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Review of rare earth activated blue emission phosphors prepared by combustion synthesis

V.B. Pawade [a], H.C. Swart [b,*], S.J. Dhoble [c,**]

[a] Department of Applied-Physics, Laxminarayan Institute of Technology, Nagpur 440033, India
[b] Department of Physics, University of the Free State, P.O. Box 339, Bloemfontein 9300, South Africa
[c] Department of Physics R.T.M. Nagpur University, Nagpur 440033, India

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ABSTRACT

The UV excited luminescent properties of Eu^{2+} and Ce^{3+} ions in the matrices of different host lattices (aluminates, aluminosilcates, halosilicates etc.) are discussed in detail. These phosphors were prepared by combustion synthesis at 550° C. The phosphors showed broad blue emission bands due to the $d \rightarrow f$ allowed transitions. These, phosphors with efficient blue emission bands are useful to fabricate primitive white LEDs, fluorescent lamps etc., which have energy saving potential over other lighting sources and have the potential to reduce the level of CO_2 emissions in the environment. This review covers the introduction on rare earths activated lamp phosphors, their applications, the synthesis techniques and the journey of the current solid state lighting technology. The need of the novel rare earth activated blue phosphors and their applications in many areas of the display technology are explained on the basis of their excitation and emission properties.

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* Corresponding author.
** Corresponding author.
E-mail addresses: vijaypawade003@gmail.com (V.B. Pawade), swarthc@ufs.ac.za (H.C. Swart), sjdhoble@gmail.com (S.J. Dhoble).

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1. Introduction

1.1. Phosphors

Phosphors are solid luminescent materials that emit photons when excited by an external energy source, such as an electron beam (Cathodoluminescence) or Ultra-violet light or any wavelength of light in the electromagnetic spectrum range. Phosphors are composed of an inert host lattice, which is transparent to the excitation radiation and an activator, typically a 3d or 4f electron metal, which is excited under energy bombardment. The process of luminescence occurs by absorption of energy at the activator site, relaxation, and subsequent emission of a photon and a return to the ground state. The efficiency of a phosphor depends on the amount of relaxation that occurs during the activation and emission. Relaxation is the process in which energy is lost to the lattice as heat needs to be minimized in order to extract the highest possible luminous efficiency. The luminous efficiency is defined as the ratio of the energy emitted to the energy absorbed. In the following section we have discussed the rare earths activated phosphors mechanism and their applications.

1.1.1. Luminescent mechanisms of phosphors

Phosphors work on the basis of excitation and emission processes. The absorption of energy, which is used to excite the phosphor material, takes place by either the host lattice or by intentionally doped impurities ions. In most cases, the emission originates from the impurity ions, when they are excited by an external energy source. When the activator ions show too weak absorption, a second kind of impurities can be added which is known as the sensitizers, which absorb the energy and subsequently transfer the energy to the impurity ions. This type of process involves transport of energy through the luminescent materials. Thus, the emission color can be adjusted by choosing the proper impurity ion, without changing the host lattice in which the impurity ions are incorporated. Phosphors for Light-Emitting Diodes (LEDs) and phosphors for Plasma Display Panels (PDPs) are treated separately as well, the processes leading to excitation and emission being comparable to those in fluorescent lamps. Phosphors for light emitting diodes (LEDs) suggest two exciting approaches for the UV-LED chip (with the wavelength of 380–420 nm) and blue-LED chip (with the wavelength of 450–480 nm) for accelerating this development. Thus, applications of phosphors depend on mostly their excitation and emission wavelength in near UV and visible regions of the spectrum.

1.1.2. Rare earths activated phosphors

Rare earth (RE) ions have attracted great interest in technological applications such as optoelectronics devices and flat panel displays because of their excellent luminescence characteristics with extremely sharp emission bands due to their tremendous allowed energy levels. Rare earth (RE) ion doped novel phosphors materials have drawn considerable attention, due to their significant technological importance, such as solid state lighting, medical labeling, imaging, radiation detection, and also used as other functional compounds based on their optical, electronic, and their chemical characteristics [1–4]. Recently, extensive research has been carried out on rare-earth activated phosphors because of several important properties, such as luminescent characteristics, thermal stability and friendly environments and corrosion-free gas emission [5]. The RE activated phosphors can be classified into two types: broad band emitting owing to the $d \rightarrow f$ transition and narrow band emitting owing to the transition between the f levels. The commonly used activators are Eu^{3+}/Eu^{2+}, Ce^{3+}, Tb^{3+}, Gd^{3+}, Yb^{3+}, Dy^{3+}, Sm^{3+}, Tm^{3+}, Er^{3+}, Nd^{3+} etc. [6]. The rare-earth-doped alkali aluminates have been of considerable interest because they exhibit good luminescent properties when they are doped with the specific impurities. Thus, need of novel phosphors for lighting is one of the most important and urgent challenges to develop fluorescent- material-based solid-state lighting (SSL).

1.1.3. Applications of phosphors

1.1.3.1. Phosphors for fluorescent lamps. In general normal lamps are made up of glass tubes (30 mm in diameter) with two sealed ends in which noble gas and Hg vapor are present at 400 and 0.8 Pa pressure. With the help of an electric discharge Hg atoms are excited to higher energy levels. When they return to ground state it emits 85% at the 254 nm wavelength, 12% at 185 nm and 3% in the visible radiation region. Thus, phosphor materials coated inside the tube essentially convert 254 and 185 nm wavelengths into visible radiation. The thickness of the phosphor coating inside the tube is in the order of 20–40 mm. Since the phosphors have direct contact with Hg a reaction between Hg and ZnS is caused when a potential phosphor such as ZnS is used. Therefore, generally oxides are used as the hosts for fluorescent lamps. Lighting consumes about one-quarter of all electricity produced in the world. The incandescent lamp, where a filament of material is resistively heated to incandescence by the passage of electrical current, is known for its pleasing appearance to the human eye and its low purchase price, but with many disadvantages. Particularly, it has a relatively short operating time (usually 1000 h) and low luminous efficacy (15 lumens/watt, lm/W). The incandescent lamp is thus a very inefficient lamp source, converting only 3–5% of the electric energy into visible light. Fluorescent lamps are known for their high efficacy and long life time, there for the replacement of the incandescent lamps with CFLs in most industrial, commercial and residential applications. The percentage energy efficiency of the phosphors is calculated as follows:

$$\eta = \eta_{\rm disch} \cdot \eta_{\rm phos} (254/550) \cdot 100 \quad (1)$$

in which 254 nm is the wavelength of the exciting Hg radiation in nm and 550 nm is the mean wavelength of the light emitted. As in current fluorescent lamp phosphors only one visible photon per absorbed UV photon is generated, the difference in photon energy represents energy loss. Thus, CFLs could yield substantial savings in energy and overall lamp life cost with concurrent reduction in energy use and greenhouse gas emission from fossil-fuel power plants.