Spectroscopic Study of $Dy^{3+}:SiO_2$ Prepared via Sol-Gel

Mona Mahdi Salih

College of Science for women- Baghdad University- Baghdad- Iraq
salihmona57@yahoo.com

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Abstract

Dysprosium ions Dy^{3+} Doped with silicon dioxide nano particular was prepared via sol–gel method. The spectroscopic properties of $Dy^{3+}:SiO_2$ sample was investigated by UV- Visible spectroscopy and fluorescence spectroscopy. The fluorescence spectrum for $Dy:SiO_2$ sample is obtain by using excitation light source at wavelength 360nm, two peaks recorded at the wavelength around 482nm and 574nm . The spectroscopic properties of $Dy:SiO_2$ show that the doped silica samples have a suitable peak emission cross-section σ_{em} in comparable with other results, thus it may suggests to use Sol – Gel to made of $Dy : SiO_2$ as solid state Laser active medium.

Keywords: Dy^{3+} fluorescence; Sol Gel.

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الخواص الطيفية لــ $Dy^{3+}:SiO_2$ و المحضرة بطريقة الصول جل

منى مهدي صالح

كلية العلوم للبنات- جامعة بغداد- بغداد – العراق

الخلاصة

في هذا البحث، أستخدمت طريقة الصول جل لتحضير جسيمات ثاني اوكسيد السيليكون النانوية والمطعمة بايونات الدسبروسيوم Dysprosium ions Dy^{3+} . جرى التحقق من الخصائص الطيفية لمادة $Dy:SiO_2$ من خلال أستخدام كل جهازي فحص الامتصاصية UV- Visible spectroscopy وجهاز فحص الفلورة fluorescence spectroscopy . وجد ان طيف الفلورة لعينة الـ $Dy:SiO_2$ يحوي على قمتين مميزتين تقعان عند الطول الموجي 482nm و 574nm (حيث استخدم في فحص الفلورة مصدر ضوئي عند الطول الموجي 360nm كمصدرة اثارة ضوئي). تم حساب peak emission cross-section σ_{em} لعينة الـ $Dy;SiO_2$ ووجد ان قيمته مناسبة جدا مما يعطي مؤشراً جيدا باتجاه الاقتراح بان استخدام طريقة الصول جل في انتاج عينات الـ $Dy:SiO_2$ كمادة فعالة ليزريا Laser active medium

الكلمات المفتاحية : طيف الفلورة لايون +Dy3، الصول جل

Introduction

These days, the Rare earth (RE) ions still have an extraordinary interest, many research concentrated on investigating of spectroscopic to RE when doped with various material. It is so much important to study the spectroscopic properties of RE, in order to make valuable information about radiative properties and peak emission cross-section. Glasses as a host for rare earth ions are good optical materials especially when we deal with visible or near infrared regions, the good thermal stability of glass makes it a favorer host for rare earth ions. In laboratory, the sol-gel process is widely used to formation of glass at room temperature. Sol-gel has so many advantages such as; the process route make doping process to be a flexible route with high rate of homogeneity, the sol gel process (hydrolysis and condensation) could easily controlled by additive of acid or base catalyzed [1-4]. One of the most popular rare earth elements is Dysprosium Dy^{3+}, which used extensively in optical devices. Several researchers have studied its spectra in various matrices [5-7], figure (1-1) show a diagram of partial energy levels of Dy3+: ZBB glass. The spectroscopic study for any laser material are useful parameters for investigate of the laser action to this material. In the present study, we have performed Sol- Gel technique to prepare of Dy^{3+} ions doped with SiO_2, the peak emission cross-section (σ_p) and radiative lifetime τ_{rad} are calculated for prepared sample to investigate the spectroscopic properties of Dy^{3+}:SiO_2.

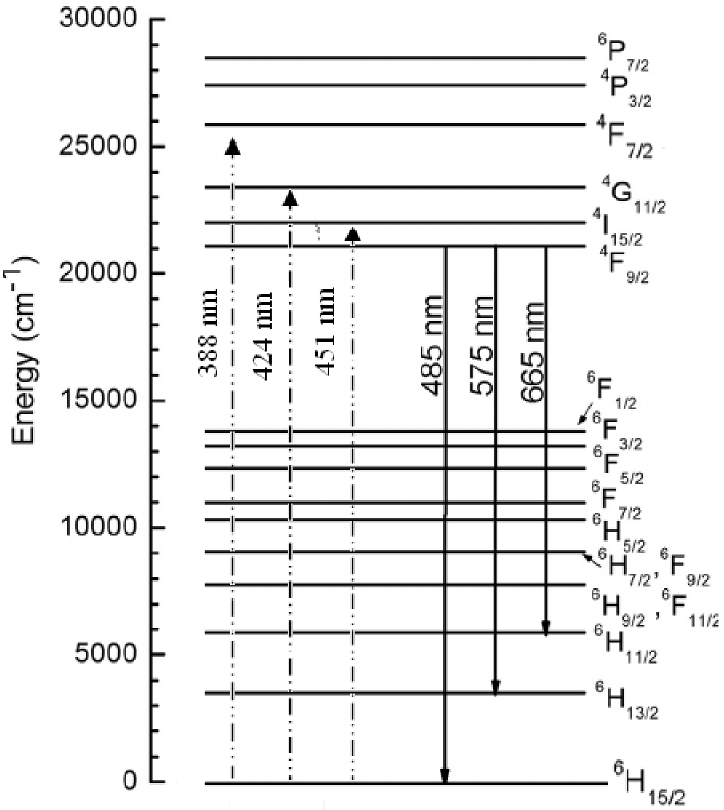

Figure (1-1): The diagram of partial energy levels of Dy^{3+}: ZBB glass [8]

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Experimental

Samples Preparation

The tatraethylourtho silecate 98% (TEOS) from Aldrech, Dysprousium (III) nitrate hydrate from Aldrech), hydrochloric acid 34.5% and Ethanol (EtOH 99.9%) used to prepare doped samples. Deiounized water is used to hydrolysis of (TEOS) to prepare of pure and doped SiO_2 sol. The amount of molar ratio of each chemical; TEOS : H_2O : EtOH : HCl = 1:1:10:0.1. Firstly, T. E. O. S. mixed with EthOH by stirring for about 10 minute, and then 0.01ml of catalysts and water mixed well before adding it to the above solution. The ratio of water to T E O S (molar ratio) is equal to 2.5. Dysprosium (I I I) nitrate hydrate is used to prepare of doped samples (doping rate equal to 5%wt), the Dysprosium (III) nitrate hydrate solved in ethanol before mixing it with TEOS. All solutions left for aged process for 24 hours, and then first drying occurred at temperature 55^{o}C. Finally, drying process done to let the solvent evaporation from samples and achieved transparent sample.

Absorbance spectrums are measured with Shimadzu UV-VIS Spectrometer. Emission spectra measured by using Shimadzu SpectroFlurometer RF1501 (light source at wavelength 340m used as excitation light).

Result and discussion

Absorbance spectrums for Dy3+ : SiO2 are presented in figure(1), the absorbance spectra have some peaks which it attributed to the electronic transitions caused by the energy level of Dy3+ ions. Pertaining to the Dy: SiO2, the absorbance bands could be attributed to the following energy level transition; the peak at 388nm is for transitions from $^6H_{15/2}$ to $^4F_{7/2}$. Peak at 424nm is for transitions from $^6H_{15/2}$ to $^4G_{11/2}$. Peak at 451nm is for transitions from $^6H_{15/2}$ to $^4I_{15/2}$ [9-11].

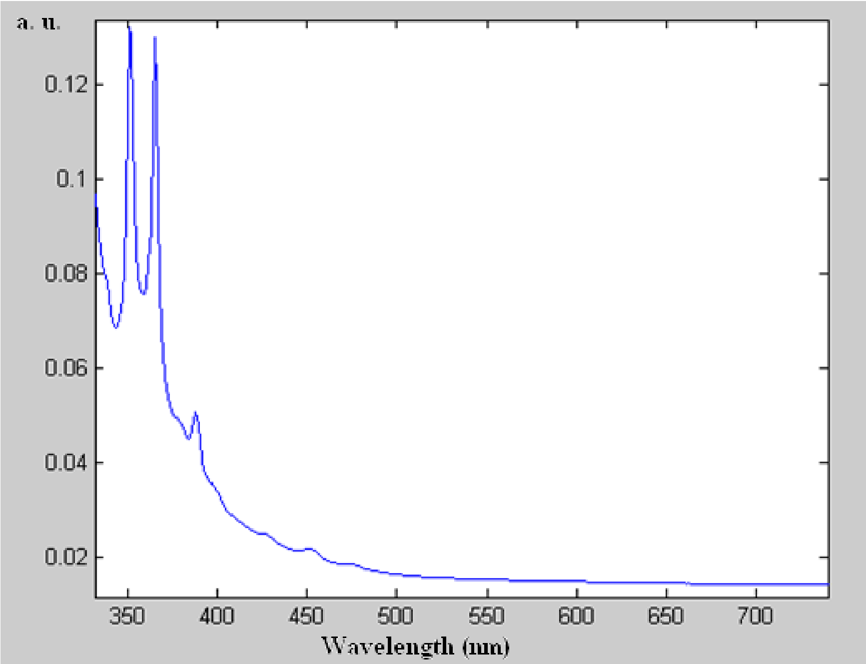

Figure 1: Absorbance spectrum for $Dy^{+3}:SiO_2$ sample.

The fluorescence spectrum for $Dy:SiO_2$ sample are shown in figure (2) (wavelength of excited light equal to 360nm). Two peaks at around 482nm and 574nm are observed in the fluorescence spectrum, first peak attributed to the transition between the levels from $^4F_{9/2}$ to $^6H_{15/2}$ while the second one is for transition between the levels from $^4F_{9/2}$ to $^6H_{13/2}$ of Dy^{3+} ion. Peak emission cross-section (σ_p) for these two transitions can be determined from the relation [12], [13]:

$$\sigma_p = \lambda_p^4 / [8\ \pi\ c\ \acute{n}^2\ \Delta\lambda_{eff.}\ \tau_{rad.}] \text{ -------- } (1)$$

Where τ_{rad} is radiative lifetime, λp is the wavelength of the fluorescence peak, $\Delta\lambda_{eff}$ is the effective fluorescence line width at the FWHM and $\acute{n}$ is founded by [12]:

$$\acute{n} = [n2\ (\lambda) + 2]\ 2 / [\ 9\ n\ (\lambda)\ ] \text{ -------- } (2)$$

Where n (λ) is Refractive index that can be expressed as [12]:

$$n\ (\lambda) = [4R / \{(R+1)2 - K2\ (\lambda)\ \}]1/2 - [(R+1)/(R-1)]. \text{-------- } (3)$$

Where $$K(\lambda) = \lambda\, \alpha(\lambda)/4\pi \text{ ----------------- } (4)$$

Bowen and Wokes [14] give empirical useful formula to get a sufficient appropriate value of radiative life-time τ_{rad} (in seconds):

$$1/\tau_{rad} = 2900\, n^2\, \acute{\upsilon}^2 \int \varepsilon(\acute{\upsilon})d\acute{\upsilon} \text{ ------} (5)$$

Where $\varepsilon(\acute{\upsilon})$ is molecular extinction coefficient, n refractive index, $\acute{\upsilon}$ (in μm^{-1}) is wavenumber and $\int\varepsilon(\acute{\upsilon})d\acute{\upsilon}$ is the area under the absorbance peaks. The molecular extinction coefficient $\varepsilon(\acute{\upsilon})$ could be founds by [14]:

$$\varepsilon(\acute{\upsilon}) = \alpha(\acute{\upsilon}) / [M] \text{ ------------ } (6)$$

Where $\alpha(\acute{\upsilon})$ is absorption coefficients, and [M] is the molar concentration (mol liter^{-1}). The τ_{rad} is attributed to the probability A_{nm} that equal to $1/\tau_{rad}$ [14,15].

The calculated results of radiative lifetime τ_{rad} and emission cross-section σ_p are listed in Table (1). The results show that $Dy:SiO_2$ sample have suitable spectroscopic properties in comparable to those results of $Dy^{3+}:LiYF_4$ (Dy^{3+}:YLF)[16], $Dy:NaF\text{-}B_2O_3\text{-}Al_2O_3$ (or $Dy:CaF_2\text{-}B_2O_3\text{-}Al_2O_3\text{-}CaSO_4$) [17], and $K_2GdF_5:Dy^{3+}$ [18], the suitable value of emission cross-section σ_p and radiative lifetime τ_{rad} indicate that $Dy:SiO_2$ prepared sample is suitable for laser action.

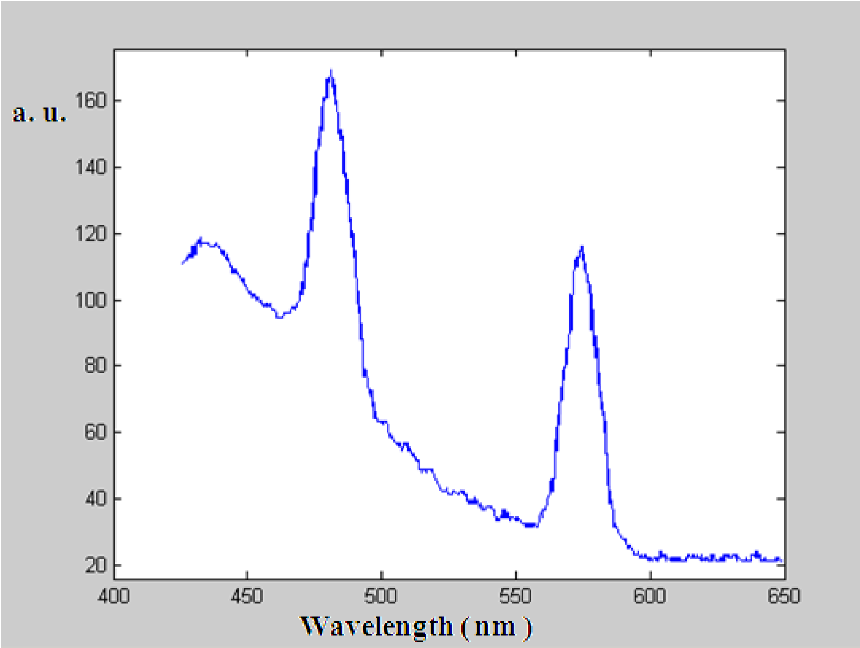

Figure 2: Fluorescence spectrum for Dy^{3+}:SiO_2 doped.

Table 1. Optical properties parameters for Dy: SiO2 sample.

Transition from $^4F_{9/2}$ *To*	λ_{em} *(nm)*	$\Delta\lambda_{eff}$ *(nm)*	τ_{rad} *(m sec)*	σ_p $*10^{-20}$ *(cm^2)*
$^6H_{15/2}$	482	18	3.017	0.0739
$^6H_{13/2}$	574	23	3.017	0.144

Conclusion

The Dy3+ ions efficiently doped with Nano Silica by wet chemical substance synthesis method. The spectroscopic properties for prepared doped sample have suitable radiative lifetime τ_{rad} and emission cross-section σ_p values, thus it may advise to use Dy: SiO_2 Derivative by sol-gel for Laser action.

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