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Optical Properties of Polymer polyvinyl chloride (PVC) doped with DCM Laser-Dye and Tio2 Thin Film

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Abstract:

polyvinyl chlorideis blended with DCM laser dye co-doped with TiO_2 nanoparticle. The thin films were prepared by using casting method.The optical properties such as absorbance, absorption coefficient, refraction index and the optical conductivity of the prepared thin film have been studied at (30^{o}C).It has been shown from the results that allowed direct electronic transitions energy gap is(1.7eV),while allowed indirect electronic transition energy gap is(1.6 eV).

Keywords: Nanoparticle thin film, DCM laser dye, Polyvinyl chloride (PVC).

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الخلاصة:

في هذه الدراسة تم مزج بوليمر بولي كلوريد الفينيل (PVC) مع صبغة (DCM) الليزرية ومع جسيمات ثاني اوكسيد التيتانيوم (TiO_2) النانوية، وحضّرت الاغشية باستعمال طريقة الصب. درست الخواص البصرية كالامتصاصية، ومعامل الامتصاص، ومعامل الانكسار، والتوصيلية البصرية للأغشية الرقيقة المحضرة عند درجة حرارة ($300\ C^0$). تبيّن من النتائج ان قيمة فجوة الطاقة المسموحة المباشرة هي (1.7 eV)، بينما فجوة الطاقة غير المباشرة فتساوي (1.6 eV).

1. Introduction:

A thinfilm is a layer of material having thickness of the order of few nanometers. The use of thin film has been growing rapidly due to their important applications in various fields of science and technology[Ueda and Millin (1975)].Polymers are macromolecules built up by small molecules which are called "monomers" and reactions which are combine then are called polymerization[Rabee and Khudair (2015)]. A polymer of a particular group is characterized by the molecular weight of the monomer unit [Alwan (2010)].Polymers are used in electrical and electronic applications widely. In early works, these materials have been used as insulators because of their high resistivity and dielectric properties, while in recent years, polymers with different optical properties have been attracted much attentions due to their applications in the sensors, light emitting diodes, controlling contents of the different concentrations, solar cells, active and passive micro miniaturized components,magnetic memory device, reflection and antireflection coating etc[Maragatham et al. (2014)]. Polymers have several advantages, such as easy processing, low cost, flexibility, high strength, and good mechanical properties[Alias (2013)].Polymer thin film technology has made tremendous advancement in the last decade because of the range of technological applications that include coatings, lithography, organic light emitting diodes, sensors and electrochemical cells. In these material effects due to confinement and interfacial interactions are responsible for different physical phenomena those change with film thickness[Kramadhati and Thyagarajan (2013)]. There are various physical and chemical methods available for preparation of thin film like,pulsed laser deposition,chemical vapor deposition[Gopalrao (2014)], ion beam sputtering, thermal evaporation, vacuum deposition, sol-gel, chemical bath deposition etc..Some important characteristic gives polymers forefront to be a host for dyes which possess many favorable optical properties in comparison with other types of solid hosts[Costela et al. (2004)]. In this study the laser dye was DCM which has been mixed with PVC and Tio2 by using casting method.

2. EXPERIMENTAL PART:

2.1.Sample preparation:

Titanium dioxide nanoparticles have been prepared by using sol-gel method with dissolving (0.01185 gm) in (10ml) of THF solvent,whileDCM dye solution, (0.0225 gm) in (10 ml) of THF solvent. Polyvinyl chloride was by using as a host polymeric material in this work, the aqueous solution of this polymer was preparing by dissolving (3 gm) of PVC in (40 ml) THF,to obtain, (1ml DCM) solution mixed with (5ml) PVC solution and stirrer about (10 minutes) to obtain homogenies solution.(1.5ml) of TiO2 nanoparticles added to the mixture of DCM and PVC after that by usingthe cast method which casting on glass as substrate at (30^{o}C) temperature.

The optical interferometer method used to measure of the thicknessof the prepared thin films. It employing He-Ne laser (0.632 µm) withincident angle (45^{o}),this method depends on the interference of the laserbeam reflected from thin film surface and then substrate, the thickness of the film (d) can be calculated by using the following relation[Nair et al. (1991)]:

$d = \frac{\lambda}{2} \cdot \frac{\Delta x}{x}$(1)

where (λ) is the wavelength of the incident photon, (Δx) width of dark fringes, and (x) width of bright fringes.

2.2 Optical properties measurements:

Theabsorption and transmission spectra of the results of thin films were recorded by using UV-VIS double beam spectrometer in the wavelength rang (190-1100) nm. The absorption coefficient (α) was calculated by using the following relation[Hussian (2017)].

$\alpha = \frac{2.303}{d} A$(2)

where (A) the optical absorbance.

The extinction coefficient(K) can be calculated in terms of the absorption coefficient by using the relation [Xue (2008)].

$K = \frac{\alpha\lambda}{4\pi}$ (3)

The refractionindex (n) of the thin films are calculated from the equation [Aziz and El-Mallah (2009)].

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

The optical conductivity of thin films can be calculated by using the following relationship[Smith (1971)].

$\sigma = \frac{\alpha n c}{4\pi}$ (5)

where (c) is the velocity of light.

The nature of transition (direct or indirect) is determined by using therelation[Elsay et al. (2015)]:

$\alpha h\upsilon = B(h\upsilon - E_g)^r$(6)

where (hυ) is the photon energy, (E_g) is baud gap energy of the band [Eid et al. (2014)], (B) constant depended on type of material and (r) exponential constant, for the allowed direct transition, (r =1/2) and for indirect transition, (r=3/ 2).

3. Results and Discussion:

The absorption spectrum for PVC and TiO_2nanoparticles thin film is as shown in Fig.(1). One can observe that the absorption increases as the wavelength increases at UV region, and then decrease at visible region.

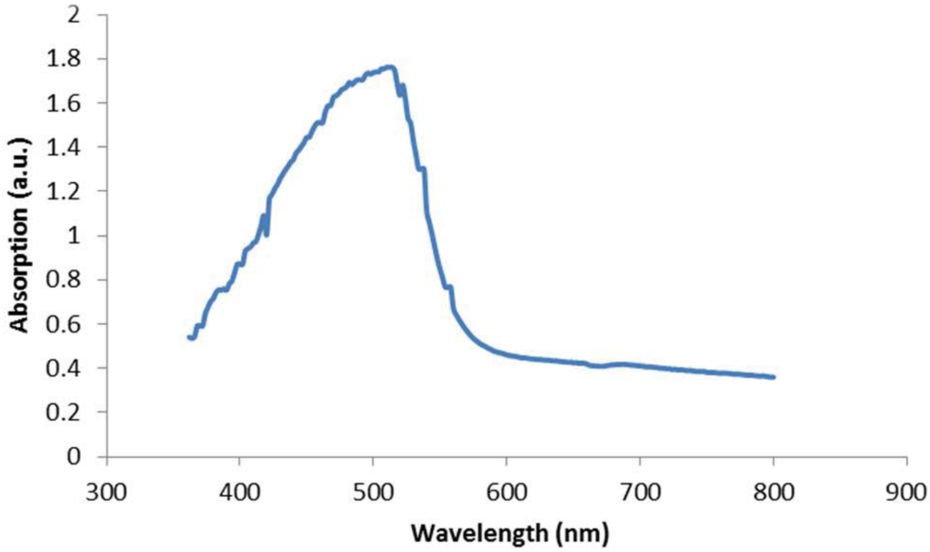

Figure (1): Absorbance for DCM-PVC doped with TiO_2 nanoparticles thin film at (30 C◦).

Fig.(2) shows the absorption coefficient for PVC doping with DCM and TiO_2 nanoparticles thin film which determined from equation(2).This coefficient of the film increasesbecause its inversely proportional to the transmittance.

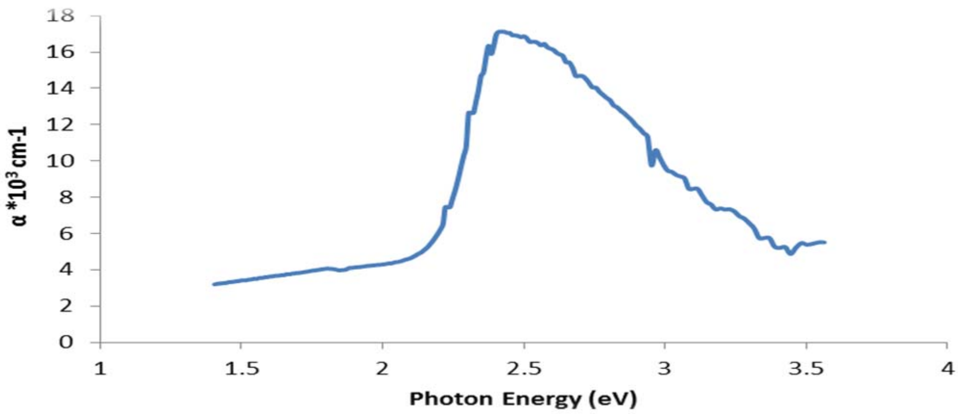

Figure (2): Absorption coefficient for DCM-PVC doped with TiO_2nanoparticles thin film at (30 C◦).

The extinction coefficient calculated from the equation(3),the absorption coefficient for PVC doping with DCM and TiO_2 nanoparticles thin film is shown in Fig(3).It is clear that the extinction coefficient is increased rapidly atvisible region and then decreased.

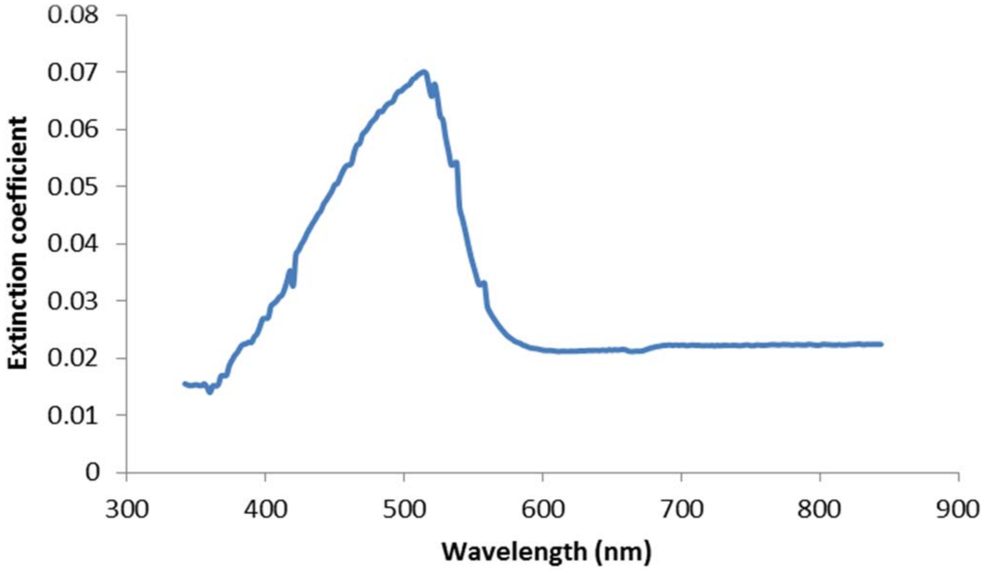

Figure (3): Extinction coefficient against the wavelength (nm).

Fig.(4) shows the reflectance spectra for film, it is clear that reflectance decrease with increasing the photon energy (UV region) where wavelength equal to (550) nm represent the center of the visible wavelength is rang increase as the photon energy increase.

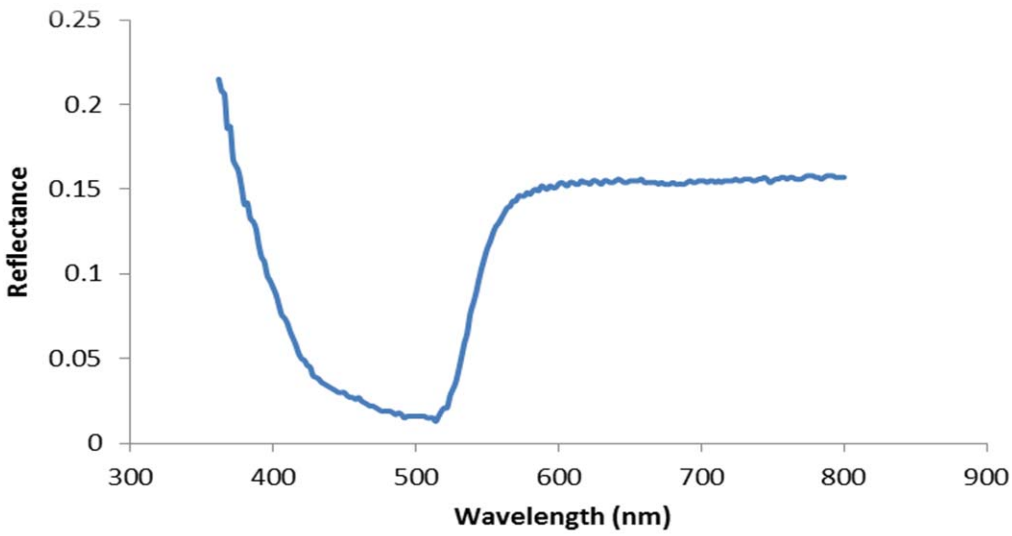

Figure (4): Reflectance for DCM-PVC doped with TiO_2 nanoparticles thin films at (30 C◦).

The refraction index of PVC and TiO_2 nanoparticles thin film can be calculated from equation (4).Fig.(5) which is seen the variation refraction index of the film is as a function of the wavelength,that the valueof this index decreases slightly with increasing the wavelength in the UV and the beginning of visible region.

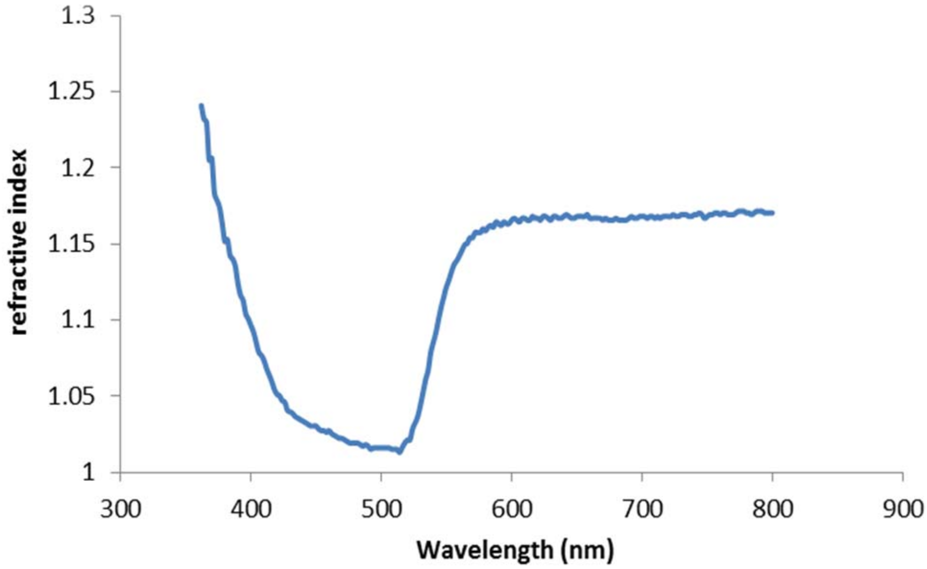

Figure (5): Refraction index for DCM-PVC doped with TiO_2 nanoparticles thin films at (30 C◦).

Fig.(6) shows the variation of optical conductivity for DCM-PVC doped with TiO_2 nanoparticles as a function of wavelength which calculated by using equation(5).

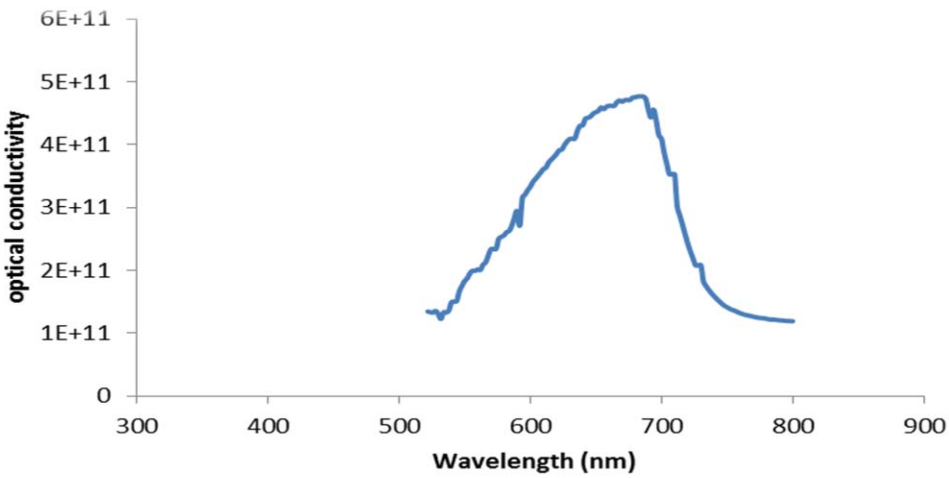

Figure (6): Optical conductivity for DCM-PVC doped with TiO_2 nanoparticles thin films as a function of the wavelength.

The variation of (αhν)2 as the incident photon energy (hν) of thin film was shown in Fig.(7). The optical band gap was determined by extrapolating the linear portion of this plot at [(αhν)2=0] which indicates that the direct allowed transition. The energy gap value depends on the films deposition condition and its preparation method [15].

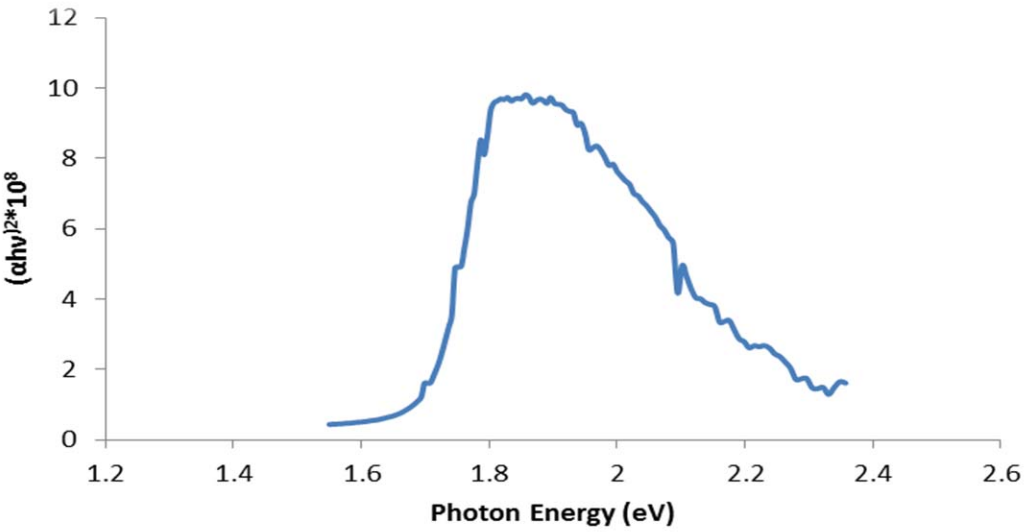

figure (7) Relationship between $(\alpha h\nu)^2$ and photon energy (eV) for DCM-PVC doped with TiO_2 nanoparticles thin films

Fig.(8) shows the variation of $(\alpha h\nu)^{1/2}$ with photon energy, which is used to estimate the indirect energy gap and the photon energy with helping of equation (6).

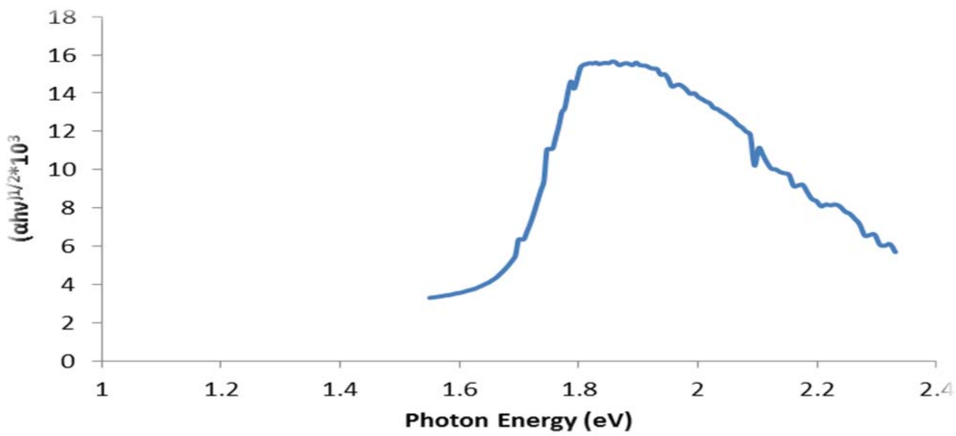

Figure (8) Relationship between $(\alpha h\nu)^{1/2}$ and photon energy (eV) for DCM-PVC doped with TiO_2 nanoparticles thin films

4. Conclusions:

The optical properties of DCM-PVC doped with TiO_2 nanoparticles thin film synthesized by using cast method were studied. The results of the optical tests show that the absorption of DCM-PVC doped with TiO_2thin film increasing with increasing wavelengths while the annealing caused increasing the absorption, the max value of the absorption was at the wavelength (500 nm). Also these results showed that the values of absorption coefficient were greater than ($2*10^3 cm^{-1}$). It is observed from results that allowed direct electronic transitions energy gap is(1.7eV)whereas the allowed indirect electronic transition energy gap was(1.6 eV).

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