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THE NANOPARTICLE Al_2O_3 EFFECT ON OPTICAL OF R6G DOPED-EPOXY POLIMER

Mustafa M. Jaber[1, *], Yasmeen Z. Dawood [1], Ali H. Al-Hamdani[2]

(1) University of Mustansiriya, Collage of education, Baghdad, Iraq.
(2) Laser and Optoelectronic Engineering Department, University of Technology, Baghdad, Iraq. Correspondence author email: mostafajaber574@gmail.com

Abstract

The optical properties of R6G dye-doped epoxy resin at different concentrations and weights of Al_2O_3 nanoparticles have been studied. The study was conducted at room temperature and using UV–Vis spectrophotometer. The results showed an increased absorption peak as the concentration and the weight of Al_2O_3 increases. On the other hand, the results showed a decrease in E_g and E_p values with increasing the concentration and the weight of Al_2O_3. Samples of R6G/Epoxy and R6G/Epoxy/Al_2O_3 were prepared and found to have a high optical conductivity of (10^9-10^{10}) sec^{-1}.

Keyword: optical properties; R6G dye; epoxy resin; Al_2O_3 nanoparticle; organic dyes.

1. Introduction:

The laser dyes are unsaturated organic compounds [1,2], which are characterized by absorbing and emitting in the visible and near-infrared region of the spectrum [3], the tunable, broad spectral bandwidth and high quantum yield [4,5]. Some properties of dye lasers are attractive in different respects, where they can be used in the solid-state, liquid-state, and different concentrations, their absorption and laser gain are readily controlled, and the cost is negligibly small [6].

Because the dye in a liquid state presents problems such as static or flowing liquid systems and perishables, the solid materials (polymers) were used as a host for the dyes. The dyes-doped polymer leads to several important advantages, such as the ease of handling, operational safety, toxicity removal, and lack of flammability [7,8]. The dyes-doped polymer has been given a great deal of attention for many years, along with its use in different applications [9,10]. One of the polymers appropriate for the dye is the epoxy resin, polymer which belongs to the polymers thermosetting resins, and their properties are one of the reasons that led to choosing it for such purpose [11].

Metal nanoparticles doped polymers attracted more significant consideration because of these hybrid materials' widened application goal. Also, polymers are a good host for the encapsulation of the nanoparticles, providing the environmental and chemical stability [12,13], (polymers such as A_2O_3 or corundum which is a transparent white oxide). There are several phases of Alumina, such as gamma, delta, theta, and alpha. But, the alpha-alumina is the most thermodynamically stable phase [14].

Optical absorption is a useful method for investigating optically to provide the information about the band structure and optical energy gap of the materials [15]. In the recent years, polymer nanocomposites' optical properties have lead to their use in many optical and electrical devices, such as electronic components, optoelectronics, electrical, optical devices, biomedical science, and sensors [16].

The object of this work is to prepare and study optical properties of R6G/Epoxy at different concentrations ($1x10^{-6}$, $5x10^{-6}$, and $1x10^{-5}$) mole/l, and R6G/Epoxy/Al_2O_3 nanocomposite with different weight of nanocomposite (0.5, 0.1, and 0.15 %). The samples were prepared by using the casting method at (0.5) mm, as thickness.

2. Experimental part:

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The dye Rhodamine 6G (R6G) supplied by the HiMedia Laboratories Pvt company, India, was used. With the molecular formula ($C_{28}H_{31}N_2O_3Cl$), molar mass (479.02 g/mol), and their structure is shown in figure 1 [17].

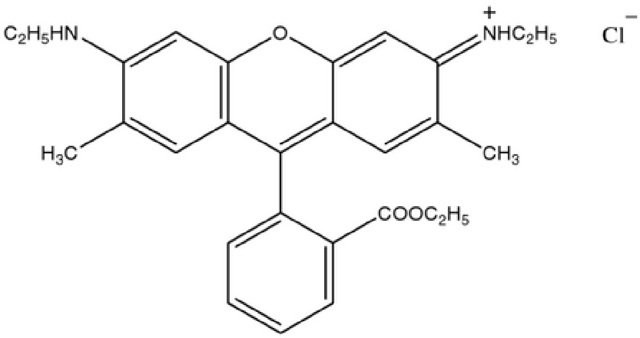

Fig. 1. Chemical structure of Rhodamine 6G dye.

The acetone solvent has the formula (CH_3COCH_3), refractive index about (1.361) at temperature 17 C^0, purity (99 %), molecular weight (58.08 $g.mol^{-1}$) supplied by Central Drug House Ltd company, Indian.

Epoxy resin polymer was used in work supplied by an Egyptian -Swiss chemical industry company. The epoxy consists of two materials, the first called epoxy resin (epoxy resin) and denoted by the letter (A), and the second material called sclerosing (hardener) and denoted by the letter (B), with a matrix ratio is (3:1) (A:B). In addition, Al_2O_3 nanoparticle with particle size (20-30) nm was used. Al_2O_3 was supplied from Intelligent Materials Pvt. Ltd company.

The appropriate weight of R6G was dissolved in 10 ml of acetone, and then the epoxy was added (B) to the solution, and mixed for about 5 min. Then, the epoxy was added (A) and mixed until the mixture became homogenous at a room temperature. To prepare nano compounds R6G/Epoxy/Al2O3, different weight of Al2O3 nanoparticles (0.05%, 0.1%, and 0.15%) wt, were added to R6G, dissolved in acetone and magnetically stirred for 4 hours to dissolve Al_2O_3, at room temperature. Then, the last steps were repeated, and the mixture was mixed with the Al_2O_3 for about 4 hours.

The samples were cast in a mold shown in figure 2 and were left to dry about four days. The samples were about 0.5 mm in thickness and by using the Spectrophotometer T60 supplied from the English company (Instruments) was used to measure the absorption spectra of samples.

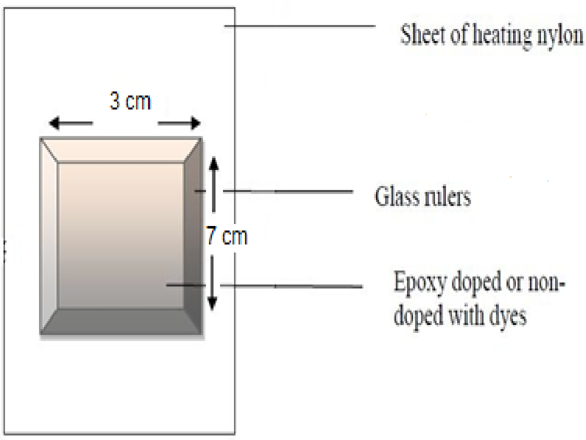

Fig. 2. Illustrate the mold with its parts.

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3. Results and discussion:

The absorption spectrum of R6G dye at different concentration (a) and weight of Al_2O_3 nanoparticle (b) are shown in figures 3. It was noted the absorption spectrum of the samples a wide range in the visible region at (540 nm), which originates from the ($\pi - \pi*$) transitions from the binding HOMO (highest occupied molecular orbital) to the anti-binding LUMO (lowest unoccupied molecular orbital) [18].

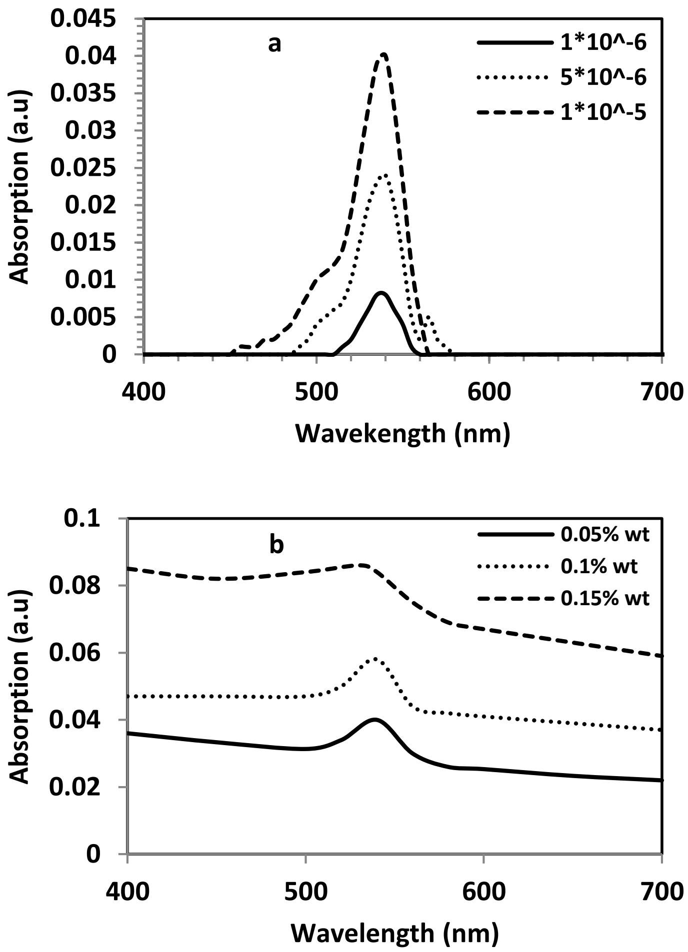

Fig. 3. Absorption spectrum of R6G dye. (a) R6G/Epoxy at different concentrations. (b) R6G/Epoxy/Al_2O_3 at a different weight of nanoparticles.

The broad spectral range can occur because they have many oscillation modes as they are very heavy [19]. The absorption spectrum's shape is due to the dye monomers and aggregates at the employed concentrations [20]. The samples' absorption peak increases as the weight ratio of Al_2O_3 nanoparticle increases, which goes along with Beer's law.

The absorption coefficiency (α) can be calculated by the equation [21]:

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

Where:
A: The absorption.
d: Thickness of the samples.

Figures 4. shows the dependence of the absorption coefficiency (α) on the photon energy (hυ) for all samples the absorption coefficiency reaches its maximum at 540 nm (2.29) eV. Also, the peak of α increases as the concentration and the ratio of nanoparticle increases. This can be due to the rise in the number of dye and nanoparticles that absorb the light.

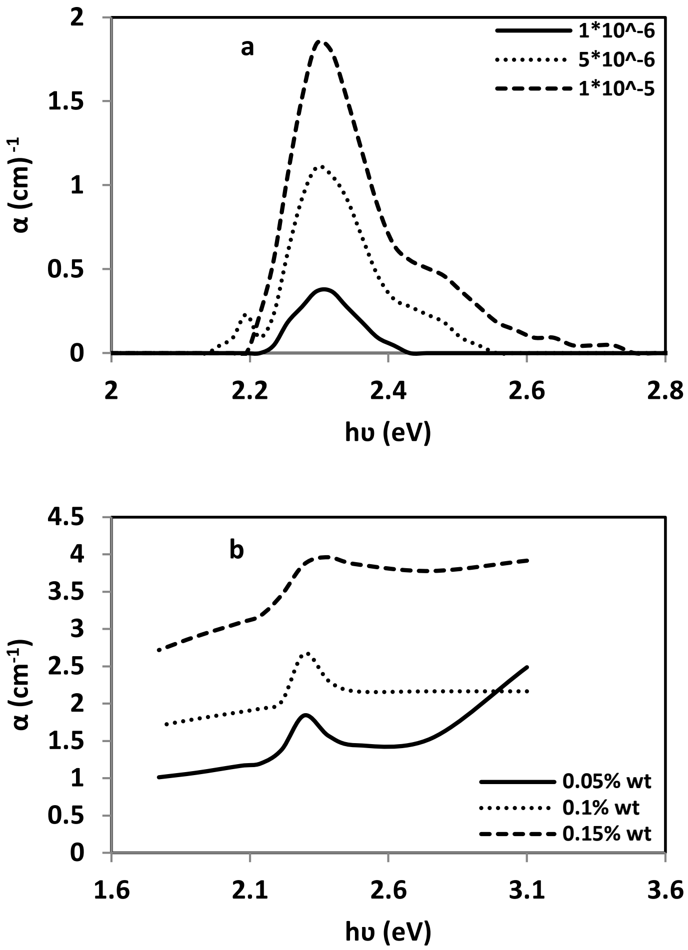

Fig. 4. Variation absorption coefficiency with a photon energy of R6G dye. (a) R6G/Epoxy at different concentrations. (b) R6G/Epoxy/Al_2O_3 at a different weight of nanoparticles.

The maximum values of the absorption coefficiency as different concentrations (a) and different weights of Al_2O_3 (3) show in table (1).

The optical energy gap (E_g) can be calculated by using the relationship between the absorption coefficiency and optical photon energy (hυ) [22,23]:

$$\alpha h\nu = A(h\nu - E_g)^r \qquad (2)$$

Where: E_g is the optical energy gap, A is a constant, and r is a constant, taken the values 1/2, 3/2, 2, or 3 depending on the type of the transition responsible for the absorption. The Eg values can be obtained by extrapolating the linear region of the plot to (αhυ) =0.

The direct optical band gap can be estimated by a plot of $(\text{axh}\upsilon)^2$ versus (hυ) by using the Kubelka–Munk model [24], as shown in figures 5.

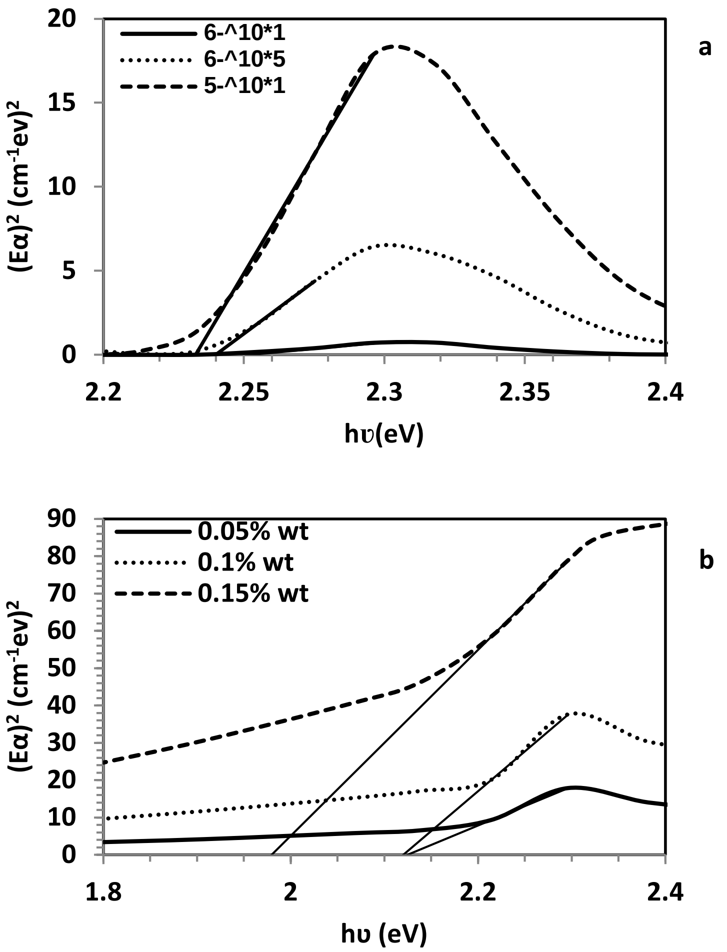

Fig. 5. Determine the optical energy gap of R6G dye. (a) R6G/Epoxy. (b) R6G/Epoxy/Al_2O_3 nanoparticle.

The energy gap for samples without the nanoparticle (a) was (2.24-2.235), where it decreases as the concentration of the dye increases because of the creation of a new energy level in the forbidden energy gap [25]. This value goes along with researchers' work [26]. Figures 3-b shows the effect of the weight ratio of Al_2O_3 nanoparticles on the energy gap. The energy gaps decrease as the nanoparticle ratio increases, as shown in table (1). Thus, the Al_2O_3 nanoparticle is enhancing the connectivity of the samples to reach about (1.98) eV.

It could determine the optical activation energy of R6G/Epoxy and R6G/Epoxy/Al_2O_3 samples as [15]:

$$\alpha = Bepx(h\nu/E_p) \quad (3)$$

B, is constant, and E_p is the activation energy. The figures 6 shows variation (lnα) with photon energy (hv) for samples at different concentrations (a) and at a different weight of nanoparticle (b). The values of (lnα) for the concentration ($1x10^{-6}$) in Figures 3-a were positive; therefore, it cannot determine the E_p.

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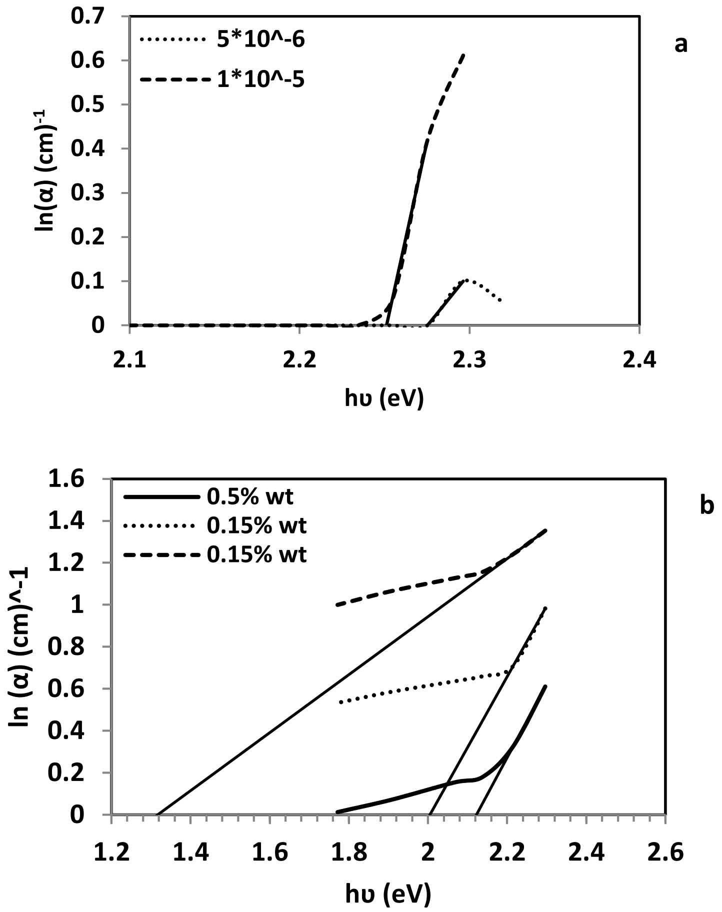

Fig. 6. Calculate activation energy (Ep). (a) R6G/Epoxy. (b) R6G/Epoxy/Al2O3.

The E_p for samples was calculated from the slope of the straight line curves of the samples. As shown in table 1, the E_p decreases values as the dye concentration and nanoparticles' weight increase. The E_p for R6G/Epoxy samples is more considerable than for the R6G/Epoxy/Al_2O_3 samples. Thus, the increase in the concentration and weight of Al_2O_3 can lead to a decrease in the energy required to induce optical transitions from the valence to the conduction band [27].

Figures 6 shows the optical connectivity as a function of the photon energy (hυ). The optical conductivity (σ) was determined for the samples by the equation [28]:

$$\sigma = nc\alpha/4\pi \tag{2}$$

Where:
n: refractive index.
c= Speed of light.
α= Absorption coefficient.

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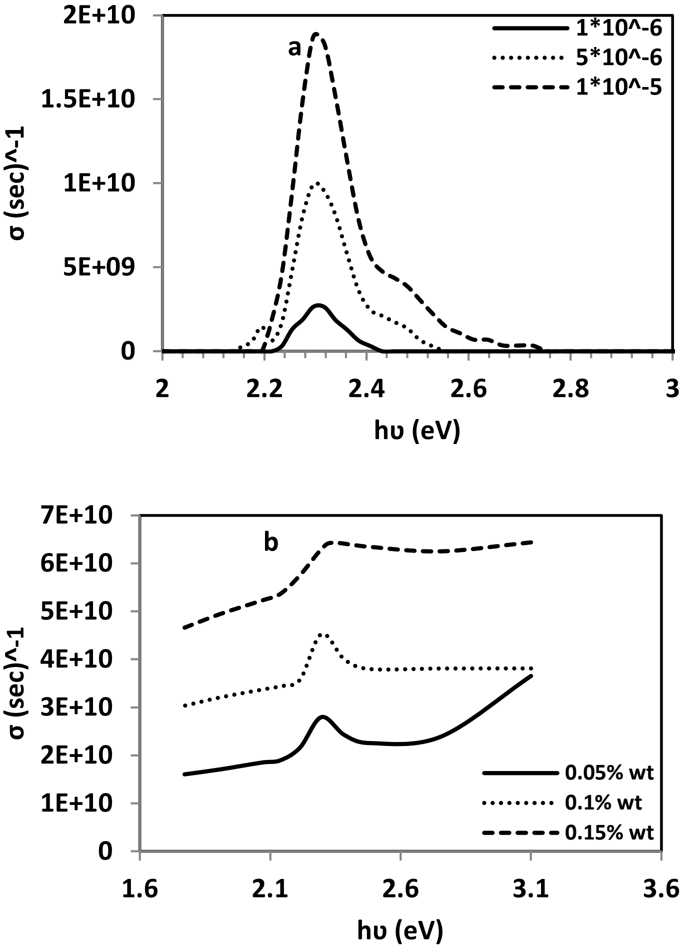

Fig. 6. Optical conductivity varies with photon energy. (a) R6G/Epoxy. (b) R6G/Epoxy/Al_2O_3.

The peak of the optical conductivity at the maximum absorption of samples was noted because of the high absorption of the samples and electron excitation by the photon energy [29]. In comparison between figures 6-a and 6-b, the optical conductivity of the samples with nanoparticles is larger than of the samples without nanoparticles, and this confirms the very high photoresponse of both samples (10^{10} sec^{-1}).

Table 1. Optoal properties of the samples.

Concentration	**Absorption λ_{max} (nm)**	**α_{max} (cm^{1})**	**E_g (eV)**	**E_p (eV)**	**σ_{max} (Sec^{1})**
$1*10^{-6}$	**540**	**1.1**	**2.25**		**2.66**
$5*10^{-6}$	**540**	**1.84**	**2.24**	**2.72**	**9.93**
$1*10^{-5}$	**540**	**5.25**	**2.23**	**2.25**	**18.8**
0.05%	**540**	**1.84**	**2.125**	**2.12**	**27.9**
0.1 %	**540**	**2.67**	**2.1**	**2**	**45.2**

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0.15%	**540**	**3.96**	**2** **1.9** **8**	**1.3** **2**	**64.2**

4. Conclusion

The R6G dye-doped epoxy polymer and R6G/Epoxy/Al_2O_3 nanoparticle films were prepared successfully using the casting method. The absorption spectrum showed that the samples work in the visible region. The absorption coefficiency of the samples depends on the energy of the photon. The samples' optical energy gap at different concentrations showed the samples belong to an insulating material (2.25-2.236) eV. Hovewer, the Al_2O_3 decreases the E_g of samples to reach about (1.98), and it is beneficial to produce polymers as a semiconductor material. Finally, the optical conductivity of samples is about (10^9-10^{10}) but, the values for R6G/Epoxy are smaller than those of R6G/Epoxy/Al_2O_3 samples.

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