Photoluminescence of Eu(III) Doped Double Perovskite Phosphor for Red LED Application

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Photoluminescence of Eu(III) doped Double Perovskite Phosphor for Red LED Application

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Abstract

The luminescence property of Ba₂CeNbO₆ has been studying by varying Eu(III) concentration. Ba₂CeNbO₆ doped with trivalent ions of Eu has a monoclinic phase with P2₁/n space group. FTIR of Ba₂CeNbO₆ gives information that phosphor has a nano-size perovskite structure with an edge-connected Nb-O octahedral. Photoluminescence properties of Eu(III) doped Ba₂CeNbO₆ have been examined with excitation wavelength 275nm and 466 nm. Luminescence emission spectra exhibited three prominent peaks around 580 nm, 596 nm, and 610nm wavelength for Eu(III). Using xenon lamp as a source and having excitation wavelength 275 and 466nm, observing that the maximum light emission yielded in the region presenting a color-correlated temperature in the range of 1500 – 2900 K.

Keywords Double Perovskite; XRD; FTIR; Photoluminescence

1. INTRODUCTION

The A₂BB'O₆ type double perovskite structure has a vital interest to materials scientists and solid-state chemists. This attention is often due to their potential application as substrates for high-T_c superconductors, especially for applications in the microwave region [1 – 5]. Double perovskite-type oxides are suitable for such purposes due to their outstanding dielectric properties, including a low dielectric loss, low chemical reactivity, and their compatibility with some of the most regularly used superconductors, particularly as a result of owning an appropriate thermal expansion co-efficient. They are concern as they give a material where the magnetic properties of lanthanides studied in a relatively significant octahedral environment [6 – 10] and have been recently reviewed for their potential use as luminescent materials [11].

Perovskite is a new derivative of a close-packed structure in which the oxygen arranged in a cubic close-packed organization except one oxygen ion is missing in every second layer, leaving a large volume void in the center. The strength of perovskite to accommodate large cations of rare earth elements makes it novel among the close-packed oxides. If the 12-coordinated cation is smaller compared to the oxide ion, the tilting of

octahedra changes the perovskite structure [12]. The modified structure produced after tilting could be tetragonal, orthorhombic, monoclinic, or sometimes without any center of symmetry. Non-centric perovskites display piezoelectricity or ferroelectricity, and synthetic perovskites used as electronic sensors. The structure of the newly discovered high-temperature superconductor shows resemblance with perovskite structure [13].

Around 90% of the natural metallic elements of the periodic table are known to be stable in a perovskite-type oxide structure. Perovskites have sub-metallic to metallic luster, colorless streak, cube-like structure along with imperfect cleavage, and brittle tenacity. Perovskites can be prepared in various forms like nanocrystalline, bulk, thin films, and rods depending on their applications [14].

It's well known that the complex oxides having perovskite-type structure usually show functional properties [15, 16]. Among them, the researcher paid attention to the $\text{Ba}_2\text{LnNbO}_6$ (Ln = lanthanide elements) compounds. $\text{Ba}_2\text{LnNbO}_6$ type perovskite compound was first synthesized by Brixner [15] and found to have a cubic perovskite-type structure for all except for $\text{Ln} = \text{La}$, which is tetragonally distorted structure, and some of them have ferroelectric properties. Later, Filip'ev et al. [17] reported that the structure of $\text{Ln} = \text{La}$ had a rhombohedral distorted structure. Anderson et al. [18], however, point out that the crystal system of $\text{A}_2\text{BB}'\text{O}_6$ double perovskites is cubic, orthorhombic, or monoclinic because the B/B'-cation arrangement is limited to be a random type, a rock salt type, or a layered type. When the B/B'- cation arrangement is a rock salt type, the crystal system should be either a cubic one ($Fm\bar{3}m$) [19, 20] or a monoclinic one ($P2_1/n$) [21, 22], for random type arrangement, the crystal system should be either a cubic one ($Pm\bar{3}m$) [20, 23] or a orthorhombic one ($Pbnm$) [21, 24] and for layered type, the crystal system should be monoclinic one ($P2_1/n$) [25].

Practically all kinds of optical centres were studied in the perovskite structure for various doped concentrations. The studies of optical properties of perovskite systems have contributed considerably to the development of many optical materials like LASER materials, solar energy conversion and many more [26, 27].

There is no reported data were found on photoluminescence properties of rare earth doped $\text{Ba}_2\text{CeNbO}_6$ during the literature survey. Our group report the photoluminescence studies of $\text{Ba}_2\text{CeNbO}_6$ doped with Eu (III).

2. SYNTHESIS AND CHARACTERIZATION

2.1 SYNTHESIS

Eu(III) doped $\text{Ba}_2\text{CeNbO}_6$ phosphor had been synthesized by the combustion method. Starting chemicals used for this objective are $\text{Ba}(\text{NO}_3)_2$, $\text{Ce}(\text{NO}_3)_3 \cdot 6\text{H}_2\text{O}$, Nb_2O_5 , Eu_2O_3 , and urea as flux. These chemicals were intimately mixed in the stoichiometric ratio corresponding to the nominal composition of Eu(III) doped $\text{Ba}_2\text{CeNbO}_6$ and transferred into alumina crucible. Then, this mixture was fired at 800°C in a muffle furnace for 3 hours and then allowed it naturally cool to room temperature. The synthesized material ground using mortar – pastel was obtained in powder form owning white color.

2.2 CHARACTERIZATION

XRD measurements of undoped and Eu(III) doped $\text{Ba}_2\text{CeNbO}_6$, were done on D8 Bruker advance X-Ray Diffractometer with the Cu $K\alpha$ radiation with 8.05keV energy, and 1.5406 Å wavelength (λ) at room temperature by step scanning in an angle range of $20^\circ \leq 2\theta \leq 70^\circ$ with increments of 0.02° . FTIR spectra of phosphors were, recorded using Jasco FTIR-4100, spectrophotometer (Japan) by mixing phosphor with KBr in mortar - pestle in a ratio of 1:10. The PL of the samples examined using a Shimadzu spectrofluorophotometer (RF-5301 PC) at room temperature with a xenon lamp as an excitation source.

3. RESULTS AND DISCUSSION

3.1 X-RAY DIFFRACTION

Figure 1 exhibits room-temperature powder X-ray diffraction pattern of undoped, and Eu(III) doped $\text{Ba}_2\text{CeNbO}_6$. The recorded patterns present sharp and well-defined peaks, indicating that prepared materials have a highly crystalline nature. There is a good agreement between the observed and calculated inter-planar spacing suggests that the compound has a monoclinic phase with a $\text{P}2_1/\text{n}$ (#14) space group. The relative coordinates and occupancy of each site for $\text{Ba}_2\text{CeNbO}_6$ are listed in Table 1. The values of bond distances of cations relative to the oxygen anion and occupancy were obtained from the Rietveld refinement are shown in Table 2. These diffraction lines are consistent and confirm the formation of a double perovskite structure for all prepared samples. The average crystalline size were estimated by the Scherrer's equation using the full width at half maximum (FWHM) of all

intense peak. The average crystalline size was calculated using the Debye-Scherrer formula [28] which is given as equation (1),

$$D = \frac{k\lambda}{\beta \cos\theta} \quad \text{-----} \quad (1)$$

Where, D is the average crystalline size, k is the constant equal to 0.94, λ is the wavelength of the X-rays equal to 0.1542 nm, θ is the Bragg angle and β is FWHM. All the reflection peaks of the X-ray profile indexed and lattice parameters are determined with the help of a standard computer program Powder-X.

Figure 1 X-ray diffraction pattern of undoped and Eu(III) doped $\text{Ba}_2\text{CeNbO}_6$.

In double perovskite oxide, the study of distortion from the ideal cubic perovskite structure is clear as the $\text{Ba}_2\text{CeNbO}_6$ complex perovskite has general formula $\text{A}_2\text{BB}'\text{O}_6$. The tolerance factor T_f [29] of the $\text{Ba}_2\text{CeNbO}_6$ is calculated by using equation (2),

$$T_f = \frac{R_{\text{Ba}} + R_{\text{O}}}{\sqrt{2} \left(\frac{R_{\text{Ce}} + R_{\text{Nb}}}{2} + R_{\text{O}} \right)} \quad \text{-----} \quad (2)$$

Where, R_{Ba} , R_{Ce} , R_{Nb} and R_{O} are the ionic radii of Ba, Ce, Nb and O respectively [30]. By the geometry of crystal, the ideal cubic structure should have $T_f = 1$, whereas it will be monoclinic structure for values of $T_f < 1$ and it following the SPuDs prediction [31]. The value of tolerance factor for $\text{Ba}_2\text{CeNbO}_6$ was found to be approximately 0.9505, which suggests that sample under study has the monoclinic structure.

Atom	Site	<i>x</i>	<i>y</i>	<i>z</i>
Ba	4e	0.5000	0.5000	0.2395
Ce	2c	0.0000	0.5000	0.0000
Nb	2d	0.5000	0.0000	0.0000
O	4e	0.2692	0.2167	0.0000
O	4e	0.2692	0.7833	0.0000
O	4e	0.5000	0.0000	0.2255

Table 1 Structural parameters of Ba₂CeNbO₆ found by Rietveld analysis of XRD data.

Cation	Anion & Multi.	Distance (Å)	Occupancy
Ce (2c)	O (4e) X 2	2.4475	1.00
Ce (2c)	O (4e) X 2	2.4475	1.00
Ce (2c)	O (4e) X 2	2.4075	1.00
Nb (2d)	O (4e) X 2	1.9824	1.00
Nb (2d)	O (4e) X 2	1.9824	1.00
Nb (2d)	O (4e) X 2	1.9785	1.00
Ba (4e)	O (4e) X 1	3.1067	1.00
Ba (4e)	O (4e) X 1	3.1471	1.00
Ba (4e)	O (4e) X 1	3.1067	1.00
Ba (4e)	O (4e) X 1	3.1471	1.00
Ba (4e)	O (4e) X 1	3.1067	1.00
Ba (4e)	O (4e) X 1	3.1471	1.00
Ba (4e)	O (4e) X 1	3.1067	1.00
Ba (4e)	O (4e) X 1	3.1471	1.00
Ba (4e)	O (4e) X 1	3.1067	1.00
Ba (4e)	O (4e) X 1	3.1461	1.00
Ba (4e)	O (4e) X 1	3.1461	1.00
Ba (4e)	O (4e) X 1	3.1636	1.00
Ba (4e)	O (4e) X 1	3.1636	1.00

Table 2 Inter-atomic distance and occupancy calculated through Rietveld refinement of experimental data.

Williamson – Hall Plot

Figure 2 (a-f) shows W-H plot of undoped and Eu (III) doped Ba₂CeNbO₆. The broadening effect of XRD peaks reflects the nanocrystalline nature of the resulting Eu(III) doped Ba₂CeNbO₆ samples. Since the effective XRD peak broadening can be caused by lattice strain and small crystallite size, these two effects have to be distinguished. This can be

calculated by plotting $\beta \cos\theta$ versus $\sin\theta$ in the following relation (equation 3) (Williamson–Hall plot) [28],

$$\beta_{hkl} * \cos\theta_{hkl} = \left(\frac{\kappa\lambda}{D}\right) + \varepsilon * \sin\theta_{hkl} \text{ ----- (3)}$$

The crystallite size and strain of Eu(III) doped $\text{Ba}_2\text{CeNbO}_6$ estimated from the intercept and slope are listed in table-3.

Figure-2 (a-f) Williamson-Hall plot of undoped and Eu(III) doped $\text{Ba}_2\text{CeNbO}_6$

Sample		Ba ₂ CeNbO ₆	Ba ₂ CeNbO ₆ : Eu ³⁺ (0.5%)	Ba ₂ CeNbO ₆ : Eu ³⁺ (1.0%)	Ba ₂ CeNbO ₆ : Eu ³⁺ (1.5%)	Ba ₂ CeNbO ₆ : Eu ³⁺ (2.0%)	Ba ₂ CeNbO ₆ : Eu ³⁺ (2.5%)
Structure		Monoclinic	Monoclinic	Monoclinic	Monoclinic	Monoclinic	Monoclinic
Space Group		P2 ₁ /n	P2 ₁ /n	P2 ₁ /n	P2 ₁ /n	P2 ₁ /n	P2 ₁ /n
Cell	a(Å)	5.9012(2)	5.9115(5)	5.9052(7)	5.9168(4)	5.9132(3)	5.9048(5)
Parameters	b(Å)	6.1043(8)	6.0854(3)	6.0986(9)	6.0943(5)	6.1013(7)	6.0972(8)
	c(Å)	8.0586(3)	8.0795(2)	8.0626(3)	8.0746(6)	8.0816(8)	8.0716(4)
	β	90.06	90.05	89.96	89.93	90.12	89.98
Volume (Å) ³		290.29	290.65	290.36	291.16	291.56	290.59
Average	Scherrer	24.1	25.4	20.8	21.1	22.1	19.8
Crystallite	Method						
Size (nm)	W-H	23.8	25.9	21.3	20.9	21.6	20.1
	Plot						
Strain (ε)		4.33 X 10 ⁻³	4.96 X 10 ⁻³	2.14 X 10 ⁻³	1.41 X 10 ⁻³	2.49 X 10 ⁻³	1.49 X 10 ⁻³

Table 3 Summary of cell parameter, volume and crystallite size of Eu(III) doped Ba₂CeNbO₆.

3.2 FTIR (Fourier Transform Infrared Spectrometry)

Figure 3 FTIR spectra of undoped and Eu(III) doped $\text{Ba}_2\text{CeNbO}_6$.

To discover the atomic bonds in a compound FTIR analysis has been carried out. In Fig.3 FTIR spectra of $\text{Ba}_2\text{CeNbO}_6$ has shown with a range of 400 cm^{-1} to 2000 cm^{-1} wavenumber. The FTIR spectrum of $\text{Ba}_2\text{CeNbO}_6$ shows some well-defined bands in the above figure. It is in good accordance with group theory predictions what orderly found for perovskite type structures [32]. In perovskite-type material, significant vibrational couplings may expect between the different coordination polyhedral compounds. All the peaks in the spectra are typical of the material. One small hump is at 1750 cm^{-1} , which is due to the presence of adsorbed moisture in KBr [33]. The lower energy band found at around $450\text{--}650\text{ cm}^{-1}$ is related to the deformational mode of CeO_6 octahedra [34]. The medium energy peak appearing near 850 cm^{-1} is due to the asymmetric NbO_6 stretching vibration [35] due to the higher charge of the cation. The strong intensity peak at approximately 1430 cm^{-1} can eventually be related to the symmetric stretching vibration of NbO_6 octahedra [36]. A small intensity peak at 1100 cm^{-1} likely corresponds to the presence of overtones of the fundamental vibrations in $\text{Ba}_2\text{CeNbO}_6$ [37]. The peak at 552 cm^{-1} is due to the Ba-O.

3.3 Photoluminescence studies

Figure 4 Photoluminescence spectra of Ba₂CeNbO₆.

Figure 4 shows room temperature excitation and emission spectra of undoped Ba₂CeNbO₆. Emission spectra of undoped Ba₂CeNbO₆ phosphor were recorded by exciting this phosphor with 254nm wavelength and excitation spectra recorded with 400nm emission wavelength.

Figure 5 represents the absorption spectra of Eu(III) doped Ba₂CeNbO₆ phosphor. These excitation spectra recorded with the 613nm emission wavelength. An intense peak at 466 nm wavelength is due to the $^5D_2 \leftarrow ^7F_0$ electric dipole transition [38]. The absorption spectra are less used and their analysis is also less useful. The main reason for this is that the most relevant transitions for the determination of the point group symmetry ($^5D_0 \leftarrow ^7F_0$, $^5D_1 \leftarrow ^7F_1$, $^5D_1 \leftarrow ^7F_0$, $^5D_2 \leftarrow ^7F_1$, and $^5D_2 \leftarrow ^7F_0$) are very weak. The absorption spectra of Eu(III) compounds allows the determination of higher energy levels of the $4f_6$ electronic configuration of Eu³⁺ ion. In the earlier literature survey, the transitions to the $^5D_0$, $^5D_1$, and $^5D_2$ levels were called the yellow, green and blue bands based on their places in the visible spectrum [39, 40]. The transitions of $^5D_0 \leftarrow ^7F_1$ and $^5D_0 \leftarrow ^7F_2$ are suitable for determining the location of the $^5D_0$ level if the $^5D_0 \leftarrow ^7F_0$ transition is forbidden.

Figure 5 Photoluminescence Excitation spectra of Eu(III) doped Ba₂CeNbO₆

For transitions to the $^5D_2$ level, the $^5D_2 \leftarrow ^7F_0$ transition is the most useful, because it allows determining the location of the $^5D_2$ level. This $^5D_2 \leftarrow ^7F_0$ electric dipole transition is hypersensitive ($\Delta J = 2$). The hypersensitivity of the $^5D_2 \leftarrow ^7F_0$ transition is very well explained by examining the europium(III) dipicolinate system [41]. The $^5D_2$ level is often used to directly excite the Eu^{3+} ion with one of the lines of an argon-ion laser (465.8 nm) or with a diode laser.

Europium (III) also shows broad absorption bands in the UV region of the electromagnetic spectrum. This broad absorption band is due to an electron transfer from one or more adjacent atoms to the Eu^{3+} ion. Eu^{3+} is the most oxidizing ion of the trivalent rare-earth ions as it requires only a single electron to achieve a half-filled stable shell. These absorption bands in the UV region are so-called charge-transfer bands (CTB) or ligand-to-metal charge transfer (LMCT) bands. These absorption bands are very intense related to the f-f transitions as these transitions are allowed by the Laporte selection rule [42]. The location of charge-transfer bands strongly depending on the nature of the ligands. The relationship between the nature of the ligands and the position of the charge-transfer bands was first recognized by Ryan and Jørgensen [43] but, it was studied by Dorenboos [44, 45] in more detail. Dorenboos gives an extensive compilation of the energies of the charge-transfer transitions of Eu(III) compounds in the solid state [45]. The general trend of the energies of the charge-transfer transitions is: fluorides > oxides > nitrides > chlorides > bromides > iodides > sulfides > selenides > phosphides > arsenides > tellurides > antimonides [38].

Charge-transfer states of Eu^{3+} at low energies possess severe consequences for the spectroscopic characteristics of Eu^{3+} ion, due to the non-negligible mixing of the $4f_6$ electronic states and the charge-transfer states. This mixing has been utilized to explain the high intensity of the $^5\text{D}_0 \rightarrow ^7\text{F}_0$ transition in some europium(III) compounds [46]. Charge-transfer bands also useful for the sensitization of europium(III) luminescence as they can work as aerial to consume energy and transfer this excitation energy to the Eu^{3+} ion.

Figure 6 Photoluminescence emission spectra of Eu(III) doped $\text{Ba}_2\text{CeNbO}_6$ with excitation wavelengths (a) 275nm and (b) 466nm.

Fig. 6 (a) and (b) depict typical PL emission spectra of Eu (III) doped $\text{Ba}_2\text{CeNbO}_6$ phosphors excited with 275nm and 466nm wavelength. In the present study, the concentration of europium ranges from 0.5 to 2.5 mole percentage. The Eu (III) doped $\text{Ba}_2\text{CeNbO}_6$ phosphors exhibit two visible emission bands around 596 and 613 nm when excited at 275nm while it displays four emission peaks at 582nm, 596nm, 613nm, and 633nm. These emission peaks are assigned to the magnetic dipole (MD) $^5\text{D}_0 \rightarrow ^7\text{F}_1$ and electric dipole (ED) $^5\text{D}_0 \rightarrow ^7\text{F}_2$ transitions of europium when excited with 275nm and 466nm. The emission peak at 596 nm is due to the magnetic dipole transition of $^5\text{D}_0 \rightarrow ^7\text{F}_1$, which has higher intensity compare to peak at 613nm of $^5\text{D}_0 \rightarrow ^7\text{F}_2$ electric dipole transition during excitation at 275nm. This asymmetry confirms that the Eu^{3+} ions are located at the non-inversion symmetric sites in host material [47 – 49]. When this phosphor was excited at 466nm emission peaks are observed at around 580-600 nm, this is mainly due to the magnetic

dipole transition of $^5D_0 \rightarrow ^7F_0$ and $^5D_0 \rightarrow ^7F_1$ and emission peak at 613nm and 633nm are due to electric dipole transition of the $^5D_0 \rightarrow ^7F_2$.

It's important to note that in both the emission spectra emission peak at around 613nm is occurred in the red region. Though an admixture of odd-parity electronic configuration to the pure 4f (like a non-centrosymmetric crystal field component) [50, 51] will allow the ED transitions partially and their possibility of occurrence is much higher than the probability of parity-allowed magnetic dipole (MD) ($^5D_0 \rightarrow ^7F_1$) transition. The site symmetry of Eu^{3+} ion in the host lattice can be predicted by asymmetry ratio, which can be defined as equation (4),

$$Asymmetry - ratio = \frac{I(^5D_0 \rightarrow ^7F_2)}{I(^5D_0 \rightarrow ^7F_1)} \text{-----} (4)$$

Where, $I(^5D_0 \rightarrow ^7F_2)$ and $I(^5D_0 \rightarrow ^7F_1)$ are the intensities of electric dipole and magnetic dipole transitions respectively. When asymmetry ratio > 1 , then Eu (III) substituted at the non-centrosymmetric site, and the asymmetry ratio < 1 then Eu(III) substituted at a centrosymmetric site in the host lattice. Table 4 shows the asymmetry ratio for both emission spectra. In the present research, the asymmetric ratio is found to be less than unity (1), indicates that Eu (III) is substituted at a non-centrosymmetric site in the host lattice, and it's in good agreement with the earlier report [49, 52 – 56]. It saw that the substitution of Eu (III) at the place of Ba (II) site in Ba_2CeNbO_6 is followed by Ba(II) ion vacancy due to a distinct ionic radius. These gaps in lattice reduce the local site symmetry at the Eu(III) site and act as a luminescence quenching center.

Sample	Asymmetry Ratio	
	at 275nm	at 466nm
$Ba_2CeNbO_6:Eu$ (0.5%)	0.550	0.974
$Ba_2CeNbO_6:Eu$ (1%)	0.419	0.896
$Ba_2CeNbO_6:Eu$ (1.5%)	0.597	0.908
$Ba_2CeNbO_6:Eu$ (2%)	0.704	0.978
$Ba_2CeNbO_6:Eu$ (2.5%)	0.933	1.055

Table 4 Asymmetric ratio of Eu(III) doped Ba_2CeNbO_6 at 275nm and 466nm emission spectra.

The results presented in Fig. 6 (a & b) reveal that the spectral profile of the phosphors show noticeable changes with increasing europium concentration and the mixed overall emission light chromaticity.

CIE (Commission International del'éclairage)

The chromaticity color coordinates of all phosphors were determined, and the results are presented in the Commission International del'éclairage (CIE) 1931 diagram, as shown in Fig. 7 (a) and (b). With increasing europium (III) concentration, the color tone of the emanating light shifts from the orange region to the red region [55, 57 – 59]. It's good to point out that the continuity of the emission tone corresponding to coordinate points shown in Fig.7 by exciting the sample at 275nm and 466nm wavelength. This allows a mixture of light with color in the white-light region supports the intense glow correlated color temperature, i.e., CCT in the 1800–5000K temperature range. We have indeed simulated the generation flow CCT white-light using xenon lamp of the phosphors reported here and the CIE1931 coordinates, and associated correlated color temperature (CCT) of the all phosphors presented in Table 5.

Figure 7 CIE diagram of Eu(III) doped Ba₂CeNbO₆ emission at (a) 275nm and (b) 466nm.

Sr. No.	Sample	275nm				466nm			
		x	y	CCT		x	y	CCT	
				Calcu.	Software			Calculated	Software
1	Ba ₂ CeNbO ₆ :Eu (0.5%)	0.55	0.32	1813.4	1825	0.40	0.55	4366.3	4359
2	Ba ₂ CeNbO ₆ :Eu (1%)	0.58	0.28	3795.6	3798	0.42	0.54	4035.8	4028
3	Ba ₂ CeNbO ₆ :Eu (1.5%)	0.56	0.26	4809.9	4813	0.45	0.51	3482.2	3476
4	Ba ₂ CeNbO ₆ :Eu (2%)	0.61	0.29	3880.2	3878	0.47	0.50	3165.4	3161
5	Ba ₂ CeNbO ₆ :Eu (2.5%)	0.63	0.30	3739.8	3742	0.48	0.49	2983.3	2981

Table 5 CIE 1931 coordinates and CCT of the emissions under (275nm and 466nm) xenon lamp excitation.

4. Conclusion

Eu^{3+} doped Barium Cerium Niobate (BCN) oxide has been synthesized by the combustion synthesis method. The X-ray diffraction measurement of Barium Cerium Niobate (BCN) oxide reveals that phosphor has a monoclinic phase with space group $\text{P2}_1/\text{n}$ (# 014). Prepared perovskite phosphor is nanocrystalline measured through Scherrer's method and Williamson-hall plot method.

FTIR of $\text{Ba}_2\text{CeNbO}_6$ gives information that phosphor has a nano-size perovskite structure with an edge-connected Nb-O octahedral. A small intensity peak at 1100 cm^{-1} likely corresponds to the overtone existence of the fundamental vibrations in $\text{Ba}_2\text{CeNbO}_6$.

A Photoluminescence study of Eu^{3+} doped $\text{Ba}_2\text{CeNbO}_6$ phosphor reveals that Eu (III) substituted at a non-centrosymmetric site in the host lattice. The substitution of Eu^{3+} at Ba^{2+} site in $\text{Ba}_2\text{CeNbO}_6$ is followed by Ba^{2+} ion vacancy due to charge imbalance and lattice strain due to different ionic radius. With increasing europium concentration, color tone of the emanating light shifts from orange to the red region. The emission color corresponding to coordinate points yields a mixture of light with color in the orange-red area with glow correlated color temperature, i.e., CCT in the 1800K – 5000K range. These phosphors have prominent applications for solid-state lighting and red LED.

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Authors Contribution

Mr. Vishwnatha R. Verma contributed synthesis, XRD analysis, manuscript preparation and communication. Dr. Nimesh P. Patel contributed in analysis of FTIR and photoluminescence. Prof. M. Srinivas contributed in manuscript preparation. Dr. K.V.R. Murthy carried out PL experiment and interpretation of PL result.

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Data Availability

All data generated or analysed during this study are included in this published article.

Compliance with Ethical Standards

Conflict of Interests

All the authors declare that they do not have any competing interest.

Code Availability

“Not Applicable”.

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Figures

Figure 1

X-ray diffraction pattern of undoped and Eu(III) doped $\text{Ba}_2\text{CeNbO}_6$.

Figure 2

(a-f) Williamson-Hall plot of undoped and Eu(III) doped $\text{Ba}_2\text{CeNbO}_6$

Figure 3

FTIR spectra of undoped and Eu(III) doped $\text{Ba}_2\text{CeNbO}_6$.

Figure 4

Photoluminescence spectra of Ba₂CeNbO₆.

Figure 5

Photoluminescence Excitation spectra of Eu(III) doped Ba₂CeNbO₆

Figure 6

Photoluminescence emission spectra of Eu(III) doped Ba₂CeNbO₆ with excitation wavelengths (a) 275nm and (b) 466nm.

Figure 7

CIE diagram of Eu(III) doped Ba₂CeNbO₆ emission at (a) 275nm and (b) 466nm.