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OPTICAL PROPERTIES OF COMPOSITE RESOL NOVOLAC RESIN (RNR) DOPED WITH RHODAMINE 6G

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ABSTRACT: *Optical characteristics of Resol Novolac Resin (RNR) films doped with different ratios of Rhodamine 6G (0.01,0.03, 0.05, 0.05, 0.07, 0.1)% wt. were studied. The composite films prepared using casting technique, the optical absorption spectra of these films in the wavelength range from 200-800 nm. The result showed that the optical absorption is due to direct allowed transitions for pure RNR and different doping ratios, while the Energy gap* E_g *of the composite films decreases with increasing doping ratios. The absorption coefficient (*α*), real and imaginary parts (*$\varepsilon_r, \varepsilon_i$*), and optical conductivity (*σ_{opt}*) were found to be increased with increasing the doping ratios.*

KEYWORDS: Resol Novolac Resin, Rhodamine 6G, Optical properties, doping effect.

INTRODUCTION

The study of the optical absorption Spectra in solids provides essential information about the band structure and the energy gap in the crystalline and non – crystalline materials [1]. The analysis of the absorption spectra in the lower energy part gives information about atomic vibration while the higher energy part of the spectrum gives knowledge about the electronic states in atom [2]. Optical properties such as refractive indices for certain range of wavelength between ultraviolet and near infrared , and optical band gap values, are becoming quite important criteria for selection of application of the fabricated films; the refractive indices of optical materials have considerable importance for applications in integrated optic devices such as switches [3] .

The absorption coefficient near fundamental absorption edge in both of crystalline and amorphous semiconductors, is dependent on the photon energy . For direct transitions, the absorption coefficient was taken on the following more general form as a function of photon energy [4,5].

$$\alpha h \upsilon = A (\alpha h \upsilon - E g)^n \qquad (1)$$

and for indirect transition

$$\alpha h \upsilon = B (\alpha h \upsilon - E g)^n \qquad (2)$$

where υ is the frequency of the incident photon , n is the number which characterizes the optical processes .n has the value 1/2 for the direct allowed transition , 3/2 for a forbidden direct allowed transition and 2 for the indirect allowed transition , A and B are constants and Eg is the optical energy gap. When the straight portion of the graph of $(\alpha h\upsilon)^n$ against $h\upsilon$ is extrapolated to $\alpha = 0$,the intercept gives the transition band gap [6].

The optical absorption coefficient α (cm^{-1}) which is a function of wavelength can be calculated from the optical absorbance spectra by using the relations:

$$I = I_0\, e^{-\alpha t} \qquad (3)$$

Where I is the incident intensity and I_0 is the penetrating light intensity, and t is the thicknesses of matter (cm) and a is the absorption coefficient $(cm)^{-1}$.

Where the amount of log I/I_0 represents the absorbance (A).

The absorption coefficient can be calculated by:

$$\alpha = 2.303(A/t) \qquad (4)$$

The refractive index n can be expressed by:

$$n = \frac{1+\sqrt{R}}{1-\sqrt{R}} \qquad (5)$$

The extinction coefficient can be calculated by:

$$k = \frac{\alpha\lambda}{4\pi} \qquad (6)$$

Where λ is the wavelength of the incident ray.

The relation between the complex dielectric constant and the complex refractive index *N* is expressed by:

$$\varepsilon = N^2 \qquad (7)$$

It can be concluded that:

$$(n-ik)^2 = \varepsilon' - \varepsilon'' \qquad (8)$$

The real and imaginary complex dielectric constants can be expressed by Equation 9 and 10, respectively:

$$\varepsilon' = n^2 - k^2 \qquad (9)$$

$$\varepsilon'' = 2nk \qquad (10)$$

The optical conductivity, σ_{opt} ,is related to light speed and can be expressed by the following equation:

$$\sigma_{opt} = \frac{\alpha n c}{4\pi} \qquad (11)$$

EXPERIMENT

Materials

The materials tested in this study were novolac, formaldehyde, sodium hydroxide, phosphoric acid, dimethyl formamide and Rhodamine 6G.

Preparation of Resol novolac Resin (RNR)

RNR can be prepared by using a three necked flask, equipped with mechanical stirrer and digital thermometer was charged with 100g (0.19mole) of novolac powder and 250 ml (3.32 mole) formaldehyde solution. The reaction mixture was mixed and 10% sodium hydroxide solution was added in order portions to control pH to about 9 while temperature of the reaction was kept at 50-60 °C for 3hrs. The reaction mixture was cooled and neutralized with 10% phosphoric acid solution, the organic layer was separated and purified by washing several times with distilled water, then curing in oven at 60c for 2hrs [7].

Doping of RNR

Doping RNR with dye Rhodamine 6G is carried out by adding the weighed dye to the appropriate weight of polymer (1g) then the mixture was dissolved in dimethyl formamide DMF after the prepared directly to give a polymer / dye system containing (0.01, 0.03, 0.05, 0.07 and 0.1) g wt% of doping reagent Rhodamine 6G [8]. The mixture was stirred well for 15 minutes to guarantee that the homogenous distribution of dye in the polymer matrix, and then coated on a glass substrate (with certain dimensions) by casting method at room temperature (RT). The thickness of the films were measured using Micrometer. The spectra of absorption was recorded for wavelengths 200-800 nm using UV-visible spectrophotometer model (U-V-25400-38) by SHIMADZU Co.

RESULTS AND DISCUSSION

Figures (1) and (2) show the relationship between absorbance versus wavelength with range of (200-800) nm at room temperature for RNR and its doping with different ratios of dye rhodamine 6G (Rh6G) thin films respectively. There is only one peak that can be seen for pure RNR at 356 nm related to π-π^*, while there are two peaks that can be observed for all doping ratios, at one about 343-354 nm related π-π^* while the other is located at about 540-557 nm related to Rhodamine 6G [9].

Figure (3) shows the relationship between absorption coefficient (α) versus photon energy (hυ) for PFA with different doping ratios.

The value of absorption coefficient larger than 10^4 cm^{-1} suggests the occurrence of vertical transition at fundamental absorption edge and is related to direct transition according to equation (1). According to equation the plot of $(\alpha h\upsilon)^2$ versus photon energy are shown in figures (4)-(9). From the figures, it can be noticed that the energy gap of the RNR films decreases with increasing doping ratio. the values of direct band gap energy with different doping ratios are tabulated in table (1).

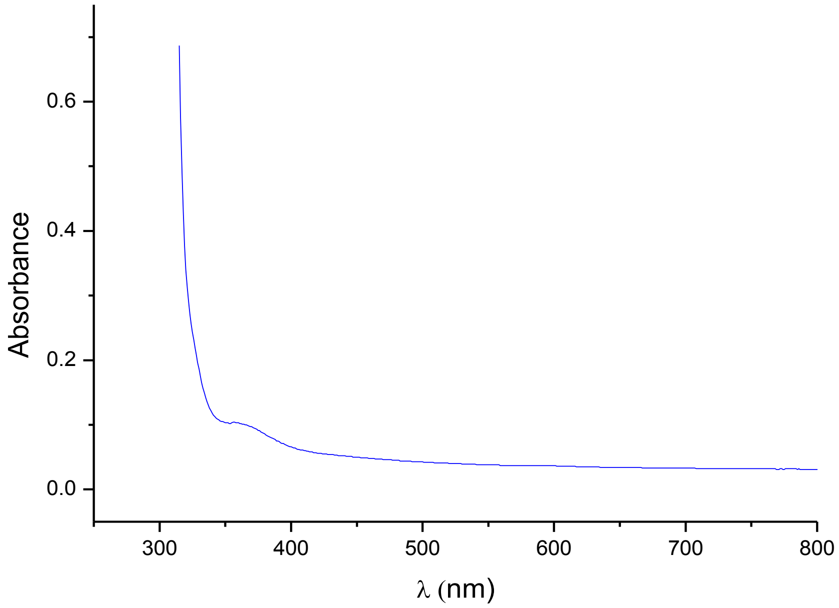

Figure (1): The relationship between absorption and wavelength for RNR.

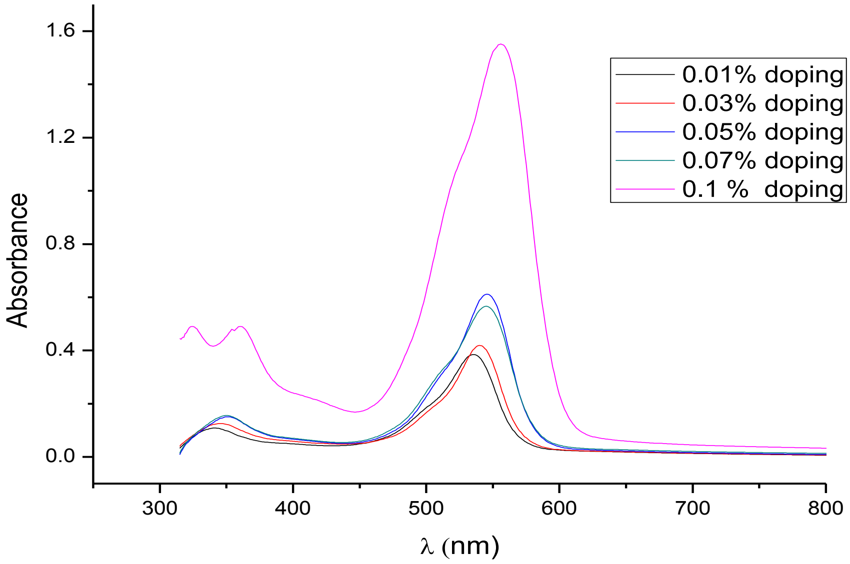

Figure (2): The relationship between absorption and wavelength for different doping ratios of RNR.

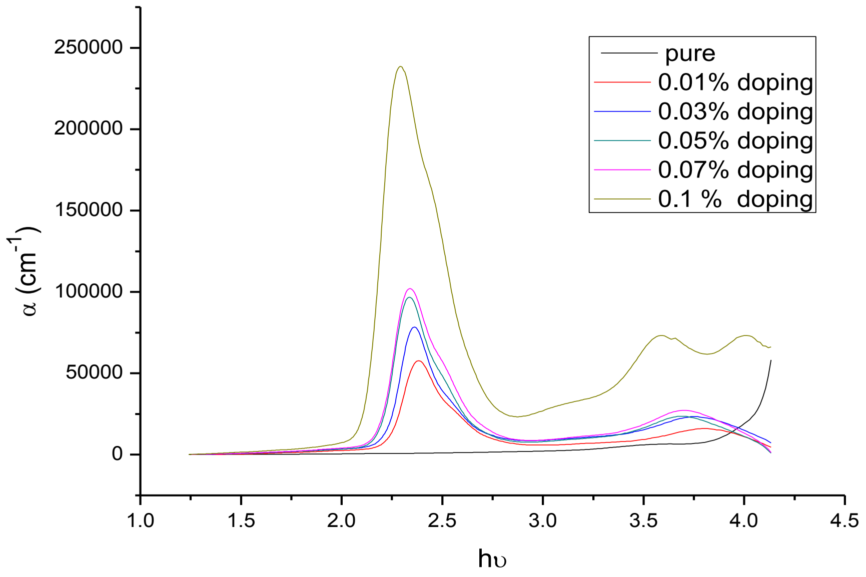

Figure (3): The relationship between absorption coefficient and photon energy for RNR with different doping ratios.

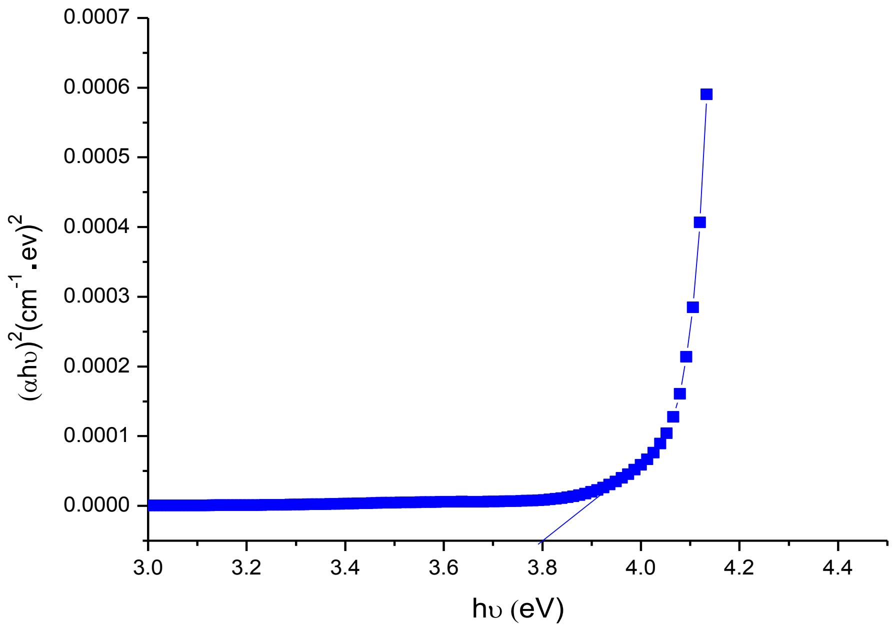

Figure (4): The relationship between $(\alpha h\upsilon)^2$and photon energy for RNR.

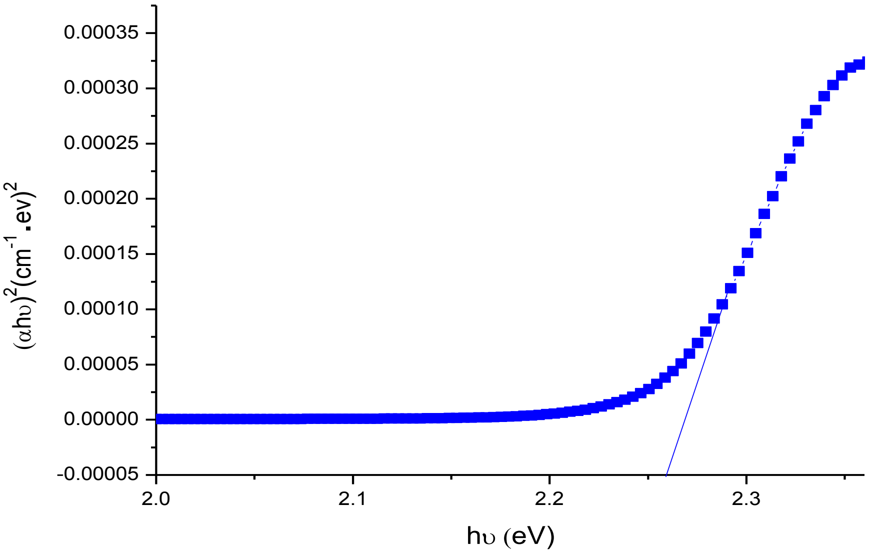

Figure (5): The relationship between $(\alpha h\upsilon)^2$and photon energy for (0.01%) of doping RNR .

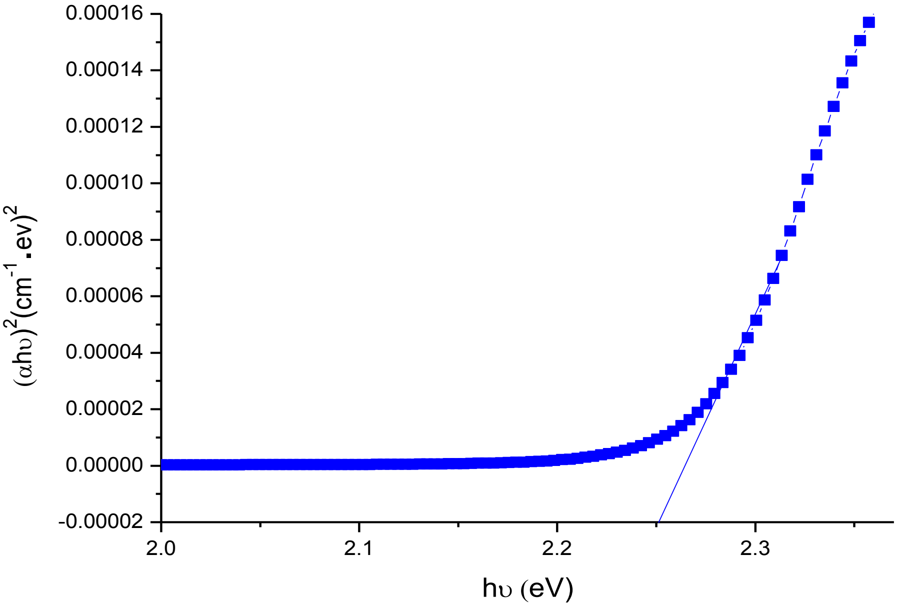

Figure (6): The relationship between $(\alpha h\upsilon)^2$and photon energy for (0.03%) of doping RNR.

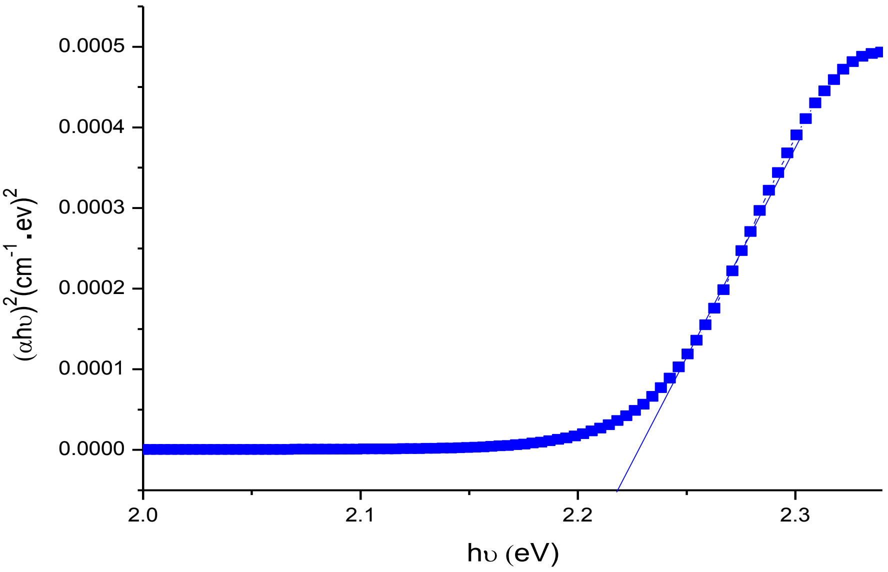

Figure (7): The relationship between $(\alpha h\upsilon)^2$and photon energy for (0.05%) of doping RNR .

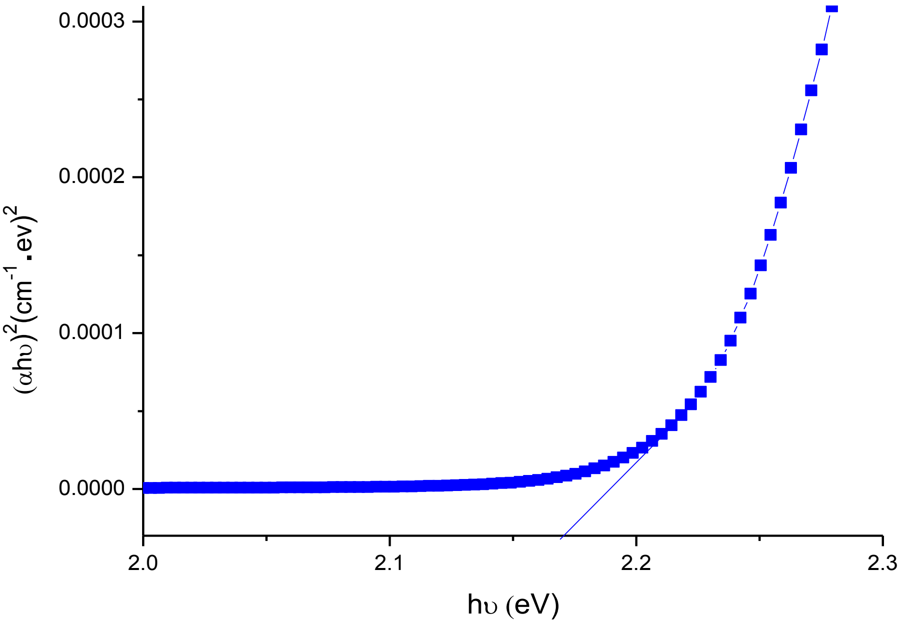

Figure (8): The relationship between $(\alpha h\upsilon)^2$and photon energy for (0.07%) of doping RNR .

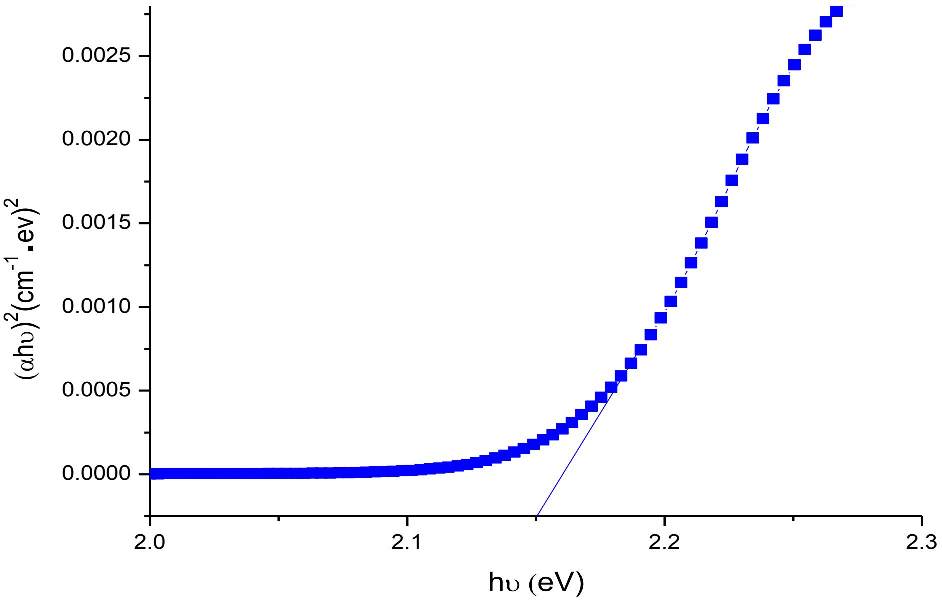

Figure (9): The relationship between $(\alpha h\upsilon)^2$and photon energy for (0.1%) of doping RNR.

Table (1): Direct band gap energy (E_g) values for doping RNR film with different doping ratios.

Doping ratio%	E_g
0	3.8
0.01	2.26
0.03	2.25
0.05	2.22
0.07	2.16
0.1	2.15

Figures (10) - (12) illustrate the relation between real part (ε_r) of dielectric constant with photon energy for pure RNR and its doping with different ratios respectively. In the range of (1.4-3.7) eV the real part of dielectric constant for RNR is independent on photon energy in this region which is corresponding to the high wavelength, while in the range of (1.5-2) eV the real part of dielectric constant for doping ratios of RNR is independent on photon energy in this region which corresponds to the high wavelength. The real part of dielectric constant was increased sharply in the high photon energy greater than 3.8 for RNR and 2.1 eV for all doping ratios. Similar behavior was observed by Ibrahim and Salem [10].

Figures (13) and (15) show the relation between imaginary part (ε_i) of dielectric constant with photon energy for pure RNR and its doping with different ratios espectively. It is clear from the figure that the imaginary part is independent on photon energy in the range (1.4-3.7) eV for

RNR and (1.5-2) eV for doping ratios. The imaginary part of dielectric constant was increased sharply in the high photon energy greater than 3.8 for RNR and 2.2 eV for all doping ratios.

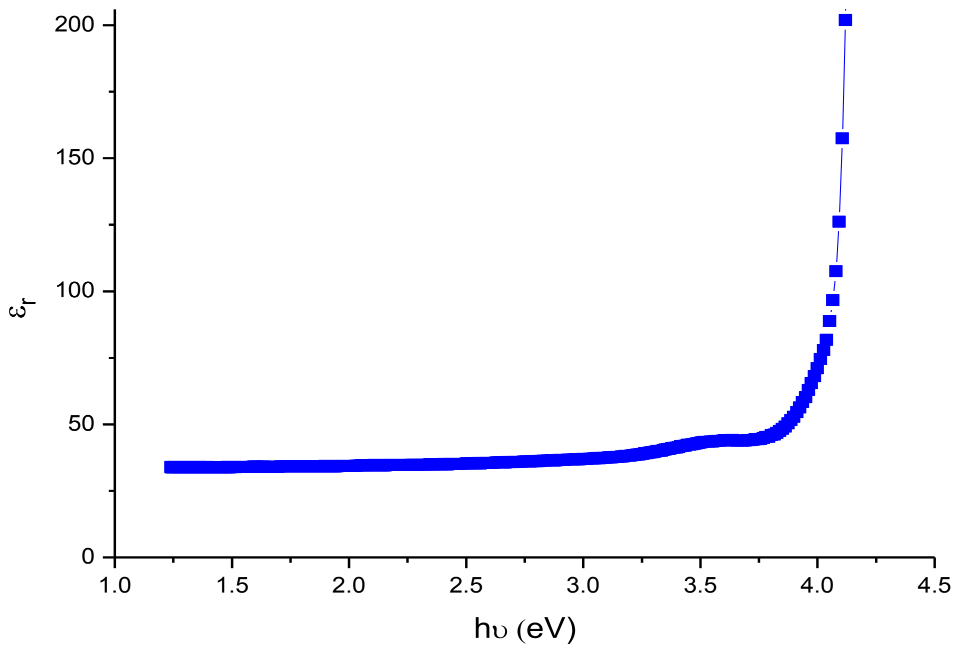

Figure (10): The relationship between real part and photon energy for RNR .

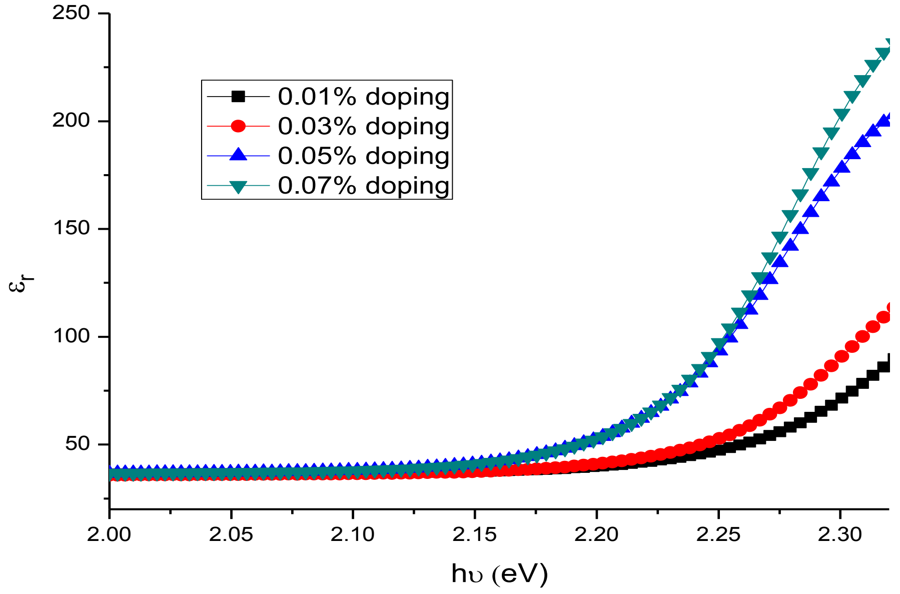

Figure (11): The relationship between real part and photon energy for RNR with different doping ratios.

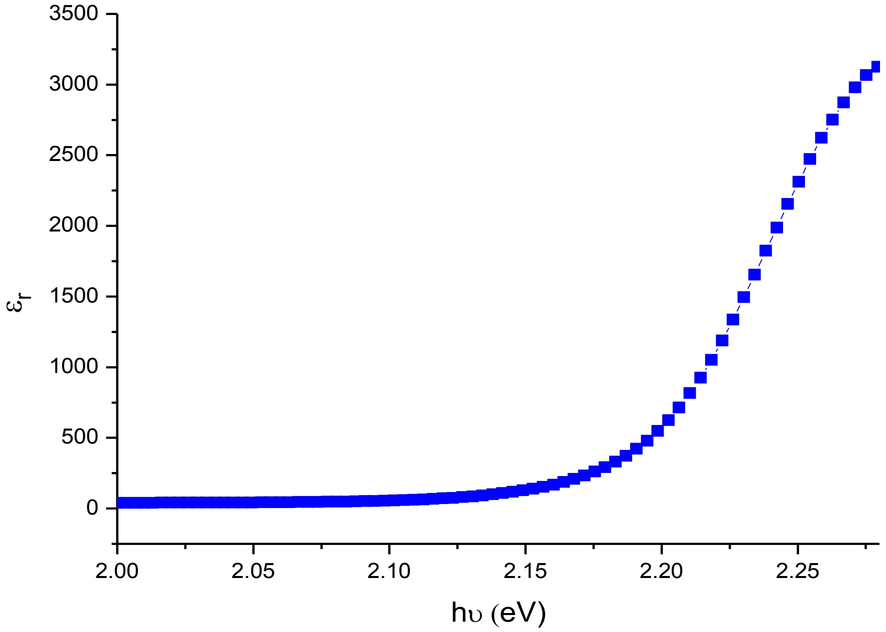

Figure (12): The relationship between real part and photon energy for RNR (0.1%) doping.

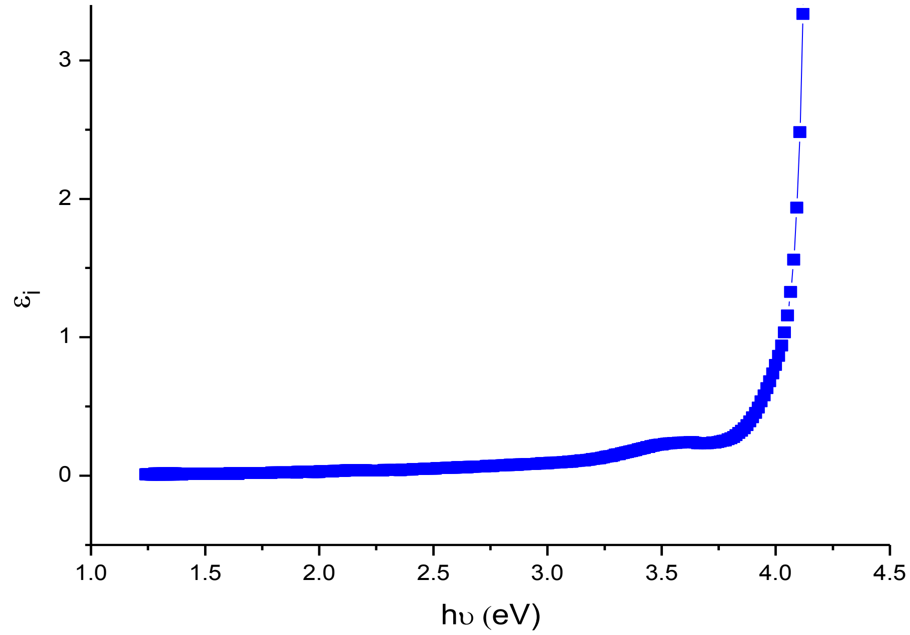

Figure (13): The relationship between imaginary part and photon energy for RNR .

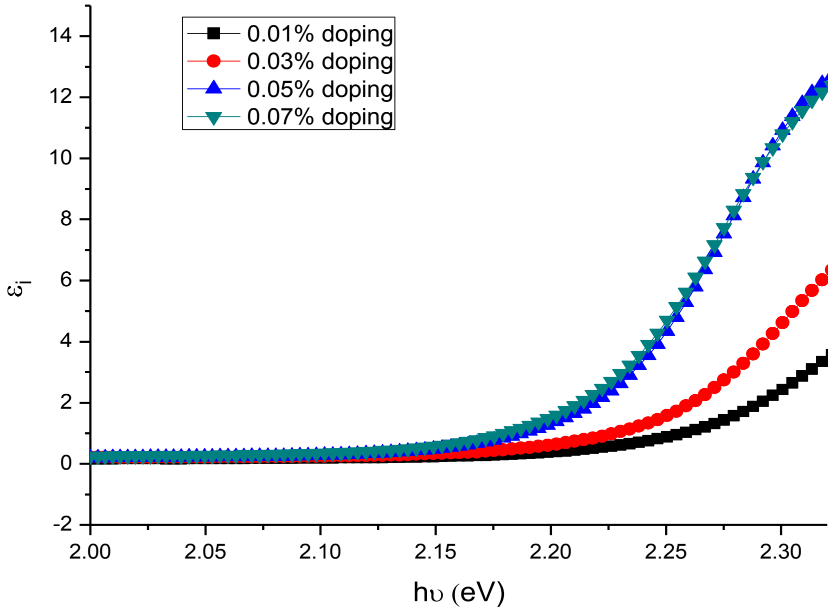

Figure (14): The relationship between imaginary part and photon energy for RNR with different doping ratios.

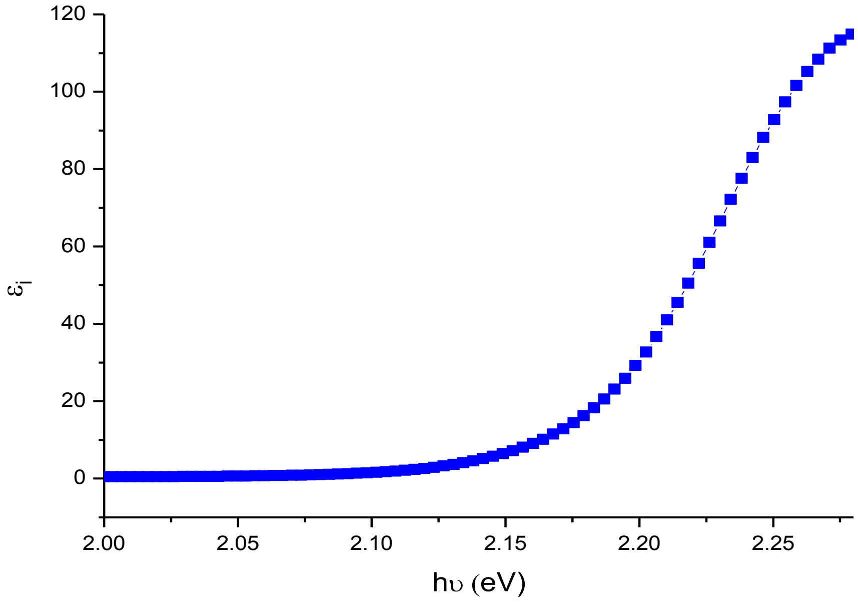

Figure (15): The relationship between imaginary part and photon energy for RNR (0.1%) doping.

Figures (16) - (18) show the relation between optical conductivity and photon energy for pure RNR and doping ratios. It is clear that an increase in optical conductivity is occurred as doping percentage increase. This means that the doping ratios increase the contribution of electron transitions between the valance and conduction bands, which lead to reduction of energy gap as a result of sit level generation [11].

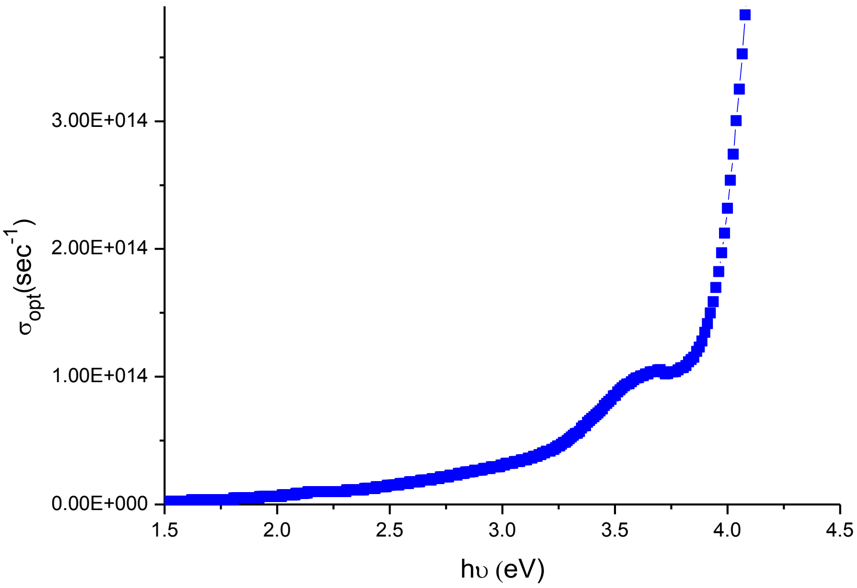

Figure (16): The relationship between optical conductivity and photon energy for RNR.

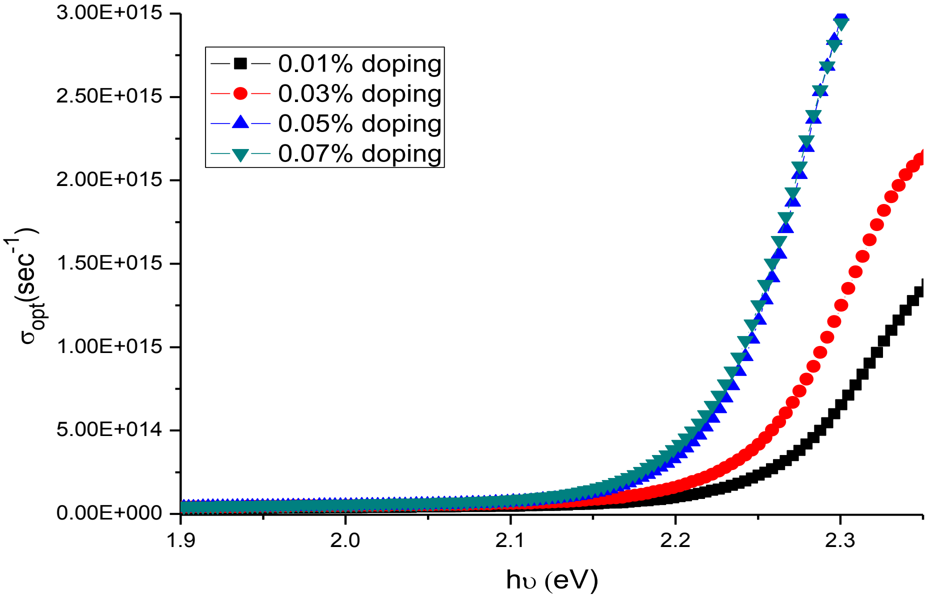

Figure (17): The relationship between optical conductivity and photon energy for RNRwith different doping ratios.

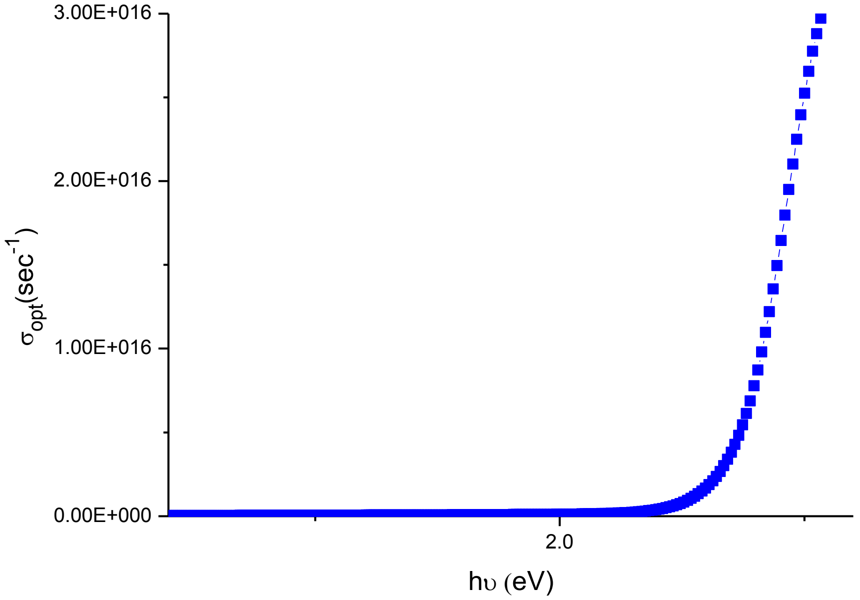

Figure (18): The relationship between optical conductivity and photon energy for RNR (0.1%) doping.

CONCLUSION

Resol Novolac Resin doped with Rhodamine 6G thin films have been prepared by cast method technique. The optical transmission spectrum is used to calculate the optical Parameters such as absorption coefficient, real and imaginary parts and optical conductivity where found to be increasing with increasing of doping ratios. The energy gap of direct transition decreases with increasing doping ratios.

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