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Narrow band UVB emitting phosphor $LaPO_4:Gd^{3+}$ for phototherapy lamp

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ABSTRACT

Gd^{3+} activated inorganic lanthanum phosphate ($LaPO_4$) has been successfully synthesized using re-crystallization method. The crystal structure and the phase purity of samples were characterized using powder X-ray diffractometer. The surface morphology was studied using Scanning Electronic Microscope (SEM). The photoluminescence spectra was studied at room temperature. The excitation spectra of Gd^{3+} activated phosphor $LaPO_4$ monitored at 312 nm shows strong absorption at 275 nm. Phosphor emitted at 312 under the excitation of 275 nm due to $^6P_J \rightarrow {}^8S_{7/2}$ transition of Gd^{3+} ions. Optimum concentration of Gd^{3+} ions in the prepared phosphor was found to be 0.04 mol. For this concentration the critical distance R_0 was calculated to be 15.37 Å. Finally, the Stokes shift for the synthesized phosphor $LaPO_4$: Gd^{3+} was calculated to be 4312 cm^{-1}.

1. Introduction

Ultraviolet radiation (UVR) makes up a fraction of the electro-magnetic spectrum. The Biological and Physical characteristic makes convenient division of ultraviolet radiation into three parts such as UV-C: the rays that do not pass through the earth's atmosphere (200–290 nm) UV-B: the rays responsible for nearly all biological effects following sun light exposure including tanning, burning and skin cancer, (290–320 nm) and UV-A: those rays closest to the visible spectrum that pass through glass and are the least harmful to the skin (320–400 nm).

Recently the treatment of skin diseases using artificial sources of ultraviolet (UV) radiation in controlled condition is well established. UV therapy is useful for treating more than 40 types of skin diseases and disorders such as psoriasis [1], or vitiligo [2], which could be treated by UV-B radiation, and lichen sclerosus [3], morphea [4] scleroderma [5], cutaneous T-cell lymphoma, lupus erythematosus [6], which could be treated by UV-A radiation. In the treatment of hyperbilirubinemia [7], commonly known as infant jaundice. The basis of phototherapy is believed to be the direct interaction of light of certain frequencies with tissues to cause a change in the immune response. In the treatment of skin diseases, few methods are currently used: phototherapy with narrowband UVB (310–313 nm) and photochemotherapy PUVA, with UVA (365 nm) and psoralens as photosensitizers. In 1976, Fischer published a study wherein he evaluated the "healing" effects of 313, 334, 365, and 405 nm light on psoriasis. He conclude that, 313 nm light exerted a potent clearing effect on psoriasis than the longer wavelength [8]. Parrish and Jaenicke revealed that wavelengths of UV that are 290 nm or shorter are erythemogenic but not effective in clearing psoriasis. Their data defined the therapeutic action spectrum for psoriasis between 296 and 313 nm, with 313 nm being least likely to induce erythema at therapeutic doses. Based on these findings, they suggested

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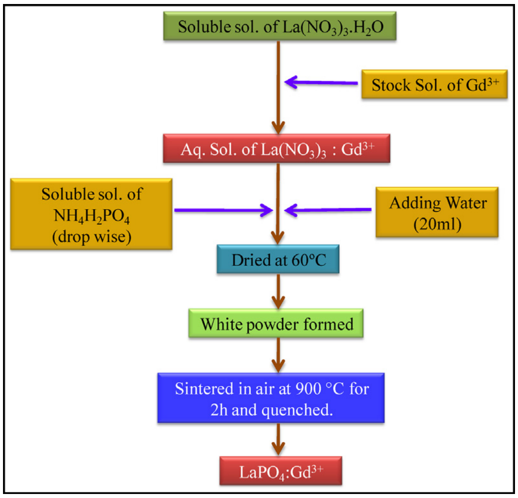

Fig. 1. Flow chart of synthesized $LaPO_4$:Gd^{3+} phosphor using re-crystallization method.

that monochromatic radiation may be more therapeutic than conventional broadband UVB (BB-UVB) sources [9]. Based on the finds phototherapy using UVB radiation discovered that the light of wavelength 310–313 nm is most effective and less phototoxic in treatment of skin diseases like psoriasis, vitiligo, suntanning, etc.

The commercial phosphor LaB_3O_6:Gd^{3+}, Bi^{3+} and $CeMgB_5O_{10}$:Gd^{3+} is used for narrow UVB phototherapy lamps. In our previous work we have reported some UV emitting phosphor materials such as $Na_2La_2B_2O_7$ [10], $Sr_2Mg(BO_3)_2$:Pb^{2+}, Gd^{3+} [11], $KCa_4(BO_3)_3$:Pb^{2+} [12], YBO_3 [13] and $Sr_2Mg(BO_3)_2$:Pr^{3+}, Gd^{3+} [14]. In recent years, $LaPO_4$ has been also shown to be a useful host lattice for lanthanide ions to produce phosphors that emit in a broad range of colors [15–19]. The Inorganic host lanthanide phosphate ($LaPO_4$) has got much attention due to very high thermal stability and high refractive index which make them suitable candidate for the production of display lamps and sensors [20–24]. After meticulous literature survey we conclude that, micro as well as nano sized lanthanum phosphate doped with different types of rare-earth ions (Eu^{3+}, Ce^{3+}, Tb^{3+}, Nd^{3+}, Er^{3+}, Pr^{3+}, Ho^{3+}, Yb^{3+}, Tm^{3+}) have been frequently reported. The Photoluminescence property of Gd^{3+} activated $LaPO_4$ has not yet been studied.

In the present work, Gd^{3+} doped $LaPO_4$ was synthesized via a re-crystallization method for the first time. The optical properties of Gd^{3+} doped $LaPO_4$ were studied and the effect of increasing concentration of Gd^{3+} on the luminescence intensity has been investigated.

2. Experimental

2.1. Synthesis of phosphors

The phosphor $LaPO_4$:Gd^{3+} was prepared for the first time by a re-crystallization method, offering a comparatively low temperature route, higher controllability and easy to soluble are the primary advantages. The stoichiometric amounts of high purity (Analytical Reagent) starting materials Lanthanum nitrate ($La(NO_3)_3$), di-ammonium orthophosphate ($NH_4H_2PO_4$), Gadolinium nitrate ($Gd(NO_3)_3$) (99.99% purity) have been used for preparation of phosphors. The raw material Lanthanum nitrate firstly dissolved in small quantity of deionized water of resistivity not less than 18.2 MΩ-cm. The stock solution of Gd_2O_3 was added in formed nitrate solution and stirrer for few minutes. The solution of di-ammonium orthophosphate was added dropped by dropped in formed nitrate solution. The entire homogenous solution was then placed on a hot plate at 60 °C for slow evaporation of excess water. The dried precursor was finally crushed and heated at 900 °C for 2 h to get white crystalline powder of $LaPO_4$:Gd^{3+}. The resultant powder sample was then characterized using powder XRD and Spectrophotometer. The complete process involved in the reaction was represented as a flow chart in Fig. 1.

2.2. Characterization of samples

The phase purities of $LaPO_4$:Gd^{3+} samples were studied using Rigaku miniflex II X-ray Diffractometer with scan speed of 6.000°/min and Cu Ka (k = 1.5406 Å) radiation in the range 10–90°. The structural and morphological characteristics i.e., particle size and shape of particle sample was studied by SEM images using a SEM instrument ZEISS EVO/18 Research. PL and PL excitation (PLE) spectra were measured on (Hitachi F-7000) fluorescence spectrophotometer at room temperature. The parameters such as spectral resolution, width of the monochromatic slits (1.0 nm), photomultiplier tube (PMT) detector voltage and scan speed were kept constant throughout the analysis of samples.