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Synthesis and Characterization of $MgY_2B_2O_7$: Eu(III) phosphors

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Abstract: The synthesis of Eu^{3+} doped novel $MgY_2B_2O_7$ phosphor by combustion technique. The luminescent properties of $MgY_2B_2O_7$:Eu^{3+} phosphors have been explored by analyzing their excitation and emission spectra with the help of photoluminescence spectrometer at room temperature. Powder X-ray diffraction analysis shows the crystalline nature of the prepared phosphor. Under UV excitation, $MgY_2B_2O_7$:Eu^{3+} show sharp emission in the orange-red region corresponding to $^5D_1 \rightarrow {}^7F_2$ transition of Eu^{3+} ion.
Keywords: combustion synthesis; photoluminescence; rare earths; $MgY_2B_2O_7$.

Introduction

A luminescence material absorbs various types of energy and emits thermal and electromagnetic radiation, which exists in the ultraviolet and infrared spectra, but more commonly in the visible spectrum. Rare earth (RE) elements have been necessary and promising activators for phosphors as their luminescence and luminescence properties depend on the 4f energy levels of the lanthanides dopants related to the valence band and the conduction band of the host of material [1]. The stability of the phosphor both chemically and thermally is a matter of concern in order to prevent degradation with temperature and time resulting in losing efficiency and causing changes in the produced light color [2]. Therefore development of persistent phosphors with better physical and chemical stability, water-resistant property is an important requirement in lamp industry.

Recently, more demand of development for novel efficient inorganic luminescent materials, Eu ion doped materials have good attention in the ultraviolet to the red region of the electro-magnetic spectrum and the emission wavelength completely depends on the nature of the host lattice due to d→f transition [3]. Yttrium based phosphors are most promising host materials because of their easy to synthesis, chemical/thermal-stabilities and gives excellent luminescence property over a wide range. It is well known that rare earth doped yttrium based materials have fairly good luminescence properties, such as $Sr_3Y(PO_4)_3$:Eu^{3+}[4], $CaYAl_3O_7$: Eu^{3+}[5], $Ba_3Y(PO_4)_3$:Eu^{3+}etc [6].

In the present paper, we have reported the preparation and characterization of $MgY_2B_2O_7$:Eu^{3+} phosphor synthesized via solution combustion method. Further, photoluminescence spectra of the $MgY_2B_2O_7$: Eu^{3+} phosphor was investigated in detail.

Experimental

The $MgY_2B_2O_7:Eu^{3+}$ samples were prepared by a combustion synthesis. The starting materials for the preparation of $MgY_2B_2O_7:Eu^{3+}$. During the synthesis, the stoichiometric of Y_2O_3 + Eu_2O_3 +HNO_3 to obtain yttrium nitrite ($Y(NO_3)_3$), magnesium nitrite ($Mg(NO_3)_2$), boric acid (H_3BO_3), urea ($CO(NH_2)_2$), and ammonium nitrite (NH_4NO_3) were mixed thoroughly in agate mortar so that the paste was formed. As prepared paste was then heated on heating menthol at nearly 60–80°C to get a clear solution from it. The solution then transferred directly to the pre-heated furnace (550°C) after warming it for 5 min the self heat generating redox reaction was completed and the fine powder of $MgY_2B_2O_7:Eu^{3+}$ was finally obtained. This raw powder was sintered for 2 h at 750°C and quenched to room temperature [7]. Above same process applied for various concentration of Eu^{3+} (Eu^{3+} = 0.1, 0.2, 0.5, 1 and 2%).

Result and Discussion

The XRD pattern of the polycrystalline powder samples of the phosphor $MgY_2B_2O_7$ have been analyzed for the structure confirmation. As the sample is first time prepared and analyzed careful for peak to peak comparison with the reported compounds, it is found that there is no standard ICDD file available to match the structure of this phosphor. Also pattern did not indicate the presence of phases or peaks from precursor material like $Y(NO_3)_3$, $Mg(NO_3)_3$, H_3BO_3, and other likely phases. So according to the stoichiometric balance calculated using chemical composition of $MgY_2B_2O_7$ we interpreted that the final product was formed in crystalline and homogeneous form called to be $MgY_2B_2O_7$ [8]. This results may indicate that the prepared samples are not the simple chemical mixtures of $Y(NO_3)_3$ (2 mole), $Mg(NO_3)_3$ (1 mole), H_3BO_3 (2 mole) but a new novel host $MgY_2B_2O_7$ material. Therefore it is indirect evidence for the complete formation of $MgY_2B_2O_7$ compound. In order to determine the crystalline phase structure of $MgY_{(2-x)}B_2O_7:xEu^{3+}$ (x=0.001, 0.002, 0.0005, 0.01 and 0.02) are shown in Fig. 1. All the XRD patterns are compared with each other; there is no markedly effect on XRD patterns of different concentration of Eu samples.

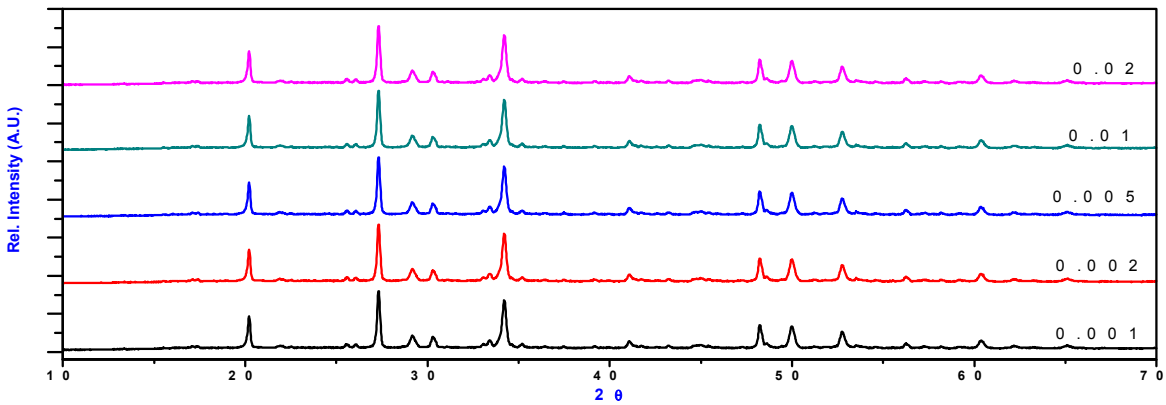

Figure 1. Powder X-ray diffraction pattern of $MgY_{(2-x)}B_2O_7:xEu^{3+}$ (x=0.001, 0.002, 0.0005, 0.01 and 0.02)

Figure 3 show combine emission and excitation spectra of $MgY_2B_2O_7:Eu^{3+}$ phosphor. The emission is monitored at 230 nm and excitation is monitored at 613 nm. The emission spectra consist of no of peaks in the wavelength region from 525 to 650 nm attributed to $^5D_0 \rightarrow {}^7F_J$ transition of Eu^{3+}. The emission spectra consist of number of peaks in range of 500 nm to 550 nm are attributed to $^5D_1$ to ^7F_J (J=0-2) transition of Eu^{3+}. On the other hand peaks from 550 nm to 700 nm corresponds to $^5D_0$ to ^7F_J (J= 0-3) transition of Eu^{3+}. The main emission at 613 nm was attributed to $^5D_0$ to $^7F_2$ transition of Eu^{3+} ions. It is well known that the relative intensity of the $^5D_0 \rightarrow {}^7F_1$ and $^5D_0 \rightarrow {}^7F_2$ transitions strongly depends on the local symmetry of the Eu^{3+} ions. When the Eu^{3+} ions occupy sites with inversion centers, the $^5D_0 \rightarrow {}^7F_1$ (the magnetic dipole) transition should be weak, while the $^5D_0 \rightarrow {}^7F_2$ (the electric dipole) transition is parity-forbidden and should be relatively strong. The emission spectra of the compound $MgY_2B_2O_7$ exhibit strong red luminescence of $^5D_0 \rightarrow {}^7F_2$ at 613 nm indicating that the Eu^{3+} ion is located in a non-centrosymmetric position in the matrix [9]. According to group theory selection rules, the magnetic dipole and the electric dipole are permitted and the electric dipole transition is the stronger one.

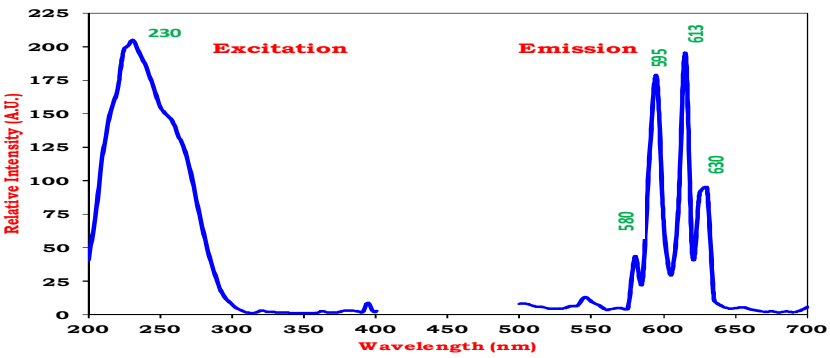

Figure 3. Excitation & Emission Spectra for $MgY_2B_2O_7$ activated with Eu^{3+}

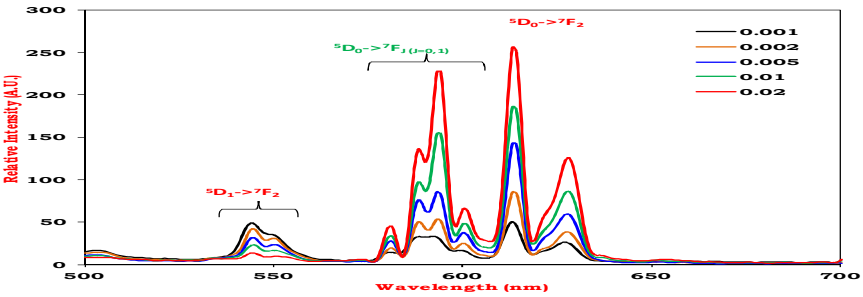

Figure 4. Emission Spectra for different concentration of Eu^{3+} in $MgY_2B_2O_7$

Figure 4 represents The phosphors $MgY_{(2-x)}B_2O_7$:xEu^{3+} doped with different molar concentration of Eu^{3+} (x=0.001,0.002,0.005,0.01 and 0.02) were prepared by the solution combustion synthesis the emission spectra of $MgY_2B_2O_7$ doped with different Eu^{3+} concentrations for the excitation wave length of 230 nm. All of the emission spectra exhibit the similar profile with different relative intensities. The emission intensity increases initially with the increase of Eu^{3+} concentration and maximum emission is observed for x=0.02 mole Eu^{3+} doping.

Conclusions

The phosphor $MgY_2B_2O_7$: Eu^{3+} was successfully prepared by a low cost, simple and time saving solution combustion technique. PL spectra of $MgY_2B_2O_7$: Eu^{3+} with 0.2 % concentration of Eu^{3+} show intense emission at 613 nm attributed to $^5D_0 \rightarrow {}^7F_2$ transition indicating that the Eu^{3+} ion is located in a non-centrosymmetric position in the matrix and also shows that the slightly weak emission at 595 nm due to $^5D_0 \rightarrow {}^7F_1$ transition. PL results indicate that the emission is in the orange-red region of the spectrum.

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