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Short note

Efficient energy transfer and fluorescence in $SrYAl_3O_7:Ce^{3+}$, Tb^{3+} phosphor

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Abstract

A green light emitting phosphor $SrYAl_3O_7:Ce^{3+}$, Tb^{3+} have been synthesized by fast solution combustion route. Structural and photoluminescence properties with energy transfer (ET) mechanism were investigated. Due to the ET from Ce^{3+} to Tb^{3+}, enhancement in the emission intensity of Tb^{3+} is observed. The prepared phosphors exhibit both the weak emission of Ce^{3+} (5d–4f) and the strong emission of Tb^{3+} ($^5D_4$–^7F_J) with considerable emission intensity. The ET mechanism from Ce^{3+} to Tb^{3+} ion has been determined to be dipole–dipole interaction, and the ET efficiency is obtained over 81%. The effect of Ce^{3+} and Tb^{3+} concentrations on luminescence intensity in single and co-doped phosphors are also studied. The phosphor has remarkable CIE chromaticity coordinates of (0.198, 0.532), which indicate that Ce^{3+} and Tb^{3+} co-doped $SrYAl_3O_7$ phosphor may be potential UV-convertible candidate with green light emitting for w-LEDs.

Introduction

White light-emitting diodes have been expected as the next generation solid-state lighting sources to replace the incandescent and fluorescent lamps because of their

numerous superior advantages such as high efficiency, long lifetime, reliability, small size, good light stability and environmental friendly [[1], [2], [3], [4], [5]]. One of promising approaches to prepare w-LEDs is by pumping blue/green/red tricolor phosphors with a near-ultra violet (360–410 nm) InGaN-based LED as the excitation source in order to obtain excellent color rendering properties. For this reason, it is necessary to develop novel phosphor having the multi-color emission in the field of optical materials [[6], [7], [8], [9]].

It has been widely recognized that ET is a prominent way to develop desired phosphors for w-LEDs. In order to generate white light, co-doping with different RE ions into a proper host is one common strategy to control the emission color via ET processes. Usually, Tb^{3+} ion is used as a significant activator for luminescent materials. Generally, it shows strong green emission at high doping concentration and blue emission at low doping contents due to transitions of $^5D_4 \rightarrow {}^7F_J$ and $^5D_3 \rightarrow {}^7F_J$ (J = 6, 5, 4, 3, 2 and 1), respectively [[10], [11], [12]]. This shows Tb^{3+} emission depends strongly on its concentration. Unfortunately, the absorption peaks of Tb^{3+} are weak and too narrow because those 4f → 4f transitions are strictly forbidden by the parity selection rule, due to this incompatibility to the tiny emission wavelength shift of LED chips and the poor emission intensity. In order to overcome this problem, Ce^{3+} can be co-doped as a sensitizer. Ce^{3+} ions usually can be strongly excited by ultraviolet irradiation in most oxides due to the strong 4f → 5d transitions and transfer the harvesting photons to other activators ion. In a proper host, the chance is high indeed that the occurrence of efficient ET from Ce^{3+} to Tb^{3+} when the emission of Ce^{3+} overlaps with the excitation of Tb^{3+}, such as KCl:Ce^{3+},Tb^{3+} [13], $K_3Gd(PO_4)$:Ce^{3+},Tb^{3+} [14], Al_2O_6N:Ce^{3+},Tb^{3+} [15], $SrMgSi_2O_6$:Ce,Tb [16]. As a promising sensitizer for Tb^{3+} ions, Ce^{3+} has been widely used in many hosts [17,18].

In last several decade, significant efforts have been devoted to prepare and investigate an important inorganic materials family having general chemical formula ABC_3O_7, (A = Ca, Sr, Ba ; B = La, Gd, Y; C = Al, Ga) as these materials have been widely applied in plasma display panels (PDP) for high definition TV (HDTV), all-solid-state lasers, diode laser pumping and tunable laser generation, and white LEDs [19,20]. As one kind of aluminates, $SrYAl_3O_7$ was selected as a host material in this work. There is not much study on $SrYAl_3O_7$ host though compounds with similar formula and structure have shows interesting properties. A fast and simple combustion method has been employed to synthesize this material. $CaYAl_3O_7$:Ce^{3+},Tb^{3+} [21], $CaYAl_3O_7$:Eu^{3+} [22], Er^{3+}/Yb^{3+} co-doped $CaYAl_3O_7$ [23], $GdCaAl_3O_7$:Eu^{3+} [24] and $LaCaAl_3O_7$ doped with variety of ns^2 and rare earth activators [25] are prepared by this method and studied earlier. To the best of our knowledge, there is no study about the luminescent properties and ET of Ce^{3+} and Tb^{3+} co-doped $SrYAl_3O_7$. In this study, we report luminescent property and ET of

$SrYAl_3O_7:Ce^{3+},Tb^{3+}$ phosphor. The results show that the Ce^{3+}–Tb^{3+} is successfully induced in the host by the ET processes from Ce^{3+} to Tb^{3+}.

Section snippets

Experimental

$SrY_{1-x-y}Al_3O_7:xCe^{3+},yTb^{3+}$ phosphors were prepared by a solution combustion method. In a typical preparation, Stochiometric amounts of $Y(NO_3)_3$, $Sr(NO_3)_2$, $Al(NO_3)_3{\cdot}9(H_2O)$, $(NH)_2.Ce(NO_3)_6$, $Tb(NO_3)_3{\cdot}6(H_2O)$ and urea (CON_2H_4) were dissolved in distilled water. A homogeneous solution was obtained after the mixture stirred vigorously for 15–20 min in a glass beaker. The solution was transferred in to a muffle furnace maintained at a temperature of 500 ± 20 °C. The reagents decomposed and released large …

XRD phase analysis

The XRD patterns of undoped $SrYAl_3O_7$ and $SrYAl_3O_7:0.02Ce^{3+}$, $0.006Tb^{3+}$ phosphors calcined at 900 °C for 2 h are shown in Fig. 1. It can be clearly observed that all the diffraction peaks are almost in good agreement with the standard data of the $SrYAl_3O_7$ (JCPDS No. 49-0604). It indicates that the obtained samples are single phase and of same structure as $SrYAl_3O_7$. No impurity peaks were observed in Fig. 1, which means that the dopant ions (Ce^{3+}, Tb^{3+}) were completely dissolved in the host…

Conclusion

A series of Ce^{3+} and Tb^{3+} singly and co-doped $SrYAl_3O_7$ phosphors have been prepared via solution combustion route using urea as a fuels. The co-doped phosphor exhibits an intense green emission under the UV excitation, and found to be greatly enhanced through an efficient ET from Ce to Tb in $SrYAl_3O_7:Ce^{3+},Tb^{3+}$ phosphor. Therefore the ET rate is much higher and due to the ET process in the Ce–Tb system is about 81%, the brightness and luminescent efficiency are better than other hosts. The ET…

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References (36)

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J. Lumin. (2013)

J. Zheng *et al.*

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Curr. Appl. Phys. (2012)

J. Liao *et al.*

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>
> ...The SEM micrographs (placed in Fig. 5(a) and (b)) revealed some aggregation of particles with a non-uniform topography. The presence of cavities and cracks confirmed the combustion synthetic route [28,29]. The SEM micrograph of as-prepared (500 °C) nanophosphor has more agglomeration as compared to the sintered one (1100 °C)....

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> ...Fig. 6(c) illustrates the SAED (selected area electron diffraction) patterns of the synthesized powder which confirms its crystalline behavior. However, the efficient doping of Er3+ into host matrix is shown in Fig. 7(a) and the compositions of elements i.e., Ba, Sr, Y, O, and Er have been confirmed by EDAX analysis which is shown in Fig. 7(b) which proves that the desired phosphors have been synthesized with a great success [30,31]. Therefore, all the investigations related to the study of morphological features of prepared nanoparticle reflect the efficient luminescence power compared to the bulk counter parts due to greater surface/volume ratio [32,33]....

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> …Fig. 2(a) shows the PLE spectra at λem = 550 nm and the PL spectra with λex = 250 nm for CHO:0.04Tb, where Tb3+ is a major activator. In the PLE spectra, a strong peak near 235 nm was assigned to the f-d transition, i.e., the 4f8d0 to 4f75d1 configurations [17]. The small structures in the range of 330–390 nm were assigned to the transitions from 7F6 to 5DJ (J = 2 and 3), 5LJ (J = 7 and 10), and 5GJ (J = 4, 5 and 6) [18]….

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