Studying the optical properties of thin films prepared from polystyrene doped with DCM dye

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ABSTRACT. Polymeric thin films of Polystyrene (PS) doped with DCM laser dye have been prepared using casting method and pure thin films of PS. Optical properties for deposed thin films on glass substrate with 0.237µm was prepared using casting method involved absorptions spectra measurement using UV mate SP-8001 double-beam spectrophotometer covering the wavelengths range 190-1100nm, where the absorption coefficient was calculated and the direct energy gap was 3.9eV for PS thin film, energy gap for PS-DCM thin film was 2.2eV. While for indirect transitions the energy gap for PS thin film was 2.25eV and phonon energy was 0.55eV, but the energy gap for PS-DCM film was 1.4eV and phonon energy was 0.5eV.

1. INTRODUCTION

Dye – doped polymers (DDP) are new materials which existing optical properties. DDP find application in fields of modern photonic technology apart from its use as an alternative to solid state laser media [1].

Organic compounds have been the subject of intense theoretical and experimental studies because of their wide range applications in different life science fields. Such as tumble solid-state dye active medium energy transfer experiments, biomedical applications, sensing and probe instruments [2]. The laser dyes is an unsaturated hydracarbonic organic compound containing a mutual series of carbon atoms, with successive single and double bonds [3].

The most important reasons to use the solid matrix as a host material for dyes is due to its obvious advantages such as rigidity and compactness, lack of toxicity and solvent evaporation [4]. Various classes of materials like porous glasses, organically modified silicates, polymers, and solgel materials were extensively studied and employed as host materials because of their optical properties and commercial viability [5].

Organic polymers used as host to organic dyes because these polymers have optical homogeneity [6]. Incorporating laser dyes in polymer hosts decreases the degradation the dye, the stability of the dye increases and the fluorescence intensity increases as well. This is due to the dimmers decomposition which terminates the absorption process that accrues in the same region of fluorescence resulting from re-absorption [7].

The polymer polystyrene (PS) is transparent plastic material with high elasticity, index of refraction and its optical proprieties are very good. It can be used with organic dyes to improve the dye laser forming dimers or molecular aggregations [8].

The organic laser dye used in this work is fluorescence dye, DCM, [2-[2-[4-(dimethylamino) phenyl] ethenyl]-6-methyl-4H- pyran-4-ylidene]-propanedinitrile, of the chemical formula C_{19}H_{17}N_{3}O and appearance: red or orange-red crystals or powder. The average size of this dye is about 1 nm [9].

In current study PS, Poly Styrene, of the chemical formula (C_8H_8)_n was used as a host to the DCM laser dye to prepare thin film and studying the optical properties of these films.
2. EXPERIMENTAL PART

To prepare $5 \times 10^{-3}$ mol/lit DCM dye solution, firstly dissolving 0.015gm in 10ml of THF to obtain 10ml laser dye solution and on the other hand the polystyrene polymer thin film was prepare by dissolving 1.5gm of PS in 30ml of THF, then 5ml of the final solution of PS dissolved in THF was mixing with 1ml of dye solution and stirred 10 minutes to obtain homogenous solution. This mixture casting on glass substrate at room temperature and atmosphere pressure.

Thickness of the thin films was measured using the optical interferometer method employing He-Ne laser 0.632μm with incident angle 45° as shown schematically in fig. (1).

![Schematic diagram of the thin film thickness measurement](image)

This method depends on the interference of the laser beam reflected from thin film surface and then substrate, the films thickness ($d$) can be calculated using the following formula:

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

The absorption spectra of the prepared samples were obtained by using UV mate SP-8001 double-beam spectrophotometer covering the wavelengths range 190-1100nm supplied by Metertech Corporation (Taipei, Taiwan). These spectra were used to calculate the absorbance ($A$).

The absorption coefficient ($\alpha$) was calculated using the equation:

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

3. RESULTS AND DISCUSSION

The absorption spectra of the thin films were measured at room temperature. Figure (2) shows the absorption spectrum of PS thin film with and without $5 \times 10^{-3}$ mol/lit DCM dye solution.
It can be seen from Fig (2) that the optical spectrum of dye – polymer influenced noticeably by the nature of the host materials. A red shift in the absorption spectrum is observed for the thin film of DCM dye solution doped with PS. This red shift is attributed to the change in the reflective index of the thin film of PS with and without DCM.

Fig.(3) shows the variation molar absorption coefficient of the PS with and without DCM dye thin film against the photon energy.

It is clear from fig. (3) that the molar absorption coefficient increases with increasing photon energy for the two films. One can notice that these films of PS with and without DCM dye have direct and indirect electronic transitions. The direct electronic transitions due to the values of molar absorption coefficient more than $10^4 \text{cm}^{-1}$ [10], while the indirect electronic transitions occur the values of molar absorption coefficient been less that $10^4 \text{cm}^{-1}$ [11] for these films.

Energy gap for direct electronic transitions of PS thin film was calculated by drawing the relationship between $(\alpha h\nu)^2$ and the photon energy as shown in fig. (4).
The relationship between \((\alpha h\nu)^2\) and the photon energy of PS doped with DCM dye thin film is shown in fig. (5), from this figure one can get the direct electronic transitions of this film.

From Fig. (4) and (5), the direct energy gap of PS thin film was (3.9)eV, this value will decrease to (2.2)eV when the PS doped with DCM dye. The decreasing in energy gap value could be attributed to the doping, where the doping leads to the Pollaronah bands formed inside the energy gap. Energy gap and phonon energy which associated to the indirect electronic transition could be calculated from fig. (6).
The relationship between $(\alpha h \nu)^{1/2}$ and the photon energy of PS doped with DCM dye thin film is shown in fig. (7), from this figure one can get the indirect electronic transitions of this film.

From fig. (6), the energy gap for indirect electronic transitions in case of PS thin film was 2.25 eV and the photon energy was 0.55 eV, while from fig. (7), the energy gap and photon energy for PS doped with DCM dye thin film was 1.4 eV and 0.5 eV respectively.

4. CONCLUSION

In this work we have studying the optical characterizations of PS and PS doped with DCM prepared using casting method. The optical absorption measurements show a red shift in the spectrum is observed for the thin film of DCM dye solution doped with PS relative to thin film of pure PS, a direct band gap of PS is found to be 3.9 eV, while this energy is found to be 2.9 eV of PS doped with DCM. The indirect energy gap of PS is 2.2 eV and the photon energy is 0.55 eV, but this values decreasing to 1.4 eV and 0.5 eV respectively.
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