Journal of Engineering and Applied Sciences 12 (Special Issue 6): 7925-7929, 2017
ISSN: 1816-949X


# Studying the Optical Properties of Rhodamine110 Dye Mixture Doped in PVC Thin Films

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**Abstract:** In this research, the optical characteristics of thin films of a laser dye Rhodamine 110 doped with PVC which prepared using the casting method at room temperature were studied. The solution of (10, 20, 30, 40 and 50%) molar ratio of Rhodamine 110 solution was mixed with fixed amount of PVC solution, the mixture casting on the glass sample at room temperature for 24 h to obtain the final thin film. The absorption spectra were studied at a range of wavelength (190-1100 nm) by (UV-VIS) beam spectrometer for all samples. Optical constants were calculated such as the absorption coefficient ($\alpha$), index coefficient (n) and extinction coefficient (k) for all samples. The concentration of laser dye effect on the allowed direct and indirect energy gaps where the increasing in dye concentration leads to decreasing in both these energy gaps. Also, it can deduce that the optical properties of the prepared samples changed by varying the molar ratio of the laser dye.

**Key words:** Optical characteristics, absorbance, extinction coefficient, reflective index, spectrometer, dye

## INTRODUCTION

Scientists are using polymers mainly because of distinctive characteristics. All industrial importance as fibers , elastic adhesives and coating is ultimately based on strength, high elongation, high hardness coefficient, Resistance to corrosion, thermal and mechanical tolerances (Tobolsky and Mark, 1971).

Polyvinyl Chloride (PVC) it is one of the most importance polymers due to its valuable characteristics, the growth of the PVC production is due to the steady expansion of its field of application (Ermakova *et al*., 2009). Polyvinyl Chloride (PVC), it is one of the most multiuse plastics. It is the second large make resin by volume all over the world (Lazaroaie *et al*., 2010). Recently, scientists were able to modify PVC by Introduction aromatic and heterogeneous anomaly through halogen displacement reaction. Thus modified, showed improved comprehensive optical characteristics (Yousif *et al*., 2007; Aliwi *et al*., 2005).

Laser dye is a large organic part with molecular weights of a few hundred. When one of these dissolved organic molecules is in a suitable liquid solvent (such as ethanol or an ethanol water mixture) it is can be used as a laser medium in a dye laser (Schafer, 1990; Duarte and Hillman, 1990).

Rhodamine 110 laser dye molecular formula: molecular weight: 366.7977 g/m, physical model: green color or red or reddish solid, fusion point: >380°C, absorption ($\lambda_{max}$) 499 nm in (MeOH); 496 nm in ($H_2O$), emission ($\lambda_{max}$) 521 nm in (MeOH); 520 nm in ($H_2O$) and the chemical structure shown in Fig. 1.

In the current study, both PVC and Rh 110 were used to synthesis PVC doped with Rhodamine 110 thin films using casting method and studying the optical characteristics of these films with different molar ratios of both PVC and Rhodamine 110 dye laser.

The laser dye absorbs the smallest wavelength and scatter the longest wavelength. The best types of lasers include coumarin and Rhodamines. The coumarin emissions are in the green zone while the Rhodamine is emitted in the yellow and red regions of the spectrum. Depending on the surrounding medium, the color emission of the laser dye. The medium in which they are sought. However, There are dozens of laser dyes that can be used to continuously stretch the emission spectrum from nearby ultraviolet to nearby infrared (Duarte, 2003).

Laser dyes are also used to dope solid-state matrices, such as Polymethyl Methacrylate (PMMA) and ORMOSILs, to provide gain media for solid state dye lasers (Duarte, 2003).

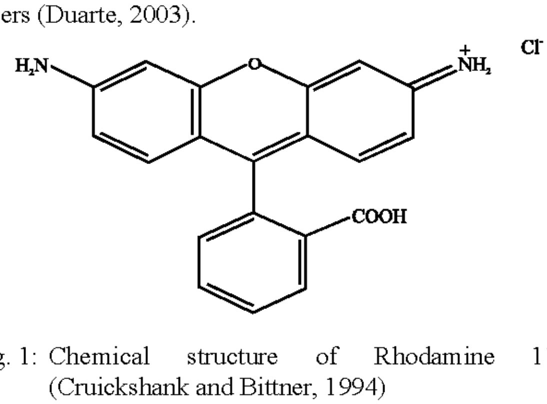


Fig. 1: Chemical structure of Rhodamine 110 (Cruickshank and Bittner, 1994)

Play thin film technique the pivotal role, especially in the field of microelectronics, optics, Integrated, optical coating and connectors superconducting, etc. changes in electrical and chemical properties by the irradiation of the thin films are used for optical and micro machines (Freeman and Poeppelmeier, 2000). Avnir *et al.* built a laser dye manner (sol gel) using a toroidal resonator consists of thin films of the dye solid condition (Fukuda and Mito, 2000).

## MATERIALS AND METHODS

**Experimental procedure:** In this study, 0.01 GM of Rhodamine 110 laser dye was dissolved in 10 mL THF and placed on a magnetic stirrer for 3 h to obtain $1\times10^{-4}$ mol/L laser dye solution. Polymer solution was prepared by dissolving 1 g of PVC in 20 mL THF and stirrer variously for 3 h to obtain the polymer solution.

To prepare the final solution (10, 20, 30, 40 and 50%) molar ratio of Rhodamine 110 solution was mixed with the polymer solution and then deposit the mixture on glass substrate at room temp. For 24 h to obtain the final thin film samples. Using the method of optical interference, thin film thickness was measured for all samples using laser He-Ne (0.632 μm) and found to (0.35 μm).

The optical absorption and transfer of the spectrum of Rhodamine 110 doped with PVC thin films using UV-VIS beam spectrometer in the wavelength range between 190-1100 mm. The absorption factor (α) was calculated using the Eq. 1 (Jadhav and Khairnar, 2005):

$$\alpha = \frac{2.303}{d}A \quad (1)$$

The direct allowed and forbidden transitions occur near top points of the Valence Band (VB) and bottom points of the Covalent Bond (CB) and the absorption factor for this transition type given (Kolinko and Bovgyra, 2007):

$$\alpha h\nu = B(h\nu - E_g)^r \quad (2)$$

Where:

$E_g$ = Energy gap between direct transition
B = Constant depended on type of material
ν = Frequency of incident photon
r = 1/2 for the allowed direct transition
r = 3/2 for the forbidden direct transition
r = Exponential constant, its value depended on the type of transition

The electron transition from VB-CB not perpendicularly where the value of the wave vector of an electron is not equally before and after the transition of electrons. In case of indirect allowed and forbidden transitions, the bottom of CB is not over the top of VB. This transition type happens with helpful of a like particle is called Phonon for conservation of the energy and momentum law. The absorption factor for transition with photon absorption is given by Thutupalli and Tomlin (1976):

$$\alpha h\nu = B(h\nu - E_g \pm E_{ph})^r \quad (3)$$

Where:

$E_g$ = Indirect transition for energy gap
$E_{ph}$ = Photon energy is (+) photon absorption and (-) photon emission
r = 2 = For the indirect transition allowed
r = 3 = For the forbidden indirect transition

Thin film refractive index (N) is calculated from the Eq. 4 (Aziz and El-Mallah, 2009):

$$n = \frac{1+\sqrt{R}}{1-\sqrt{R}}$$

We can find the coefficient of extinction by the absorption factor of the Eq. 5 (Xue *et al*., 2008):

$$K = \frac{\alpha\lambda}{4\pi} \quad (5)$$

The real complex dielectric constant and imaginary complex constant can be expressed by Eq. 6 and 7, respectively (Al-Ramadin, 2000; Elangovan and Ramamurthi, 2003):

$$\varepsilon_r = n^2 - K^2 \quad (6)$$

$$\varepsilon_i = 2nK \quad (7)$$

## RESULTS AND DISCUSSION

Absorption spectrua for all samples was shown in Fig. 2. It can be noticed from these spectra that the

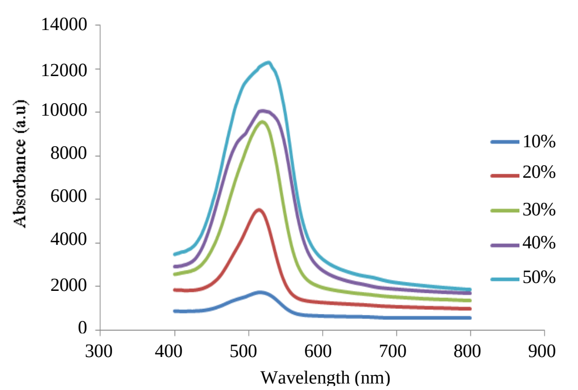


Fig. 2: Absorption spectra at different molar ratio for Rh 110 doped with PVC

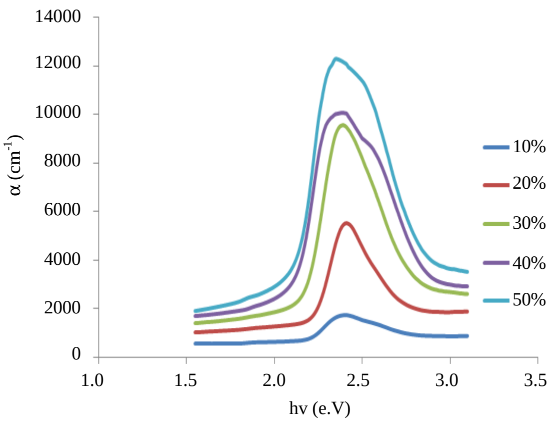


Fig. 3: Absorption coefficient at different molar ratio for Rh 110 doped with PVC

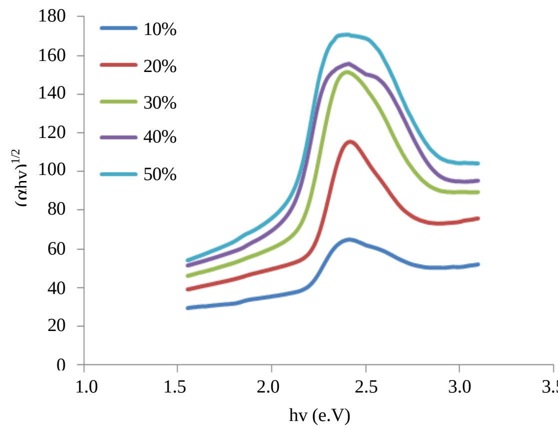


Fig. 5: Relationship between ahv$^{1/2}$ and photon Enregy for Rh 110 doped with PVC

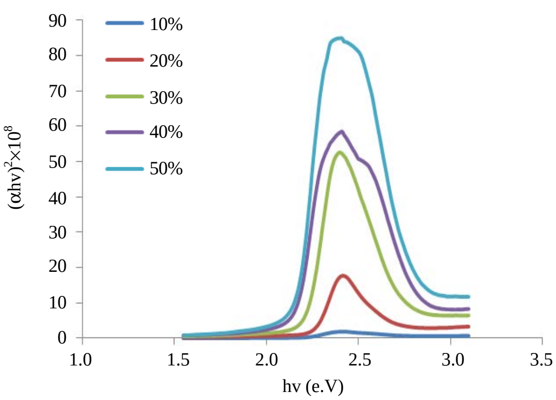


Fig. 4: Relationship between $(\alpha h\nu)^2$ and photon energy for Rh 110 doped with PVC

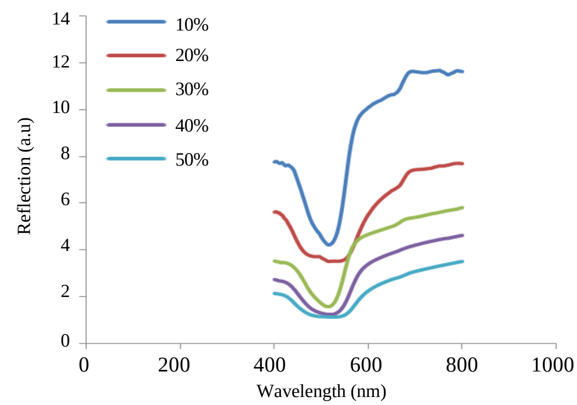


Fig. 6: Reflection spectra against wavelength (nm) for Rh 110 doped with PVC

intensity of absorption was increased with increasing the weight ratio of the (Rhodamine 110) with constant weight of the host (PVC polymer). Also one can see the red shift with increasing the absorption intensity. These effects in the absorption spectra due to the increase the number of dye molecules in the sample which act as absorption centration.

Figure 3 and 4 shows the relationship between the absorption coefficient with a wavelength of PVC doped with different weight ratio of (Rhodamine 110). The molar absorption factor were increased with increasing the weight ratio of (Rhodamine110), this due to the direct dependence of absorption factor on the absorption of the spectrum.

The direct electronic transition due to the valuable of absorption factor more than $10^{4}$ $cm^{-1}$ while the indirect electronic transition happen when the absorption factor been less that $10^{4}$ $cm^{-1}$ (Mohamed, 2016) for all samples.

Table 1: Allowed direct electronic transition

| Molar ratio of Rh 110 (%) | Allowed direct band gap (e.V) | Allowed indirect band gap (e.V) |
|---|---|---|
| 10 | 2.29 | 1.96 |
| 20 | 2.26 | 1.93 |
| 30 | 2.20 | 1.84 |
| 40 | 2.14 | 1.81 |
| 50 | 2.11 | 1.75 |

Table 1 shows the valuable of allowed direct electronic transition band energy gap and indirect transitions for prepared thin films which calculated from the relationship between $\alpha h\nu^{1/2}$ and the incident energy of photon hv. Figure 5 shows the dependence of reflectance with the wavelength.

Figure 6, one can notice that the reflectance for all samples have a minimum value at the peaks of the absorption spectra. Also, its clear from Fig. 6, that the reflection of thin film effects with the concentration of Rh 110 laser dye where the increasing in in dye concentration causing a decreasing in the absorption

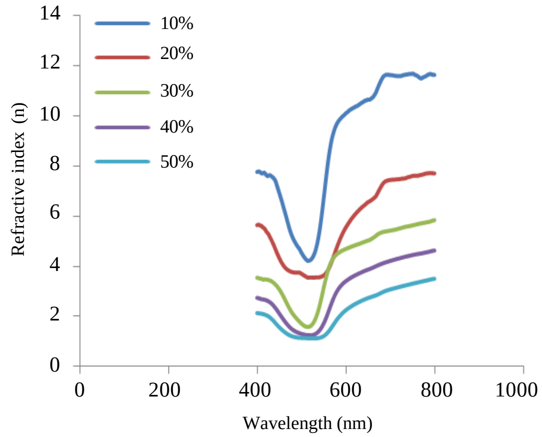


Fig. 7: Reflective index and wavelength (nm) for Rh 110 doped with PVC

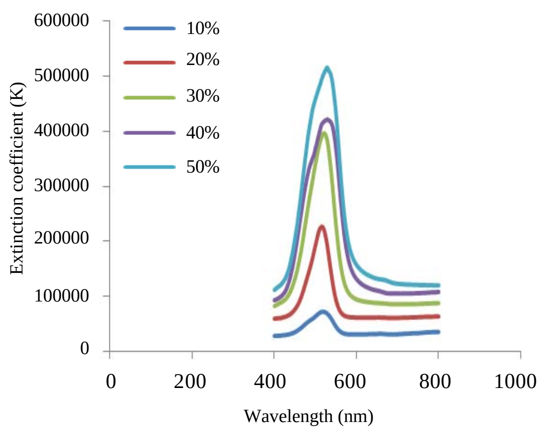


Fig. 8: Extinction coefficient dependence on the wavelength (nm) for Rh 110 doped with PVC

of the spectrum. The refractive coefficient of the prepared thin-film was calculated from the Eq. 4 and the behavior of (n) with the wavelength is shown in Fig. 7.

From Fig. 7, it's clear that the that the refractive Coefficient decreasing with increasing the dye concentration and the behavior of the reflective index depends on the reflectance spectra accordance the mathematical formula of the refractive coefficient.

Extinction convictions of the thin-film were calculated from Eq. 5 and it is done in Fig. 8.

The extinction confections of the samples affected by the dye concentrations, the absorption spectra and the wavelength. The main factor responsible of the variation in the extinction confections is the laser dye concentration, where the increasing in the concentration causes increases in extinction confection. This due to the increasing in the number of dye molecules in the samples.

## CONCLUSION

Throughout studying to the dye solution Rhodamine 110 in THF co-doped with PVC, one can conclude that the increasing in the concentration of the dye leads to increasing in the intensity of the absorption spectra and causing a red shift in these spectra. From results of energy gaps, it is found that the values of allowed direct electronic transition energy gaps decreasing from (2.29 e.V) at 10% molar ratio of Rh 110 dye concentration to (2.11 e.V) at 50% molar ratio while the values of allowed indirect electronic transition energy gaps decreasing from (1.96 e.V) at 10% molar ratio of dye concentration to (1.75 e.V) at 50% molar ratio.

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