Synthesis and study of novel dysprosium doped yttrium calcium borate ($Dy:Y_2CaB_{10}O_{19}$) crystalline materials for white LED applications

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Phosphor converted white light emitting diode (pc-wLED) has become the best sustainable and reliable lighting source due to their longer life span, energy saving and enhanced optical properties as compared to the conventional solid-state lighting systems. It has wide range of applications including industrial, outdoor lighting, roadways, parking, traffic signals and etc. The most extensively commercially used phosphor material employed in pc-wLED is the versatile yellow light emitting cerium-doped yttrium aluminium garnet, $Ce^{3+}:Y_3Al_5O_{12}$ (Ce:YAG) material coated over blue light emiting InGaN-GaN-based blue LED chip. The judicial combination of down-converted yellow light (540 nm) emitted by Ce:YAG phosphor excited by high energy blue light (460 nm) and the blue light emitted by InGaN-GaN-based blue LED chip gives rise to the generation of efficient white light.

Due to the deficit of red component, Ce:YAG based white LED has a limitation in its application in order to satisfy higher color rendering index (CRI) and low correlated color temperature (CCT) as well. The three primary colors i.e. red, green and blue emitting phosphors excited by ultra-violet (UV) LED are modelled to get white light. However, in this case the light conversion efficiency is less due to the strong reabsorption of blue light by the red and green emitting phosphors which hinders the optical properties i.e. CRI, CCT, luminous efficacy (LE), and etc.

A series of novel phosphor material, dysprosium doped yttrium calcium borate (Dy:YCB) with varying dopant (Dy^{3+}) concentrations were synthesized by high temperature solid-state reaction method for the first time by us. The phase formation of the synthesized phosphor material was confirmed by x-ray diffraction technique. It is observed that the material possess monoclinic crystal structure with lattice parameters a = 18.47 nm, b = 7.62 nm, c = 14.47 and $\beta = 98.71°$. The crystallite size of the prepared samples was calculated by using the Scherrer's equation. The optical characteristics were analyzed from the absorption spectra and the band gap energy was found to be 4.75 eV for the host YCB and 4.80 eV for Dy^{3+} doped YCB. The presence of functional groups and their vibrations were analyzed from the FTIR spectra. The emission spectra confirm the successful incorporation of Dy^{3+} ions in the host lattice by the characteristic emission peaks at 480 nm, 490 nm and 577 nm due to 4f-4f transition of Dy^{3+} ions. From the emission spectra, optimal dopant concentration was found to be 1 mol % to prevent luminescence quenching. The energy transfer phenomena between the host and dopant were also analyzed briefly. CIE chromaticity co-ordinates were found to be x = 0.33, y = 0.37 from CIE chromaticity diagram and color temperature of the synthesized phosphor material was calculated using Mccamy's equation. It is realized that single composition of Dy^{3+} doped YCB can be used as a white light emitter.

This synthesized phosphor material can be subjected to fabricate phosphor in glass (P-i-G) materials to enhance the efficiency of lighting source and to get better optical properties. This additionally offers enhanced thermal and chemical stabilities due to the presence of transparent glass materials.