Improved visible emission and color purity of Ce^{3+} and Eu^{3+} doped TAG

Suman Rani

Department of Physics, School of Chemical Engineering & Physical Sciences,

Lovely Professional University, Punjab-144411, India.

Abstract

$Tb_3Al_5O_{12}$(TAG) ,Ce and Eu doped TAG were prepared by sol gel technique followed by sintering at 1100^oC .Structural phase was analysis from the XRD spectra .XRD studies confirmed the formation of nano material and has cubic structure. Spectra power distribution curve was obtained from emission data excited by 280 nm. From SPD curve , Color co-ordinates(CIE),color correlated temperature (CCT) and color purity were calculated for undoped and doped TAG .Ce doped TAG has CIE coordinates 0.34,0.39 which is close to ideal value 0.33,0.33(white light) ,CCT 5254K and color purity 16.4% indicates the potential nanophosphor for the white light emission .

Key words: CIE coordinates, CCT, color purity, TAG, Ce, Eu

1. Introduction

Industrial revolution increases the demand of electricity and major part of the electricity is used for lighting. These demands attract the attention of researcher to build an efficient energy lighting system. For this, there is a need to design the phosphor which can absorb energy in UV and emit in visible region mainly red, blue and green colors (primary colors). These ions when doped in a crystalline host do emit in diverse regions of seen spectrum making those fabric potential applicants for white light . Terbium aluminum garnet (TAG, Tb_3 Al_5O_{12}) high value of Verdet constant and large transmission range (350–1500 nm) due to which it is an important host material for magneto optical application .[1-5]. Recently, rare-earth (RE) doped TAG [6, 7] has been studies due to its capability applications like medical dosimetry, X-ray imaging, and blue-LED based totally white LED and many others. In this look at, TAG and Ce, Eu doped TAG had been prepared by way of sol gel approach and studied its traits for white mild supply.

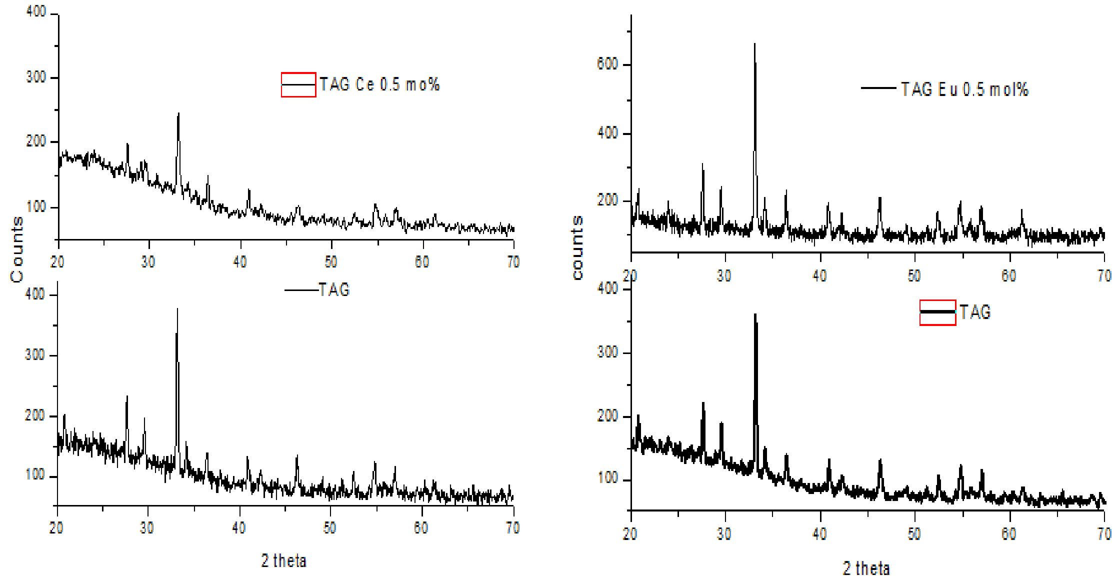
2. Experimental detail

TAG, Ce doped TAG and Eu doped TAG were synthesised by sol–gel method [6] .The material used for the undoped TAG were Terbium nitrate and Aluminium nitrate in 3:5 molar ratio. The chemical used as dopants in TAG were cerium nitrate and europium oxide. Precursor obtained was sintered at 1100^oC .

3. Result and Discussion

3.1. Phase Studies

Room temperature powder XRD spectrum of the TAG : Ce and Eu(0.5mol%) are shown in Figure 1(a) and 1 (b) respectively.XRD spectra was indexed by using JCPDS file no. 17-0735 [6]. The crystallites size(S) was calculated are given in the table I and samples sintered at 1100^oC indicating the nanostructure.



(a) **(b)**

Fig.1: XRD image of (a) TAG and TAG: Ce (b) TAG and TAG: Eu

3.2 Photoluminescence (PL)

Spectral power distribution (SPD) of undoped TAG ,TAG: Ce and Eu with 0.5 mol % doped powder excited by 280 radiation Figure 2(a,b,c) .The emission spectra of TAG resulted in emission peaks as shown in the figure 2 out of which prominent peaks are 491nm and 550 nm. From figure2, it is clear that there is enhancement of intensity due to doping and broad spectrum was obtained from 450 to 700 nm.

CIE coordinates, Color correlated Temperature (CCT), and color purity [8-9] of the prepared undoped TAG, Ce and Eu doped TAG were calculated from SPD in the figure 2(a, b, c) [6]. Purity, which is equivalent to saturation when talking about x y chromaticity, describes how “pure,” or monochromatic, a color is at a given lightness. Color purity(CP) is a unit less number between 0 to 100. For white light color purity is less. The formulae used for color purity and CCT are given in equation 1, 2 [10].

Table: I Main Observation from the XRD data

Sample (mol %)	**2θ (deg.)**	**F W H M (deg.)**	**S (nm)**
TAG	20.80	0.3290	25.66
	33.17	0.1573	55.08
	34.39	0.8041	10.81
TAG: Eu 0.5	20.71	0.1979	42.64
	33.47	0.3283	26.40
	34.13	0.2259	38.43
TAG: Ce 0.5	22.97	0.4722	17.94
	33.17	0.2491	34.77
	35.55	0.2813	30.99

The color purity and chromaticity coordinates of the luminescence is calculated for TAG and doped TAG.

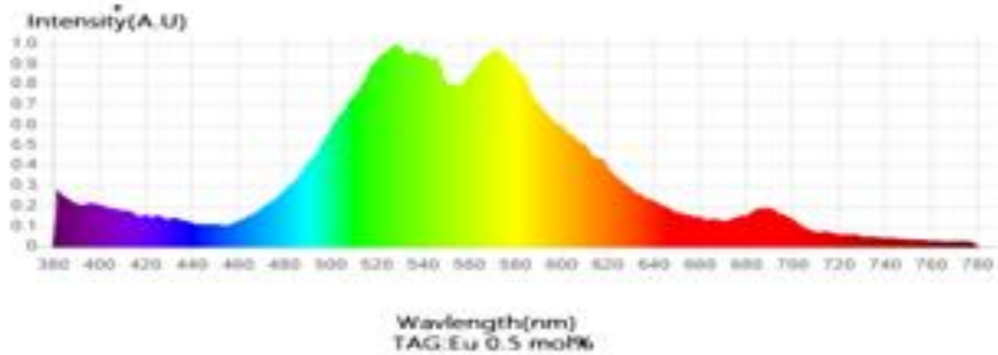
$$CP=\frac{\sqrt{(x_s-x_i)^2+(y_s-y_i)^2}}{\sqrt{(x_d-x_i)^2+(y_d-y_i)^2}}\ x\ 100\ \% \qquad (1)$$

In which (x_s,y_s) are the chromaticity co ordinates of prepared phosphors,(x_i,y_i) are the CIE coordinates of typical white light and (x_d,y_d) are the coordinates of dominant wavelength. The coordinated color temperature (CCT) was calculated from the following equation

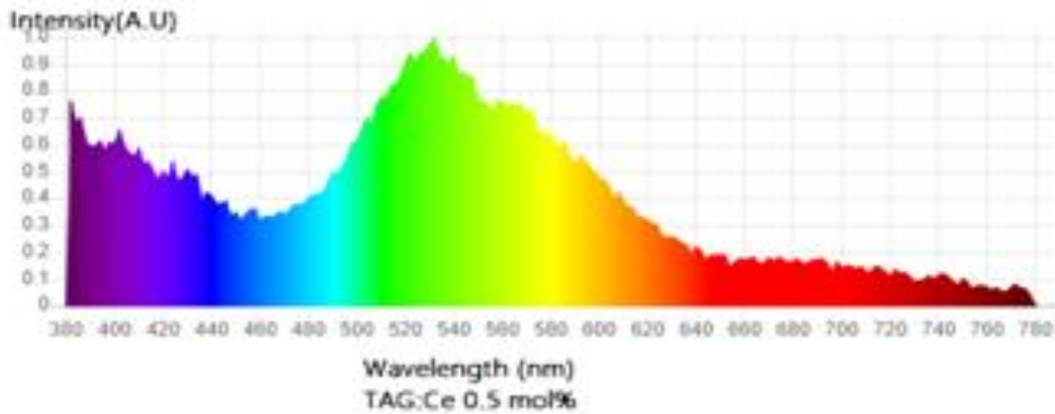
$$CCT= -449n^3+ 3525n^2-6823.3n+5520.33 \qquad (2)$$

Where $n=\frac{x-x_e}{y-y_e}$ is the inverse of slope line and (x_e,y_e) are (0.332,0.186) are chromatic epicenter.

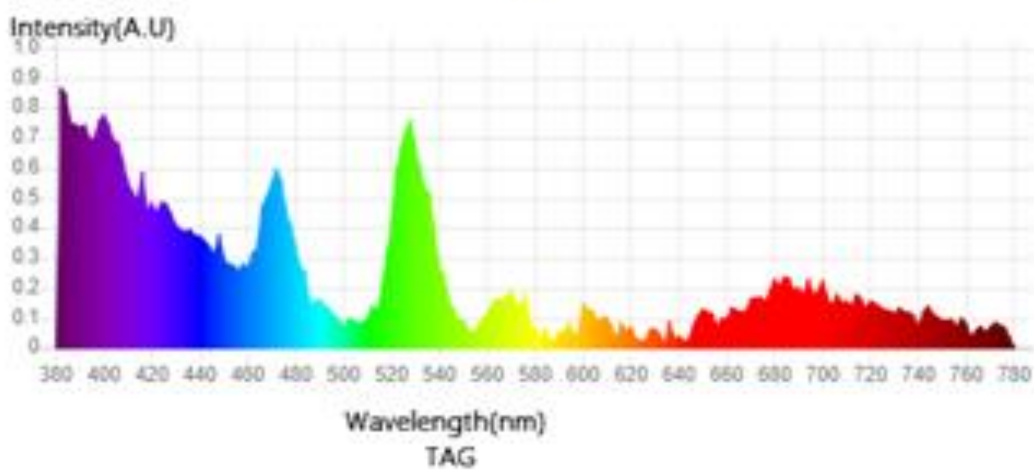
It has been seen in table II that undoped TAG has high value of color purity and it decreases with doping of Ce and Eu ions. The decrease in color purity indicates the purity of white light emission. The color purity of Ce doped TAG is minimum as compared to undoped TAG and Eu doped TAG indicating it a potential material for white light emission. Also, the CIE coordinates



(c)



(b)



(a)

Fig.2 Spectral power distriubtion of (a) undoped TAG, (b) Ce doped TAG(c) and Eu doped TAG.

Table. II : CIE coordinates, CCT and color purity of Ce and Eu doped TAG compared with undoped TAG.

S.No	Phosphors (mol%)	CIE coordinates	CCT(K)	Color purity (%)
1.	TAG	0.21,0.21	18,7615	75.75

2	TAG: Ce 0.5	0.34,0.39	5254	16.40
3.	TAG: Eu 0.5	0.41,0.47	3896	43.50

of Ce doped TAG is (0.34, 0.39) which is close to the ideal coordinates (0.33, 0.33). CCT temperature is 5254K which indicates that it is a cool white light.

4. Conclusion

Undoped TAG, Ce doped TAG and Eu doped TAG was synthesized by sol gel technique. XRD studies reveal that the prepared samples were nanophosphor .From SPD color purity, CIE coordinates and CCT were calculated .With Ce and Eu doping in TAG decreases color purity. The color purity value is minimum for Ce doped TAG indicating it potential material for white light emission.

References

[1] C. B. Rubinstein, L. G. Van Uitert, W.H. Grodkiewicz ,"Magneto- optical properties of rare earth (III) aluminum garnets", J. Appl. Phys. , Vol 35, pp 3069–3070, 1964.

[2] W.B.White, V.G.Keramids ,"Vibrational spectra of oxides with the C-type rare earth oxide structure" , Spectrochim. Acta, Part A. ,Vol 28, pp 501-509, 1972.

[3] J. Koningstein "Energy levels of trivalent europium in yttrium gallium garnet" J Chem Phys , Vol 42, pp 3195, 1965.

[4] W. H. Van der Weg, J. A. Popma Th, A. T. Vink "Concentration dependence of UV and electron-excited Tb^{3+} luminescence in $Tb_3 Al_5O_{12}$" J Appl Phys, Vol. 57, pp 5450–5456 ,1985.

[5] M. Veith, S. Mathur , A. Kareira , M. Jilavi , M. Zimmer , V. Huch "Low temperature synthesis of nanocrystalline$Y_3Al_5O_{12}$:and Ce-doped $Y_3Al_5O_{12}$: via different sol-gel methods". J Mater Chem , Vol. 9, pp 3069, 1999.

[6] S. Sharma,N. Brahme, D. P. Bisen And P. Dewangan" Cool white light emission from Dy3+ activated alkaline alumino silicate phosphors" Optics Express, Vol. 26, pp 29495-29508,2018.

[7] M. Batentschuk, A. Osvelt , G. Schierning ,A. Klier , J.Schneider , A. Winnacker "Simultaneous excitation of Ce and Eu ions in $Tb_3Al_5O_{12}$. Radiat Meas , Vol. 38, pp 539–543, 2004.

[8] A. C. Harris, I. L. Weatherall, "Objective evaluation of color variation in the sand-burrowing beetle Chaerodes trachyscelides White (Coleoptera: Tenebrionidae) by instrumental determination of CIE LAB values" Journal of the Royal Society of New Zealand. Vol. 20 , pp 253–259, 1990.

[9] Peter van der Burgt and Johan van Kemenade "About color rendition of light sources: the balance between simplicity and accuracy" COLOR research and application 35, pp 85-93, 2010.