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Study the Optical Characteristics of Epoxy Panel doped with Fluorescein-Sodium Dye

دراسة الخصائص البصرية لألواح الإيبوكسي المطعمة بصبغة الفلورسين-صوديوم

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Abstract:

In this study the luminescent solar concentrators (LSC) plates doped with fluorescein-sodium dye laser have been prepared in the laboratory at room temperature with(0.5mm) thickness .The concentration of the fluorescein-sodium dye laser were(10^{-5},10^{-4}) mol/L. Then they compared with pure epoxy panel. The optical characteristics have been studied like (absorption, transmittance, reflectance and energy gap) also the optical constant were calculated including (absorption. coefficient, refraction index and extinction coefficient) for all panels.

The effect of increasing concentration leads to shift the absorbance, absorption coefficient and extinction coefficient towards higher wavelength, their values also increase with increasing the concentrations. With regard to transmission ,reflectance and refractive index the concentration effect also leads to the same displacement, but their values decrease with increasing the concentration.

The results also shown that the value of the energy gap is decreased from (3.6eV) for epoxy resin to (2.3,2.25)eV for the both concentrated panels.

الخلاصة:

تم تحضيرألواح الإيبوكسي المطعمة بصبغة الفلورسين –صوديوم الليزرية (LSC)في المختبر وبدرجة حرارة الغرفة وبسمك (0.5 ملم) وكانت تراكيز الفلورسين-صوديوم هي(10^{-4},10^{-5}) مول/لتر ثم قورنت النتائج مع لوح الإيبوكسي النقي.

درست الخصائص البصرية مثل (الإمتصاصية،النفاذية، الإنعكاسية وفجوة الطاقة) وكذلك تم حساب الثوابت البصرية التي تشمل (معامل الإمتصاص ،معامل الإنكسار،و معامل الخمود) لجميع الألواح.

وجد أن تأثير زيادة التركيز أدى إلى إزاحة الامتصاصية ومعامل الامتصاص ومعامل الخمود نحو الأطوال الموجية الأعلى وبزيادة التركيز فإن قيم الإعلومات أعلاه سوف تزداد. بالنسبة إلى النفاذية والإنعكاسية ومعامل الإنكسار فإن تأثير التركيز يؤدي إلى نفس الإزاحة أعلاه، لكن في قيمها قلت بزيادة التركيز.

اظهرت النتائج إن قيمة فجوة الطاقة قلت من (3.6 الكترون فولت) للايبوكسي النقي إلى (2.3، 2.23) الكترون فولت لكلا اللوحين المركزين.

Introduction:

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 sun light and emit light at longer wavelength [1].(LSC) in our work was made by dissolving fluorescein sodium dye(FS) in epoxy resin. In 2008,Suma made (LSC) plates by dissolving Rohdamine 6G dye in epoxy resin, she studied the optical properties and optical constants for all pure and doped epoxy plates at many thickness and concentrations, she found that the effect of plates thickness confront the effect of dye concentration[2].

Polymeric structures are divided into two types, namely thermoplastic and thermoset polymers, thermoset polymers have a distinct structure called ‘cross-linked networks’ between the polymer chains, epoxy resin is one of the thermoset polymers [3].The first production of epoxy resins occurred simultaneously in Europe and in United States in the late 1930_s and early 1940_s[4].Then they were first commercialized in 1946 and are widely used in industry as protective coating and for structural application such as laminates and composites, tooling ,molding ,casting, bonding, adhesives [5] ,aerospace[6],and spacecraft industries[7].

The ability of the epoxy ring to react with a variety of substrates gives the epoxy resins versatility[5].the epoxy resins offer unique combination of properties that are unattainable with other thermoset resins[8].Some of the characteristics of epoxy resins are high chemical and corrosion resistance ,good mechanical (strength and stiffness),thermal properties[9],excellent weather resistance),excellent performance at elevated temperature[10],low cost, low toxicity[8] and versatility in processing.[10].The simplest epoxy resin is prepared by the reaction of bisphenol A with epichlorohydrine as shown in fig.(1)[7].

Epoxy resins systems are made up of an epoxy resins and curing agent (also called a hardener or catalyst).Many epoxy products also contain additives such as organic solvents, fillers such as fiber glass or sand and pigments[6]. The choice of curing agents depends on the required physical and chemical properties ,processing methods and curing conditions[11].when epoxy resin systems are used,single molecules(monomers) of the epoxy resin chemical and the curing agent combine to form long chains of molecules (polymers).As the mixture "cures", it becomes a hard polymer .Some epoxies curves in a few minutes at room temperature other need additional time or heat to harden[5].

Laser dyes is one of the organic luminescent materials rather of complex chemical structure with high molecular weight because of they are consist of carbon atoms chain connected alternatively by single and double band called chromfore[12].Laser dyes are classified according to chemical structure into some classifications. Xanthenes dyes is one class of them, emission range to them about (500-700)nm[13].Xanthenes class also classified into two types one of them is flourescencein type[14] ,it's diagram shown in the fig.(2)[15].

The purpose of the present work is to fabricate (LSC) by doping the fluorescence dye in epoxy resin and study the effect of the floursine-sodium dye concentrations on the optical characteristics of the epoxy panel and compared them with pure ones.

Experimental Details

1- Preparation of the samples:

All fluorescence panels are prepared in the laboratory with thickness (0.5 mm) for pure and all different doped rates .The chemical epoxy name isbisphenol -A- (epichlorhydrin) .epoxy resin (number average molecular weight 700 g/mol ,and it is of limpid color. The molecular formula of fluorescein-sodium dye laser is $C_{20}H_{10}Na_2O_5$,it's molecular weight 376.27gm/mol and it's color Orange -red to dark red.

The processes of preparing panels are as follows:

1-Prepare the desired concentration of the dye by weighting the right amount of dye by the equation[16] :

$$W = \frac{M_w \times V \times C}{1000} - - - - - (1)$$

Where W weight of the dissolved dye (g)
M_w Molecular weight of the dye (g/ mol)
V the volume of the solvent (ml)
C the dye concentration (mol / L)

2- Dissolving the amount of the dye that was weighing in the specified size of an epoxy resin solvent A and mix well for ten minutes to ensure dissolving well and the high concentration increases the time required for melting .

3-Add hardener (B) to resin (A) which doped by dye at the requirement concentration, with constant stirring for a specified period depends on the type of epoxy used, (to the epoxy for this study 5 min).

{For pure epoxy add hardener (B) to resin (A)}

5- The mixture is placed in the mold to create fluorescence panels and is left for 24 hours at room temperature in order to be fully polymerization process and could raise the panels from the mold .Where the processing casting molds according to the desired measurement is (10×10) cm^2.

6- Homogeneity was confirmed for all Luminescent Solar Concentrator (LSC) through the examination of optical properties for samples that include (absorbance, transmittance) from different parts of the plate.

The concentrations prepared are(1×10^{-5}, 1×10^{-4})mol/L.

Measurements:

Spectrophotometer SP 8001 proved from Metertech company was used to measurement the absorption and transmition spectra in the wave length range (190-1100)nm for all panel samples.

2-Results and Discussions:

Absorbance Spectra:

The absorption spectra of pure and doped epoxy with different concentration of FS dye laser are shown in fig(3).The absorbance of pure epoxy has higher absorption at (280 nm), in ultra-violent region. But when it doped with floursine- sodium dye laser the absorption spectra shifted to a higher wavelength in the visible region. Fig.(3) also illustrated that as the concentration of FS dye laser increases, the absorbance intensity increases with a little shifting towards higher wavelengths, this agree with beer-Lambert law.

Transmission Spectra:

Fig.(4) shows the optical transmission spectra of pure and doped epoxy of FS dye laser, it has opposite behavior of the absorbance spectra for all samples. A high optical transparency of about (85-92)% in the visible region is observed for pure epoxy. With regard to doped epoxy the transmission spectra displaced to higher wavelength, they have transmission lower than pure one .

Absorption Coefficient:

Absorption coefficient represents the attenuation that occurs in incident photon energy on the material for unit thickness, and main reason for this attenuation is attributed to the absorption processes [17].

From the absorbance data, the absorption coefficient (α) was calculated in the fundamental absorption region using Lambert law[18] :

$$Ln(I_0/I) = 2.303A = \alpha d -----(2)$$

$$\alpha = 2.303A/d -----(3)$$

Where I_o and I are the intensity of incident and transmitted light respectively ,(A)the optical absorbance and (d) the film thickness . Fig.(5) shows the variation of absorption coefficient with photon energy for pure and doped epoxy where their values increase rapidly beyond absorption edge regions for the two situations(pure and doped epoxy).

Reflectance:

Fig.(6) shows the optical reflectance spectra for pure and doped epoxy. The reflectance has been found by using the relationship[18]:

$$R + T + A = 1 ----- (4)$$

For pure epoxy the fig. shows a low reflectance about (0.07-0.04) at visible wavelength region, while the doped samples have reflectance higher than pure one about at the range of wavelength (560-1100)nm.

The highest reflectance value is nearly (0.2) for all pure and doped samples at different wavelengths for each one.

Refractive Index:

The refractive index (n) was calculated by using the following relationship[18]:

$$n = [(\frac{1+R}{1-R})^2 - (K^2+1)]^{1/2} + \frac{1+R}{1-R} ------ (5)$$

The refractive Index (n) versus wavelength (**λ**) curves of pure and doped epoxy samples are shown in fig.(7). The behavior of this fig. is similar to the behavior of reflectance spectra in fig(6), because of the strong dependence calculation of the refractive index values on the reflectance values and because of the low values of extinction coefficient as above relationship[19].

For pure epoxy ,as seen in the figure ,that the refractive index has the largest value (n=2.64) at wavelength (327 nm),then it decreases with increasing the wavelength until it reaches to the visible region where the refractive index is low.

Its preferably to use a material with low refractive index because it leads to increase the number of losing luminescent photons from the bottom surface through the critical angle(θ_c), so that refractive index is inversely proportional to the type of losses calculated by the equation[2]:

$$\theta_c = \sin^{-1}(\frac{1}{n}) ----- (6)$$

For doped samples the refractive index decreases with increasing the concentration of FS dye at the visible and infrared region.

Extinction Coefficient

Extinction coefficient (k) for all samples was calculated by using the relation [18]:

$$K = \frac{\alpha\lambda}{4\pi}. ------ (7)$$

Variations of extinction coefficient as a function of wavelength are shown in fig.(8). It can be seen from fig.(7) and fig.(8) that at every lowest value of refractive index there is highest value for extinction coefficient [19].

Energy Gap:

Study of material by means of optical absorption provides a simple method for explaining some features concerning the band structure of material. For determination of optical band gap energy, the method based on the following relation[19]:

$$\alpha h\nu = A(h\nu - E_g)^r ------ (8)$$

Where hυ is the photon energy, E_g the band gap energy, A and r are constants. The value of r depends on the nature of the transition. In this case it's value was found to be 1/2 (which corresponds to direct band to band transition)[20]. The figures(9,10,11) show the plot of $(\alpha h\upsilon)^2$ vs. hυ for pure and doped epoxy . The linear nature of the plot indicates the existence of direct transitions.

In above figures, from the straight line obtained at high photon energy the direct allowed energy gap could be determined**.** The value of the optical energy gap was highest in the pure epoxy sample while the lowest value was found with the sample having the highest concentration of FS dye laser i.e, the doping effect of epoxy with FS dye leads to decreasing the energy gap to the visible region which it is the active region in solar cell. This may be attribute to the formation of a localized states inside the band gab upper the valance and lower the conduction bands edges which refer the dopant atoms.

The values of the above optical parameters at energy gap for pure and doped samples are expressed in table (1).

Table (1)

FS concentration	E_g(eV)	λ_c (nm)	T%	α $(cm)^{-1}$	R	n	K
zero	3.6	344.44	73.7	7.2	0.14	2.207	1.8×10^{-5}
1×10^{-5}	2.3	539.130	70.6	8.7	0.144	2.22	2.9×10^{-5}
1×10^{-4}	2.25	551.111	57.1	12.9	0.19	2.5	5.2×10^{-5}

Conclusions:

1- Epoxy resin is a good solvent to fluorescein-sodium dye.

2-The pure epoxy which was used as a base in preparing the luminescent solar concentrators plates were suitable to be used as solar cell plate because of:

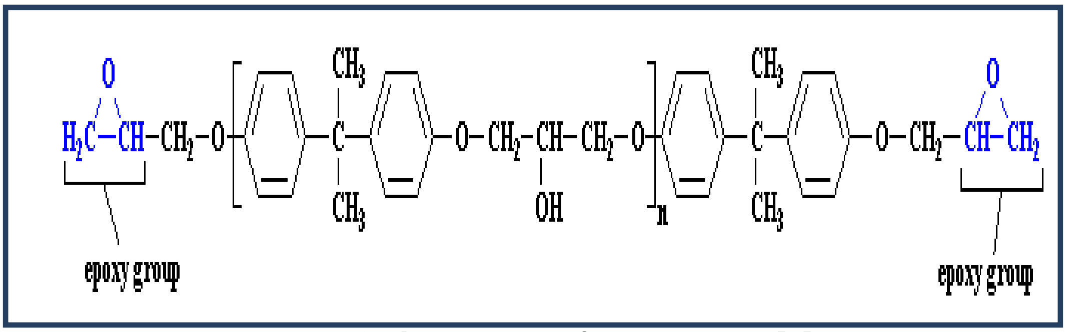
a- their absorption peak lies in UV region, exactly at wavelength (280 nm) which leads to absorb the high energy photons in the UV and decrease the temperature.

b-it's transmission range between (85-92)% in the visible light region which considered to be effective region for absorption of both cell and laser dye used.

3- Optical band gap E_g was determined from the absorption coefficient values, the value of optical band gap was highest in the pure epoxy(3.6eV),while the lowest value was found at doped epoxy plates (2.3, 2.25) eV which within the limits work of solar cell energy gap.

4-The refractive index decreases with increasing the concentration of fluorescein-sodium dye in the visible region.

5-Reflectance also decreases with increasing the concentration of fluorescein-sodium dye in the visible region.



Fig(1) The structure of epoxy groups [9]

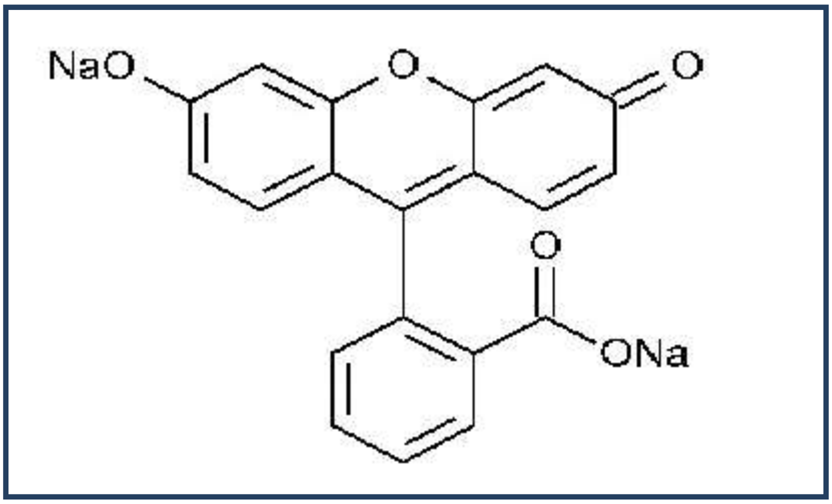


Fig.(2) The structure of fluorescein-sodium [18]

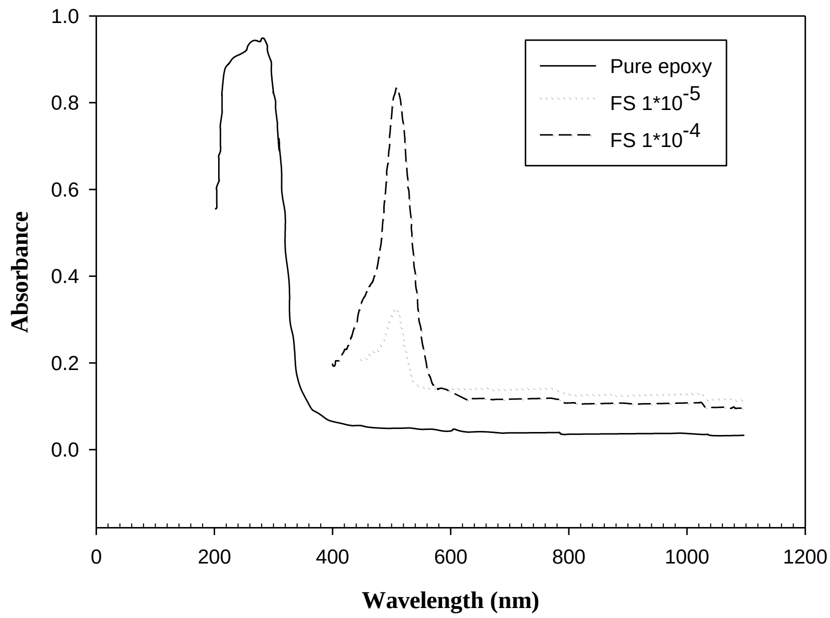


Fig.(3) Optical absorbance spectra of pure and concentrated epoxy with fluorescein- sodium dye.

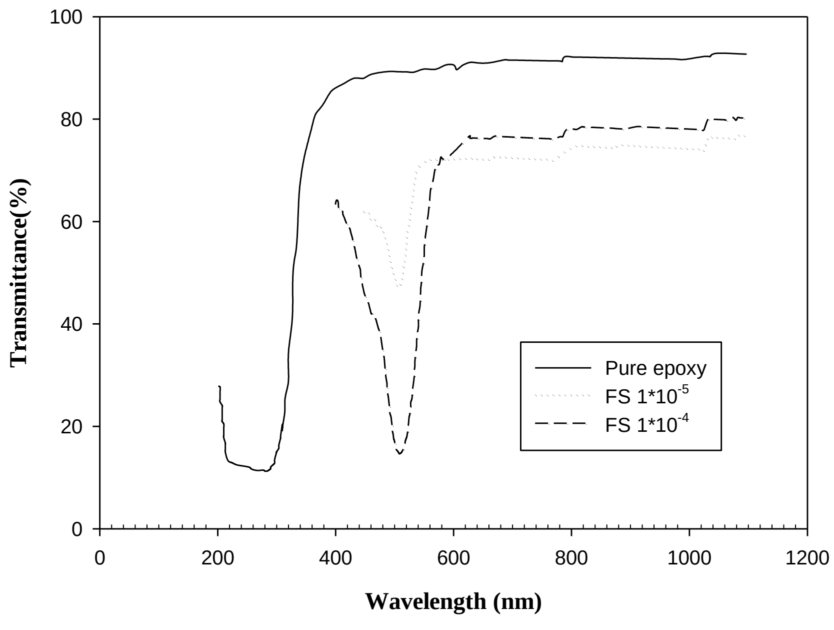


Fig.(4) Opticaltransmittence spectra of pure and concentrated epoxy with fluorescein- sodium dye.

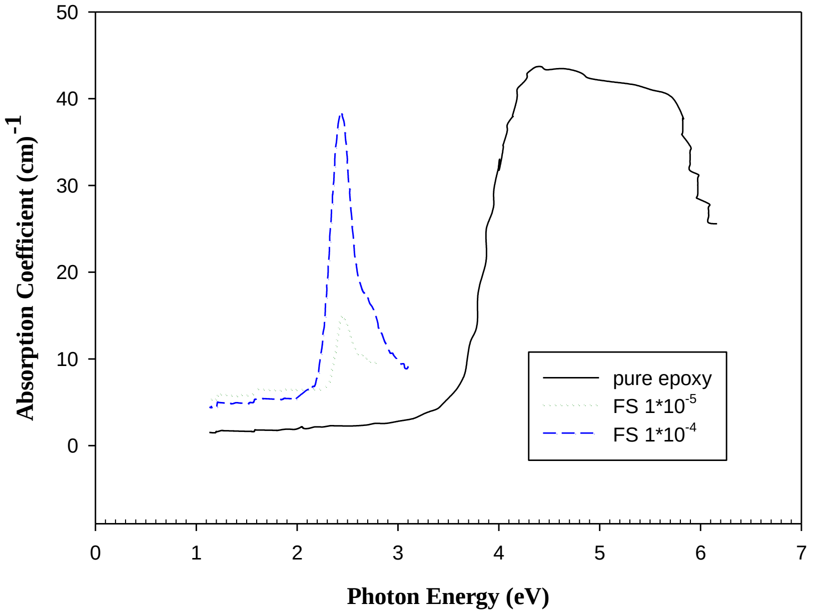


Fig.(5)Optical absorption coefficient vs. photon energy of pure and concentrated epoxy with fluorescein- sodium dye.

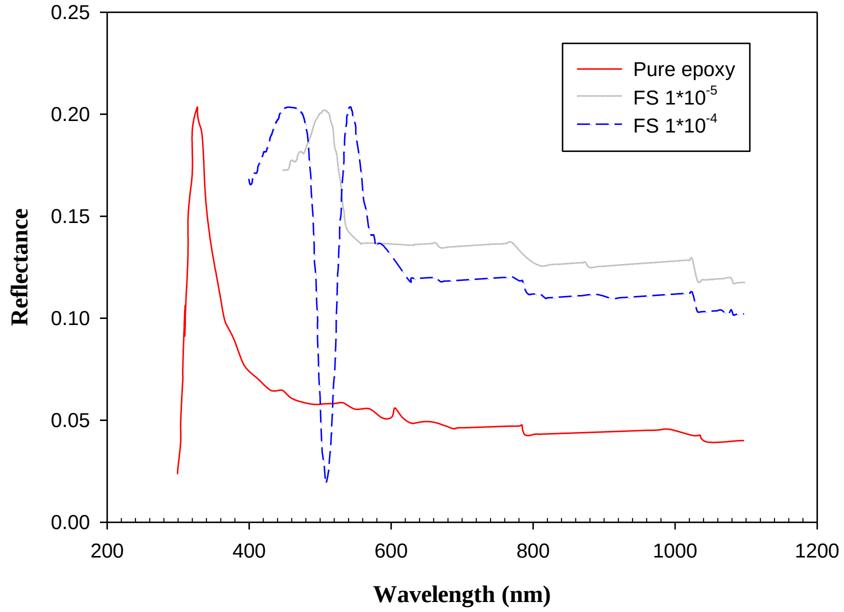


Fig.(6) Reflectance vs. wavelength of pure and concentrated epoxy with fluorescein- sodium dye.

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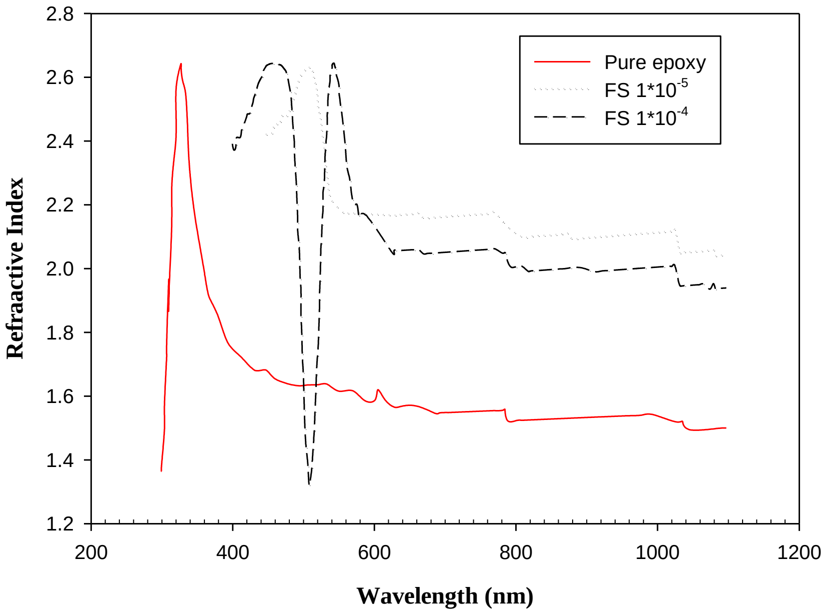

Fig.(7) Refractive index vs. wavelength of pure and concentrated epoxy with fluorescein- sodium dye.

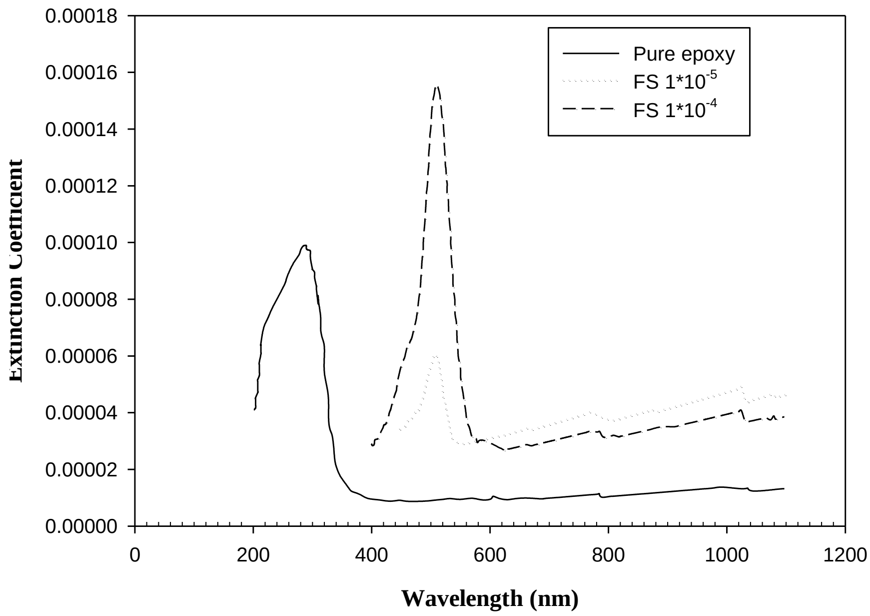

Fig.(8) Extinction coefficient vs. wavelength of pure and concentrated epoxy with fluorescein- sodium dye.

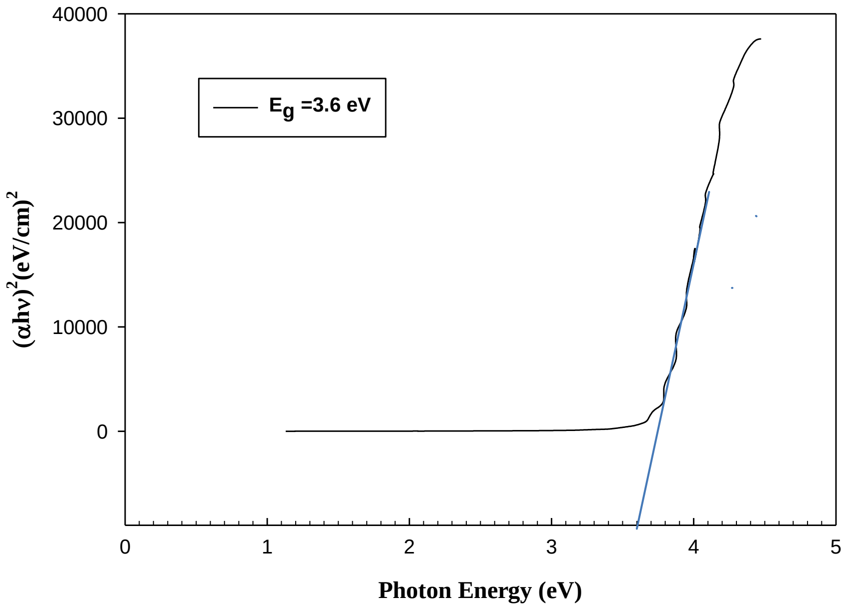

Fig.(9) Variation of $(\alpha h\upsilon)^2$ with photon energy for pure epoxy sample.

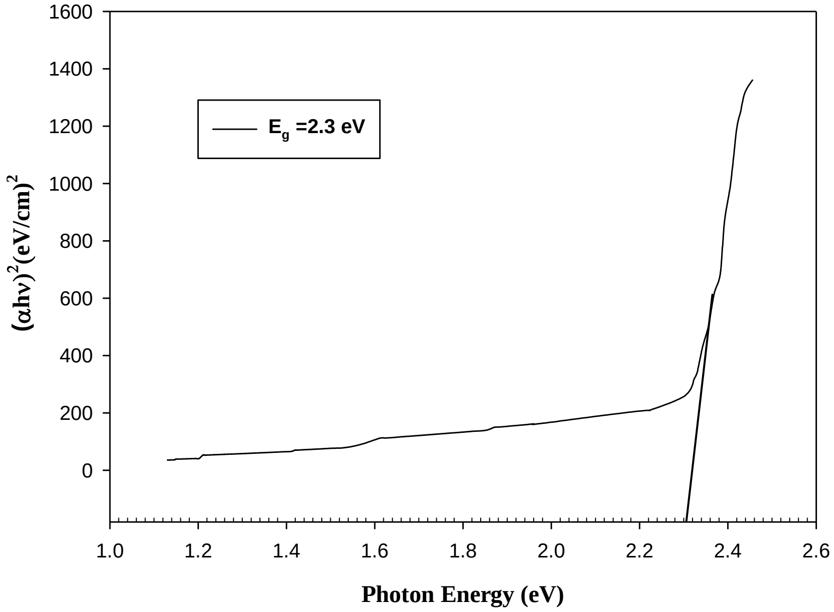

Fig.(10) Variation of $(\alpha h\upsilon)^2$ with photon energy for the concentration $(1\times10^{-5})$of doped epoxy sample.

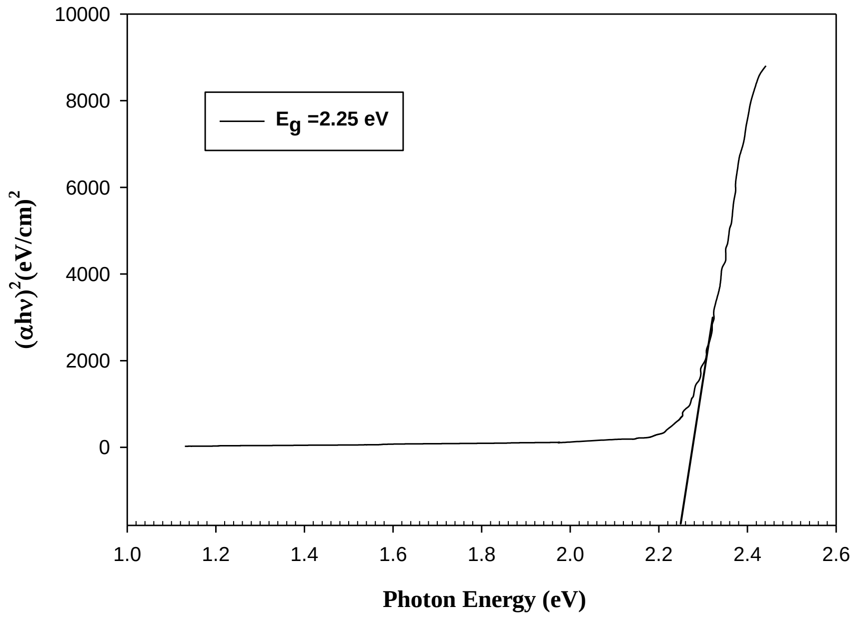

Fig.(11) Variation of $(\alpha h\upsilon)^2$ with photon energy for the concentration $(1\times10^{-4})$of doped epoxy sample.

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