Linear Optical Properties of Organic Laser Dye Doped with PMMA Polymer

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Abstract

In this work, linear optical characteristics of Azure B organic laser dye doped with PMMA polymer dissolved in DMF solvent at concentration (1×10^{-3} M) were studied. This research includes presenting the results and discussing the absorption spectra and linear optical properties (transmission, linear absorption and refraction coefficient), by studying the effect of adding polymer (PMMA) with different ratios on this pure dye. The result showed that possibility of using this dye in liquid state laser.

Key Words: Organic Laser Dye, Linear Optical Properties, PMMA Polymer.

DOI Number: 10.14704/nq.2022.20.3.NQ22329 **NeuroQuantology 2022; 20(3):364-367**

Introduction

Organic dyes is an unsaturated hydrocarbon compound with a rather complex structure because it contains a series of carbon atoms that are bonded to a single and double bond, called the chromosphere system. The chromophore is differentiated by absorption ($S_0 \rightarrow S_1$) occurs in the visible region [1]. Chromophores are the group that is responsible for giving the particle a chromatic character, so that the dye molecule that absorb wavelength (400- 700 nm) (visible light) in a certain color. Each organic dye has a special absorbance and fluorescence band, which is triggered by the use of flashlights or by using a solid-state laser such as a double-frequency sapphire laser or a gaseous laser such as an Argon ion laser or a Nitrogen laser [2]. In this work, linear properties of Azure B organic laser dye doped with PMMA polymer dissolved in DMF solvent at different concentrations were studied.

Linear Optical Characteristics

The optical characteristics of a material are determined by the interaction between the kind and distribution of charges inside the material (electronic, molecular, and ionic) and electromagnetic radiation falling on the substance. When an electromagnetic beam collides with a substance, a number of processes can occur as some of the light radiation is absorbed by the medium and converted to heat. The other part is called transmitted radiation because the input goes through the material without losing energy, while the rest of the light is reflected off the material's surface (reflected) [3]. The permeability, absorbance, and reflectivity of the electromagnetic radiation falling on the material should be determined in order to get insight into its internal structure and the nature of its bonds. Ultraviolet spectroscopy can identify energy beams and the quality of transitions within a material, for instance. Material-related applications will yield the same frequency when monochromatic light enters a linear optical system with constant wavelength.

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Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Received: 12 February 2022 **Accepted:** 18 March 2022

For example, if red light enters a lens, it will remain red when it emerges. Visible should be investigated because of this phenomenon [4].

Absorbance (A)

The absorbance (A) or optical density represents the amount of sports that binds the density of the particles (concentration) in the sample and the thickness of the sample (optical path length) [5]:

$$A = \log(I_0/I) \qquad (1)$$

Where I_o: is the intensity of light before entering the sample or the intensity of the light dropping, and I: refers to the intensity of light at the wavelength of (λ) that passes through the sample (the intensity of light is in the middle). If the absorbed energy value is more than the value of the dissociation of a bond or its transfer to a higher energy level, the material's absorption in the falling rays creates electron activity, which may lead to the disintegration of its molecules. The absorption potential increases by increasing the amount of matter at the low energy level and the number of photons that descend [5]. The chance of photon absorption is directly proportional to the concentration of absorbed molecules in the sample and the thickness of the model (the length of the optical path), according to the law of Beer-Lambert.This experimental relationship ties the absorption of light to the properties of the material through which the light passes. The law says that the number of particles in a material that can absorb radiation is directly related to the amount of radiation it can absorb. If the radiation goes through a solution, the amount of light that is absorbed or turned on is proportional to the amount of solute in the solution. As in the equation [6]:

$$I/I_o = e^{\alpha_{op} C m \, L} \qquad (2)$$

α_{op}: represents the optical absorption coefficient. L: optical path length.

C_m: molars concentration. The equation can be written as follows [6]:

$$\ln I_o / I = \alpha_{op} C_m L = A \qquad (3)$$

Absorption Coefficient

The absorption coefficient may be described as the percentage of reduction in the emission of the radiation energy per unit of distance towards the propagation of the wave inside the medium, and it is dependent on the photon's energy (hυ) and the characteristics of matter. According to the law of Beer-Lambert, the absorption coefficient is [7]:

$$\text{Log}\,(I_o / I) = 2.303\,A = \alpha_o\, d \qquad (4)$$

$$2.303\,A / d = \alpha_o \qquad (5)$$

(d) the thickness of the sample for the game in which the material is placed.

The Refractive Index (n)

The light travels at all wavelengths at its maximum velocity in vacuum. It is a constant quantity. Any other media reduces this value. The wavelengths cause it to alter in physical circles. The mean refractive index of a wave defines the ratio between its velocity in the vacuum and its velocity in any given medium for a particular wavelength [7].

$$n = c / v \qquad (8)$$

Where:

(c) The speed of light in vacuum, (v) the speed of light in the material.

The refractive index of an electromagnetic wave is not constant and varies with its length. As well as some materials whose refractive index varies depending on the direction in which an electromagnetic wave advances through the material, and these materials are utilised to modify the polarisation direction of such waves . The refractive index calculated as the following equation[7]:

$$n_o = \frac{1}{T}\left[\left(\frac{1}{T^2} - 1\right)\right]^{1/2} \qquad (9)$$

Materials Used

A. Azure B

Azure B is a class of thiazine and a container of nitrogen and sulfur atoms within the middle ring. Its structural formula ($C_{15}H_{16}N_3SCl$), its molecular weight (305.8 g) dissolves in water and is low in ethyl alcohol. Its peak absorption lies at a range of wavelengths (648-655nm) for this to be a blue color[8].The molecular structure of Azure B dye is shown in Figure (1).

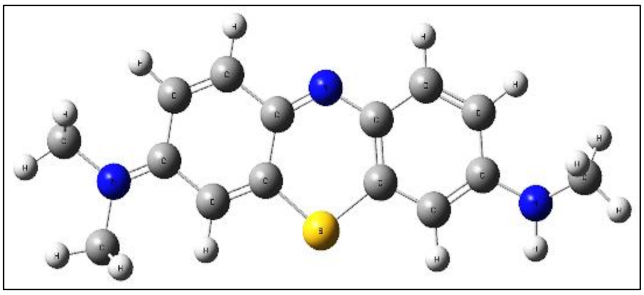

Figure 1. Molecular structure of (Azure-B) dye[8]

eISSN 1303-5150

B. Poly Methyl Methacrylate (PMMA)

PMMA is the most common abbreviation for this polymer, which is the most significant of the commercial acrylic polymers. Poly (acrylic acid), [—CH_2CH (CO_2H)—]$_n$ is the source of these polymers. This derivation may be thought of as replacing the tertiary hydrogen atom with a methyl group, CH_3, and esterifying the carboxylic acid group with methanol, CH_3OH, in the case of PMMA [8].

Preparation of Solutions

To make a dye solution of (Azure-B) with a concentration of (1×10^{-3} M), (0.0030gm) of dye powder in a size of (10 cm^3) of ethanol solvent was used in the study [9]:

$$Wm = \frac{C \times V \times M.W}{1000} \quad (10)$$

Where:
W_m: In gm units, the weight of dye required to achieve the given concentration.
C: Unit M will prepare the concentration.
V: The amount of solvent to be applied to the substance in cm3
M.W: The molecular weight of the dye utilised (g/mol).
Lighter concentrations (3×10^{-5} M) must be prepared. The following connection, known as the dilution relationship, is used to calculate the concentration [9]:

$$C_1V_1 = C_2V_2 \quad (12)$$

Where:
C_1: First Concentration (Higher).
C_2: The second focus (lightest).
V_1: The required volume of the first concentration.
V_2: For the second concentration, the size had to be added to the first concentration.

To prepare the liquid solutions of the polymer with the dye, (2gm) of polymer (PMMA) was dissolved in (50 ml) of (DMF) solvent and then left for (24) hours to be completely dissolved, after that a volume of (1 and 3.5 ml) was withdrawn and added. For a volume of (5ml) of the dye solution and for the selected concentrations (3×10^{-5} M) and the resulting mixture left for (30) minutes in order to get a complete homogeneity solution formed of polymer and dye.

Calculation and Results

The absorption and transmission spectra of (Azure-B)organic dye dissolved in (DMF) solvent at concentration (3×10^{-5} M) were studied using UV-Visible Spectrophotometer as displayed in Figure (2) and Figure (3) respectively. Figure (4) and Figure (5) show the absorption and transmission spectra of (Azure-B dye doped with polymer) at volume ratios (1,3 and 5 ml) of polymer (PMMA) dissolved in (DMF) solvent to a fixed volume (5 ml) of Azure B dye solution at concentration (3×10^{-5} M). The coefficients of linear absorption (α_o) and linear refraction (n_o) for the produced materials at various concentrations were computed after obtaining the absorbance data. After getting the absorbance findings, the coefficients of linear absorption (α_o) and linear refraction (n_o) were calculated for the prepared samples at different concentrations. Table (1) show the linear optical characteristics of the prepared samples. It is clear in table that increasing the volume ratios of the polymer leads to a decrease in the absorbance (A), and a decrease in the values of the linear refractive index (n_o) and absorption (α_o).

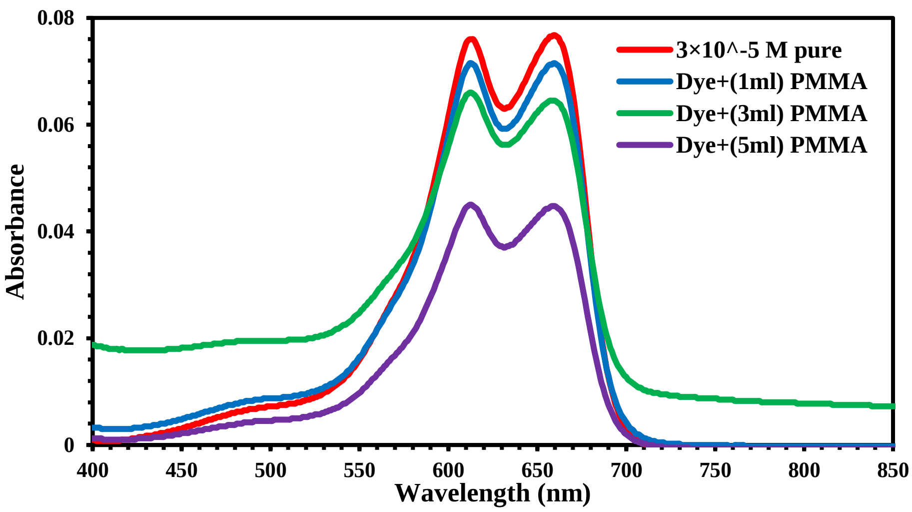

Figure 2. Absorption spectra of the Azure-B dye dissolved in DMF Solvent

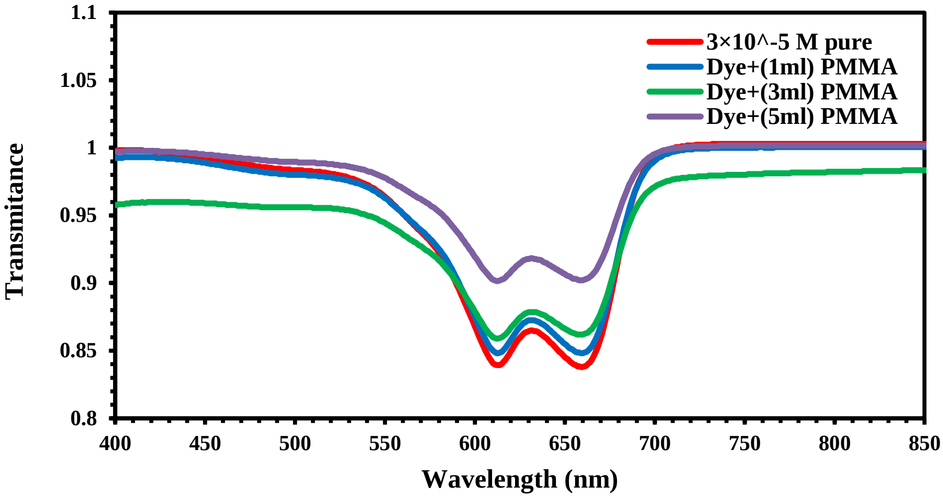

Figure 3. Transmission spectra of Azure-B dye dissolved in DMF Solvent

Table 1. Linear Optical Properties of Prepared Samples of Azure B Dye as Pure and after Doped with PMMA Polymer at Concentration (3×10^{-5}) M

Samples	λ_{max} (nm)	A	T	(cm^{-1}) α_o	n_o
Pure Dye (5ml) M 3×10^{-5}	612	0.076	0.832	0.175	1.838
Dye + (1ml) PMMA	612	0.071	0.849	0.164	1.803
Dye + (3ml) PMMA	612	0.066	0.859	0.151	1.760
Dye + (5ml) PMMA	612	0.045	0.902	0.103	1.589

Conclusions

The result show that increasing the volume ratios of the used polymer dissolved in the same dye solvent and added to a fixed volume of dye in different concentrations leads to a decrease in the absorbance curve accompanied by an increase in transmittance. The linear refractive index and absorption are reduced when the volume ratios of the polymer utilised are increased and the absorbance values are decreased.

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