

Enhancing spectral properties and resonances energy transfer for F8PT: Au Nanocomposite

Authors Names	ABSTRACT
Fatima Mohsen Nawaf ^a Asmahan Asaad Muhmood ^b <i>Publication date: 30 / 6 / 2026</i> <i>Keywords:</i> <i>F8BT, Energy Transfer, Active Laser Medium</i>	In this work, the optical and spectral with energy transfer for F8PT light emitting polymer were studied before and after Au nanoparticles addition. Three different concentrations (1×10^{-5} , 1×10^{-6} , 1×10^{-7}) Ml of polymer were prepared by dissolving polymer with xylene. Nd:YAG laser with 1064 nm wavelength used to syntheses Au NPs by laser ablation techniques in different pulses number (400,600, and 800). The synthesized NPs examined by FE-SEM and the results show that the particles were spherical and in the range of (37.93-51.97) nm. UV-Vis spectrophotometer used to clear the optical properties for the samples before and after nano addition. the results show that the F8PT have two absorption peaks in uv and visible region but after Au NPs addition a third peak appear in uv region because of splitting in energy level of polymer.

1. Introduction

A Conjugated polymers represent an advanced generation of organic semiconductors, combining excellent optical properties with ease of fabrication [1]. It is also an important category due to its low cost, ease of manufacture, environmental friendliness, and flexibility [2]. It shows promising potential for use in organic lasers, organic light-emitting diodes (OLEDs), and sensors for biological and explosive species [3]. Among the most important conjugated polymers, Poly(9,9-dioctylfluorene-alt-benzothiadiazole) (F8BT) F8BT polymer is a donor-acceptor conjugate polymer consisting of alternating fluorine (F8) and benzothiadiazole (BT) units. This polymer has excellent optical and electronic properties due to the BT units' strong charge localization [4-5]. F8BT has high laser efficiency and is used as a gain medium in organic lasers because of its ability to provide high optical gain [5]. From an optophysical standpoint, F8BT has a broad absorption spectrum that extends into the blue region, while its photoluminescence is concentrated in the green region at about 540 nm [5-6]. The polymer also can function in energy transfer systems, which improves optical device performance and lowers the laser emission threshold [4]. Because of its conjugated

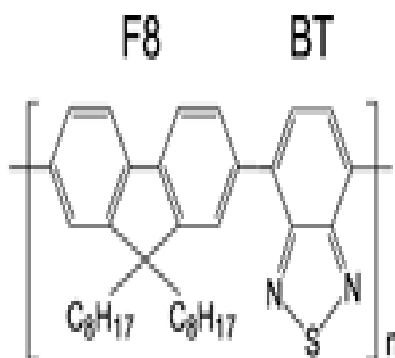


Fig. 1. The chemical structure of F8BT [7].

^aDepartment of physics, faculty of science, University of Kufa, 540011 Najaf, Iraq., E-Mail: fatimam.alsaeaydani@student.uokufa.edu.iq

^bDepartment of physics, faculty of science, University of Kufa, 540011 Najaf, Iraq., E-Mail: asmahan.alnaseefi@uokufa.edu.iq

polymer nature, it has distinct charge mobility, with holes moving quickly and electrons moving slowly, influencing transport processes within the material. Figure (1) depicts the molecular structure of the F8BT polymer. In this work, the optical and spectral properties of the polymer before and after the addition of gold nanoparticles will be studied.

2-Theoretical part:

2.1. Surface Plasmon Resonance (SPR)

When light bombards small spherical metallic nanoparticles, the oscillating electric field causes the conduction electrons to vibrate coherently [7]. Surface Plasmon Resonance (SPR) is a phenomenon in which photons of visible light with a specific angle of incidence excite electrons in the metal surface layer, which then travel parallel to the metal surface[8].

2.2. Linear Optical Properties:

Absorption occurs only when the incident photon energy equals the energy difference between the two states. The logarithmic relative decrease in intensity is defined as absorbance[9].

$$A = \log_{10} \left(\frac{I_0}{I} \right) \dots \dots \dots (1)$$

The definition of absorption coefficient (α) is a material's capacity to absorb light of a specific wavelength. The optical absorbance (A) aided in the calculation of the absorption coefficient, according to equation (2)[10].

According to the Beer-Lambert law, the absorption coefficient is:

$$A = \log_{10} \left(\frac{I_0}{I} \right) = \alpha \cdot d \dots \dots \dots (2)$$

$$\alpha \cdot d = 2.303 A \dots \dots \dots (3)$$

Where d represents: thickness and its value (1 cm).

Transmittance is defined as the ratio of transmitted light intensity to incoming light intensity. Transmittance (T) is calculated by dividing the intensity of the rays passing through the film (I) by the intensity of the original incident rays (I0), as shown in (4) [11].

$$T\% = (I/I_0) \times 100\% \dots \dots \dots (4)$$

$$A = \log_{10} \left(\frac{1}{T} \right) \dots \dots \dots (5)$$

Light travels at its maximum speed in all wavelengths in a vacuum, which is a fixed quantity that decreases in any other medium as it changes in material media with different wavelengths. The mean refractive index of a wave is defined as the ratio of the speed of light in a vacuum to the speed of light in any given medium for a certain wavelength[11].

$$n = c/v$$

$$n = \left(\frac{R+1}{R-1}\right) + \left(\frac{4R}{1-R^2} - K^2\right)^{\frac{1}{2}} \dots (6)$$

As stated in equation, the energy conservation law states that light beams are partially transmitted, absorbed, and reflected as it shown in equation (7). The energy conservation law can be used to calculate reflectance (R) [12].

$$R + T + A = 1 \dots \dots \dots (7)$$

The frequency response of a substance when it is bombarded by light is its optical conductivity. Optical characteristics such as optical absorbance, reflectance, and absorption coefficient are used to calculate optical conductivity (opt.). Using the following relationship, the optical conductivity (opt.) was calculated using the absorption coefficient (α) and the refractive index (n): [12]

$$\sigma_{opt} = \frac{\alpha n c}{4 \pi} \dots \dots \dots (8)$$

The extinction coefficient (k) acts just similar the absorption coefficient(α) because they are joined by the previous relation[13].

$$K = \alpha \lambda / 4 \pi \dots \dots \dots (9)$$

3. The Spectral properties:

3-1. Fluorescence:

Fluorescence refers to the capacity of certain compounds to produce visible light later absorb non-visible radiation, such as ultraviolet light. This trait has a wide range of applications. [14]

3-2. Radiative Lifetime:

Radiative lifetime (FM) is defined as the inverted rate of fluorescence probability emission (KFM) with the unit (sec-1), which is defined as the radiative transition time from the lower vibrational level to the excited electronic state, then to the ground vibrational level, and back to its first state after this time [15]

$$\tau_{FM} = 1/KFM \dots \dots \dots (10)$$

3-3. Fluorescence Quantum Efficiency:

The proportion of quanta emitted numbers to quanta absorbed numbers is defined as the fluorescence quantum efficiency (qFM). The relative fluorescence quantum intensity at a frequency (ν) normalized by the equation characterizes the molecular fluorescence spectrum; F (ν). [16]

$$q_{FM} = \frac{\text{number of emitted photons}}{\text{number of excited photons}} \dots \dots (11)$$

$$q_{FM} = KFM [M^*] / I_a \dots \dots (12)$$

K_{FM} is the rate of fluorescence emission. $[M^*]$ is the molar concentration of excited molecules. I_a is the intensity of light absorbed. Quantum efficiency can be ascertained by the total area under the fluorescence curve, depending on the equation [17]

$$q_{FM} = \int_0^{\infty} f(\nu) d\nu \dots (13)$$

$F_{(\nu)}$: is the intensity of the fluorescence spectrum.

3-4. Fluorescence lifetime:

As shown in the following relation, which is the equation employed in the calculations in this work, the fluorescence lifetime may be determined from a standard compound known as the fluorescence lifetime, as well as the area under the curve. [16,17]

$$\tau_F = \frac{a * \tau_{FRB}}{a_{RB}} \dots (14)$$

τ_{FRB} . Fluorescence lifetime is the mensural compound, a_{RB} is the area under the fluorescence curve of dye, a : area under the required compound curve. The Einstein coefficient for self-emission is given by [18]

$$A_E = K_{FM} = 2.88 * 10^{-9} * n^2 * \nu^2 \int \epsilon(\nu) d\nu \dots (15)$$

4. Experimental Part:

The semiconductor polymer used in this work is F8BT polymers (with M_w ranging from 10,000 to 100,000 g/mol), purchased from Xi'an Polymer Light Technology Corp. The solvent used was xylene, from Riedel-de Haën. gold (Au) nanoparticles' were prepared using laser ablation.

The polymer solutions were prepared by dissolving 0.035g of F8BT in xylene solvent (10 ml), and the initial concentration (10^{-3}) was determined according to the equation.

$$W = \frac{M_w * \nu * C}{1000} \dots (16)$$

Where: M_w = polymer molecular weight (gm/mol),

W = dissolved dye weight (gm),

V = solvent volume (ml), C = polymer concentration.

To get a different concentration, three concentrations were prepared of polymer based on the dilution equation.

$$c_1 \nu_1 = c_2 \nu_2 \dots (17)$$

Where: C_1 = the main concentration, C_2 =the new concentration, V_1 = volume before dilution, V_2 = volume after dilution.

5. Results and discussion

5.1. Au NPs

Nd:YAG laser with wavelength 1064 nm, 3 Hz, 600 mJ, (400,600,and 800) pulse, and pure gold target immersed in distilled water used to synthesis Au NPs. Figure (2 A,B) show the images made by FE-SEM apparatus which clear the spherical shape of Au NPs and the nano size of these particles in the range of (37.93-51.97) nm. Figure (3) clear the relationship between wavelength and absorption intensity. As seen from the figure, the absorption peaks are located in 520-524) nm that match with published studies [18,19]. These peaks appear because of Surface Plasmon Resonator (SPR) which is a special character for metallic nanoparticles due to a large scale for surface charge reorganization to the external field is very quick of oscillation surface- charge can happened [20]. Figure (4) exposes the experimental set up

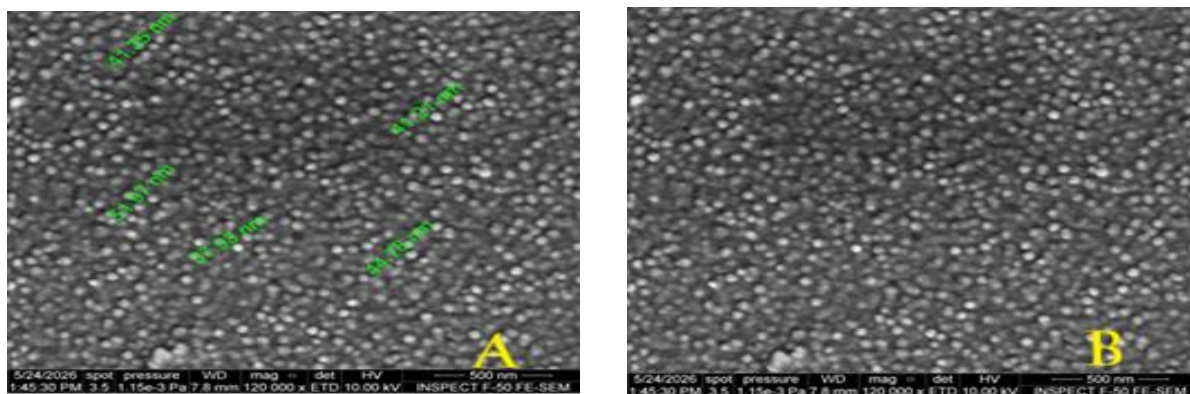


Fig. (2) A&B images of FE-SEM for Au nano samples

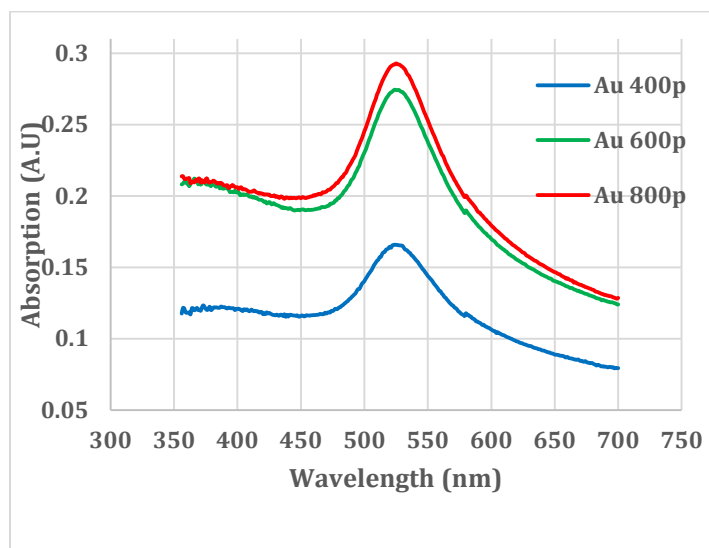


Fig. (3) Absorption spectra of Au NPs for different pulses no.

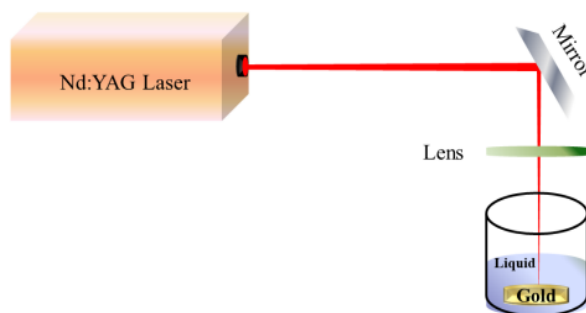


Fig. (4) experimental set up for laser ablation in water

5.2 Optical properties

The optical properties of prepared samples before and after nano addition were found by UV-Vis spectrophotometer and set of equations (1-9).

Before nano addition, figure (5) shows the absorption spectra for three different concentrations their peaks increase with increasing the concentration which make matching with beer-Lampert low.

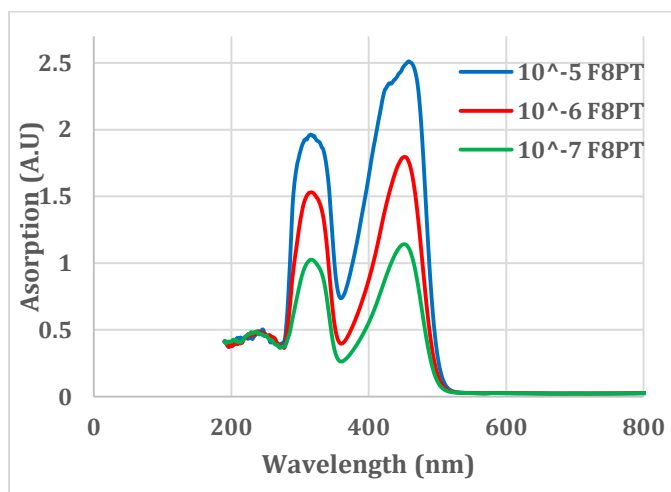


Fig. (5): Absorption spectra for F8PT samples before nano addition

As seen from fig. (4) the F8PT polymer have two peaks the first one in UV region about (325 nm) and the second peak in the visible region about (465 nm). The two peaks appear because of alternated the donor-acceptor chemically structure backbone of the polymer [21].

The first peak in UV region (325 nm) is a high energy peak and it is attributed to $\pi-\pi^*$ transition that originating from localized fluorenes chops within the chain of conjugate polymer [22]. Another peak which in visible region (465 nm) is the lower energy, notables bands idealizes interchain (charge-transfer) transition or the that the electronic transition occur across entire backbone of conjugate polymer. This

peak gives the polymer its signature for optical absorption and also the tactics visible photoluminescence [23].

The other properties of these samples before Au nano addition are clear in table (1)

Table (1) the optical properties of F8pt samples.

C	λ nm	A	T%	R	α cm-1	n	σ * 10^{10}	$K * 10^{-5}$
F8BT(10^{-5})	302	1.86	1.38	0.292	4.284	3.35	3.426	1.029
	447	2.43	0.37	0.229	5.596	2.84	3.79	1.99
F8BT(10^{-6})	306	1.45	3.55	0.252	3.339	3.02	2.407	8.131
	451	1.794	1.604	0.207	4.132	2.67	4.41	1.48
F8BT(10^{-7})	305	0.94	11.48	0.207	2.165	2.67	1.38	5.25
	452	1.141	7.220	0.073	2.628	1.74	2.80	9.45

Au NPs addition enhances the optical properties also the lasing properties for F8PT light emitting polymer. The hybrid interaction utilizes primarily to enhance the efficiency in optoelectronics device scope [22]. Figure (6) show the absorption spectrum for the polymer of ($1 * 10^{-7}$) Ml concentration with Au NPs in mixing ratio (1:4).

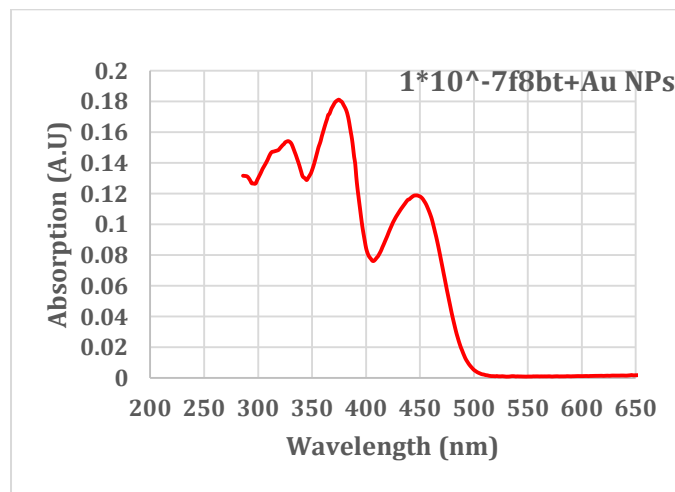


Fig. (6) absorption spectrum after Au NPs addition

As seen from fig. (5), Au NPs enhanced the high energy absorption peak and a new peak about (380 nm) appear in the region with shifting of two peaks to long wavelength (red shift). This shifting happened because of combining between Au NPs with the polymer due to plasmon – exciton hybridism (formation of polariton) and strong coupling of electromagnetic [24]. The red shift physically happened the system of a material has multiple energy peaks; the hardy coupling could split or shifting individual peaks to uniquely directions [25].

5.3. spectral properties

Figure (7) clear the relation between fluorescence intensity and wavelength for three different samples of polymer before nano addition. As it seems, the intensity peak is in visible region (525 – 529) nm and the intensity increased with increasing concentration. increasing of concentration means more in fluorophore intensity in the same volume which means more F8PT chains that intersect the excitation of light path and cause a higher total absorption for incoming light, this is going with the low of Beer-Lambert. Appearance of one peak is a result of the conjugating, Donor-Acceptor alternately (D-A) architecture and basic rules of photo physic [26].

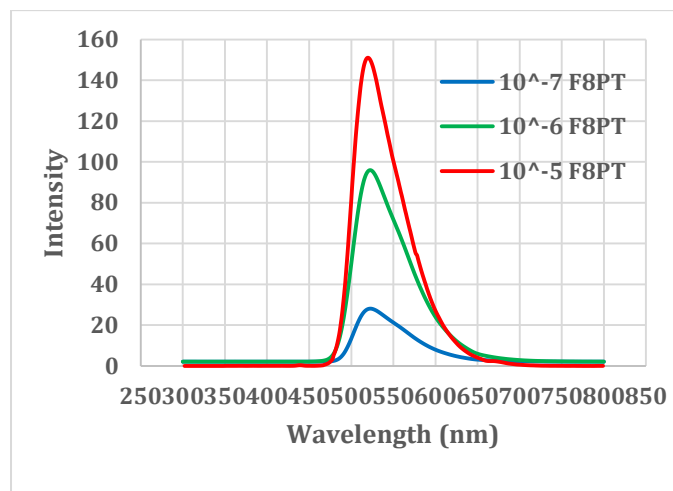


Fig. (7) fluorescence intensity for F8PT samples before Au NPs addition

After Au NPs addition in (1:4) mixing ratio to three different concentrations of F8pt polymer, the intensity of fluorescence examined by Spectrophotometer F96 PRO in the range of (200-800) nm. Figure (8) shows that there is an increase in the intensity of fluorescence with increasing the concentration of polymer.

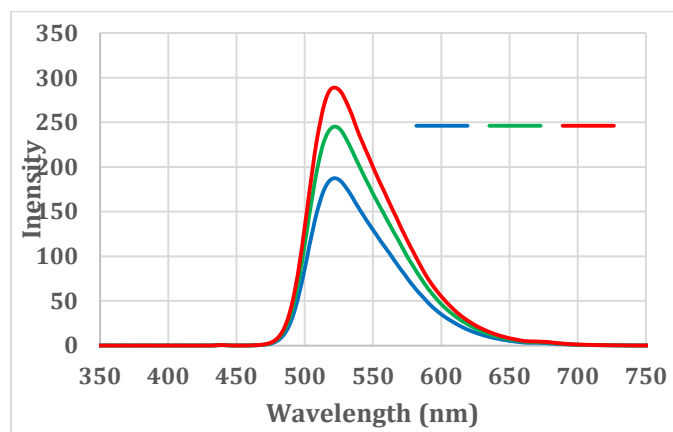


Fig. (8) fluorescence intensity for F8PT samples after Au NPs addition

This increasing is drove by metal enhancing fluorescence phenomenon (MEF). Whenever Au NPs presented, they formatting a more pervasive, strong electromagnetic environment can amplify the emission of light surrounding F8PT polymer [27].

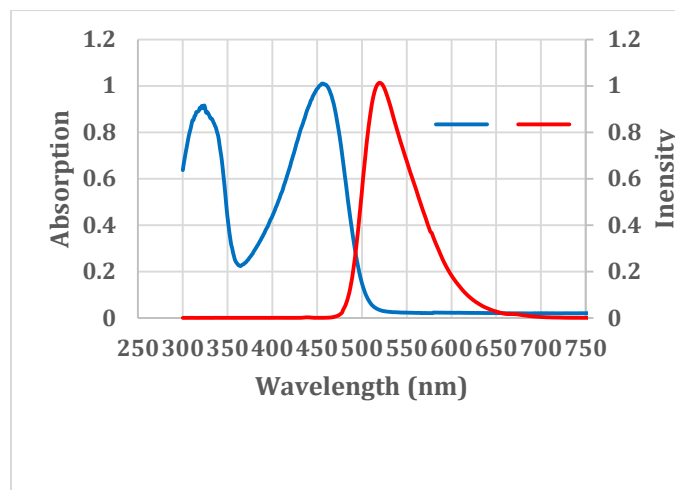


Fig. (9) The overlapping between absorption spectrum and fluorescence spectrum.

To enable studying the energy transfer, the overlapping between absorption and fluorescence spectra drawn as a function of wavelength as in figure (9).

Table (2) show the spectral properties of F8PT polymer after Au NPs addition.

Sample	Q_{fm}	K_{fm}	$1//K_{fm}$	τ_f
$10^{-7} + \text{Au NPs}$	32.0	5.39E+06	1.85E-07	5.94E-10

6. Conclusion

F8pt polymer is an efficient material that could be used to prepare an active medium for random laser. It has two absorption peaks in uv and visible region (blue) but its excitation peak located in visible region (green). The addition of Au NPs enhanced the optical and spectral properties of the polymer. After AuNPs addition, the spectral results show that the energy transfer was in nano second scale which make the polymer a perfect for random laser as active medium

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