REVIEW ON PHOTOLUMINESCENCE PROPERTIES OF BISMUTH SILICATE PHOSPHORS

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Abstract

In this article, we have discussed about the significance of bismuth as host in the development of LEDs . As a result of the growing usage of phosphors in LEDs, the term "phosphor-converted LEDs" was coined (pc-LEDs). This manuscript provides a full description of the various bismuth phosphors with different doping and there emission spectra in photoluminescence studies. the increasing use of phosphors in LEDs has led to the development of pc-LEDs, which have numerous applications in various industries. The synthesis of phosphors for pc-LEDs involves several methods, and the materials used in their fabrication are critical in determining the performance of the pc-LED. Ongoing research in the field of phosphors and pc-LEDs is expected to lead to the development of more efficient and cost-effective lighting solutions.

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Introduction

Since ancient times, humans have been attracted with luminescence, the emission of light by a substance after it has been subjected to ultraviolet and infrared radiation, electron bombardment, X-rays, or any other means of excitation. Luminescence is a type of cold body radiation since it is the emission of light by a material that does not come from heat. Incandescent light refers to the phenomenon of hot radiation emission. The current work relates to luminous substances that can exhibit non-linear optical phenomena including "photon up-conversion," "photon down-conversion," "photon down-shifting," and scintillation in the form of doped particles (such as micro- or nano-sized particles). The up-conversion phenomena involve the successive absorption of two or more photons, which results in the emission of photons with energy greater than that of the excitation photons. Two or more photons with energy below that of the excitation photons are released during down-conversion. Researchers have been studying the luminous characteristics of different host lattices that have been doped with rare-earth ions activators for several years. It has been possible to employ extremely precise spectrum distributions with the effectiveness required for industrial applications by using ions as activators. Phosphors doped with rare-earth ions are expensive, but their usage in phosphor production is justified by the benefits they bring. A substantial market for rare earth doped phosphors has emerged in recent years. As a result of their high quantum efficiency and excellent stability, they have been extensively researched. Rare earth has been observed to occupy a variety of lattice positions. Variable rare-earth ions produce various luminous defects or defects with varying luminescence properties. In the host lattice, at least one kind of oxide is used, such as sulfide aluminate, borate, silicate, halides, nitrides, manganese, oxynitrides, or aluminum silicate. The activators are generally rare earth metals that enhance the light emission of a host material. In the initial decade's scientists used to be attracted towards the sulfur-based hosts, but their emission isn't strong enough and the afterglow doesn't last more than a few hours. It wasn't until the mid-1990s when rare-earth-doped aluminates such as MAl_2O_4 (M = Sr, Ca, and Ba) were studied as a way to overcome the limitations of sulfur-based hosts. When exposed to water, aluminates' luminescence is diminished, and they are not chemically stable, limiting their use in paints and pigment. When it comes to enhancing emission efficiency, the choice of the host material is equally crucial. Synthesized and studied alkaline earth silicate phosphors have shown that they are ideal hosts with good chemical stability and strong water resistance in recent years. Silicate-based phosphors, on the other hand, offer several meritorious benefits, such as heat stability, high luminescent intensity, cheap cost of raw materials, a range of luminescent colors from blue to yellow, rigid crystal structure, Because of this, silicate-based phosphors have attracted a lot of academic and commercial attention, and are considered one of the most promising host.

Materials and Synthesis methods

In this article we have discussed about the different host and the raw materials used with the different methods of synthesis. Some of the reviewed phosphor materials are listed below

Host materials	Synthesis method	Emission wavelength
$Bi_{12}SiO_{20}$: Pr^{3+}/Cr	Czochralski techniques	720nm
$Bi_4Si_3O_{12}$:Dy	Sol gel	488nm, 576nm, 460nm
$Bi_4Si_3O_{12}$:Dy,Eu,	Bridgman method	368nm,560nm
$Bi_4Si_3O_{12}$:Sm	Melt quenching method	562nm, 598nm
Bi_2SiO_5: Dy/Eu	Combustion method	452nm,413nm, 567nm
$Bi_4Si_3O_{12}$:Dy	Bridgman method	487nm, 574nm, and 662nm
$Bi_4Si_3O_{12}$:Sm/Pr	Co-precipitation methd	613nm, 627nm
$Bi_4Si_3O_{12}$, $Bi_{12}SiO_{20}$	Solid state synthesis	460nm

A brief review of the work already done in the field

R.N Panda (2002) have reported and studied the Raman and PL studies on single crystals of undoped and doped (Cr and Pr) bismuth silicon oxide ($Bi_{12}SiO_{20}$) BSO crystals were grown by Czochralski techniques. The PL studies indicates bathochromic shift of the absorption edge in Pr-doped crystals compared to Cr- doped crystals. The structure of the material was checked by X-ray diffraction techniques using Cu-Kα_1 radiation and Ni filter. For the first-time centers responsible for PL in the 720nm region are generated in Pr-doped crystals.

Qinhua Wei (2013) did luminescence studies of a novel white emitting phosphor $Bi_4Si_3O_{12}$:Dy prepared by sol-gel method. The material exhibits a direct white light when excited under UV-light of 270nm having doped concentration of 4mol% Dy. Photoluminescence(PL) emission peaks of BSO:Dy were observed at 488nm and 575nm. Pure BSO emission peaks were observed at 460nm. Calculated CIE values of sample at different temperature show that the white light phosphors possess a good thermo stability. The TL glow curve of sample consists of two bands peaking at 400K and 440K corresponding to the trap depth at 1.225ev and 1.527ev.

Xiong(2014) studied pure and rare earth doped bismuth silicate crystals, synthesized by Bridgman method. The emission spectra of BSO crystals doped with Ce^{3+}, Y^{3+}, Gd^{3+} and Yb^{3+} ions were similar to that of pure BSO crystals with a band at 480nm. Whereas Dy^{3+} and Eu^{3+} doped bso crystals show sharp emission peaks. TL glow curve of pure and Y^{3+}, Gd^{3+} and Yb^{3+} doped BSO crystals were similar but Eu^{3+} doped BSO crystals shows strong peaks at 380nm and 560nm. No TL found for BSO:Ce crystal. Dy^{3+} ions replace some Bi^{3+} ions and hence become new luminescent centre. It was found that BSO:Dy is a potential excellent scintillator.

V. Thomas (2016) have optical analysis of Samarium doped sodium bismuth silicate glass. Synthesis was done by the melt quenching method. Spectroscopic studies of glassy material were done using the Judd-Ofelt analysis of the UV-VIS-NIR absorption spectra and photoluminescence emission spectra. The transitions $^4G_{5/2} – {}^6H_{5/2}$ and $^4G_{5/2} – {}^6H_{7/2}$ (at 562nm and 598nm) provide favorable lasing action , high gain bandwidth and optical gain for amplifier application. The CIE co-ordinates confirms emission in the orange range, which increases its use in display devices.

Pushpa Kumari in (2017) investigated optical properties of Dy:Eu codoped Bi_2SiO_5 phosphors. Synthesis was done by hydrothermal method. The energy transfer process was establish between Dy^{3+} and Eu^{3+} ions, which was valid in two ways (i.e Dy→Eu and Eu→Dy) interactions on excitation with 452nm and 413nm, respectively. The synthesized nanophosphors exist different molecular vibrations which were examined by Fourier Transformed Infrared Absorption Spectra analysis. A white light emission was stimulated and characterized by CIE co-ordinates in the co-doped system which indicates emission of day white light.

Yang (2014) investigated Dy-doped Bismuth Silicate $Bi_4Si_3O_{12}$ (BSO) crystals. Synthesized by the bridgmen method. A study was conducted on the luminous characteristics of LEDs. Under UV stimulation, photoluminescence experiments revealed a rapid energy shift from the Bi ion to the Dy ion. Emissions were detected at 487nm, 574nm, and 662nm. However, Dy3+ doping had a minimal influence on diffraction patterns, as seen by the XRD patterns. It was found that when the excitation wavelength changed from UV to n-UV, there was a stable yellow light produced. A Dy3+ doped BSO crystal might be used as a yellow-emitting phosphor in yellow light production.

ZHANG (2017) utilised the same host phosphor doped with Eu3+ and produced it using a rapid and energy-efficient microwave irradiation technique. It was discovered that the sample had a cubic structure and a single phase XRD pattern. Because of the 4f→4f transitions of Eu3+ and 6s2→6s6p of Bi3+, the excitation spectra covered a wide range of wavelengths from 220nm to 350nm. An electric-dipole emission at 610nm for Eu3+ has been seen for the first time! Energy transfer between Eu3+ions in the non-radiative process causes the luminescence decay of the sample to decrease with temperature. As a result of the observed thermal quenching effect, a T50 value of 398k has been determined, as well as a thermal activation energy of 0.24ev. For NUV LEDs, this particular phosphor is a competitive and attractive option due to its strong and wide absorption band in the NUV area.

Sm^{3+} and Pr^{3+} co-doping of $Bi_4Si_3O_{12}$ phosphor for white LED application was proposed by Yuqiao Shen in April 2017. Solution combustion was used as synthesis method to produce phosphors. In order to characterise the sample, it was subjected to XRD and SEM. The Sm3+ ion's 4G5/2→6H7/2 transition produced the highest peak at 607nm, according to the photoluminescence spectroscopy (PL) investigations. Photoluminescence intensities were increased by doping with Pr^{3+} in $Bi_4Si_3O_{12}$. Maximum doping concentrations for Sm3+ and Pr^{3+} were found to be 4mol% and 0.1mol% respectively. In the presence of near UV or blue light, Pr^{3+} ions transfer energy to Sm^{3+} ions, which increases the red emission characteristics. There was a little shift towards red in the colour coordinates (0.58, 0.414) of the phosphor in Bi4SiO12: Sm^{3+} and Pr^{3+}, which would be preferable when applied to white LEDs.

Lei Zhang (2019) reported Sm, Dy, and Eu doped single-phase phosphors prepared using the sol-gel method. Due to inadequate energy transfer from the host matrix to Ln^{3+}, the Bi4Si3O12:Ln3+ samples emit wide band emission from the Bi4Si3O12 host and typical Ln3 sharp emission lines. It is therefore possible to tailor emission colours from blue-green to white light and finally orange or reddish orange in the visible area by systematically changing the doping concentrations of activator ions such as Sm3+ or Eu3+. The chromaticity coordinates (x, y) of Sm3+, Dy3+, and Eu3+ doped Bi4Si3O12 with suitable concentrations may be produced to be fairly close to the CIE coordinate of warm sunlight (0.333, 0.333). To add to that, as-fabricated WLED devices that combine a UV LED chip with Bi4Si3O12:Ln3+ phosphors can emit strong white light, confirming that the Bi4Si3O12:Ln3 phosphors might be considered as possibilities for solid-state lighting.

Conclusion

Bismuth silicate phosphor can indeed be a good choice for solid-state lighting applications, especially for use in light-emitting diodes (LEDs). Bismuth silicate phosphor is a type of phosphor material that can absorb energy from a light source, such as a blue or ultraviolet LED, and then emit light at a longer wavelength, typically in the green or red part of the spectrum. One advantage of bismuth silicate phosphor is that it has a high quantum efficiency, which means that a high percentage of the absorbed energy is converted into emitted light. This can result in brighter and more efficient LEDs. Bismuth silicate based phosphor is stable and does not degrade easily over time, which can lead to longer-lasting and more reliable LED lighting systems. Overall, in this review paper we can state that bismuth silicate phosphor is a promising material for solid-state lighting applications and is being actively researched and developed by scientists and engineers in the field.

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