Optical Properties Of Dye(P- Naphtholbenzein(α))

Abdulameer Imran Al-Mansaf

Department of Physics ,College of Education ,University of Basrah Basrah,Iraq

ISSN –1817 –2695

((Received 23/3/2011, Accepted 11/5/2011))

Absract

Thin film of a dye(p_Naphtholbenzein(α))was prepared by spin-coating technique on glass.The optical properties of the P-Naphtholbenzein(α)(with thickness $4\mu m$)were investigated at room temperature and they include absorbance/transmittance/reflectance, spectra, absorption coefficient ,extinction coefficient ,optical conductivity and complex dielectric constant.The data of absorption coefficient indicated for direct transition with direct energy gap (E_g).We have also studied Ubrach energy (ΔE) and the ratio of carrier concentration to the effective mass (N/m^*) .

Keywords: optical properties , dye, naphtholbenzein, optical constant, optical energy gap.

Introduction

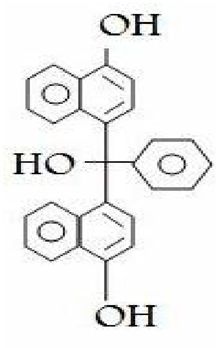
Optical properties have been the subject of numerous investigations by both theoreticians and experimentalists in recent years due to the potential applications in optical signal processing and computing. Detailed investigations of linear and nonlinear optical coefficients enable to fabricate materials, appropriately designed at the molecular level for specific applications such as optoelectronic devices[1,2]. Knowledge of optical constants of the materials (optical band gap and extinction coefficient) is vital to scrutinize the atomic structure, electronic band structure and electrical properties. The refractive index provides information about the chemical bonding and electronic structure of the material. An accurate measurement of the optical constant can be easily performed on semiorganic crystals [3].

Dye has received great attention due to its environment stability, ease of preparation, and its optical and electrical properties, the dyes color result from absorbance in the visible region of the spectrum due to the delocalization of electrons [4]. Absorbance of dye(p_ Naphtholbenzein(α)) in the visible region of the spectrum due to the delocalization of electrons in the benzene[4].

In the present work,we report the determination of the optical constants such as refractive index ,extinction coefficient, dielectric constants ,energy gap and optical conductivity of the p-Naphtholbenzene(α) dye thin film using optical spectra .

Experimental

Dye (P-Naphtholbenzein(α)) was prepared by chemical method according to reference [5].The molecular structure of the dye are illustrated in the following state :



Fig(1):Molecular structure of Dye(P-Naphtholbenzein(α))($C_{27}H_{20}O_3$).

The naphtholbenzon dye was prepared by spin-coating technique on glass .the dye powder were dissolved in DMSO solvent and stirred at room temperature for 3-4 hrs.The stirred solution was cast on the substrates cited horizontally to get a homogenous thickness.The solution allowed to evaporate slowely at room temperature followed by vacuum drying.

Theory

The optical absorption coefficient (α) was calculated using the following relation [6].

$$\alpha = \frac{2.303 Log(\frac{1}{T})}{d} \quad ....(1)$$

where T is the transmittance and d is the thickness of the material.The other optical constants were calculated using the following theoretical formulae [6,7].The extinction coefficient is obtained in terms of the absorption coefficient,

$$K = \frac{\lambda\alpha}{4\pi} \quad ....(2)$$

Where λ is the wavelength

The reflectance (R) was calculated by using the equation

$$T = (1-R)^2 e^{-2.303\alpha.d} \quad ....(3)$$

and the linear refractive index (n)is given by

$$n = \frac{1+\sqrt{R}}{1-\sqrt{R}} \quad ....(4)$$

Also the complex dielectric constant is defined as

$$\varepsilon = \varepsilon_r + \varepsilon_i \quad ....(5)$$

the real and imaginary dielectric constant is, respectively,

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

$$\varepsilon_i = 2n.K \quad ....(7)$$

The optical conductivity(σ_{op}) is a measure of the frequency response of the material when irradiated with light .

$$\sigma_{op} = \frac{\alpha.n.c}{4\pi} \quad ....(8)$$

where(c) is the light speed.

Results and discussion

Fig. (2) shows the optical absorbance spectra for the p-Naphtholbenzein (α) thin film. It has been observed that the low absorbance in visible and near infrared regions and the high absorbance in the ultraviolet region .The peak is observed in the wavelength 470nm.There is a distortion near the peak because of the small strange parts in the dye. Fig. (3) shows the transmittance spectra for the film. At $\lambda < 400nm$ fast increase was shown in small range but this increase becomes more slowly at $\lambda > 400nm$ because the change in the Absorbance curve. Fig. (4) shows the optical absorption coefficient is exponentially dependent on the incident photon energy and obeys the empirical Urbach rule [8]

$$\alpha = \alpha_0 .\exp(\frac{h\nu}{\Delta E}) \text{........(9)}$$

where ΔE is the Urbach energy and it can be evaluated as the width of the localized states, fig.(5) shows The relation between ln(α)and photon energy, the value of ΔE was found from this fig.(ΔE =0.474 e.V).

The determination of band gap energy(E_g)is often necessary to develop the electronic band structure of film material .Absorption coefficient(α)is related to the energy(E) of the incident photons by the relation[9] .

$$\alpha.E = B(E - E_g)^r \text{..............(10)}$$

where $E= h\upsilon$, E_g the optical energy gap, B is a constant and r is an index which can be assumed to have values of 1/2, 3/2, 2 and 3, depending on the nature of the electronic transition responsible for the absorption. r =1/2 for allowed direct transition, r = 3/2 for forbidden direct transition and r =3 for forbidden indirect transition, with r =2 refers to indirect allowed transitions [10], the energy band gap can be obtained by plotting($\alpha h\nu$)$^{1/2}$.
versus($h\nu$)in the high absorption range followed by extrapolating the linear region of the plots to (($\alpha h\nu$)$^{1/2}$=0).

Fig. (6) shows the relation between $(\alpha h\nu)^{1/2}$ and photon energy. It has been observed from this figure Eg=2.8 e.V . Fig. (7) shows the optical reflectance spectra for the p-Naphtholbenzein(α). The reflectance has been found by using the equation(3).There is a high reflectance in visible and near ultra violt region ,also it has been observed that the low reflectance is in infrared and near infrared region. The extinction coefficient has been measured as a function of photon energy fig. (8), this behavior is due to the variation in the absorbance. Fig. (9) shows the variation of optical conductivity with the incident energy, the optical conductivity increases with increasing photon energy range. The real and imaginary part of dielectric constant has been determined .Fig. (10) and (11) shows the variation in the real and imaginary part of dielectric constant with the incident photon energy, real part of the dielectric increases with increasing photon energy in low and middle range but it decreases in high range , two peaks appeared in the figure has small distortion, it results from strange parts in the material, imaginary parts of the dielectric constant increases with increasing photon energy range.The relation between real dielectric constant ε_r and the square of wavelength λ^2 is given by [11]

$$\varepsilon_r = \varepsilon_\infty - \frac{e^2}{\pi^2 c^2} \frac{N}{m^*} \lambda^2 \text{..................(10)}$$

Where ε_∞ is the infinity frequency dielectric constant, e is the electronic charge and N/m^* is the ratio of carrier concentration to the effective mass. The values of ε_∞ and N/m^* counted from fig. (12)

$\varepsilon_\infty = 1.744$, $N/m^*=3.13*10^{35}$ $kgm^{-1}.m^{-1}$

Conclusion

From this study it can be concluded that the film was found to exhibit high transmittance (80%-100%), low absorbance and low reflectance were found in the visible and near infrared region up to 900nm.

The energy gap has found (E_g=2.8 e.V)also we determined Ubrach energy (ΔE) 0.474 e.V and the ratio of carrier concentration to the effective mass (N/m^*) $3.31*10^{35}$ $kgm^{-1}.m^{-1}$. Value of energy gap and material nature influence on values of N/m^* and ΔE , Shajo Sebastian and M . Abdul Khadar studied the optical properties of 60B_2O_3–30 PbO–10 $PbCl_2$ [12] and found (E_g=3.21 e.V , ΔE =0.41 e.V , (N/m^*) =$2*10^{30}$ $kgm^{-1}.m^{-1}$) while J.C.Osuwa and C.I.Oriaku studied the optical properties of $Cu_{0.11}Cd_{0.40}S_{0.49}$ [13] and found(E_g=2.48 e.V , (N/m^*) =$5.51*10^{47}$ $kgm^{-1}.m^{-1}$).

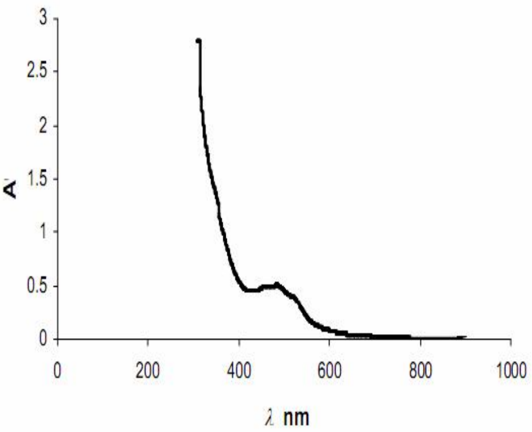


Fig. (2): The spectral absorbance (A)As afunction of wavelength(λ)

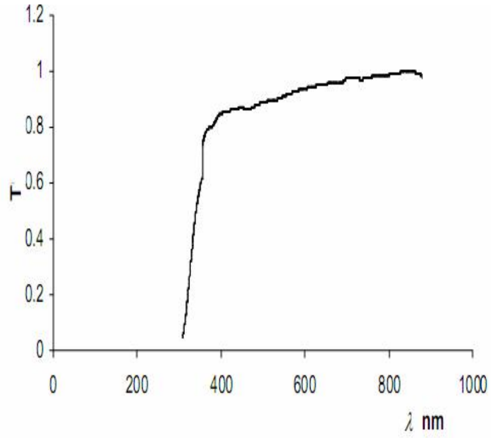


Fig.(3):The spectral transmission(T)As afunction of wavelength(λ)

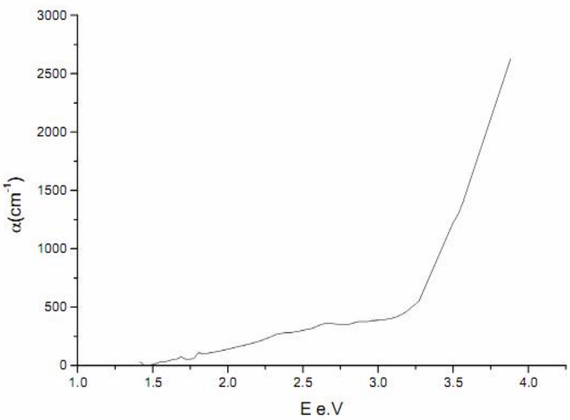


Fig. (4): Absorption coefficient (α) as function of photon energy(E).

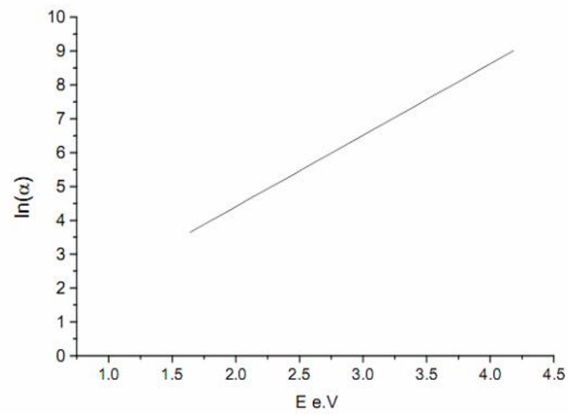


Fig.(5):Ln of absorption coefficient(α) as function of photon energy(E).

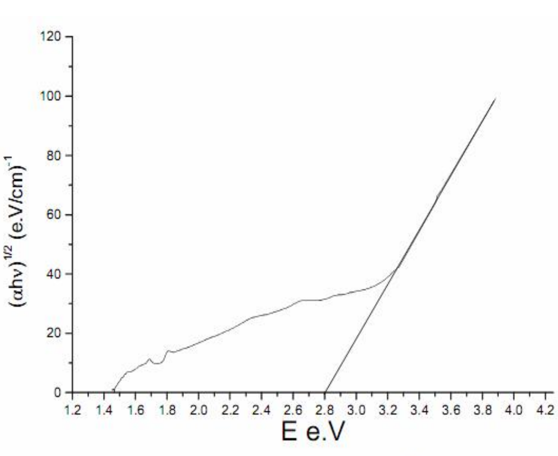


Fig. (6):Dependence of $(\alpha h\nu)^{1/2}$ on the photon energy(E)

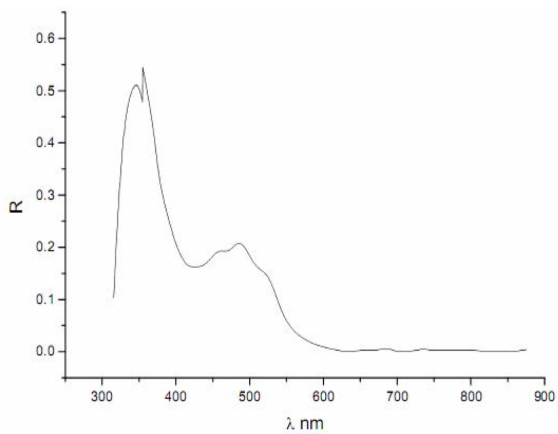


Fig. (7):Reflectance (R)as a function of wavelength(λ)

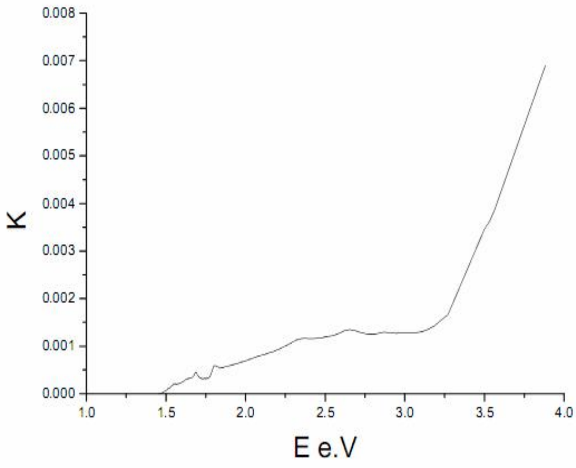


Fig. (8): Extinction coefficient (K)as function of photon energy(E)

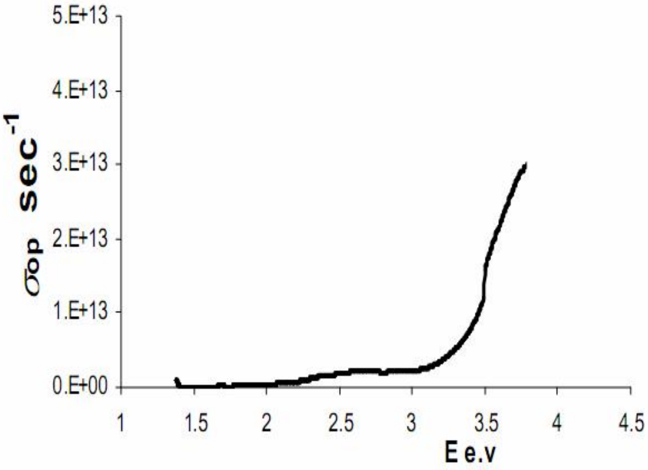


Fig. (9): Optical conductivity(σ_{op})as a function of photon energy(E)

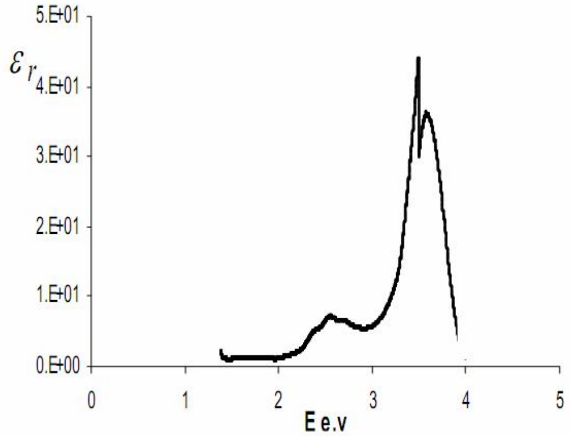


Fig. (10): Real part of dielectric constant(ε_r) as a function of photon energy(E)

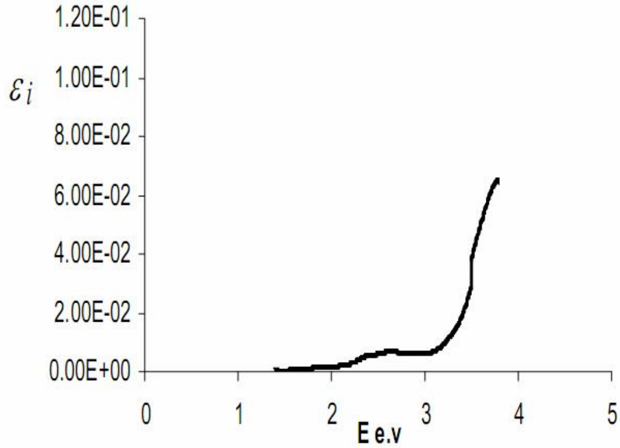


Fig. (11): Imaginary part of dielectric constant (ε_i) as a function of photon energy(E)

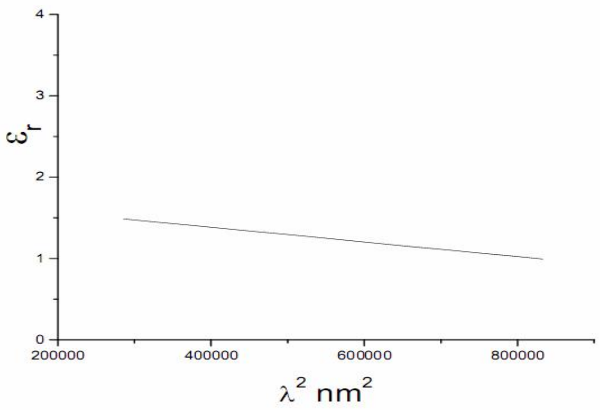


Fig. (12) :Real part of dielectric constant (ε_r)as a function of square of wavelength (λ^2)

References:

[1] J. L. Bredas, C. Adant, P. Tackx, and A. Persoons, Chem Rev. 243 (1994).
[2] P. V. Metha, N. Tripathi, and S. K. Kumar, Chalcogenide Lett. 2 39 (2005).
[3] M. Dongol, Egypt. J. Sol. 25 33 (2002).
[4] M.S.Aziz and H.M.El_Mallah,Indian journal of Pure& Applied Physics Vol45 p530 (2009)
[5] Aldrish ,fine chem. (1986-1987) .
[6] P. A. Henikhena, African Phys. Rev. 2, 68 (2008).
[7]J. I. Pankove, Optical Processes in Semiconductors (Prentice Hall, New York, 1971).
[8] F. Urbach. Phys. Rev. , 92, 627 (1966).
[9] T.Chen,Z.M.Zhang,Z.J.Ding,R.Shimizu,K.Goto, J.of Elect.Spectro.And Related Phemo.159 62 (2007).
[10]I.B.Lucy,J.Beynon,D.N.Waters,J.Mater.Sci. Lett.14 515 (1995).
[11]Tariq J.Alwan,Malaysian Polymer Journal Vol.5 p204 (2010).
[12] Shajo Sebastian and M . Abdul Khadar ,Indian Academy of Sciences (Bull. Mater. Sci.), Vol. 27, No. 2, p207. (2004) .
[13] J.C.Osuwa and C.I.Oriaku,Journal of Non-Oxide Glasses,Vol..2,No 1,p1,(2010).

الخلاصة:

تم معرفة الخواص البصرية لفلم (α)p_Naphtholbenzein المحضر بسمك 4 μm والتي تشمل طيف (الامتصاص والنفاذ والانعكاسية) و معامل الامتصاص ومعامل الخمود والتوصيلية البصرية وثابت العزل المعقد ضمن مدى الطول الموجي nm(300-900) و كذلك حساب بعض الثوابت الاساسية البصرية في درجة حرارة الغرفة .حيث تم تحديد قيمة فجوة الطاقة ب(2.8 e.V) و حساب طاقة Ubrach كذلك نسبة تركيز الالكترون الى كتلته المؤثرة (N/m^*) وثابت العزل الكهربائي في التردد اللانهائي(ε_∞) .