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Luminescence investigation of $K_2Ca_2(SO_4)_3$: Tb^{3+} Phosphor for Solid State Lighting applications

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Abstract
An intense green phosphor, K2Ca2(SO4)3: Tb3+, was synthesized by wet chemical synthesis method. The photoluminescence excitation and emission spectra, XRD are investigated in detail.
And it is well match with the data available in ICDD. Consequently, white-light with CIE chromaticity coordinate in Tb3+ (x=0.265 and y=0.723) at an optimized amount of prepared phosphor has been achieved.The results show that an efficient non-radiative energy transfer from Tb3+occursand. Results demonstrate that Tb3+ ion with low 4f–4f absorption efficiency can play a role of activator in narrow green-emitting phosphor potentially useful in solid state lighting through efficient energy feeding by allowed f-f absorption of Tb3+ with high oscillator strength.
Keywords:- Photoluminescence, phosphor, XRD

Introduction

The rare earth ions activated materials are widely used as lamp phosphors, cathode ray tube phosphors and scintillator phosphors, because of their unique spectroscopic properties [1,2]. New hosts doped with rare earth ions are getting much attention owing to their potential applications. [3] Rare earth ions have been playing an important role in phosphor duo to the abundant emission colors based on their 4f-4f or 5d-4f transitions,[4] Under ultraviolet irradiation, these phosphors emit in the green, which is attributed to the $^5D_4$-$^7F_5$ transition of Tb^{3+} and is not related to the host material.[5]Now a day, much attention has been paid to the improvement of white-light emitting diodes (W-LED) [6,7] due to their extensive application in consumer electronics and in solid state lighting. A stable white light has been obtain through a blue LED (GaN chip) precoated with a yellow phosphor $(Y_{1-a}Gd_a)_3(Al_{1-b}Ga_b)_5 O_{12}:Ce^{3+}$ (YAG:Ce) [8] and has been extensively used in various applications for example full-color displays, liquid crystal display back lighting and traffic signals [9]. Though, this kind of white light has a low color rendering index (R_a<80) since the yellow light emission from the phosphor YAG:Ce lacks enough red emission. Hence, white light production has been proposed to combine LED chip with three-phased [10] (red [11,12], green [13] and blue [14] phosphors, but in this three-color-converter system, the blue emission effectiveness is poor because of the strong re-absorption problem of the blue light by the red and green emitting phosphors. To beat problems related to this for W-LED, single-phased white- light (SPWL) phosphors [6,10,15,16,17] have been an vigorous investigation area in the study of luminescent materials. Although single- composition white-light phosphors for near-UV or UV excitation have been reported in the literature, satisfactory solution are much harder and novel phosphor is still desirable. In the present study we describe the fluorescence study of Tb^{3+} activated $K_2Ca_2(SO_4)_3$ green emitting phosphor for white LED's application

Experimental

Powder samples $K_2Ca_2(SO_4)_3$: Tb^{3+} have been prepared by a wet chemical synthesis method. The raw materials were KNO_3 (A.R), $Ca(NO_3)_2$, (A.R), K_2SO_4(A.R), Tb_4O_7 (99.99%) . The raw materials were intimately mixed in the requisite proportions in distilled water. The mixtures were first mixed with the help of magnetic stirrer. After that kept the solution in oven for getting final product in the form of white powder. The phases of the obtained samples were identified by X-ray powder diffraction (XRD) with Cu Ka(l=1.5418˚ A) radiation at a scanning step of 0.021in the 2yrange from 101to 901, operated at 36 kV and 30 mA (Rigaku ModelD/max-2200). The photoluminescence (PL) spectra were measured with a HITACHI F-7000 fluorescence spectrophotometer, using a static 150 W Xe lamp as the excitation source. All the measurements were carried out at room temperature.

Result and Discussion

XRD

Fig. 1shows the XRD patterns of $K_2Ca_2(SO_4)_3$ phosphor. The obtained patterns indicate that the phosphor is single phase and consistent with JCPDS No. 74-0323. No impurity peaks were detected in the experimental range. In this study, in order to obtain the data accurately, specimens were measured within the same sample holder to ensure the consistent amount of phosphor materials in all samples

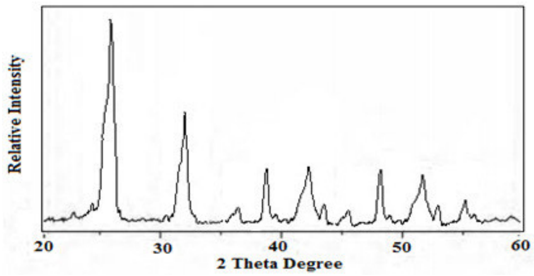

Fig 1 XRD of $K_2Ca_2(SO_4)_3$ phosphor

Photoluminescence Study of $K_2Ca_2(SO_4)_3:Tb^{3+}$ phosphor

The photoluminescence properties of the phosphors (excitation and emission) were measured using a Shimadzu RF5301PC Spectroflurophotometer at room temperature. As shown in fig. 02 and fig03, excitation spectrum observed at 545 nm emission wavelength of $K_2Ca_2(SO_4)_3$ activated with Tb^{3+} consisting of a broad band as well as some sharp lines. The broad band is due to f-d interaction while sharp lines are due to f-f transitions. The emission spectrum fig 02 has sharp lines on account of f–f transition of Tb^{3+} ions.

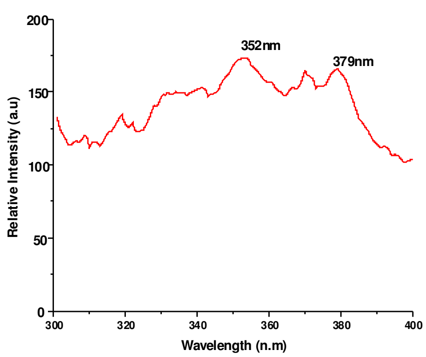

Fig2: Excitation spectra of $K_2Ca_2(SO_4)_3:Tb^{3+}$ phosphor

The emission spectrum usually has major contribution from $^5D_4$–$^7F_5$. The Tb^{3+} ions used as an activator of green emitting luminescent materials showing emission lines peaking at 545 nm, which are due to the distinctive $^5D_4$-$^7F_5$ transitions of trivalent Tb^{3+} ions which is the most intense luminescence emission under UV radiation this can also be observed with the naked eye. As shown in fig.02 the emission intensity of $^5D_3$ level is very weaker and weakens further with increasing Tb^{3+} concentration, followed by the enhancement of the emission from the $^5D_4$ level. This occurs due to non-radiative cross-relaxation via the resonant energy transfer process between $^5D_3$ and $^5D_4$ levels.

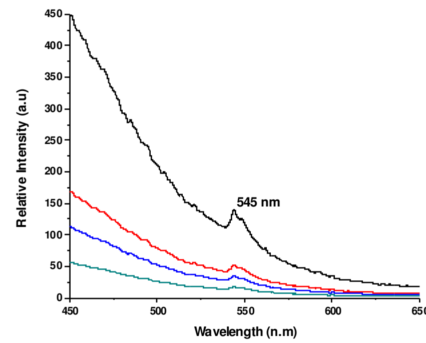

Fig3: Emission spectra of $K_2Ca_2(SO_4)_3:Tb^{3+}$ phosphor

Chromaticity Coordinates

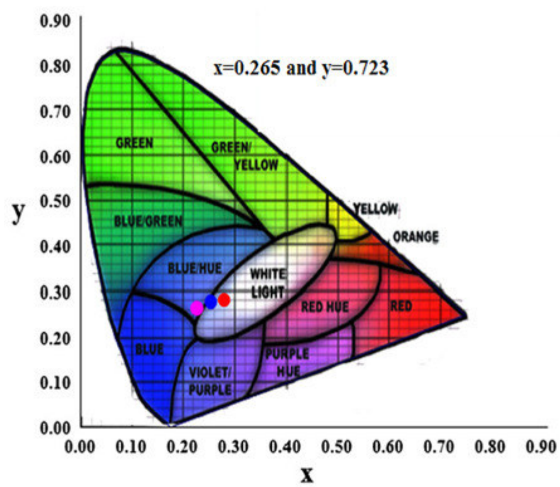

Fig:4 CIE color coordinates of $K_2Ca_2(SO_4)_3:Tb^{3+}$ phosphor

The chromaticity diagram established by the Commission International de l'Eclairage (CIE) in 1931 is a two dimensional graphical representation of any color perceivable by the human eye on an x–y plot. Fig. 3 depicts the chromaticity coordinates of $K_2Ca_2(SO_4)_3:Tb^{3+}$ phosphors sintered in air atmosphere under the excitation of 352nm. The color coordinates for prepared phosphors found to be x=0.265 and y=0.723.

Conclusion

In this work we studied the photoluminescence properties of Tb^{3+} activated $K_2Ca_2(SO_4)_3$ phosphor. A phase of $K_2Ca_2(SO_4)_3$ phosphor was confined from x-ray diffractometer . From the results obtained it is fulfilled that, $K_2Ca_2(SO_4)_3$ host is suitable for Tb^{3+} emission which is peaking at 545nm, which are due to the distinctive $^5D_4$-$^7F_5$ transitions. This kind of materials plays a relevant role in the applications as a green emitting phosphor for solid-state lighting.

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