Fluorescence Quenching in Laser Dye Doped Nanoparticles

Preprint · January 2020

Hayder G. Fahad
Al-Iraqia University

Fluorescence quenching in Laser Dye Doped Nanoparticles

Hayder G. Fahad[1*] **N. K. Hassan[2]**

[1*] Department of Physics, College of Education, Al-Iraqia University, Baghdad, Iraq

[1*] Department of Physics, College of Education for Pure Sciences, Tikrit University, Tikrit, Iraq

[2] Department of Physics, College of Education for Pure Sciences, Tikrit University, Tikrit, Iraq

[*] Email: haydar8626@gmail.com

Abstract

We report the study of fluorescence quenching from Rhodamine B and SiO_2 nanoparticles. Spectral properties of Rhodamine B laser dye were studied on different conditions, such as varied excitation wavelengths, SiO_2 nanoparticles amounts. We found that when increasing amount of SiO_2 nanoparticles led to enhancement in absorbance intensity of laser dye. Also fluorescence emission is increased up to 0.010g, but more of amount these particles led to decreasing in fluorescence intensity i.e., fluorescence quenching. Finally fluorescence intensity dependent on excitation wavelengths.

***Keywords*:** Nanoparticles; Rhodamine B dye; quenching

Introduction

Laser dyes، in general، have attracted considerable attention recently because of their connection with possible applications such as organic light emitting diodes and solar energy concentrators. The photophysical and photochemical processes are determined by the polarity of the solvent. Generally, the emission of the dye is a result of intramolecular charge transfer between electron-donating and electron-accepting units. The emission intensity of a dye dissolved in a solvent depends on factors such as the absorption and emission cross section, the fluorescence lifetime, and the quantum yield [1]

The most important property of dyes is the possibility of changing the wavelength to a range of approximately 60nm, which is known as (tuning).

The visible radiation emitted by most organic dyes has helped to be used as an effective medium in dye laser. These fluorescent dyes contain a high concentration of active atoms of the volume unit when compared to the invasive medium [2]

Rhodamine dyes, belonging to the family of xanthenes, are extensively employed [3,4]. And it occupy an important position because their useful photophysical and photochemical properties among different dyes [5]. Due to their higher absorption coefficient and broad fluorescence in the visible region of electromagnetic spectrum, high fluorescence quantum yield and photo stability, they have been widely applied as the active medium of tunable laser radiation in the visible region [4,6]. Rhodamine dyes have high sensitivity to the temperature change [7].

As the most used Rhodamines, Rhodamine B (RB) is a well-known water soluble fluorophore, and presents an interesting behavior with pH and solvent polarity [4,8].

Rhodamine B in solutions have been found successful in lasing [9]. The lasing emission of RB dye is dependent on the type of solvent used for dissolving this dye to solution form. For example the wavelength of lasing when changing the solvent from ethanol to ethylene is increased by about 43 nm [10].

Using high dye concentration may cause the dye molecules to form dimers which increase the absorption losses; this can be overcomed by using polymer solution as a host to the organic dye. For the liquid sample, this problem can be eliminated by using diluted concentrations [11].

Experimental

The Rhodamine B (RB) laser dye solution was prepared by dissolving the required amount of the dye in the solvents (water). This amount of the dye (*W*) was weighed using a precise digital balance of 10^{-3}g sensitivity and can be calculated using the following equation:

$$W = \frac{MW.V.C}{1000} \qquad (1)$$

Where M_W is the molecular weight of the dye (g/mol), V is the volume of the solvent (ml) and C is the molar concentration (mol/liter).

Then, different amounts of SiO_2 nanoparticles was dispersed in 10 m1 of ethanol containing 10^{-5}M of Rhodamine B dye.

The spectroscopic characteristics (absorption spectra) of the dye solution were measured by a UV-visible spectrophotometer (K-MAC Spectra Academy SV-2100) in the range 200-900 nm with an optical resolution of about 0.2 nm, while the fluorescence was measured by a fluorescence spectrophotometer (F96 instrument from Shanghai LengGuang Tech.) in the emission wavelength range of 250-900 nm with a xenon CW lamp as an excitation source.

Results and Discussion

The absorption spectrum of the Rhodamine B dye with, $5x10^{-3}$M concentration dissolved in water, was recorded in the spectral range 200-900 nm, as shown in Fig. (1). The spectroscopic measurements to introduce the effect of adding SiO_2 nanoparticles to the dye solution sample was carried out using this concentration.

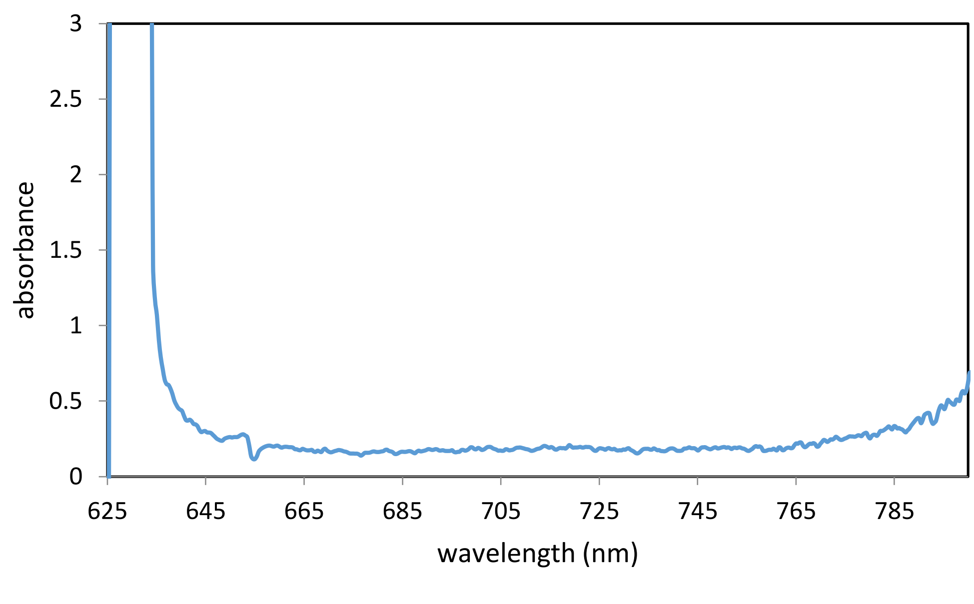

Fig. (1) The absorption spectrum of the Rhodamine B dye with, $5x10^{-3}$M concentration dissolved in water

Fig. (2) Shows the absorption spectra of $5x10^{-3}$ M Rhodamine B dye solution with different amounts of SiO_2 nanoparticles (0.002, 0.004, 0.006, 0.008, 0.010, 0.012 and 0.014 g). The highest absorbance was measured when 14 mg of SiO_2 nanoparticles added to the dye solution.

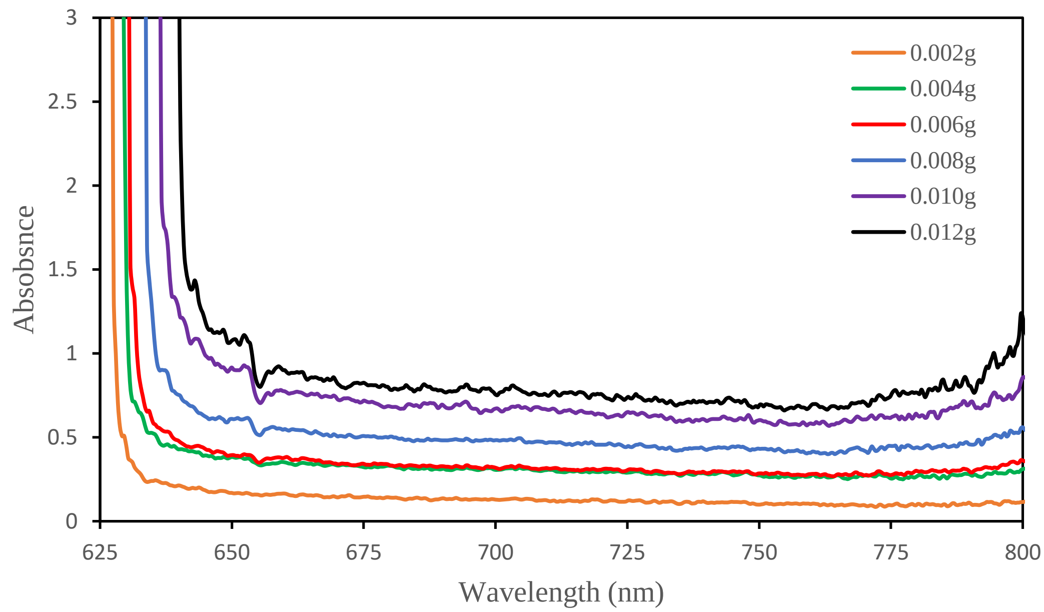

Fig. (2) The absorption spectra of $5x10^{-3}$ M Rhodamine B dye solution with different amounts of SiO_2 nanoparticles

Theoretically, increasing the amount of nanoparticles would lead to increase the absorbance; however, the effect of saturation makes a limitation on the amount of nanoparticles that can be added to the dye solution.

Figure (3) shown the transmission spectra of the samples prepared at different concentrations of Rhodamine B dye dissolved in water with amount of SiO_2 nanoparticles, where the transmission decreased with increasing for amount of SiO_2 nanoparticles.

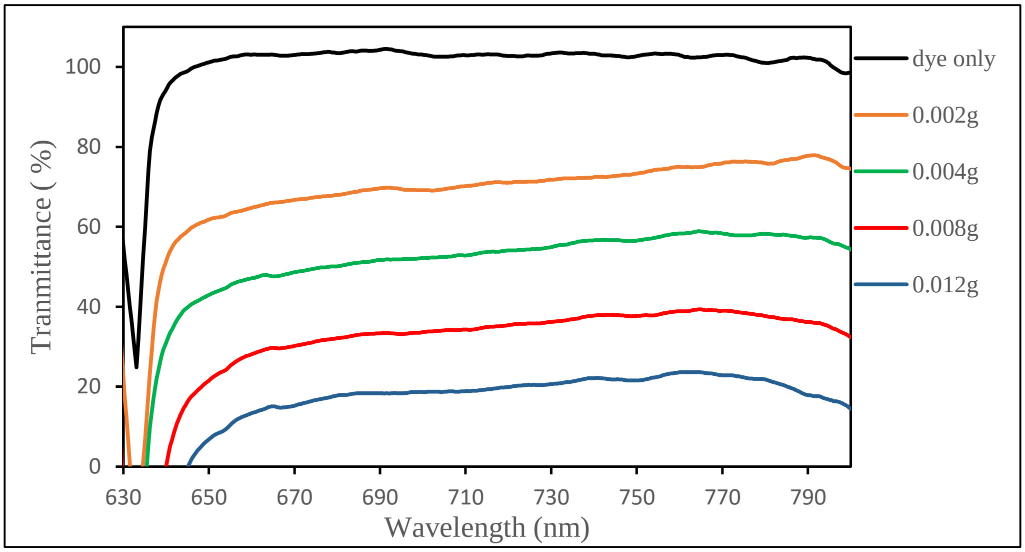

Fig. (3) The transmission spectra at different concentrations of Rhodamine B dye dissolved in water with amount of SiO_2 nanoparticles

Figure (4) shown the fluorescence spectrum of RB dye without nanoparticles.

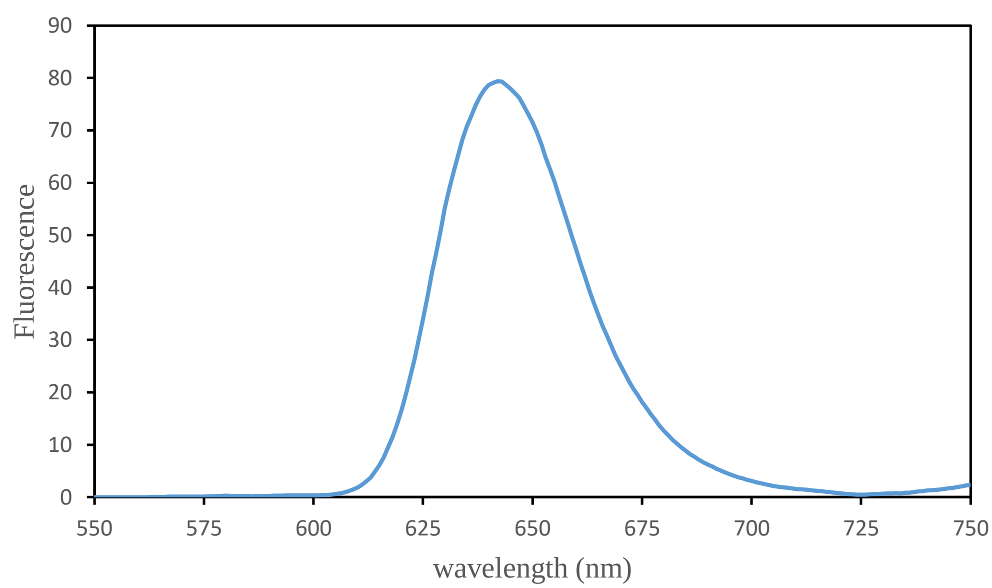

Fig. (4) The fluorescence spectrum of RB dye without nanoparticles at 380nm excitation wavelength

Figure (5) shown effect of excitation wavelength on fluorescence spectra at different Rhodamine dye concentrations dissolved in water. Where from this figure, it is clear that decreasing the wavelength excitation led to decreasing the fluorescence intensity.

Generally, Kasha's rule indicates that fluorescence normally occurs on the lowest vibrational level of the first excited electronic state, so fluorescence emission of molecules should be independent of the excitation wavelength. When the excitation wavelength was gradually changed from 350 nm to 380 nm, the emission maxima of RB solution showed a concomitant red shift. The maximum wavelength of emission spectrum, which depended on the excitation wavelength, showed the red-edge effect (REE). It indicated that these molecules formed different conformational isomer due to the C-N rotating of dialkylamine group of RB.

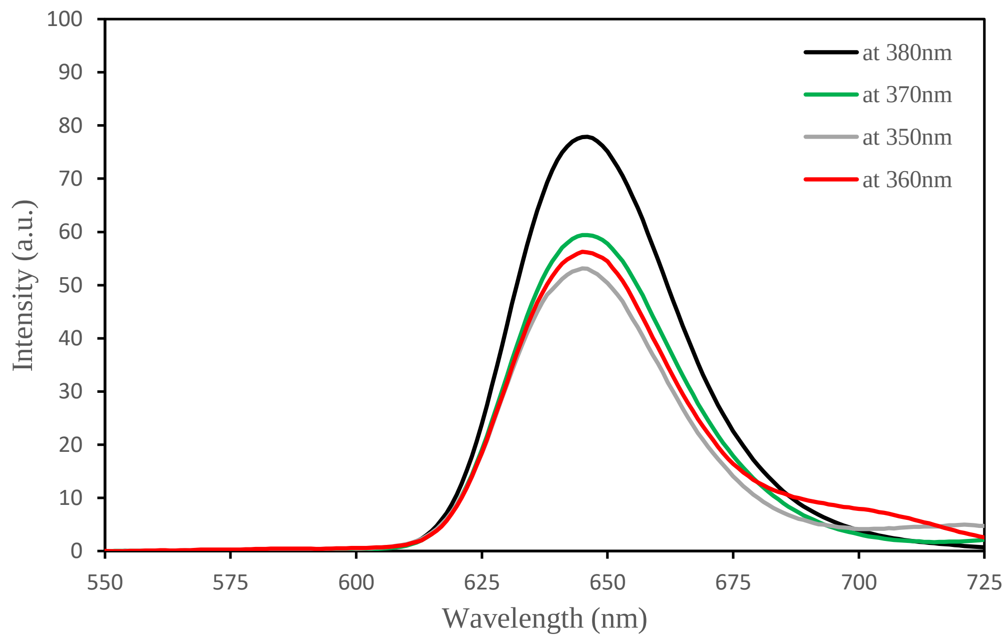

Fig. (5) Effect of excitation wavelength on fluorescence spectra at $5x10^{-3}$M concentration dissolved in water

The assessment of nanoparticles in dye solution can be determined by measuring the fluorescence spectra as the contributions of nanoparticles is observed by further increase in fluorescence intensity when compared to the fluorescence of laser dye. Figure (5) shown that the fluorescence intensity increases with increasing the amount of SiO_2 nanoparticles added to the RB dye solution.

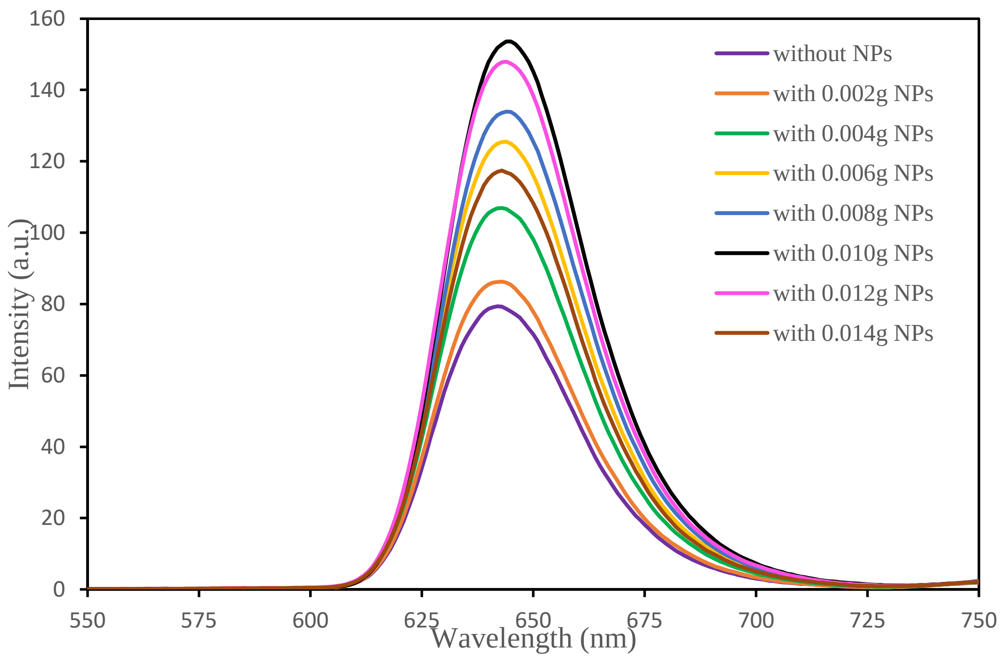

Fig. (6) The fluorescence intensity with amount of SiO_2 nanoparticles

The behavior of fluorescence enhancement of SiO_2 nanoparticles with Rhodamine B dye can be explained by high Rayleigh scattering effect of electromagnetic field by dielectric nanoparticles.

The behavior of SiO_2 nanoparticles quenching with Rhodamine B dye also can be explained by effect of non-radiative energy transfer. Figure (7) shown that.

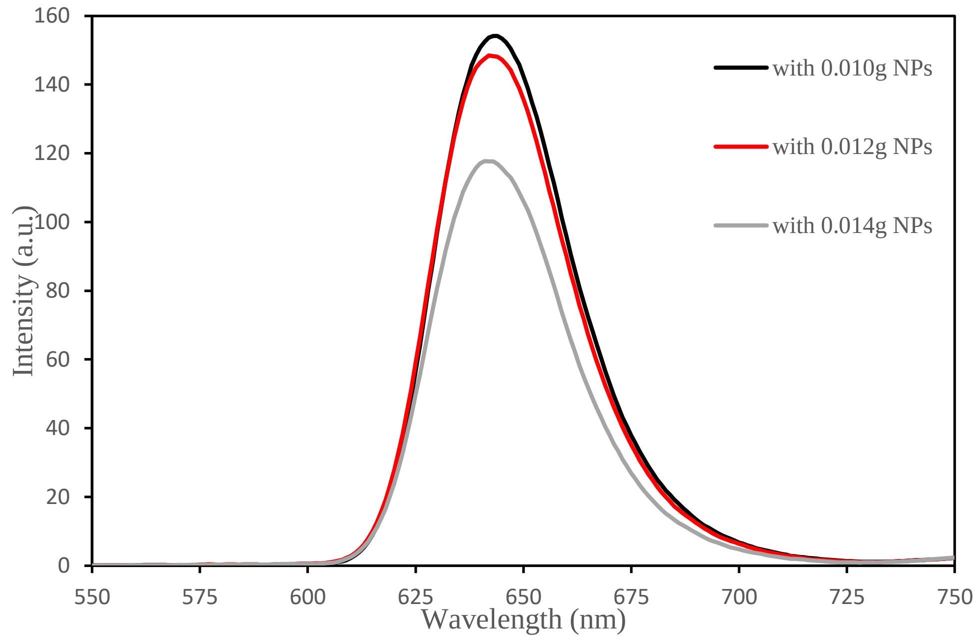

Fig. (7) Behavior of SiO_2 nanoparticles quenching with Rhodamine B dye

Conclusion

In this work, we investigated the impact of colloidal SiO_2 nanoparticles with variable amounts on the quenching of the dye fluorescence. And can be concluded that fluorescence quenching of Rhodamine B by SiO_2 nanoparticles is due to dynamic quenching.

References

[1] C. Mowatt, S. M. Morris, M.H. Song, T.D. Wilkinson, R.H. Friend, et al, Comparison of the performance of photonic band-edge liquid crystal lasers using different dyes as the gain medium, J.Appl. Phys. 107, doi: 10.1063/1.3284939, (2010).

[2] S. A. Razzak, L. H. Aboud and G. Al-Dahash, “Effect of Addition Au Nanoparticles on Emission Spectra of Laser Dye”, International Journal of Applied Engineering Research, Vol. 12, No. 24, pp.14833-14841, (2017).

[3] B. M. Estevão, I. Miletto, L. Marchese and E. Gianotti, “Optimized Rhodamine B labeled mesoporous silica nanoparticles as fluorescent scaffolds for the immobilization of photosensitizers: a theranostic platform for optical imaging and photodynamic therapy”, Phys.Chem.Chem.Phys, DOI: 10.1039/c6cp00906a, (2016).

[4] X. H. Zu, W. Y. Tang, G. B. Yi, J. Yang and X. D. Chen, “Synthesis and Optical Properties of a New Lipophilic Derivative of Rhodamine B”, Russian journal of physical chemistry, Vol. 32, No. 8, (2013).

[5] F. Yang, Y. Chu, L. Huo, Y. Yang, Y. Liu, and J. Liu, “Preparation of uniform Rhodamine B-doped SiO_2/TuO_2 composite microspheres”, Journal of Solid State Chemistry 179, pp. 457-463, (2006).

[6] M. F. Al-Kadhemy, I. F. Alsharuee and A. A. D. Al-Zuky, “Analysis of the Effect of the Concentration of Rhodamine B in Ethanol on the Fluorescence Spectrum Using the “Gauss Mod” Function”, Journal of Physical Science, Vol. 22(2), pp. 77-86, (2011).

[7] I. Shishkin, T. Alon, R. Dagan and P. Ginzburg, “Rhodamine B as a probe for phase transition in liquid solutions”, arXiv:1609.09284vl [cond-mat.soft], (2016).

[8] D. Moreau, C. Lefort, R. Burke, Ph. Leveque, and R. P. O'Conner, "Rhodamine B as an optical thermometer in cells focally exposed to infrared laser light or nanosecond pulsed electric fields", biomedical express, Vol. 6, No. 10 (2015).

[9] J. Muto, "Optical Properties of Rhodamine B in the Solutions of Ethanol, Acetic Acid and Water", Keio Engineering Reports, Vol. 25, No. 6, pp. 71-84, (1972).

[10] M. A. Hameed, O. A. Ali, and S. Al-awadi, "Silicon Dioxide Nanostructures-Coated External Cavity for Gain Enhancement of Rhodamine B Lasing Dye", Iraqi Journal of Applied Physics Vol. 14, No. 1, pp.3-10, (2018).

[11] Boris I. Shapiro, "Molecular Assemblies of Polymethine Dyes", Russian Chemical Reviews, Vol. 75, No. 5, (2006).