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Synthesis and Photoluminescence Properties of $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Ln}$ (Ln: Dy^{3+} , Eu^{3+} and Sm^{3+}) Phosphors for near UV-based solid state lighting

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The wet chemical synthesis of $\text{Ca}_5(\text{PO}_4)_2\text{F}$ host with lanthanide doped Dy^{3+} , Eu^{3+} and Sm^{3+} was reported. The X-ray diffraction (XRD), structural and photoluminescence characteristics of phosphors were thoroughly investigated. The hexagonal system with the space group P 63/m (176) was verified by X-ray powder diffraction. Under UV excitation (352 nm), $\text{Ca}_5(\text{PO}_4)_2\text{F}:\text{Dy}^{3+}$ emits 481 nm (blue) and 575 nm (yellow), corresponding to $^4\text{F}_{9/2} \rightarrow ^6\text{H}_{15/2}$ (magnetic dipole) and $^4\text{F}_{9/2} \rightarrow ^6\text{H}_{13/2}$ (electric dipole) transitions, respectively. When $\text{Ca}_5(\text{PO}_4)_2\text{F}:\text{Eu}^{3+}$ phosphor was excited at 394 nm, the emission spectra showed strong bands at 591 nm (orange) and 614 nm (red). When excited at 403 nm, the emission spectra of Sm^{3+} activated $\text{Ca}_5(\text{PO}_4)_2\text{F}$ phosphor displayed emission peaks at 565 nm (yellow) and 599 nm (orange), respectively. The research analyses the photoluminescence characteristics of $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Ln}$ (Ln: Dy^{3+} , Eu^{3+} and Sm^{3+}) as a possible material for near UV-based solid-state lighting.

Keywords: Wet chemical synthesis, XRD, Photoluminescence, Phosphor, Lanthanide doped, CIE chromaticity coordinates, Solid state lighting.

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Introduction

Inorganic luminescent materials/phosphors play an important role in lighting (e.g., fluorescent tubes and LEDs), displays (e.g., cathode tube display and field emission display), imaging (computed tomography), and other applications [1-2]. Because of their great efficiency, compactness, extended operating lifetime, and environmental friendliness, LEDs for illumination are gaining popularity [3]. As awareness grows, experts are looking for new ways to reduce global energy use and provide environmentally friendly lighting. Solid state white light-emitting diodes (w-LEDs) have garnered major consideration due to their great efficiency as an excellent energy-saving, prospective, and eco-friendly choice for general illumination [4]. As a result, one of the most essential problems in the design of luminescent devices for Solid State Lighting (SSL) is the creation of novel rare earth doped phosphors.

Rare earth phosphors are exciting because of their

excellent luminescence capabilities based on 4f-4f or 5d-4f transitions, as well as their wide variety of applications in display devices and solid state lighting [5]. The current focus in this field is on improving the distinctive luminescent properties of lanthanide-based materials for interdisciplinary research and innovative applications. When phosphors are doped with appropriate auxiliary activators, their luminous performance can be considerably increased. The majority of lanthanides occur in a trivalent form and exhibit distinct optical characteristics. Samarium is an active ion for several inorganic host lattices and often operates as a potent emitting centre due to its energy level structure and high luminescence efficiency [6].

Various attempts have been made in the last decade to examine the luminous properties of $\text{Ca}_5(\text{PO}_4)_3\text{F}$ doped with rare earth (RE) or transition metal ions such as $\text{Ca}_5(\text{PO}_4)_3\text{X}:\text{Sb}^{3+}$, Mn^{2+} , and various metal-doped $\text{Ca}_5(\text{PO}_4)_3\text{F}$ with exciting spectroscopic features have been identified [7]. $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Eu}^{3+}$ was synthesised in solid

form, and three distinct types of calcium substitutional Eu^{3+} sites were discovered in this host, as well as the charge compensating species associated with each of these sites [8]. Eu^{3+} are especially useful as a probe of the local crystal field that influences RE^{3+} . As a result, it is known that the number of observed lines of the strong and easily recordable ${}^5\text{D}_0 \rightarrow {}^7\text{F}_{0,1,2}$ emission allows Eu^{3+} identification in locations with varied site symmetry [9]. In this work, Dy^{3+} , Eu^{3+} and Sm^{3+} doped $\text{Ca}_5(\text{PO}_4)_3\text{F}$ phosphor was created using wet chemical synthesis. $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Dy}^{3+}$, Eu^{3+} and Sm^{3+} were found to be a blue-yellow, orange-red and yellow-orange emitting phosphor under near-UV excitation general illumination, solid state white light-emitting diodes (w-LEDs).

I. Experimental

Wet chemical synthesis was used to create Dy^{3+} , Eu^{3+} and Sm^{3+} ion doped $\text{Ca}_5(\text{PO}_4)_3\text{F}$ phosphors. The sample was prepared using calcium fluoride nitrate, ammonium dihydrogen phosphate, sodium fluoride, dysprosium oxide, europium oxide and samarium oxide. The materials and chemicals utilised are all of Analytical Reagent (AR) quality. To measure samples stoichiometrically, first place them on the sample weighing and weight box, then in a Borosil beaker, and last in suitable quantities of distilled water. Dy_2O_3 was dissolved in the test tube using diluted nitric acid (dil. HNO_3) and transformed to nitrate form. Following that, the dopant was added to a beaker and the solution was created. Following 30 minutes of stirring, the sample became clear; after heating at 100°C for 10 hours in a Hot Air Oven, a powder product was created. A pestle and mortar were used to form a fine powder out of this crystalline powder. Finally, the powder was annealed in a 600°C furnace for three hours. Similarly, two more samples were produced using the dopants Eu_2O_3 and Sm_2O_3 . We synthesised the necessary phosphors and cooled them to room temperature before characterising them. The sample's structural characteristics were determined using an X-ray diffractometer. The photoluminescence excitation and emission spectra were measured with a fluorescence spectrophotometer

II. Results and discussion

2.1. X-ray diffraction (XRD) pattern of $\text{Ca}_5(\text{PO}_4)_3\text{F}$ phosphor

The XRD patterns for the $\text{Ca}_5(\text{PO}_4)_3\text{F}$ phosphors are well matched to the conventional JCPDS PDF Card number 2104744 pattern, as shown in Fig. 1. The XRD pattern of the sample matches the standard data file, indicating that the right host lattice was formed during the wet chemical synthesis procedure. Based on this discovery, $\text{Ca}_5(\text{PO}_4)_3\text{F}$ powder with no impurity phases was generated, demonstrating that the homogeneous chemical was effectively synthesised. To study crystal structures, X-ray diffraction (XRD) data from a Rigaku D/Max-2200 X-ray diffractometer and Cu-K radiation ($\lambda = 1.54059$) are obtained. The XRD pattern was recorded in the 10-100 range with a step size of 0.02. The optimal peak obtained in XRD has a peak location of 31.91° , which

corresponds to the hump formed in amorphous XRD, showing the suggested $\text{Ca}_5(\text{PO}_4)_3\text{F}$ phosphor sample. The pattern is a hexagonal system with the space group P 63/m (176) [10]

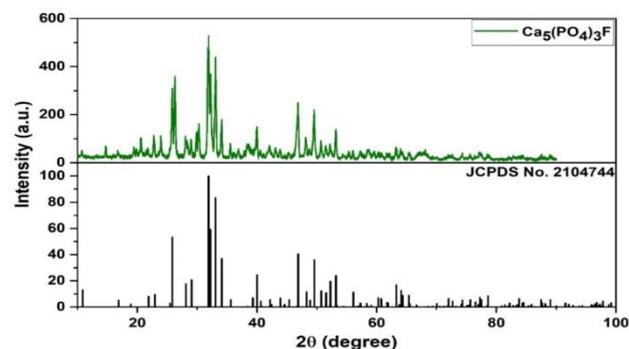


Fig. 1. XRD patterns of $\text{Ca}_5(\text{PO}_4)_3\text{F}$ Phosphor.

2.2. Photoluminescence

2.2.1. Photoluminescence properties of $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Dy}^{3+}$ phosphor

The excitation spectra of $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Dy}^{3+}$ phosphor, monitored at blue emission at wavelength 481 nm (${}^4\text{F}_{9/2} \rightarrow {}^6\text{H}_{15/2}$ transition), are shown in Fig. 2. The excitation spectrum depicts a series of narrow bands in the near UV and visible (blue) region, which are attributed to the transition from the ground state (${}^6\text{H}_{15/2}$) to the respective higher energy levels ${}^4\text{F}_{5/2}$ (327 nm), ${}^6\text{P}_{7/2}$ (352 nm), ${}^6\text{P}_{5/2}$ (365 nm), and ${}^4\text{F}_{7/2}$ (387 nm) [11] as shown in Fig. 2. The peak at 352 nm has the maximum intensity of all the peaks and is thus considered for the excitation of the $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Dy}^{3+}$ phosphor.

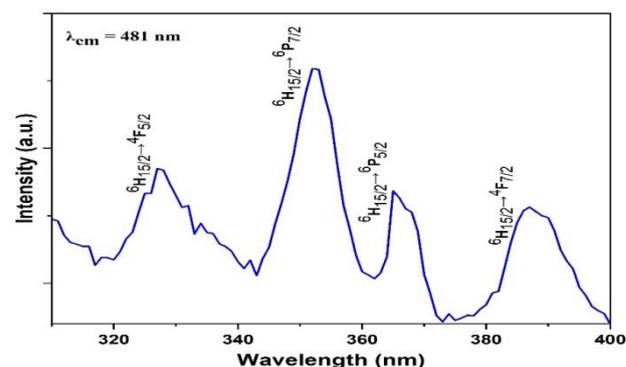


Fig. 2. Excitation spectrum of the $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Dy}^{3+}$ phosphor monitored at 481 nm emission.

The emission spectrum of $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Dy}^{3+}$ phosphor in the spectral region 425-600 nm after excitation at 352 nm is shown in Fig. 3. This emission spectrum has two primary emission peaks 481 nm (${}^4\text{F}_{9/2} \rightarrow {}^6\text{H}_{15/2}$) (MD transition) in the blue region and 575 nm (${}^4\text{F}_{9/2} \rightarrow {}^6\text{H}_{13/2}$) (ED transition) in the yellow region [12]. The observed emission spectra of $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Dy}^{3+}$ phosphor in this work show that the blue emission at 481 nm is larger than the yellow emission at 575 nm. In this matrix, the combination of blue and yellow emission results in white light emission. The emission spectra of the materials stimulated by 352 nm are clearly shown in Fig. 4. The inset shows the 481 nm and 575 nm emission intensities

of $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{x}\text{Dy}^{3+}$ ($0.1 \leq x \leq 1$) phosphors with varying Dy^{3+} concentrations. The Emission intensity of both primary peaks in blue (481 nm) and yellow (575 nm) origin increases with Dy^{3+} concentration up to 0.5 mole %, then decreases with concentration quenching under the excitation of 352 nm [13].

The processes for emission are presented in Fig. 5. schematic energy diagram of Dy^{3+} ions. Dy^{3+} ions are stimulated from the ground state to the $^6\text{P}_{7/2}$ state via excitation at 352 nm. The excited Dy^{3+} ions in the $^6\text{P}_{7/2}$ state then non-radiatively relaxed to occupy the $^4\text{F}_{9/2}$ state. Finally, the Dy^{3+} ions in the $^4\text{F}_{9/2}$ level relaxed radiatively to the $^6\text{H}_{15/2}$ and $^6\text{H}_{13/2}$ states, resulting in increased blue and yellow emissions at 481 nm and 575 nm, respectively [14].

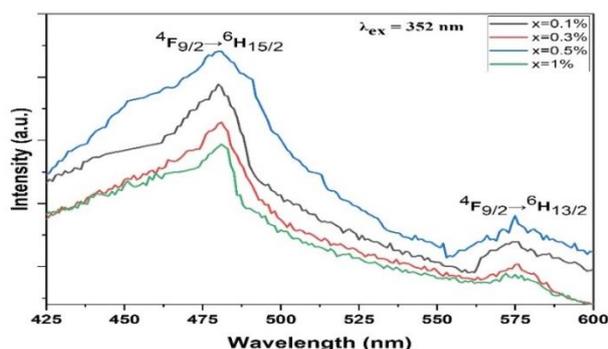


Fig. 3. Photoluminescence emission spectrum of $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Dy}^{3+}$ when excited at 352 nm.

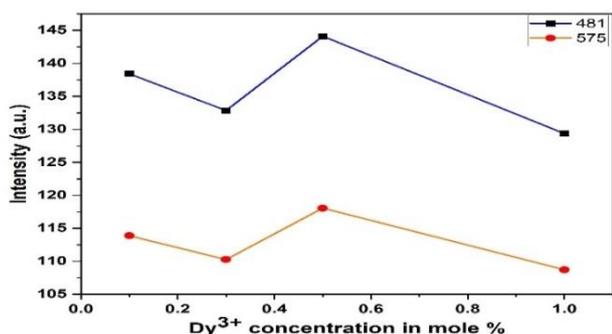


Fig. 4. Variation in the emission intensity with different doping concentration of Dy^{3+} in the $\text{Ca}_5(\text{PO}_4)_3\text{F}$ phosphor.

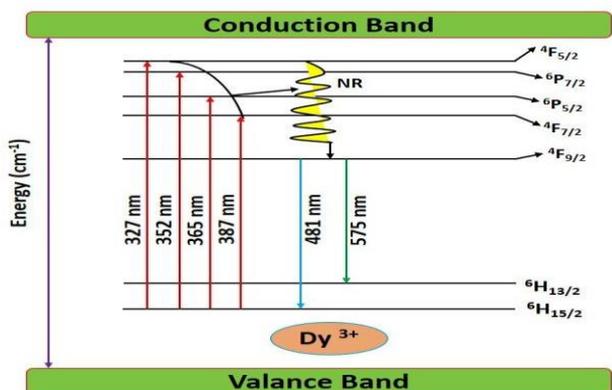


Fig. 5. The schematic energy level diagram of Dy^{3+} ions in $\text{Ca}_5(\text{PO}_4)_3\text{F}$ phosphors.

2.2.2. Photoluminescence properties of $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Eu}^{3+}$ phosphor

Fig. 6. The intra-configurational 4f-4f transitions of Eu^{3+} in the matrix were attributed to a sequence of acute excitation bands between 350 and 420 nm with the electronic transitions $^7\text{F}_0 \rightarrow ^5\text{D}_4$, $^7\text{F}_0 \rightarrow ^5\text{G}_3$, $^7\text{F}_0 \rightarrow ^5\text{G}_2$, $^7\text{F}_0 \rightarrow ^5\text{L}_6$ and $^7\text{F}_0 \rightarrow ^5\text{D}_3$ at wavelengths 361 nm, 377 nm, 383 nm, 394 nm, and 416 nm, respectively [15]. The peak absorbance band of the $^7\text{F}_0 \rightarrow ^5\text{L}_6$ transition at 394 nm corresponds to the output wavelength of near-UV chips in phosphor-converted w-LEDs. As a result, the $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Eu}^{3+}$ phosphor performed admirably in white light emitting diodes with near-UV excitation (w-LEDs).

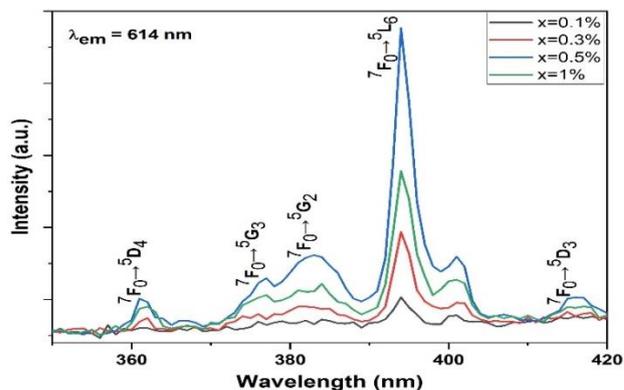


Fig. 6. Excitation spectrum of the $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Eu}^{3+}$ phosphor monitored at 614 nm emission.

The emission spectra of Eu^{3+} doped $\text{Ca}_5(\text{PO}_4)_3\text{F}$ phosphors are shown in Fig. 7. The emission band region from 550 to 650 nm and includes several typical emission bands that might be attributed to the transition from $^5\text{D}_0 \rightarrow ^7\text{F}_1$ and $^5\text{D}_0 \rightarrow ^7\text{F}_2$ which are properties of Eu^{3+} ions. The emission spectra show a prominent red emission band at 614 nm owing to the electric dipole transition of $^5\text{D}_0 \rightarrow ^7\text{F}_2$ and a weak emission peak at 591 nm due to the magnetic dipole transition of $^5\text{D}_0 \rightarrow ^7\text{F}_1$ [16]. As a response, the $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Eu}^{3+}$ phosphor was shown to be excellent for use in near-UV exciting solid state lighting. Fig. 8. depicts the emission spectra ($\lambda_{\text{ex}} = 394$ nm) and fluctuation of integrated emission intensities of $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{x}\text{Eu}^{3+}$ phosphors. The activator concentration has little effect on the peak profile but has a significant effect on peak intensity. The luminescence intensity increases with increasing the Eu^{3+} doping ratio due to a rise in absorption sites and reaches a maximum at $x = 0.5$ mole %, indicating that concentration quenching occurs [17].

Fig. 8 shows a schematic energy level diagram. The higher energy levels ($^5\text{D}_4$, $^5\text{G}_3$, $^5\text{G}_2$, $^5\text{L}_6$, and $^5\text{D}_3$) of the Eu^{3+} ions become populated under varied Eu^{3+} excitation (361 nm, 377 nm, 383 nm, 394 nm, and 416 nm). Due to an inadequate energy difference between the states, the ions relaxed to the ground state ($^5\text{D}_0$) of the excited level via non-radiative transitions (phonon relaxation). Finally, it descends to separate ground-level states ($^7\text{F}_1$ and $^7\text{F}_2$), emitting orange and red photons that correspond to the $^5\text{D}_0 \rightarrow ^7\text{F}_1$ and $^5\text{D}_0 \rightarrow ^7\text{F}_2$ transitions of the Eu^{3+} ions [18].

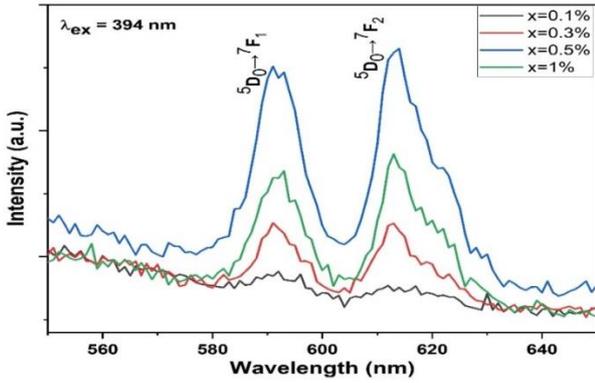


Fig. 7. Photoluminescence emission spectra of $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Eu}^{3+}$ when excited at 394 nm.

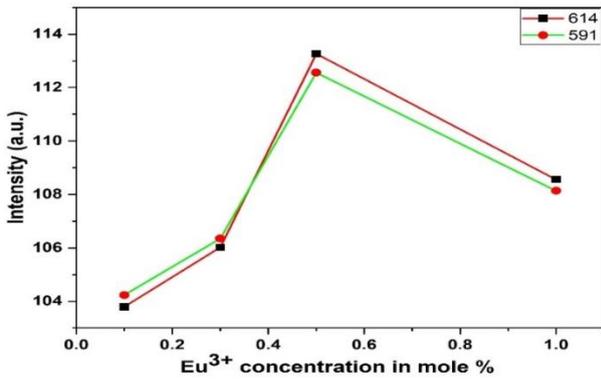


Fig. 8. Variation in the emission intensity with different doping concentration of Eu^{3+} in the $\text{Ca}_5(\text{PO}_4)_3\text{F}$ phosphor.

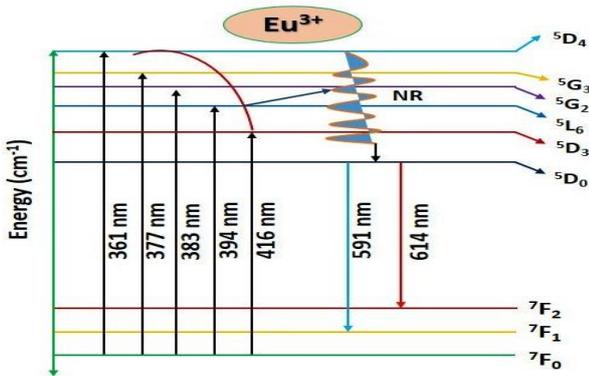


Fig. 9. The schematic energy level diagram of Eu^{3+} ions in $\text{Ca}_5(\text{PO}_4)_3\text{F}$ phosphors.

2.2.3. Photoluminescence properties of $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Sm}^{3+}$ phosphor

Fig. 10. The excitation spectrum ($\lambda_{\text{em}} = 599 \text{ nm}$) consisted of several peaks at 345 nm (${}^6\text{H}_{5/2} \rightarrow {}^4\text{H}_{9/2}$), 362 nm (${}^6\text{H}_{5/2} \rightarrow {}^4\text{D}_{3/2}$), 376 nm (${}^6\text{H}_{5/2} \rightarrow {}^4\text{D}_{1/2}$), 403 nm (${}^6\text{H}_{5/2} \rightarrow {}^4\text{F}_{7/2}$) and 418 nm (${}^6\text{H}_{5/2} \rightarrow {}^6\text{P}_{5/2}$), which are attributable to the f-f forbidden transitions of Sm^{3+} , are seen within the wavelength range of 330 nm to 430 nm [19]. As a consequence, the $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Sm}^{3+}$ phosphor proved excellent for near-UV excitation white light emitting diodes (w-LEDs).

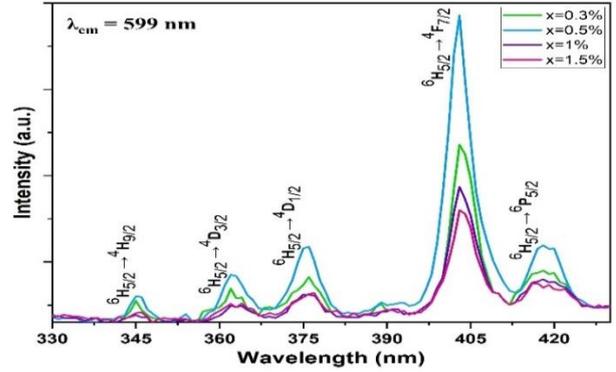


Fig. 10. Photoluminescence excitation spectra of $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Sm}^{3+}$ ($x = 0.3\text{--}1.5\%$) phosphors ($\lambda_{\text{em}} = 599 \text{ nm}$).

Fig. 11. shows the emission spectra of Sm^{3+} doped $\text{Ca}_5(\text{PO}_4)_3\text{F}$ phosphors excited by an electron beam. According to the results, the whole emission spectrum from 525 nm to 625 nm is constituted of dominant yellow and orange emission peaks situated at 565 nm and 599 nm, respectively, which are ascribed to ${}^4\text{G}_{5/2} \rightarrow {}^6\text{H}_{5/2}$ magnetic-dipole (MD) permitted and ${}^4\text{G}_{5/2} \rightarrow {}^6\text{H}_{7/2}$ magnetic-dipole (MD) permitted transitions of Sm^{3+} ions [20]. Fig. 12. shows the emission spectra of $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Sm}^{3+}$ phosphors ($x = 0.3, 0.5, 1$ and 1.5%). There were no noticeable variations in the location of the emission peaks across all $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Sm}^{3+}$ samples. The variation in emission intensity with Sm^{3+} ion concentrations under 402 nm excitation [21]. The intensity of the emission increases initially, reaching a maximum at 0.5 mole % Sm^{3+} ion, and then drops as the concentration climbs further.

Fig. 13. shows the electronic transitions in an energy level diagram to describe the photoluminescence process of $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Sm}^{3+}$. Under the excitation of 403 nm light, electrons are transported from the ground level (${}^6\text{H}_{5/2}$) to the ${}^4\text{F}_{7/2}$ level, and subsequently, the non-radiative (NR) process occurs, resulting in the population of the ${}^4\text{G}_{5/2}$ level. Following that, the distinctive emission bands of Sm^{3+} attributable to the ${}^4\text{G}_{5/2} \rightarrow {}^6\text{H}_{5/2}$ (565 nm) and ${}^4\text{G}_{5/2} \rightarrow {}^6\text{H}_{7/2}$ (599 nm) transitions are observed [22].

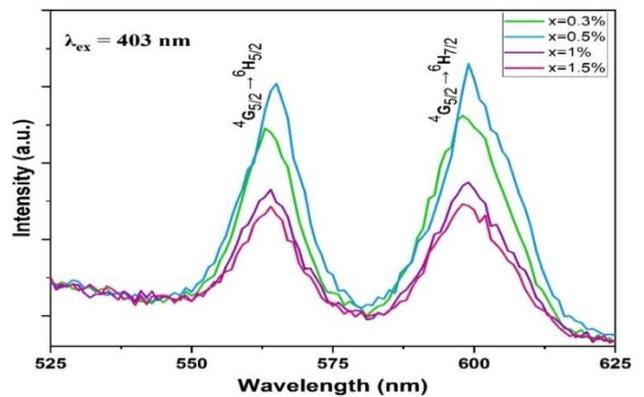


Fig. 11. Emission spectra ($\lambda_{\text{ex}} = 403 \text{ nm}$) of samples $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Sm}^{3+}$ for different Sm^{3+} concentrations: $x = 0.3\%, 0.5\%, 1\%$ and 1.5% , respectively.

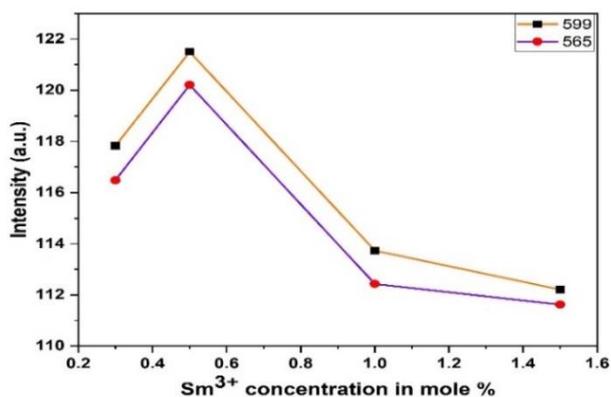


Fig. 12. Variation in the intensity 565 nm and 599 nm as function of the Sm^{3+} ion concentration in $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Sm}^{3+}$ phosphor.

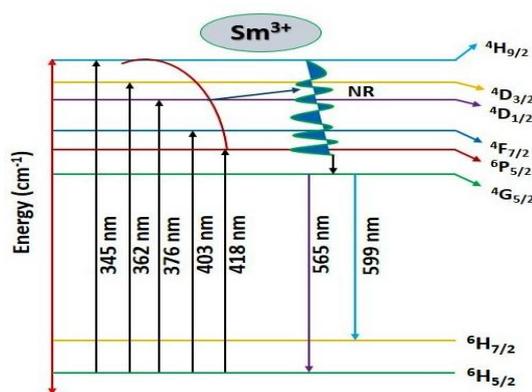


Fig. 13. Fig. 9. The schematic energy level diagram of Sm^{3+} ions in $\text{Ca}_5(\text{PO}_4)_3\text{F}$ phosphors.

2.3. Chromatic properties of Dy^{3+} , Eu^{3+} and Sm^{3+} doped $\text{Ca}_5(\text{PO}_4)_3\text{F}$ phosphor

The Commission Internationale de l'Eclairage (CIE) system recognises three primary colours in the human visual system: red, green and blue [23]. Every natural colour, such as blue, yellow, orange and red, may be identified by (x, y) coordinates. The CIE chromaticity coordinates of Dy^{3+} , Eu^{3+} , and Sm^{3+} doped $\text{Ca}_5(\text{PO}_4)_3\text{F}$ phosphor are shown in Fig. 14. It shows that the colour of the $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Dy}^{3+}$ phosphor with varied concentrations is blue-yellow for prepared with CIE values ranging from ($x=0.087$, $y=0.144$) to ($x=0.478$, $y=0.520$). The CIE coordinates for $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Eu}^{3+}$ were orange ($x=0.580$, $y=0.418$), red ($x=0.677$, $y=0.322$) and $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Sm}^{3+}$ were yellow ($x=0.408$, $y=0.589$), orange ($x=0.622$, $y=0.377$), respectively [24]. The present results indicate that $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Ln}$ (Ln = Dy^{3+} , Eu^{3+} and Sm^{3+}) phosphor produced via a wet chemical technique can be a potential blue-yellow, orange-red, and yellow-orange emitting phosphor pumped by a near UV source that is a strong candidate for solid state lighting applications.

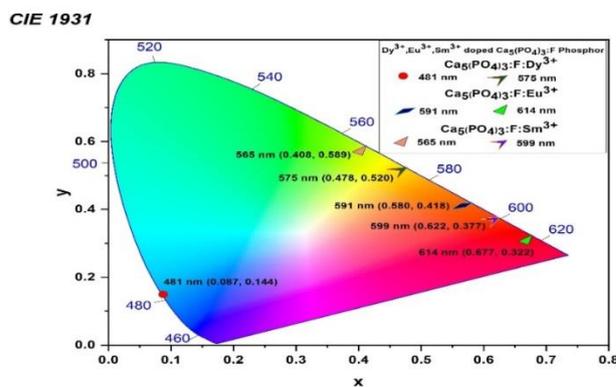


Fig. 14. CIE diagram showing the CIE Coordinates of $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Ln}$ (Ln = Dy^{3+} , Eu^{3+} and Sm^{3+}) Phosphors.

Conclusions

This research investigates the $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Ln}$ (Ln: Dy^{3+} , Eu^{3+} and Sm^{3+}) phosphors generated via wet chemical synthesis, as well as their X-ray diffraction pattern and photoluminescence characterisation. The hexagonal phase of the samples was verified by XRD analysis. Under UV excitation (352 nm) $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Dy}^{3+}$ shows emission 481 nm (blue) and 575 nm (yellow). In the Eu^{3+} activated $\text{Ca}_5(\text{PO}_4)_3\text{F}$ phosphor, the emission spectrum showed a dominant peak at 591 nm (orange) while others are at 614 nm (red) when excited at 394 nm. When $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Sm}^{3+}$ phosphor was excited at 403 nm, the emission spectrum showed intense bands at 565 nm (yellow) and 599 nm (orange). According to the results, all produced phosphors have a strong photoluminescence intensity in the Dy^{3+} , Eu^{3+} and Sm^{3+} regions. The photoluminescence emission spectrum of $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Ln}$ (Ln: Dy^{3+} , Eu^{3+} and Sm^{3+}) phosphors may be useful near UV-based solid-state lighting devices.

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Credit authorship contribution statement

C. M. Nandanwar: Conceptualization, Investigation, Writing-original draft, Writing, review and editing. N. S. Kokode: Investigation, original proposal writing, Writing, review and editing, supervision.

Declaration of Competing Interest

The authors declare that they do not have any known competing financial interests or personal ties that may seem to have influenced the work reported in this paper.

Data availability

No data was used for the research described in the article.

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Синтез і фотолюмінесцентні властивості люмінофорів $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Ln}$ (Ln: Dy^{3+} , Eu^{3+} і Sm^{3+}) для твердотільного освітлювача на основі ультрафіолету

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Наведено результати дослідження вологого хімічного синтезу $\text{Ca}_5(\text{PO}_4)_2\text{F}$ -господаря із Dy^{3+} , Eu^{3+} та Sm^{3+} , легованим лантанідом. Ретельно досліджено рентгеноструктурні та фотолюмінесцентні характеристики люмінофорів. Гексагональна система із просторовою групою $\text{P } 63/m (176)$ перевірена методом порошкової рентгенівської дифракції. При УФ-збудженні (352 нм) $\text{Ca}_5(\text{PO}_4)_2\text{F}:\text{Dy}^{3+}$ випромінює 481 нм (синій) і 575 нм (жовтий), що відповідає $^4\text{F}_{9/2} \rightarrow ^6\text{H}_{15/2}$ (магнітний диполь) і $^4\text{F}_{9/2} \rightarrow ^6\text{H}_{13/2}$ (електричні дипольні) переходам, відповідно. Коли люмінофор $\text{Ca}_5(\text{PO}_4)_2\text{F}:\text{Eu}^{3+}$ збуджувався при 394 нм, спектри випромінювання показали сильні смуги при 591 нм (помаранчевий) і 614 нм (червоний). При збудженні при 403 нм спектри випромінювання люмінофора $\text{Ca}_5(\text{PO}_4)_2\text{F}$ активованого Sm^{3+} демонструють піки випромінювання при 565 нм (жовтий) і 599 нм (помаранчевий,) відповідно. Проаналізовано фотолюмінесцентні характеристики $\text{Ca}_5(\text{PO}_4)_3\text{F}:\text{Ln}$ (Ln: Dy^{3+} , Eu^{3+} і Sm^{3+}), як можливого матеріалу для твердотільного освітлення на основі ультрафіолетового випромінювання.

Ключові слова: Вологий хімічний синтез, XRD, фотолюмінесценція, фосфор, легування лантанідами, СІЕ хроматичні координати, твердотільні освітлювачі.