Ultra Scientist Vol. 28(4)B, 88-93 (2016). ISSN 2231-3478 (Print)
www.ultrascientist.org 2319-8052 (Online)

# Sol gel synthesis and optical characterization of the SrAlO:Dy nano phosphor

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**(Acceptance Date 2nd August, 2016, Online Publication date 2nd Sep. 2016)**

## Abstract

Dy doped SrAlOnano phosphors were synthesized by adopting a simple Sol-Gel Method. X-Ray Diffraction (XRD) profile confirms the monoclinic nature of Dydoped SrAlOnano phosphors. The results show that SrAlO:Dy with an average particle size of 80 nm is formed. In addition, Scanning electron microscopy (SEM), Photoluminescence(PL) and Fourier-Transform IR spectroscopy (FTIR) were also used to characterize the synthesized phosphor. The efficiency of the prepared phosphors was analyzed by means of its emission spectral profiles. We also observed a rich IR emission from the prepared phosphors under a Ultra-Violet (UV) source. Such luminescent powders are expected to be applied as IR sensor and MRI device applications.

*Key words:* Phosphors, optical properties, luminescence, XRD, SEM, Dysposium.

## Introduction

In recent years, the strontium aluminates have attracted intense research around the world,as they offer excellent properties such as high quantum efficiency, long persistence of the phosphorescence and good stability. Also, the importance of rare earth ions as efficient emitter in avariety of solid-state matrices is well known. Among rare earth ions, Eu/Dy is often employed byresearchers for making red emitting phosphors, where the prominent 612 nm emission band arisesfrom electric dipole moment allowed transitions[1]. The long lasting phosphors (LLP) oxidematerials have been developed to replace the conventional sulfide afterglow materials because oftheir improved luminescent properties such as high initial brightness, long lasting time, suitableemission color and satisfactory chemical stability[2–4],

which result in an unexpectedly largefield of applications e.g. luminous paints in highways, airports, buildings and ceramic products[5]. With the development of newer technologies, several kinds of chemical synthesistechniques such as co-precipitation[6], sol–gel[7], reverse micro emulsion[8] and combustionmethods[9-10] have been employed to prepare $SrAl_2O_4$ and its phosphors[11]. Comparing these methods, sol-gel synthesis possesses some benefits, namely, relatively low preparation temperature, easy control of the stoichiometry, high levels of product homogeneity, and no need for the use of expensive equipment. In this article, we reported the synthesis of nanostructured $SrAl_4O_7$ doped with Dy via Sol Gel synthesis and effects on PL properties were investigated.

**Experiment**

The materials used for synthesis are strontium nitrate aaluminium nitrate and all other materials are 99.9% pure.The procedure of synthesizing nanoparticles is thoroughly described as follows: 98 wt.% of 2M Strontium acetate [$(CH_3.COO)_2$ $Sr.2H_2O$ was dissolved in 25ml of 2-methoxyethanol with vigorous stirring. 1 wt.% of 2M Dysposium nitrate [$(CH_3.COO)_2Dy.2H_2O$] was dissolved in 25ml of 2-methoxyethanol with vigorous stirring. Simultaneously, 1 wt.% of 2M Aluminum acetate [$C_4H_6AlO_4.4H_2O$] was dissolved in 25ml of 2-methoxyethanol with vigorous stirring and subsequently, it was added to the to the first solution to reach 50 ml in total. Then it was stirred for 30 min at room temperature for the second time. Ammonia was slowly added to this solution with a constant stirring until a pH of 10.5 was achieved. After the stirring of the solution for 30min, acetic acid and ethylene glycol in the ratio1:1 was added to the solution. The sol was heated at 80°C while being mechanically stirred with a magnetic stirrer. As the evaporation proceeded, the sol turned into a viscous gel. The gel was aged for 2h and then dried at 100°C for about 5h. The resulting materials were well grinded and annealed at 950°C for 5h to obtain Dy doped $SrAl_4O_7$ nanopowders. For the preparation of the gel precursors with different wt%, the same procedure was repeated with the wt% of Dysprosium nitrate being varied to 0.5,2, 3,4 and 5.

*Characterization.*

*1.X-Ray Diffraction (XRD).*

The structure and phase purity of the $SrAl_4O_7$:Dy phosphor were investigated by XRD. The XRD patterns were obtained and are shown in Fig.1 for SrA1O: Dy. Diffraction patterns were obtained using CuKa radiation ($\lambda$=1.54051 $A^0$),at 30kV and 15mA. Measurements were made from $2\theta=10^0$ to $80^0$ with steps of $0.02^0$. The XRD patterns of the powders revealed that the structure of $SrAl_4O_7$ is Monoclinic, which is match with JCPDS data card No. 25-1289. The crystallites are less than approximately 50-90nm in size appreciable broadening in the X-ray diffraction lines. SEM images $SrAl_4O_7$: Dy, which is un-uniform and may be due to the formation of fractal attribution to sort of self organization. SEM image of $SrAl_4O_7$ sintered at 900ºC for 3hrs appears to irregular shape

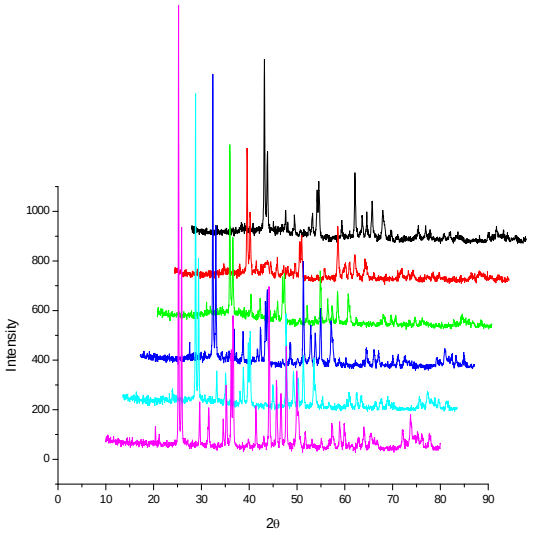


Fig. 1XRD patterns of $SrAl_4O_7$:Dy

*2. SEM Analysis :*

The SEM study is carried out to investigate the surface morphology and theaverage crystallite size of the synthesized phosphors. Fig. 2 shows the representative SE Mmicro-graphs taken for $SrAl_4O_7$ : Dyphosphors at different Dy concentrations. Generally the-particles are of irregular shape. SEM was used to study the surface morphology of thefilms. A representative micrograph of the film is shown in Fig. 2. The micrograph also showed that the particles were interlinked with each other, leading to the formationof big crystals. Also, it is found that some irregular aggrega-tionsformed in the sample. The particle sizes are 80,77,78,75,40,49 respectively.

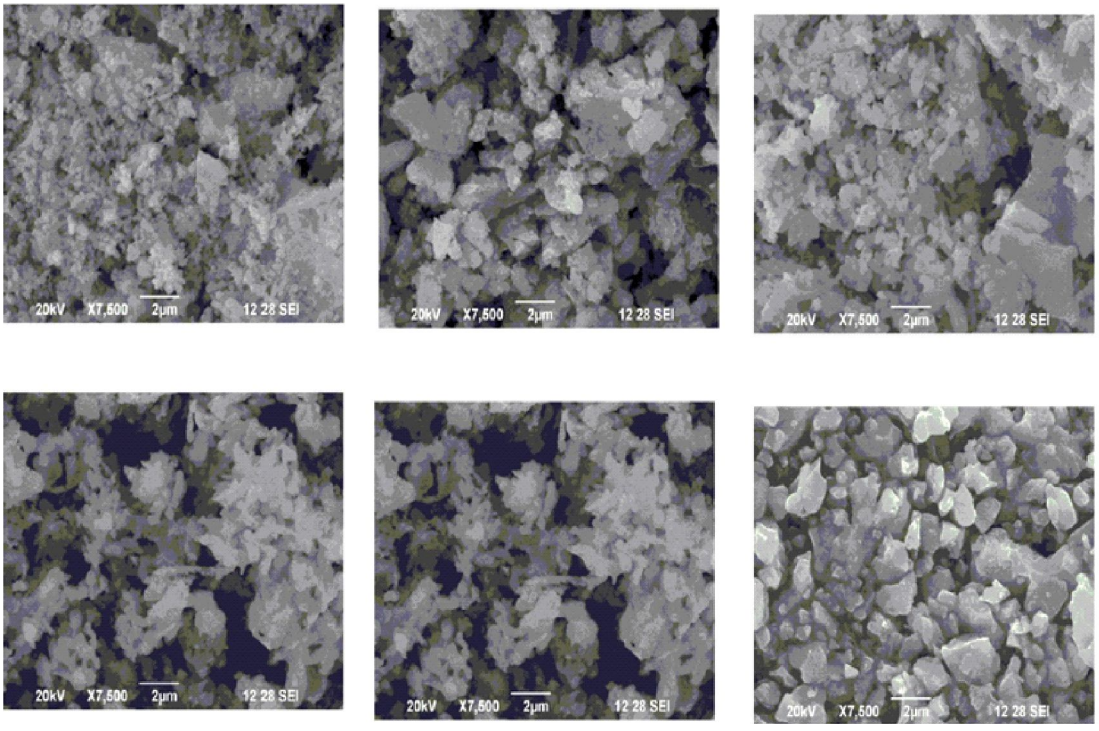


Fig. 2. SEM pictures of $SrAl_4O_7$:Dy

*3. FTIR :*

The FT-IR spectra ofDy doped SrAlO at 0.5%, 1%, 2%, 3%, 4%, and 5% of Dy are shown in Fig. 3. These shows typical metal-oxygen absorption peakat 857 $cm^{-1}$ and 550 $cm^{-1}$. The strong IR absorption at 857 $cm^{-1}$ indicates the stretching vibrations of Sr–O bonding and vibration peakat 550 $cm^{-1}$ is attributed to Al–O bonding. The absorption peaks in the550–850 $cm^{-1}$ region are attributed to the SrAlO characteristicabsorption corresponding to the Al–O stretching and bending modesin $AlO_4$ tetrahedral There is a distinguishable and repeatablepeak near 3540 $cm^{-1}$; assigned to the stretching vibration of O–H onthe films surface. As can be seen in figure, the six X-ray emission peaks at 0.53, 1.27, 1.50, 1.82, 6.52, 9.66keV, 14.22 and 15.8 can be attributed to the characteristic X-ray emissions of O(Kα1), Dy(Mα1), Al(Kα1), Sr(Lα1), Dy(Mα1), Au(Mα1) & Au (Lα2) and Sr(Lα1) respectively. The Au element in the specimen was introduced in the process of Au sputtering for the SEM and elemental analyses. These data indicate that the $Dy^{3+}$ ions have entered in to the host $SrAl_4O_7$.

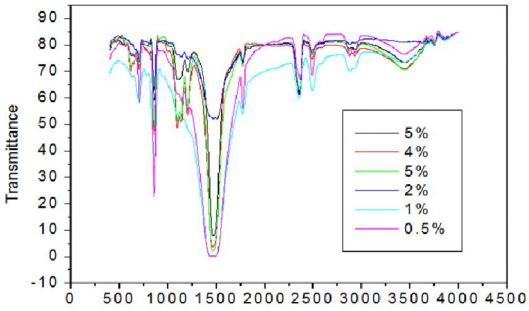


Figure. 3 FTIR spectra of Dy doped $SrAl_4O_7$ at different wt% of Dy.

*4. DRS Spectrum :*

The band gap energy (Eg) for the Dy doped Strontium Aluminate nanostructures were determined by theplot of the square of the modified Kubelka_Munk function vs.the photon energy $(hv)^8$, shown in Fig. 4. Thebandgap can be obtained from a linear extrapolation of theabsorbance edge to the wavelength axis. Thebandgap (Eg) of strontium aluminatesamples are found to be in the range of 3.16 to 3.3eV.

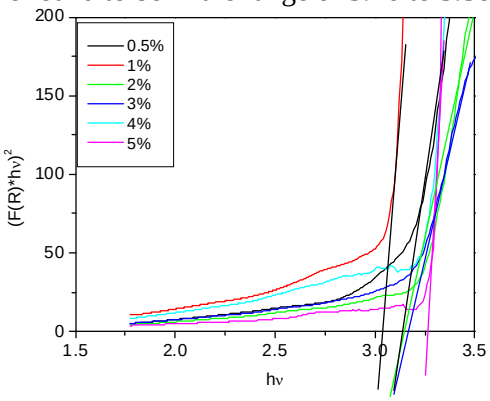


Figure 4. DRS spectra of Dy doped $SrAl_4O_7$ at different wt% of Dy.

*5. Photoluminesence :*

The photoluminescence spectra of $SrAl_4O_7$:Dynanoparticles under 360 nm excitation wavelength is shown in Fig. 5. The PL emission spectra of all samples exhibit three emission bands with corresponding peak wavelengths of 395 nm, 520 and 790 under excitation of 360nm.The strong peak showing blue emission at 395 nm was due to the exciton emission, and weak green emission at 520 nm was due to oxygen interstitial.The strong UV emission corresponds to the exciton recombination related near-band edge emission of nanoparticles. The green emissions are possibly due to surface defects in the nanoparticles.

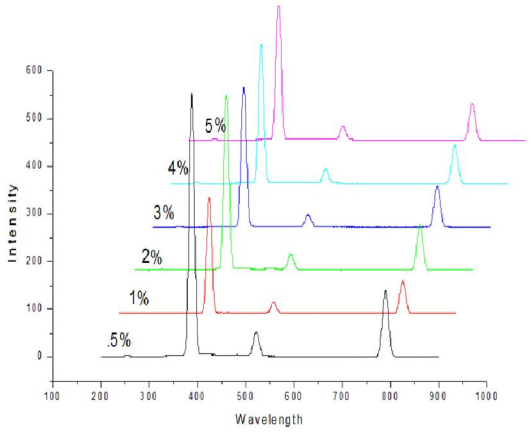


Fig. 5. Photoluminescence Spectra of Dy doped $SrAl_4O_7$ at different wt% of Dy.

The photoluminescence emission spectrum of SrAlO: Dy is shown in fig 5.which is obtained under the excitation wavelength 360nm. The spectra consist of three emission bands: a emission band at ~396 a week blue–green band at ~ 520 nm and a strong IR band at ~800 forSrAlO:Dy. The strong UV emission corresponds to the exciton recombination related near-band edge emission of nanoparticles. The weak blue and weak blue–green emissions are possibly due to surface defects in the nanoparticles. The week green band emission corresponds to the singly ionized oxygen vacancy in SrAlO: Dy. The low intensity of the green emission may be due to the low density of oxygen vacancies during the preparation of the nanoparticles, where as the strong room-temperature UV emission intensity should be attributed to the high purity with perfect crystallinity of the synthesized nanoparticles. It is well known that Dy doped strontium aluminates phosphors show long phosphorescence in green region. But in our case both samples doped or undoped give green emission peak at 520nm with 360nm excitation. The fact that the emission characteristics are excitation dependent shows the emission mechanism is governed mainly by defect controlled processes. Further the emission does not arise from the activator ions (as seen in the undoped sample) suggesting that the defect centers act as trap levels in bringing out various emission features. To explain the decrease in photoluminescence intensity, we suggest that incorporation of Dy ions reduce the defects (exciton, oxygen vacancies), which act as sensitizers for energy transfer due to strong mixing of charge transfer.

## Conclusion

The phosphors $SrAl_4O_7$:Dy (at 0.5, 1, 2, 3, 4 and 5 wt% of Dy) with a monoclinic structure were successfully prepared by Sol-Gel method. The characteristic peaks of $SrAl_4O_7$:Dy phosphors were observed and they are located at 395nm, 520nm and 800nm which are corresponding exciton emission and the oxygen interstitial.The luminescent intensity of Dy doped $SrAl_4O_7$ nanoparticles increases with increase in the Dy dopant concentration at first and then it decreases. The maximum intensity was achieved for about 1 mol% $Dy^{3+}$. The photoluminescence investigations reveals that the emission mechanism is governed mainly by defect controlled processes. The bandgap (Eg) of strontium aluminate samples are found to be in the range of 3.16 to 3.3 eV.

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