. 39	12. 0052	0. 0832	0. 0586
1*10-5	12. 38	71. 1 2	5. 5416	0. 1804	0. 1283
3*10-5	19. 74	94. 41	1. 5225	0. 6568	0. 6173
5*10-5	33. 45	76. 22	1. 008	0. 9913	0. 7556
7*10-5	38. 84	68. 66	0. 7962	1. 2559	0. 8623
1*10-4	54. 58	58. 96	0. 6939	1. 441	0. 8496

References

[1] Dale R. Pfost,"Laser Tape Systems",United States Patent, No. 4, 523, 319, Jun. 11 (1985).

[2] Maeda, M. Laser Dyes" Properties of Organic Compounds for Dye Lasers" Academic Press, Orlando, Fla., (1984).

[3] Alaverdyan R.B., Dadalyan T K, Karapetyan A S, and Torosyan N S "Luminescence Spectrum Thermal Properties of Rhodamine 6G Doped Polymethyl Metacrylate film Sandwiched between Cholesteric Liquid Crystal Layers", International Symposium on Optics and its Applications (OPTICS2011), Journal of Physics :Conference Series 350 ((2012).

[4] G´omez.L., Cuppo F.L.S. and A. M. Figueiredo Neto, Brazilian Journal of Physics, **33** (2003).

[5] Bahattab M.A., Mohammad Ahmad M. and King T.A., International Journal of Pure and Applied Physics, **3**, 22 (2007).

[6] Ali B.R, International Journal of Application or Innovation in Engineering &Management, **2**, 525 (2013).

[7] Ali H. Al-Hamdani, Yasmeen Z. Dawood, Shafa Majeed Jaseem, International Review of Chemical Engineering (I.RE.CH.E.), **5** (2013).

[8] Ali H. Al-Hamdani, Rajaa Nader, Rafah Abdul Hadi, IOSR Journal of Research & Method in Education (IOSR-JRME), **4**, 68 (2014).

[9] Ali H. Al-Hamdani, Adnan F. Hassan, Faiz Salih Abbas, "The Effect of Concentration on Spectroscopic Properties of Fluorescein Sodium dye in Ethanol", **6**, 112 (2014).

[10] Ali H. Al-Hamdani, Shaima Khyioon, Rafa abdul Hadi, "Calculation the Quantum Efficiency of Mixture of Rhodamine (RC and R6G) dyes dissolved in Chloroform», 1st energy and Renewable energy conference, university of technology, Energy and Renewable Energies Technology Center, Baghdad, IRAQ (2013).

[11] Ali H. Al-Hamdani, Rafa, abdul Hadi, Raja Nader, Iraqi Journal of Physics, **12**, 59 (2014).