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Effect of Alumina Nanoparticles on the Photoluminescence of Rh110 Laser Dye Doped with organically modified silicate (ORMOSIL)

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Abstract:

Alumina nanoparticles was synthesized using sol-gel technique and the structural characteristics of these nanoparticles were investigated using AFM where found the size of particles about (80- 100 nm), and it has been studying the effect of these nanoparticles on photoluminescence (absorption and fluorescence) of Rh110 dye laser solution also doped it with non-organic media (ORMOSIL). FTIR analysis has been recorded to the final sample to investigate the vibrational mode of both the silica and the alumina bonds.

Keyword: Laser Dye, Sol-Gel Technique, Alumina Nanoparticles, Photoluminescence.

Introduction:

There are many techniques can be synthesized for Al_2O_3 nanoparticles including ball milling, sol-gel, pyrolysis, sputtering, hydrothermal, and laser ablation[1,2,3]. Sol-gel is one of the most successful techniques to fabricate high photocatalytic Alumina nanostructures [4].

Sol- gel method could get certain properties of heterogeneous materials are required, such as mechanical hardness, optical permeability, chemical stability, porosity required, and size appropriate [5].

Sol–gel, a commonly used technique, involves the formation of an amorphous gel from a precursor solution. This method based on molecular precursors usually makes use of metal alkoxides as raw material. Some advantages of the sol–gel method are better homogeneity and purity from raw material, lower preparation temperature which save energy cost and the ability to form unique composition [6].

There are number of materials which have been used as solid hosts for laser dyes such as: polymers, porous glasses, organically modified silicates or silicate nanocomposites, and polycom glass (combination of polymer and sol–gel) [7].

A polymer was first reported as a medium for organic laser dye. Which many defects of polymer as host for laser dye such as low the rmoconductivity and laser damage threshold [8]. In contrast, sol-gel technology makes it possible to doping of organic dyes into inorganic matrices by low-temperature solution processing. The anti-irradiating property, mechanical and chemical stability of inorganic matrices are better than those of organic matrices [9].

The purpose of the current work is using sol-gel method to synthesis of Al_2O_3 nanoparticles as scattering particles, and study the spectroscopic properties of these nanoparticles doped on silica matrix and organic compound (Rh110 laser dye).

Experimental Part

Alumina nanoparticles (Al_2O_3) were prepared via sol-gel method using the precursor aluminum trichloride ($AlCl_3$) as the starting materials. 28% of ammonia was added slightly to stirred ethanolic solution of aluminum chloride (0.1 M). The gel was let to maturate for 30 hours at room temperature. After filtering in vacuum system, drying at 100°C for 24 h in an oven, and annealing at 1000°C.

Rhodamine 110 solution was prepared by dissolving 7.34×10^{-4}gm in 10 ml of absolute ethanol and stirrer about 30 minutes to obtain homogenous solution of concentration 2×10^{-4} mol/liter, then diluting to 1.5×10^{-4}, 1×10^{-4}, 0.5×10^{-4} mol/liter.

Silica gel (ORMOSIL) host samples doped with Al_2O_3 nanoparticles-R110 mixture were prepared as follows; TEOS and ethanol were mixed at molar ratio of 1:4 to prepare silica solution. The catalyst solution was contained deionized water of unity pH (using 0.15 M of hydrochloric acid HCl) mixed with ethanol at molar ratio of 2:4. Then Al_2O_3 nanoparticles-R110 mixture were added. The final sol was left stirrer for half hour. Finally, the final sample casting at 60ºC. The gel phase was obtained after a few days, and the drying process reaction temperature 90°C drying two hours.

Atomic force microscopy (AFM) was used to achieve the morphology of Al_2O_3 nanoparticles. Alumina film was made by preparing suspension as film by spin coating process.

The absorption spectra of the prepared samples were obtained using UV-VIS double beam spectrometer in the wave length range from 190 to 1100nm, while the fluorescence spectra were done using F96 spectrophotomer.

Results and discussion

In order to study the surface topography of the Alumina nanoparticles at the preparation conditions on it, atomic force microscope (AFM) was used as it has the ability to produce micrographs and analyze the surface of the samples under investigation to give very precious statistical values of average grain size and grains distribution as well as providing a lot of important information. Figure (1) shows the (AFM) micrographs of Alumina nanoparticles.

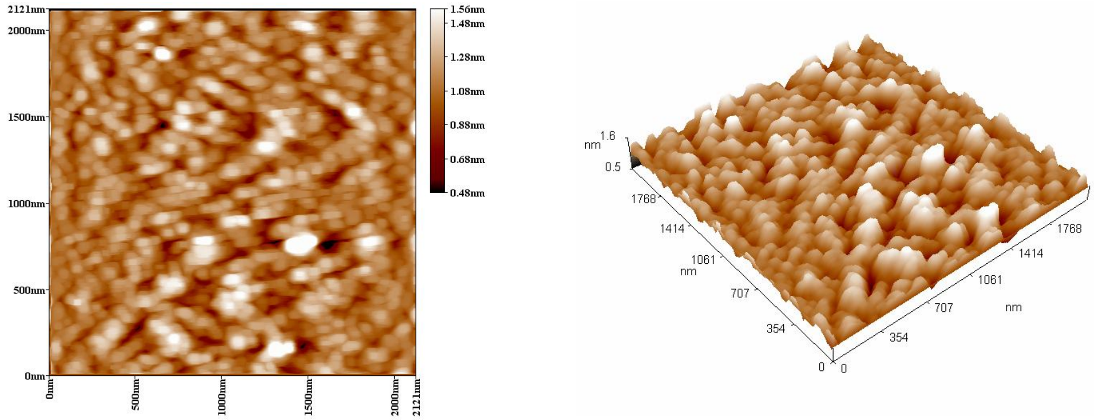
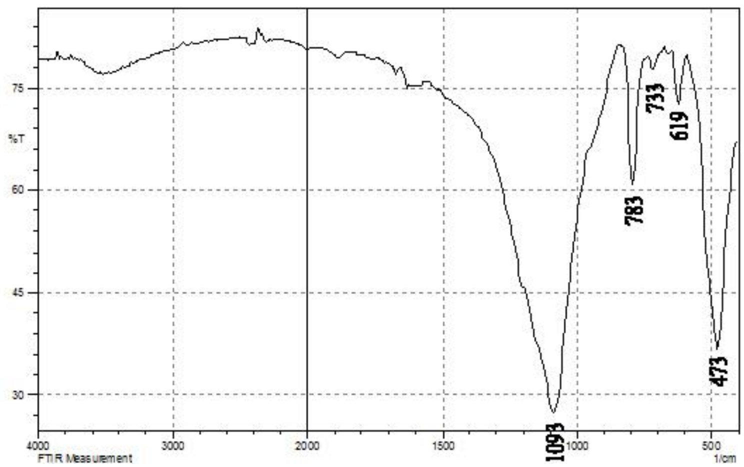


Figure (1): the (AFM) micrographs of Alumina nanoparticles.

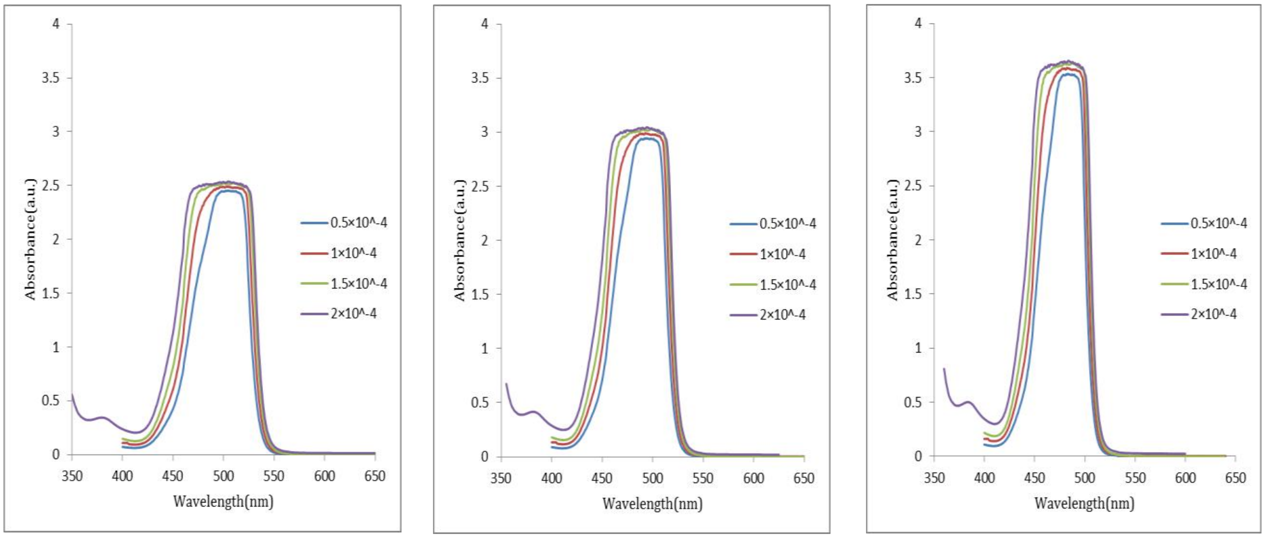
The FTIR spectrum of the composite Al_2O_3 and SiO_2 shown in Figure (2)



Figure(2) FTIR spectrum of the composite Al_2O_3 and SiO_2

Figure (2) shows the peaks at the wave number of 1093 cm^{-1}, 473 cm^{-1} are caused by bending vibration of functional group of Si–O [10]. The bands at 619 cm^{-1}, 783 cm^{-1} are ascribed to vibration modes of Al-O [11], and 733 cm^{-1} are attributed to the Al–O mode of boehmite [12].

Figure (3) shows the absorption spectra for dye solution at different concentrations dissolved in ethanol and mixture with Al_2O_3 and doped in silica gel. The maximum absorption intensity peak occurs at 505nm of dye in ethanol solution at 2×10^{-4} mol/lit.



(a) Rh110 dye solution **(b) R110/Al_2O_3** **(c) silica gel doped with R110/Al_2O_3**

Figure (3): The absorption spectra for Rh110 dye solution dissolved in ethanol and mixture with Al_2O_3 and doped in silica gel

It can be seen that, for the dye solutions, the intensity of absorption band is increased with increasing the dye concentration from 2×10^{-4} to 0.5×10^{-4} mol/liter as shown in figure (3-a). This causes the blue shift in the absorption spectrum with 2×10^{-4} mol/lit dye concentration.

In the case of dye mixed with Al_2O_3 nanoparticles samples, the absorption intensity at the peak of each band increased with increasing of dye concentration as shown in figure (3-b). This causes in the absorption spectrum due to the corresponding increase in the cross section area of the particle inside the sample where more absorption of light.

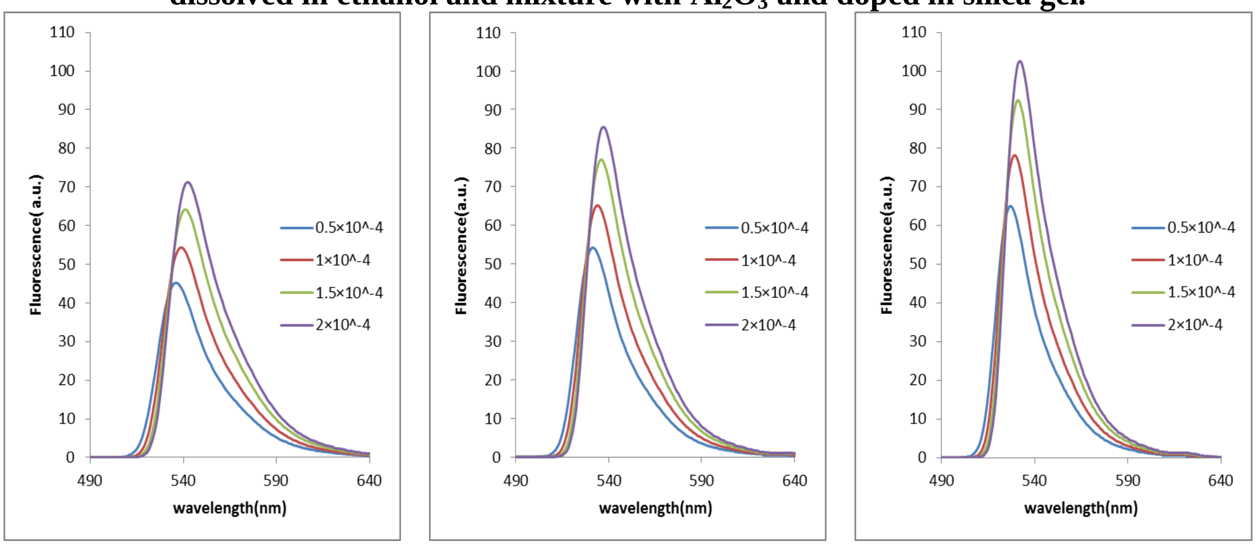
When the absorption spectra of Al_2O_3- Rh110 nanoparticles mixture doped in silica gel, the absorption intensity at the peak of each band increased with increasing of dye concentration as shown in figure (3-c).The reason of these shifts is due to increasing of dye concentration which causes increasing in the number of molecules in volume unit which leads to change in energy level of dye as result of increasing in perturbation field on the molecules, this agree with the explanation of Chen and Fox (1977) [13].

Table (1) shows the change of different parameters of absorbance with concentration of Rh110 dye solution in ethanol, Rh110/Al_2O_3 mixture and R110/Al_2O_3 doped with sol-gel wavelength corresponding to the maximum absorbance and full width at half maximum FWHM.

Table (1): Rh110 dye solution in ethanol, Rh110/Al_2O_3 mixture and R110/Al_2O_3 doped with sol-gel different parameters of absorbance

Concentration mol/lite	Rh110 dye solution			R110/Al_2O_3			silica gel doped with R110/Al_2O_3		
	Max. Abs.	λ (nm)	FWHM (nm)	Max. Abs.	λ (nm)	FWHM (nm)	Max. Abs.	λ (nm)	FWHM (nm)
0.5×10^{-4}	2.455	504	60	2.943	491	53	3.535	483	47
1×10^{-4}	2.493	503	72	2.99	492	62	3.590	482	56
1.5×10^{-4}	2.524	500	79	3.035	490	69	3.642	480	61
2×10^{-4}	2.538	505	86	3.047	494	75	3.656	483	67

Figure (4): shows the fluorescence spectra for dye solution at different concentrations dissolved in ethanol and mixture with Al_2O_3 and doped in silica gel.



Rh110 dye solution **R110/Al_2O_3** **silica gel doped with R110/Al_2O_3**

Figure (4): The fluorescence spectra for Rh110 dye solution dissolved in ethanol and mixture with Al_2O_3 and doped in silica gel

From figure (4-a), for the dye solutions, the intensity of the fluorescence have a maximum value at 2×10^{-4}mol/lit dye concentration at 542nm. Higher concentrations give the lower fluorescence intensity, which may attributed to the concentration quenching process that becomes more active at high concentration levels.

By comparing figures (4-a) and (4-b), it is obvious that the spectral broadening for the Rh110 dye solution is higher in magnitude than that in silica gel matrix. While when one compare figures (4-a,b) with (4-c), it could be notices that the fluorescence intensity in case of silica gel doped with R110- Al_2O_3 nanoparticles more intense than the case (a) and (b). This could attribute to the random unconstrained motion of the liquid molecules which is larger than that of the solid molecules. This results in a dissipation of energy due to molecules collisions indicating that the broadening mechanism is homogeneous in type. Since the inter - molecular distance in the solid is small, the collisions between molecules are so rare and thus, no noticeable energy loss is observed, which coincided with the results of Antony Streeter in 2002 [14].

Table (2) shows the change of different parameters of fluorescence with concentration of Rh110 dye solution in ethanol, Rh110/Al_2O_3 mixture and R110/Al_2O_3 doped with sol-gel wavelength corresponding to the maximum fluorescence and full width at half maximum FWHM.

Table (2) Rh110 dye solution in ethanol, Rh110/Al_2O_3 mixture and R110/Al_2O_3 doped with sol-gel different parameters of fluorescence

Concentration mol/lite	Rh110 dye solution			R110/Al_2O_3			silica gel doped with R110/Al_2O_3		
	Max. Flu.	λ (nm)	FWHM (nm)	Max. Flu.	λ (nm)	FWHM (nm)	Max. Flu.	λ (nm)	FWHM (nm)
0.5×10^{-4}	45.2	536	31	54.2	531	28	65	527	24
1×10^{-4}	54.3	539	32	64.1	534	30	78.1	529	26
1.5×10^{-4}	64.2	541	33	77	536	31	92.4	531	27
2×10^{-4}	71.2	542	34	85.4	537	33	102.5	532	28

Conclusions

In summary alumina nanoparticles were synthesized using sol-gel method. The morphology of these particles was investigate using AFM technique and the effect of these particles is clear on the photoluminescence of Rh110 in sol-gel matrix. The scattering particle (Al_2O_3 nanoparticles) has a huge role in both absorption and fluorescence intensities of Rh110 laser dye in case of the solution and the bulk samples.

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تأثير جسيمات الالمونيا على الضيائية لمحلول صبغة الرودامين110 الليزرية المطعمة في وسط سيلكا معدلة عضوياً

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الخلاصة

تم تحضير جسيمات ثاني اوكسيد الالمنيوم النانوية بأستخدام تقنية السول–جل، تم اجراء فحص AFM للجسيمات المحضرة وكان حجم العدد الاكبر من الجسيمات بحدود (80-100 nm). وقد تم دراسة تأثير هذه الجسيمات على ضيائية (الامتصاص والفلورة) محلول صبغة الرودامين 110 كذلك تم تطعيم هاتين المادتين بوسط لاعضوي ودراسة تأثير الجسيمات في هذا الوسط. فحص FTIR بين اسلوب الاهتزاز لأواصر السليكا والالمونيا لنموذج النهائي.