Research Article Open Access

Efficiency of Energy Transfer for TiO_2 Nanoparticles with Fluorescein Dye

Mahasin F. Hadi Al-Kadhemy, Asrar Abdulmunem, Husam Sabeeh Al-Arab*
Department of Physics, College of Science, Mustansiriyah University, IRAQ
*Correspondent author email: husam.sabyh84@gmail.com

Article Info

Received
28/11/2017

Accepted
06/03/2018

Published
05/05/2019

Abstract

For different amount of masses of TiO_2 nanoparticles in dye solution, absorption and Fluorescence profiles of the suspension for TiO_2 nanoparticles with Fluorescein (F) in distilled water solution, has been explored. An absorption spectra enhancement was detected for changed amount of masses, which specifies that the doping with TiO_2 nanoparticles have a major effect on the dye absorption spectra. Contrarily, all fluorescence emission spectra for the dye were quenched as TiO_2 nanoparticles amount of masses increases because of Förster resonance energy transfer (FRET).

Keywords: Fluorescence Quenching, TiO_2 Nanoparticles, Fluorescein, Absorption Spectra, Energy Transfer Efficiency.

الخلاصة

تم بحث اطياف الامتصاص والفلورة لمحلول يحتوي على جسيمات ثنائي اوكسيد التيتانيوم النانوية مع صبغة الفلورسين المذابة في الماء المقطر ولعدة كتل مختلفة من جسيمات ثنائي اوكسيد التيتانيوم النانوية مع محلول الصبغة، وقد تم ملاحظة تحسن اطياف الامتصاص مع اختلاف الكتل، مما يكشف عن ان التطعيم بجسيمات ثنائي اوكسيد التيتانيوم النانوية له تاثير كبير على اطياف الامتصاص. على العكس من ذلك، فان جميع اطياف الفلورة تم كبتها كلما ازدادت كتل جسيمات ثنائي اوكسيد التيتانيوم النانوية لحدوث انتقال فورستر الرنيني للطاقة (FRET).

Introduction

There are many spectral studies of the absorption and fluorescence emissions, of the colloidal suspension of metal nanoparticles and non-metal nanoparticles in dye solutions, for its position in tuning luminescence intensity in medical and biological applications[1-6], and for examining optical properties of scattering media as in unsystematic laser dynamics. A normal random laser procedure contains a dye solution and nanopowder acts as the scatters wherein the emission properties depend on the dye amount of masses, the pumping power and scatter density. D.Q. Hoa, *et al.* inspected doping nanoparticles of gold with (DCM) dye on a laser-active medium[7]. J. John, *et al.* studied the optical characteristics of fluorescein dye mixed with gold nanoparticles[8] and M. Barzan and F. Hajiesmaeilbaigi[9] considered the gold nanoparticles effect on the optical properties of Rhodamine 6G, whereas Brito-Silva *et al.*, identified the particle size influence and concentration on laser action[10]. Here, the Fluorescein spectral Characteristics with TiO_2 nanoparticles have been evaluated, according to different amount of masses of TiO_2 nanoparticles with dye molecules via absorption and fluorescence spectroscopy.

The process of Förster resonance energy transfer (FRET) occurs when the fluorescence spectrum of a laser dye, known as the donor, overlaps with the absorption spectrum of other molecule, known as the acceptor. No matter that the acceptor is fluorescent or not. The efficiency of Energy-transfer E can be calculated by[11]:

$$E = 1 - \frac{F}{F_o} \quad (1)$$

Where F and F_o are the fluorescence intensities of dye in presence and the absence of nanoparticles, respectively. The correlation of Stern–Volmer, gives us an exploration for the photophysical intermolecular deactivation kinetics of the (quenching) process. Overall, this process can be denoted by[9]:

$$\frac{F}{F_o} = 1 + K[Q] \qquad (2)$$

Where K is the quenching constant of Stern-Volmer equation, [Q] is the amount of mass for the quencher. So, plotting F_0/F and [Q] would give a straight line, the slope of this line is equal to the quenching constant K.

Materials and Methodology

Suspension of TiO_2 nanoparticles (with an average diameter of 15 nm, Purity: 99%) in Fluorescein ($C_{20}H_{12}O_5$, AnalaR, M_W=332.306 g/mol) with distilled water were prepared. The Fluorescein dye concentration was (1×10^{-5} M). A UV-visible spectrophotometer (T70/T80) used to observe absorption, while emission spectra were detected using spectro-fluoro-photometer (SHIMATDZU RF-5301pc). Different amount of masses of nano TiO_2 were inspected for dye solution varying from 0.0005 g to 0.002 g. All samples prepared by using hot plate stirrer until the TiO_2 nanoparticles homogeneously diffused through the Fluorescein solution.

Results and Discussion

Figures 1 and 2, displays the spectra of absorption and fluorescence of Fluorescein with distilled water, without nanoparticles of TiO_2. The greatest absorption wavelength (λ_{abs}) was 490 nm, whereas the fluorescence wavelength (λ_f) was 514 nm.

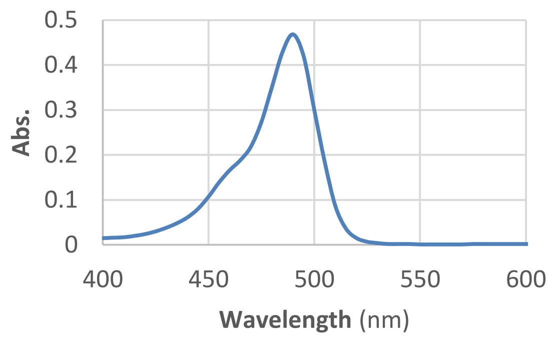

Figure 1: Absorption spectrum of Fluorescein without TiO_2 nanoparticles.

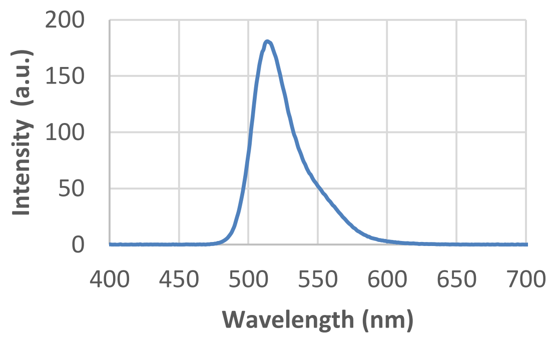

Figure 2: Fluorescence spectrum of Fluorescein without TiO_2 nanoparticles.

Doping the Fluorescein dye with TiO_2 nanoparticles led to spectral intensity improvement of absorption, while lowering the spectral intensity of the fluorescence by rising TiO_2 amount of masses as shown in Figures 3 and 4, respectively.

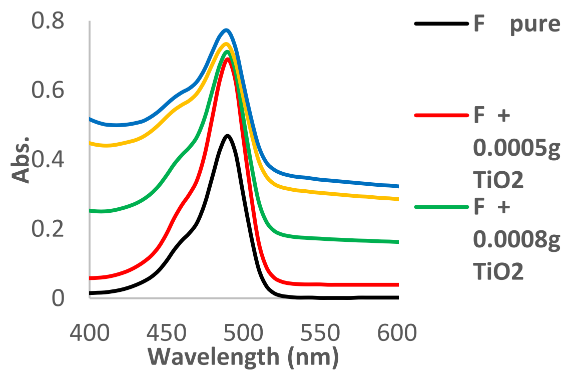

Figure 3: Absorption spectra of Fluorescein with different amount of masses of TiO_2 nanoparticles.

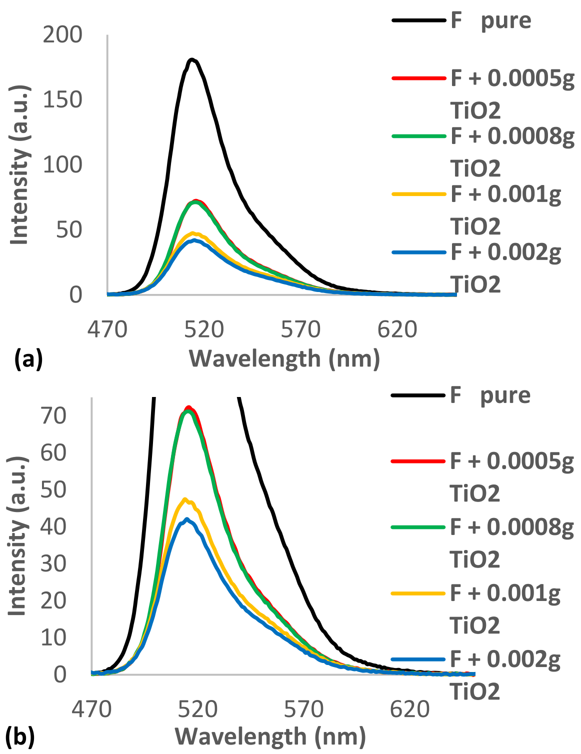

Figure 4: (a) Fluorescence intensity Spectra of Fluorescein doped with TiO_2 nanoparticles of different amount of masses (b) the enlarged section of the dye doped with TiO_2 nanoparticles of different amount of masses.

Table 1 express that with the raising the amount of masses of TiO_2 has led to improve the spectral intensity for absorption, and lowering or quenching the spectral intensity of the fluorescence. Besides, Table 1 indicates very little spectral red shift, by increasing the amount of masses of TiO_2 nanoparticles, the reason for that is, applying scatters to the dye solution gives longer random walk and also more absorption for emitted photons, so that the re-absorption and re-emission has led to red shift.

Table 1: Spectral data.

F_o	TiO_2 (g)	F	E
180.8	0	180.8	0
180.8	0.0005	72.37	0.942
180.8	0.0008	71.19	0.948
180.8	0.001	47.48	0.964
180.8	0.002	42.11	0.970

A dynamic quenching become governing and fluorescence intensities drops down simultaneously, with increasing TiO_2 nanoparticle amount of masses. This action could be clarified on the basis of energy transfer between donor (Fluorescein) and acceptor (TiO_2 nanoparticle). The efficiency of Energy-transfer E can be calculated by eq. (1). The values of energy-transfer efficiencies of the samples listed in table 2.

Table 2: Efficiencies of Energy-transfer for the samples.

	TiO_2 (g)	Absorption intensity	λ_f nm	Fluorescence intensity
(F) 10^{-5}M	0	0.468	٥١٤	180.8
	0.0005	0.689	٥١٦	72.37
	0.0008	0.71	٥١٥	71.19
	0.001	0.731	٥١٤	47.48
	0.002	0.771	٥١٥	42.11

From information of Table 2, it clear that the energy-transfer (quenching) efficiencies increased with rising the TiO_2 nanoparticles amount of masses. The famous Stern-Volmer equation, equation (2), can describe the lowering in the fluorescence intensity of Fluorescein dye with the addition of TiO_2 nanoparticles.

The resulted straight line from the F_0/F versus [Q] plot is presented in Figure 5. The value of the Stern-Volmer quenching constant, *K*, is 1820 M^{-1}. This high amount of the quenching constant infers an efficient quenching of Fluorescein fluorescence with TiO_2 nanoparticles.

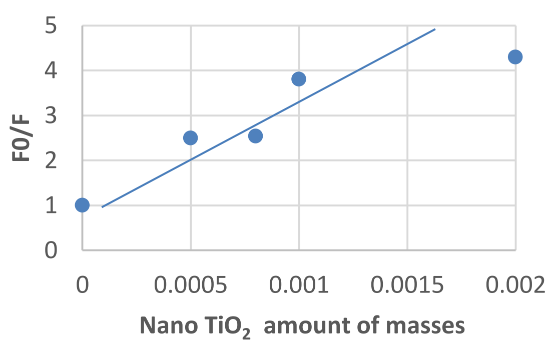

Figure 5: The plot of Stern-Volmer for the Fluorescein with nano TiO_2 amount of masses.

Conclusions

This work implies that the amount of masses of TiO_2 nanoparticles is an important factor for enhancing the absorption and quenching the fluorescence of Fluorescein dye, by observing the spectra of absorption and fluorescence. With help of the Stern-Volmer equation, a relatively high value for the quenching constant is acquired, and it is hinted a proficient quenching in fluorescence of the Fluorescein dye with TiO_2 nanoparticles. Lowering the fluorescence intensity alongside the increasing amount of TiO_2 nanoparticles can be described by perception of energy transfer process between Fluorescein and silver nanoparticle.

References

[1] E. S. Thrall, " Spectroscopic Studies of Abiotic and Biological Nanomaterials: Silver Nanoparticles, Rhodamine 6G Adsorbed on Graphene, and c-Type Cytochromes and Type IV Pili in Geobacter sulfurreducens", Ph.D. thesis, Graduate School of Arts and Sciences, COLUMBIA UNIVERSITY, (2012).

[2] S. A. Umoren, I. B. Obot, Z. M. Gasem, "Green Synthesis and Characterization of Silver Nanoparticles Using Red Apple (Malus domestica) Fruit Extract at Room Temperature", J. Mater. Environ. Sci. 5 (3) (2014) 907-914.

[3] K. Chubinidze, B. Partsvania, L. Devadze, T. Zurabishvili, N. Sepashvili, G. Petriashvili, and M. Chubinidze, "Gold Nanoparticle Conjugated Organic Dye Nanocomposite Based Photostimulated Luminescent Enhancement and Its Application in Nanomedicine", American Journal of Nano Research and Applications, (2017) 5 (3-1): 42-47.

[4] A. K. Dikshit, “Development of laser dye-doped silica nanoparticles embedded optical preform for bio-analysis”, Optical Materials 34 (2012)1054–1061.

[5] H. N. Tran, T. H. Lien Nghiem, T. T. Duong Vu, M. T. Pham, T. V. Nguyen, T. T. Tran, V. H. Chu, K. T. Tong, T. T. Tran, T. T. Xuan Le, J. C. Brochon, T. Q. Nguyen, M. N. Hoang, C. N. Duong, T. T. Nguyen, A. T. Hoang and P. H. Nguyen, “Dye-doped silica-based nanoparticles for bioapplications”, Adv. Nat. Sci.: Nanosci. Nanotechnol. 4 (2013) 043001 (13pp).

[6] W. Liana, S. A. Litherlandb, H. Badranea, W. Tanc, D. Wud, H. V. Bakera, P. A. Guliga, D. V. Lime, S. Jin, “Ultrasensitive detection of biomolecules with Xuorescent dye-doped nanoparticles”, (Analytical Biochemistry 334 (2004) 135–144.

[7] D.Q. Hoa, N.T.H. Lien, V.T.T. Duong, V. Duong, and N.T.M. An, “Optical Features of Spherical Gold Nanoparticle-Doped Solid-State Dye Laser Medium”, Journal of Elec Materi (2016) 45: 2484–2489.

[8] J. John, L. Thomas, N. A. George, A. Kurian and S. D. George, "Tailoring of optical properties of fluorescein using green synthesized gold nanoparticles", Phys. Chem. Chem. Phys., 17 (2015) 15813-15821.

[9] M. Barzan and F. Hajiesmaeilbaigi, "Effect of gold nanoparticles on the optical properties of Rhodamine 6G", Eur. Phys. J. D (2016) 70: 121.

[10] A. M. Brito-Silva, A. Galembeck, A. L. Gomes, A. J. Jesus-Silva, C. B. Araújo, “Random Laser Action in Dye Solutions Containing Stöber Silica Nanoparticles”, J. Applied Physics, 108 (2010) 1-5.

[11] Y. Manman, X. Xiaoli & Y. Pin, "The equal-efficiency-proving of fluorescence quenching and enhancement equation", Chin. Sci. Bull. 50 (2005) 2571-2574.