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Photoluminescence Behaviour of Pure $GdAlO_3$ for Different Annealing Temperature Synthesized by Solution Combustion Method

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Abstract

Pure $GdAlO_3$ phosphor was synthesized by solution combustion synthesis method using urea as fuel. The phosphor was characterized by X-ray diffraction (XRD) and scanning electron microscopic (SEM) technique. The variation in photoluminescence behaviour with different annealing temperature was studied by recording emission spectra under 335 nm excitation. All the phosphor gives similar emission peaks centered at UV region at 315 nm and in red region at 623 nm. Emission intensity increases with increasing annealing temperature.

1. Introduction:-

$GdAlO_3$ is a provoskite based phosphor material. It belongs to the family of rare earth aluminates that crystallize in a slightly distorted orthorhombic provoskite structure [1]. This has potential application as phosphor [2], scintilator [1], and regenerator material for cryo-coolers [3]. In the low phonon energy hosts, rare-earth aluminates, $REAlO_3$, have favourable optical, thermal and mechanical proper ties, and are suitable hosts. Among these compounds, gadolinium alumininate, $GdAlO_3$ (GAP), is an important phosphor host material with a perovskite structure. The crystal structure belongs to orthorhombic with space group Pbnm [4]. Several chemical techniques, such as the polymerized complex route, combustion synthesis, sol–gel have been utilized to synthesize gadolinium aluminate ($GdAlO_3$) based perovskite powder [4-8].
In this paper, we have synthesized pure $GdAlO_3$ phosphor by means of combustion synthesis process. The particle size and phase of prepared phosphor was determined by X-ray diffraction method and scanning electron microscopy method. The luminescence behaviour of the phosphor was studied by recording its emission spectra under 275 nm excitation.

Synthesis & Experimental detail:-

$Gd(NO_3)_3.6H_2O$, $Al(NO_3)_3$ purchased from Sigma Aldrich were used as precursor material and urea was used as fuel for the synthesis of the phosphor. Aqueous solutions of precursor materials and fuel were prepared in distilled water. Stoichiometric amount of precursor solutions were added in a beaker followed by addition of urea in 2:1 ratio. The solution was stirred on a hot plate at 60°C to change the mixture into a gel form. This gel form was transferred into an alumina crucible and placed into a preheated muffle furnace maintained at 600°C. The sample undergoes spontaneous combustion and a powdered sample was obtained. The sample was further annealed at 900°C for 2 hrs [9]

X-Ray Diffraction analysis:-

The powder obtained was characterized by X-ray diffraction analysis for phase analysis. Fig. 1 shows the XRD pattern of the sample. The diffraction pattern is in good agreement with the JCPDS card no 32-0383 and shows orthorhombic phase [10]. The average crystal size determined from the X-ray line broadening using Scherrer's formula [11]. The obtained crystal size was obtained around 10 nm. Figure 2 shows the proveskite crystal structure of the sample, it was prepared by FULLPROF programme [12-14]

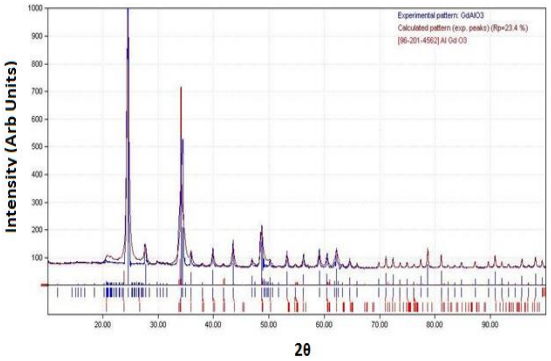

Figure 1. XRD pattern of pure $GdAlO_3$ phosphor

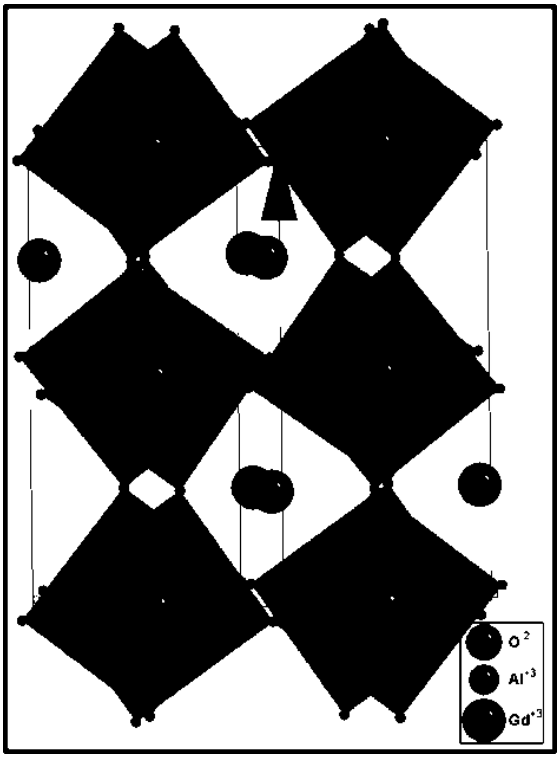

Figure 2. Proveskite structure of the sample [12]

Scanning electron Microscope results:-

The morphology of the sample was inspected using Scanning electron microscopy. SEM image of the sample annealed at 900°C is shown in fig 2. It can be observed from the image that the sample is uniform, crack free and agglomerated with an average crystal size of 12nm.

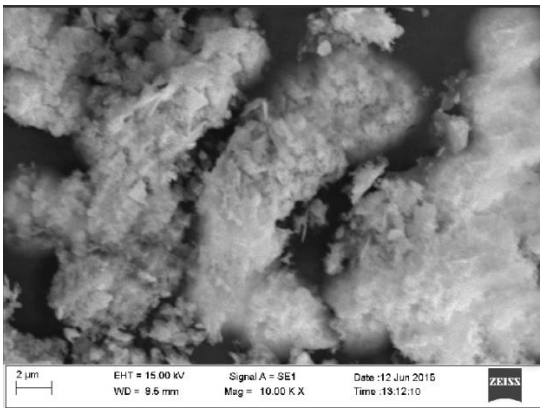

Figure 3. SEM image of $GdAlO_3$ phosphor annealed at 900°C

EDX:-

Elemental composition of the sample was inspected by energy dispersive X-ray diffraction spectra. The spectra have peaks of Gd, Al and O which confirms the formation of $GdAlO_3$ phosphor (Fig 4).

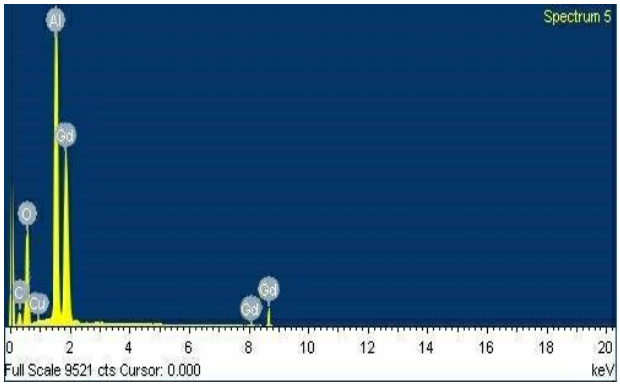

Figure 4. EDX spectra of $GdAlO_3$ sample

Photoluminescence:-

Under UV excitation of 335 nm the emission spectra of the $GdAlO_3$ sample was recorded. Fig 5 shows the emission spectrum of the sample. The emission spectrum has emission peaks at UV region at 309 nm and 357 nm and in visible red region at 615 nm. All the emissions were due to transition between the energy levels of Gd^{3+} ion. $^8S_{7/2}$ level of Gd^{3+} ion absorbs two 335 nm photons and gets excited by two photon process and jumps to charge transfer band at $4f^6$ 5d level, which non radiatively populates ^6G_J level. The transition from ^6G_J to ^6P_J level is responsible for visible emission at red region centered at 615 nm. The emission at UV region centered at UV region at 309 nm is due to transition from ^6P_J to $^8S_{7/2}$ level (Fig 6) [15]. The Emission spectra were recorded for the samples annealed at 600 and 900 °C. It was observed that the intensity of emission peaks increases with annealing (Fig 7).

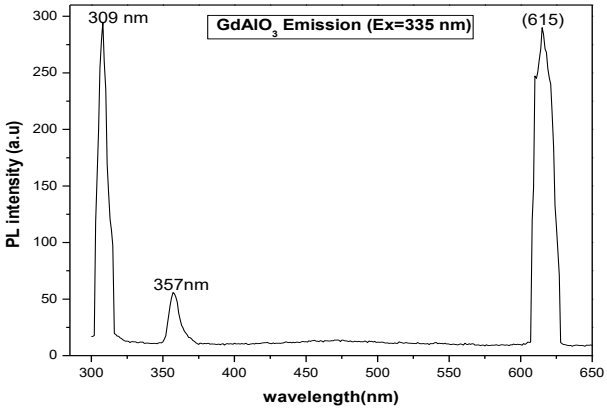

Figure 5. Emission spectra of the $GdAlO_3$ phosphor under 335 nm excitation

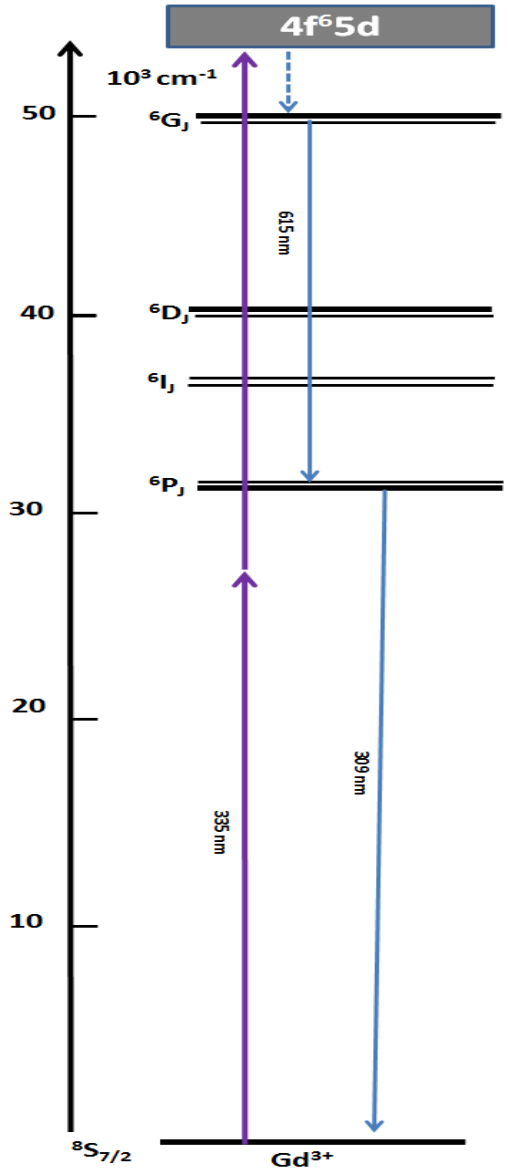

Figure 6. Mechanism of emission spectra in $GdAlO_3$

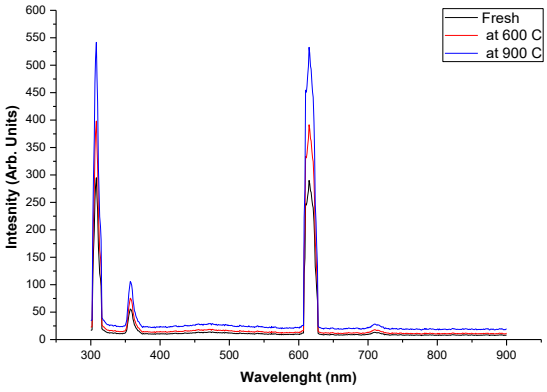

Figure 7. Effect of annealing on $GdAlO_3$ phosphor

CIE :-The visible emission colour was determined by identifying CIE coordinates X and Y. These coordinates have values 0.534 and 0.317 respectively which resembles with red emission.

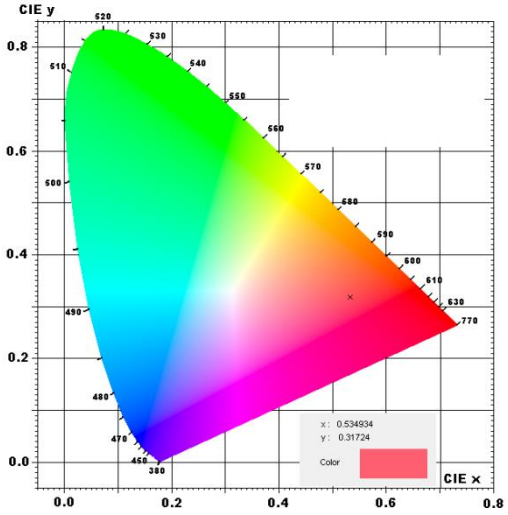

Figure 8. CIE coordinate diagram for emission spectra

Conclusion:-

Orthorhombic $GdAlO_3$ phosphor was synthesized by combustion synthesis method. Crystal size was obtained 10 nm by XRD analysis. Emission spectrum was monitored under 335 nm excitation and has peaks at UV and red region centred at 315 and 615 nm respectively. The photoluminescence behaviour follows two photon processes. CIE confirms emission of red colour by the phosphor.

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