SYNTHESIS OF SOLID STATE LIGHTING WITH INTENSE BLUE COLOR FOR PLANT PHYSIOLOGY

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Abstract:

Carotenoid is a photosynthetic pigment available in plants which absorbs blue light having frequency 400 nm to 500 nm. Using this background, blue light emitting materials such as Eu^{2+} =0.1 mol% doped $YGdO_3$ was synthesized by wet chemical method. Further synthesized phosphor is characterized by X-ray diffraction (XRD), SEM, FTIR and optical properties were investigated. The XRD pattern of $YGdO_3$ revealed a cubic crystalline structure. The XRD and FTIR spectra of $YGdO_3$:Eu^{2+} was highly consistent with standard Y_2O_3, which indicate total incorporation of Eu^{2+} ions in the $YGdO_3$ matrix. The Eu^{2+} doping in $YGdO_3$ produced intense peak in blue region which is centered around 430 nm and a broad peak covering whole visible region under NUV (near ultra violet) excitation radiation. Thus, present study reveals that prepared phosphor material can be used for white light emitting lamp, which may help to enhance physiological growth of the plants.

Keywords: LEDs, Plant physiology, XRD, SEM, FTIR.

Introduction :

White light emitting diodes (WLEDs) which converted blue or near-ultraviolet (NUV) LED chips as their exciting source are thought to be the simplest, most practical, longest-lasting, and most reliable for creating cool, eco-friendly white light [1]. Blue light is highly absorbed by carotenoid, chlorophyll a and chlorophyll b. LEDs with more intense blue color play important role in the physiological growth of a plant. However, action spectrum shows the variation in photosynthetic response to blue light which is highly changeable within species depending on quantity of blue light in a spectrum [2]. Fluorescent lamps, white light emitting diodes, field emission displays, plasma display panels and fibre amplifiers are few examples of contemporary lighting, displays and optical communications devices that utilize inorganic luminescent materials, particularly those activated by divalent europium, Eu^{2+} [3]. To modify the optical characteristics of PL materials activated by europium ions, Eu^{3+} must be converted to Eu^{2+}. To do this, we typically subject the compound containing Eu^{2+} to a calcinations process in a reducing atmosphere such as H_2 / N_2, CO, etc. [4-5].

However, in other study publications it is also mentioned that even when the chemical containing Eu^{3+} is synthesized in an oxidizing atmosphere, that is, in air or pure O_2 gas, Eu^{3+} ions deoxidized to Eu^{2+} in three-dimensional (3D) contained oxide crystal formations [5]. In the present study, we report the first observation of the Eu^{3+}-->Eu^{2+} reduction event using

measurements of the emission and excitation spectra in $YGdO_3$. The photoluminescence properties were discussedand a charge compensation mechanism was used to explain this reduction. One of the major obstacles for white light-emitting diodes is the preparation of solid-state materials for a blue light and near UV light stimulated, Eu^{2+} doped oxide-based phosphors. (WLEDs). Broadband red emission is produced by the selective occupancy of Eu^{2+} in inorganic materials with low coordination numbers due to improved 5d level crystal field splitting. [6]. One of the smart materials, Y_2O_3, exhibits adjustable characteristics when doped with rare earth and non-rare earth ions [7]. Seyed Mahdi Rafiaei et al, [8-12] prepared Y_2O_3:Gd^{3+}, phosphor nanostructures were prepared homogeneously by the combustion synthesis method using water tand urea as the solvent and fuel, respectively. Also, they have calcinated the sample at different temperature and revealed that maximum concentration quenching takes place at 7% Gd^{3+}.

Experiments :

Gd_2O_3 (99.99%), Y_2O_3 (99.99%), Eu_2O_3 (99.99%), HNO_3 (AR) were used as starting material purchased from the Indian business Loba Scientific. First, diluted HNO_3 (AR) was used to dissolve Gd_2O_3, Eu_2O_3, and Y_2O_3 in order to create nitrate solution with a stoichiometric ratio of the starting material. In this solution-based combustion technique, a stoichiometric quantity of glycerin is used as a reducing agent while maintaining a 2:1 molar ratio between glycerin and nitrate. After that, the mixture was ground into a smooth paste. Finally, paste was put into a crucible and heated in a furnace for 5 to 10 minutes at 450 ^{0}C to 550 ^{0}C until any surplus free water evaporated and spontaneous ignition occurred. The fluffy white $YGdO_3$: Eu^{2+} phosphor was then ground into a fine powder and maintained in a furnace at 800 ^{0}C for six hours. The prepared phosphor material was then used to obtain powder X- ray differaction pattern, SEM, FTIR, PL excitation and emission measurement.

Results and Discussion:

1. XRD Results :

The XRD pattern of the $YGdO_3$ phosphor is shown in Fig. (1). From the diffraction pattern it has been found that, $YGdO_3$ phosphor belongs to cubic crystal structure which matches with the diffraction data of the standard JCPDS file no. 00-041-1105. Also, the XRD pattern also reveals that, there is homogeneous incorporation of Gd^{3+} and Eu^{3+} ions in the host matrix $YGdO_3$ matrix. Cu K radiation (= 1.5406 A°) was used to generate all diffraction patterns, with a typical setting of 45 kV and 40 mA. Measurements were taken in steps of 0.017° from 0° to 90° while maintaining a scan step time of 25.196 seconds.

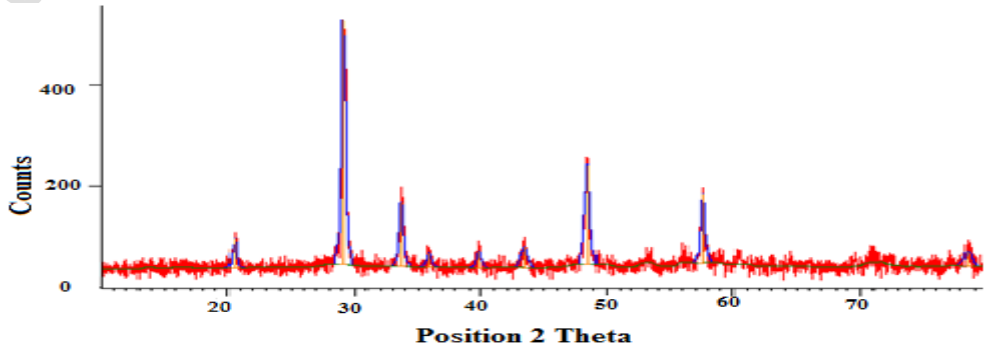

Fig.1: X - Ray Diffraction Pattern of $YGdO_3$:Eu^{2+}

The average grain size of the particles of powder samples were calculated using Debye Scherrer's equation -

$$\mathbf{D} = \frac{0.94\lambda}{\beta cos\theta}$$

Where, λ is incident wavelength of X - ray, θ is Bragg's angle, D is average grain size and β represents the Full Width at Half Maximum (FWHM) of XRD lines. The average grain size of the $YGdO_3$with small concentration of europium is found to be 54.33 nm.

2: Emission spectra and its effect on Plant Physiology :

The excitation spectra of $YGdO_3 : Eu^{2+}$ = 0.1mol % under 540 nm is shown in the figure 2. From the figure it can be clearly seen that, $YGdO_3 : Eu^{2+}$ = 0.1 mol % sample gives the excitation peak at three different wavelength namely 365 nm, 380 nm and 394 nm.

Fig. 2: Excitation spectra of $YGdO_3$:Eu^{2+} = 0.1mol % under 540 nm

The emission spectra for $YGdO_3 : Eu^{2+}$ = 0.1mol % is shown in Fig. 3. It shows a strong peak at blue region and a broad asymmetric band extending from 500-700 nm. Since blue emission peak of europium ions in $YGdO_3$ host, under 394 nm excitation, is the typical peaks of Eu^{2+} ions, it indicates that reduction of Eu^{3+} to Eu^{2+} occurred [4,10]. Selective occupation of Eu^{2+} in inorganic polyhedral with small coordination numbers results in broad-band red emission as a result of enhanced crystal-field splitting of 5d levels. As per Bardun study, it can be revealed that, PL peak of Europium in simple host at around 428 nm is due to oxygen vacancies related to irradiative combination [14]. On the Similar line, it can be state that the peak at 428 nm may be due to formation f-centre vacancies and the broad peak covering whole range from 500 nm to 700 nm is approximately same as observed by Osipov et. al., that described due to metal-oxygen recombination of donor acceptor pairs [15].

Such defect-related luminescence phenomenon is due electro negativity of oxygen which increases crystal field splitting of the 5d levels and the center of gravity of the 5d states at lower energy. The observed unusual long-wavelength excitation and emission bands result from the disturbance in Y^{2+} -O^{3-} in presence of Gd^{3+} surrounding of Eu^{2+} ions [16]. The more intense peak of $YGdO_3$ with Eu^{2+} doping sample was found at blue region in the wavelength range 400 nm –450 nm as shown in Fig. 3. Such solid state light with high intense blue light may be cause eye damage in humans but in some Species such as cucumber, radish, pepper, and lettuce have can easily show increases in photosynthetic rates when grown under such solid state light [17].

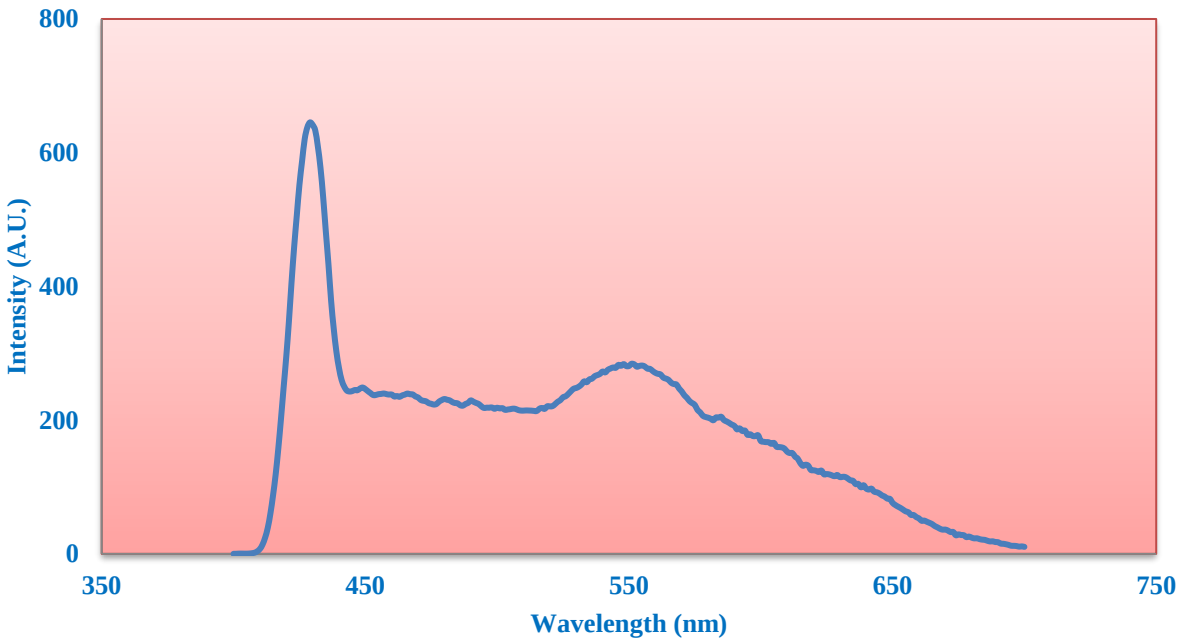

Fig. 3: Emission spectra of $YGdO_3:Eu^{2+}$ = 0.1 mol% under 395 nm excitation

The present emission spectra of $YGdO_3:Eu^{2+}$ = 0.1 mol% belongs in visible region and it can be a useful potential candidate for single phase LED (Light Emitting Diode) application. However this type solid state lighting used within finfish aquaculture operations is a common method used to holdup sexual maturation and make larger fish [18].

3: FTIR :

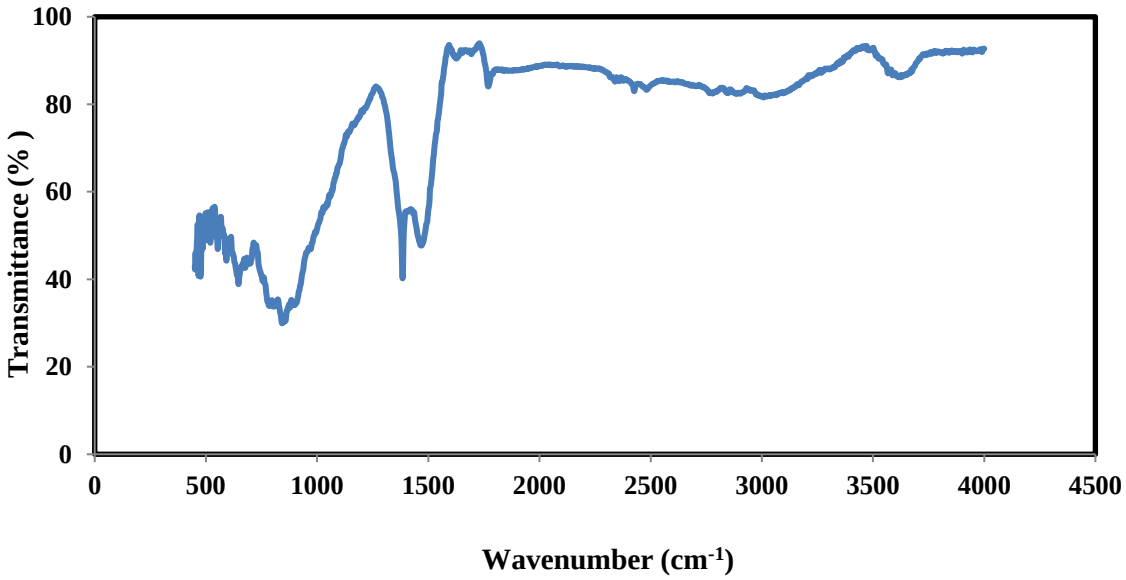

Fig.4: FTIR spectra of $YGdO_3$ with Eu^{2+}

FTIR spectra of $YGdO_3$ with Eu^{2+} doping is given in Fig. 4, which shows a broad peak at around 885 cm^{-1} is assigned to the C-O and stretching, symmetric and asymmetric vibrations of nitrate complex, the bands from 500cm^{-1} to 800 cm^{-1} region is attributed due to the characteristic metal-oxygen vibrations. The O–H stretching and H–O–H bending vibration gives bands at 3646 and 1827 cm^{-1} which are due to absorption of water on the sample surface. Typical of whewellite stretching absorption peaks observed at 1386 cm^{-1} and 1489 cm^{-1}.

4: Scanning electron microscopy (SEM) Result :

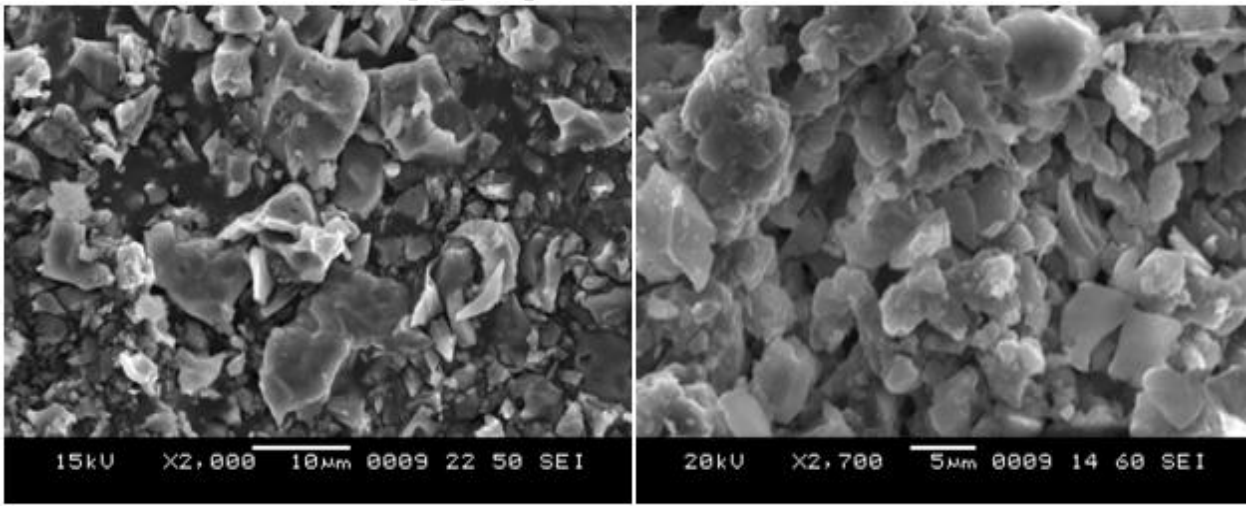

Fig.5: SEM images of $YGdO_3$: Eu^{2+} under 10 µm and 5 µm resolution

The scanning electronic microscope (SEM) images of $YGdO_3$:Eu^{2+} of powder form is as shown in figure 5, under different resolution, reveals the plates like morphology. The results also indicate the interconnected particles and inherent nature of the prepared sample. The average particles size powder $YGdO_3$:Eu^{2+} is after heating at 800 ^0C for 6 hr is about 105nm to 130 nm.

Conclusion :

The prepared sample shows a intense broad peak at blue region which help to increase growth of the plants. The XRD pattern confirms the cubic crystal structure of sample. The XRD and FTIR spectra pattern indicates the total incorporation of Gd^{3+} and Eu^{2+} ions in the $YGdO_3$ host matrix. SEM and XRD authenticate the crystallites nature of the prepared sample. The PL emission spectra of $YGdO_3:Eu^{2+}$ was observed in the range 400-700 nm under near ultra violet region. This spectra shows that, the peak at 428 nm is due to presence of f-centre vacancies, while a broad peak is a result of formation of metal-oxygen recombination of donor acceptor pairs. The prominent peak at 428 nm indicate the reduction of Eu^{3+} to Eu^{2+} in the host matrix. Since all emission peaks belongs in visible region, hence the present material may have potential applications for single phase Light Emitting Diode.

References :

- Qiang Long, Yanyan Li, and Yuhua Wang (2016), RSC Advances 6(77), 73063-73069.
- Murray Moo-Young,(2019)"Comprehensive Biotechnology", ISBN:978-0-444-64047-5.
- C. Kim, I. Kwon, C. Park, Y. Hwang, H. Bae, B. Yu, C. Pyun, and G. Hong (2000) J. Alloys Compd.; 311, 33-39.
- P. Dorenbos, (2005) Chem. Mater. 17, 6452 -6456.
- Bitao Liu, Yuhua Wang, Jun Zhou, Feng Zhang, and Zhaofeng Wang (2009) JOURNAL OF APPLIED PHYSICS 106, 053102-5.
- Jianwei Qiao, Lixin Ning, Maxim S. Molokeev, Yu-Chun Chuang, Qinyuan Zhang, Kenneth R. Poeppelmeier, and Zhiguo Xia , Angew .(2019) Chem. Int. Ed. 58 , 2 – 8,
- Maria Sonmez, Mihai Georgescu , Laurentia Alexandrescu, Dana Gurau , Anton Ficai, Denisa Ficai , Ecaterina Andronescu (2015) Current Pharmaceutical Design, 21.
- P. Turalska, N. Sobczak, G. Bruzda, I. Kaban, N. (2019) Mattern, Jou. of Mat. Eng. Perfotmance, 7 (28), 3912-3921.
- Seyed Mahdi Rafiaei, Aejung Kim, Mohammadreza Shokouhimehr. (2016) Current nanoscience, 12, 244-249.
- Dong Kye Lee, Sang Bae, Jin Hwa Lee, (2007) Jou. of Korean Che. Soc.24, 238-245
- L. Zhou, B. Yan (2006) Ceramic Int.; 32 , 2007-2011.
- Jia-fang Lu, K. takaichi, T Uematsu, A. Sirakawa,(2003) Laser Physics,13(7), 940-942.
- Zhen Liu, Dihu Chen Sun Yat-Sen University, Guangzhou, China (2019), Optoelectronics Global Conference, 3-6.
- O. M. Bardun, (2002) Jou. of Applied Spectroscopy, 69, 430-441.
- V. V. Osipov, A. V. Rasuleva, V. I. Solomonov (2008) Opt. Spect.105, 524-530.
- Qiang Long, Yanyan Li, and Yuhua Wang (2016) RSC Advances, 6(77), 73063-73069.
- Yuzeir Zeinalo, Liliana Maslenkova,(2000), BULG. J. PLANT PHYSIOL, 26(1–2), 58–69. [18] Aquaculture Collaborative Research and Development Program (ACRDP), 22 December, 2013, "Ecological effects of blue LED lights used at marine finfish aquaculture sites in British Columbia".