JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

SYNTHESIS AND CIE CHROMATICITY OF Ce^{3+} ACTIVATED $GdPO_4$ PHOSPHORS

[1]Lokeshwar Patel, [2]Rashmi Sharma

[1]Department of Physics, Govt. L.P.P. College, Sarangarh (C.G.), 496445, India

[2]Department of Physics, Swami Atmanand Govt. English Medium Model College Atari, Raipur (C.G.), 492010, India

Abstract

In the present work, Ce^{3+} activated $GdPO_4$ phosphors were synthesized by the solid-state reaction method. Gadolinium orthophosphate ($GdPO_4$) phosphors are used as multimodal agents and are beneficial for optoelectronic and biomedical applications. The present investigation focused on the CIE chromaticity diagram of the Ce-doped $GdPO_4$ phosphor, which was obtained with the help of the PL emission spectrum using the photo-luminescent data and CIE software. The result revealed that the luminescence colors of $GdPO_4$:Ce^{3+} phosphor are found in the yellowish-green region.

Keywords: Orthophosphate, CIE, luminescence.

1. Introduction

Recently, Gadolinium orthophosphate ($GdPO_4$) phosphors activated with rare earth ions attracted researchers due to multimodal agents being mainly used for optoelectronic and biomedical applications [1-5]. This attention is generated because of their higher quantum yields, lower photo-bleaching potential, excellent ability to host activator ions in their lattice, high chemical and thermal stability, importantly low toxicity and bio-compatibility nature [6].

Several investigations have been carried out for Gd-based inorganic compounds such as $GdVO_4$, $GdBO_3$, GdF_3, $NaGdF_4$, $BaGdF_5$, Gd_2O_3, $GdPO_4$, etc. that established as a good host material for different rare earth ions because of their low solubility, special fluorescence properties [7–12]. Amongst them, the monoclinic structure of $GdPO_4$ has been recognized to be an outstanding host lattice for various photoluminescence applications [13,14].

Nowadays LEDs have been considered as the subsequent generation lighting source which is very useful in different lighting industrial fields, such as plasma panel devices (PPDs), displays devices, fat panel devices (FPDs), solid-state devices, and optical devices.

Halappa et al., synthesized the Eu^{3+} activated $GdPO_4$ phosphors by the conventional solid-state method. The Commission International de l'Eclairage (CIE) chromaticity coordinates of Eu^{3+} doped $GdPO_4$ phosphors were obtained from the PL emission spectra at excitation of 238 nm wavelength. The CIE chromaticity diagram indicated that the color coordinates lie in the orange-red region. Hence, these materials are more appropriate for red light production in domestic appliances [15]. Yang et al., successfully prepared the $GdPO_4$ nanorods by hydrothermal method at 180 °C and it was transformed to $GdPO_4$ nanocrystals with the monoclinic phase at heating above 800 °C. The purpose of the investigation is to comprehend the tunable color of white light in a single-phase host for UV-excited WLEDs. It was found that due to the energy transfer from Tb^{3+} to Eu^{3+} ions, the color tone of the samples changed from green and white to red by doping Eu^{3+} ions at different concentrations under direct excitation at 368 nm. The electric quadrupole-quadrupole interaction mechanism occurs at a 12 mol% concentration of Eu^{3+} where the energy transfer efficiency reached around 96.1% Thus results indicated that this material with variable colors might potentially be used in warm-white display fields [16]. Furthermore, the narrow line emission bands of rare earth ions ascribed to the 4f-4f transitions are responsible for the color tuning of the phosphors [17,18].

A $GdPO_4$ activated with different concentrations of Sm^{3+} has been prepared through the combustion method. The CIE chromaticity coordinates obtained from the PL spectra upon excitation at 229, 273, and 407 nm as a function of Sm^{3+} concentration for the luminous color. Under excitation of 229 nm, a cool white light was obtained. However, under excitation through 273 nm and 401 nm, the synthesized samples emitted in the reddish-orange region. Hence, this material could be a suitable candidate for display and solid-state lighting applications [19].

In the present study, Ce^{3+} activated $GdPO_4$ phosphor has been prepared by the solid-state reaction method and focused on the CIE chromaticity coordinates, which were obtained with the help of the PL emission spectrum of the Ce-doped $GdPO_4$ phosphor using the photo-luminescent data and CIE software.

2. Experimental details

Ce^{3+} activated $GdPO_4$ doped phosphors synthesized by the solid-state reaction method. Himedia chemicals of gadolinium oxide (Gd_2O_3) and di-ammonium hydrogen phosphate $(NH_4)_2HPO_4$ were used for the synthesis of the samples. Ce_2O_3 was used as a dopant source with varied concentrations from 1 to 5 mol%. The stoichiometric amount of starting materials was homogeneously mixed and continuously grounded in a mortar pestle. Then the mixture was transferred into the crucible and kept for the calcination process at 850°c for 8h inside the muffle furnace. The product was taken out from the furnace and allowed to cool at room temperature, then used for further characterization studies

3. CIE chromaticity coordinates of Ce-doped $GdPO_4$ phosphor

In 1931 for a standard observer, the International Commission on Illumination (CIE) suggested two groups of color-matching functions that are known as CIE RGB and CIE XYZ. William David Wright and John Guild conducted many investigations in the year 1920s and on the justification of their studies, the coordinates of color spaces have been defined by CIE [20-21]. The CIE chromaticity diagram is one of the internationally approved techniques used to specify the spectral colors and their mixtures. By using 3D representation, generally, the visualization and interpretation of colors become complicated, thus by using 2D graphs color can be visualized in a better way [22]. Chromaticity mainly consists of two parameters i.e., hue and saturation, and any color can be distinguished by its brightness, hue, and saturation [23]. In white LED applications, "Color coordinate is a significant characteristic in determining the color quality of any phosphor material. The primary colors are red, green, and blue, any color can be formed by using these colors. are also known as primary colors, and by combining any two colors another color can be produced are called tristimulus values and which is represented by X, Y, and Z respectively".

Red or orange hues represented the large values of x, green, blue-green, or yellow-green represented the values of y, and blue, violet, or purple hues represented the large values of z. The relative amount of the sum of all these values has to be equal to unity i.e. $x+y+z=1$. And third tri-chromatic coefficient value can be evaluated by using the other two values of tri-chromatic coefficients. Thus, the CIE chromaticity diagram represents the basic visual concepts of the properties of spectral colors [23].

The CIE chromaticity diagram was obtained with the help of the PL emission spectrum of the Ce-doped $GdPO_4$ phosphor using the photo-luminescent data and the interactive CIE software. Figure 1 depicts the CIE Chromaticity Diagram of $GdPO_4:Ce^{3+}$. Each spectral color can be distinguished by (x, y) coordinates that are merged inside the chromatic shoe. Luminescence colors of $GdPO_4:Ce^{3+}$ phosphor are found in the Yellowish green region.

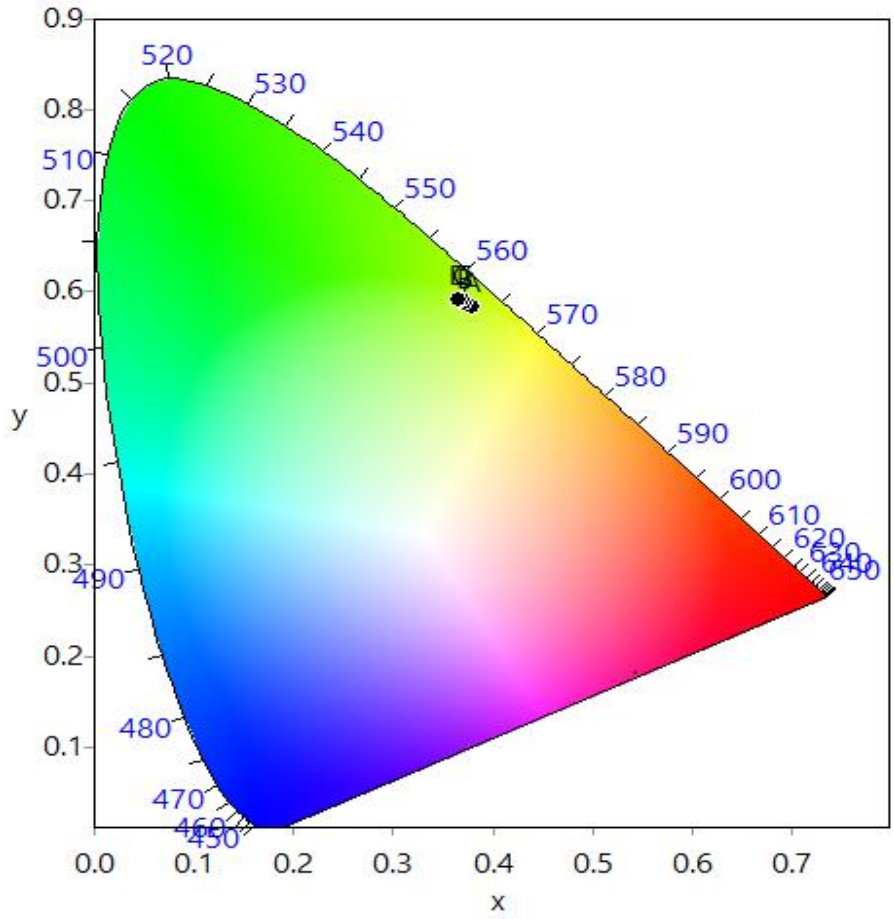

Figure 1 CIE Chromaticity Diagram of $GdPO_4:Ce^{3+}$.

4. Conclusion

$GdPO_4:Ce^{3+}$ phosphors have been successfully synthesized by solid-state reaction method with a varying dopant concentrations. The optical properties of the synthesized phosphor were investigated in the form of photoluminescence. The CIE chromaticity diagram was obtained with the help of the PL emission spectrum of the Ce-doped $GdPO_4$ phosphor using the photo-luminescent data and CIE software, which revealed that Luminescence colors of $GdPO_4:Ce^{3+}$ phosphor are found in the Yellowish green region. Thus, the investigated results indicated that the synthesized phosphor could be a potential candidate for solid-state lighting and biomedical applications.

5. References

[1] Sahu, N. K., Singh, N. S., Pradhan, L., & Bahadur, D. (2014). Ce^{3+} sensitized $GdPO_4$: Tb^{+} with iron oxide nanoparticles: a potential biphasic system for cancer theranostics. *Dalton transactions*, *43*(30), 11728-11738.

[2] Yi, Z., Lu, W., Qian, C., Zeng, T., Yin, L., Wang, H., ... & Zeng, S. (2014). Urchin-like Ce/Tb co-doped $GdPO_4$ hollow spheres for in vivo luminescence/X-ray bioimaging and drug delivery. *Biomaterials science*, *2*(10), 1404-1411.

[3] Rodriguez-Liviano, S., Becerro, A. I., Alcantara, D., Grazu, V., De la Fuente, J. M., & Ocana, M. (2013). Synthesis and properties of multifunctional tetragonal Eu: $GdPO_4$ nanocubes for optical and magnetic resonance imaging applications. *Inorganic chemistry*, *52*(2), 647-654.

[4] Kumar, V., Rani, P., Singh, D., & Chawla, S. (2014). Efficient multiphoton upconversion and synthesis route dependent emission tunability in $GdPO_4$: Ho^{3+}, Yb^{3+} nanocrystals. *RSC advances*, *4*(68), 36101-36105.

[5] Fu, Z., Sheng, T., Wu, Z., Yu, Y., & Cui, T. (2014). A novel and tunable upconversion luminescent material $GdPO_4$: Yb^{3+}, Ln^{3+} (Ln= Er, Tm, Ho). *Materials Research Bulletin*, *56*, 138-142.

[6] Zhang, L., Yin, M., You, H., Yang, M., Song, Y., & Huang, Y. (2011). Mutifuntional $GdPO_4$: Eu^{3+} hollow spheres: synthesis and magnetic and luminescent properties. *Inorganic Chemistry*, *50*(21), 10608-10613.

[7] Muhr, V., Buchner, M., Hirsch, T., Jovanović, D. J., Dolić, S. D., Dramićanin, M. D., & Wolfbeis, O. S. (2017). Europium-doped $GdVO_4$ nanocrystals as a luminescent probe for hydrogen peroxide and for enzymatic sensing of glucose. *Sensors and Actuators B: Chemical*, *241*, 349-356.

[8] Grzyb, T., Kubasiewicz, K., Szczeszak, A., & Lis, S. (2015). Synthesis and spectroscopic properties of Yb^{3+} and Tb^{3+} co-doped $GdBO_3$ materials showing down-and up-conversion luminescence. *Dalton Transactions*, *44*(9), 4063-4069.

[9] Guan, H., Sheng, Y., Xu, C., Dai, Y., Xie, X., & Zou, H. (2016). Energy transfer and tunable multicolor emission and paramagnetic properties of GdF_3: Dy^{3+}, Tb^{3+}, Eu^{3+} phosphors. *Physical Chemistry Chemical Physics*, *18*(29), 19807-19819.

[10] Villanueva-Delgado, P., Biner, D., & Krämer, K. W. (2017). Judd–Ofelt analysis of β-$NaGdF_4$: Yb^{3+}, Tm^{3+} and β-$NaGdF_4$: Er^{3+} single crystals. *Journal of luminescence*, *189*, 84-90.

[11] Zhang, H., Wu, H., Wang, J., Yang, Y., Wu, D., Zhang, Y., ... & Yang, S. (2015). Graphene oxide-$BaGdF_5$ nanocomposites for multi-modal imaging and photothermal therapy. *Biomaterials*, *42*, 66-77.

[12] Santos, T. H., Grilo, J. P., Loureiro, F. J., Fagg, D. P., Fonseca, F. C., & Macedo, D. A. (2018). Structure, densification and electrical properties of Gd^{3+} and Cu^{2+} co-doped ceria solid electrolytes for SOFC applications: Effects of Gd_2O_3 content. *Ceramics International*, *44*(3), 2745-2751.

[13] Yang, J., Xiong, H., Dong, J., Yang, C., Gan, S., & Zou, L. (2017). Facile hydrothermal synthesis and luminescent properties of Sm^{3+}/Eu^{3+} codoped $GdPO_4$ phosphors. *Journal of Physics and Chemistry of Solids*, *111*, 355-363.

[14] Goderski, S., Runowski, M., Stopikowska, N., & Lis, S. (2017). Luminescent-plasmonic effects in $GdPO_4$: Eu^{3+} nanorods covered with silver nanoparticles. *Journal of Luminescence*, *188*, 24-30.

[15] Halappa, P., Mathur, A., Delville, M. H., & Shivakumara, C. (2018). Alkali metal ion co-doped Eu^{3+} activated $GdPO_4$ phosphors: structure and photoluminescence properties. *Journal of Alloys and Compounds*, *740*, 1086-1098

[16] Yang, J., Wang, X., Song, L., Luo, N., Dong, J., Gan, S., & Zou, L. (2018). Tunable luminescence and energy transfer properties of $GdPO_4$: Tb^{3+}, Eu^{3+} nanocrystals for warm-white LEDs. *Optical Materials*, *85*, 71-78.

[17] Singh, B. P., Parchur, A. K., Ningthoujam, R. S., Ramakrishna, P. V., Singh, S., Singh, P., ... & Maalej, R. (2014). Enhanced up-conversion and temperature-sensing behaviour of Er^{3+} and Yb^{3+} co-doped $Y_2Ti_2O_7$ by incorporation of Li^+ ions. *Physical Chemistry Chemical Physics*, *16*(41), 22665-22676.

[18] Runowski, M., Grzyb, T., Zep, A., Krzyczkowska, P., Gorecka, E., Giersig, M., & Lis, S. (2014). Eu^{3+} and Tb^{3+} doped $LaPO_4$ nanorods, modified with a luminescent organic compound, exhibiting tunable multicolour emission. *RSC Advances*, *4*(86), 46305-46312.

[19] Ouertani, G., Ferhi, M., Horchani-Naifer, K., & Ferid, M. (2021). Effect of Sm^{3+} concentration and excitation wavelength on spectroscopic properties of $GdPO_4$:Sm^{3+} phosphor. *Journal of Alloys and Compounds*, *885*, 161178..

[20] Wright, W. D. (1929). A re-determination of the trichromatic coefficients of the spectral colors. *Transactions of the Optical Society*, *30*(4), 141.

[21] Guild, J. (1931). The colorimetric properties of the spectrum. *Philosophical Transactions of the Royal Society of London. Series A, Containing Papers of a Mathematical or Physical Character*, *230*(681-693), 149-187.

[22] Choudhury, A. K. R. (2014). *Principles of colour and appearance measurement: Object appearance, colour perception, and instrumental measurement*. Elsevier.

[23] Nixon, M., & Aguado, A. (2019). *Feature extraction and image processing for computerS vision*. Academic press.