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Nanocrystalline SrS:Ce^{3+} system for the generation of white light-emitting diodes

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ABSTRACT: Nanocrystalline SrS phosphors doped with Ce^{3+} ions at different concentrations (0.5, 1, 1.5 and 2 mol%) are synthesized via the solid-state diffusion method (SSDM), which is suitable for the large-scale production of phosphors in industrial applications. The as-prepared samples are characterized using an X-ray diffraction (XRD) technique, field emission scanning electron microscopy (FESEM), high-resolution transmission electron microscopy (HRTEM) and energy-dispersive X-ray (EDX) analysis. The optical properties of these phosphors are analyzed using reflectance spectra, photoluminescence spectra and afterglow decay curves. The cubic structure of the SrS phosphor is confirmed by XRD analysis and the crystallite size calculated by Scherer's formula using XRD data shows the nanocrystalline nature of the phosphors. No phase change is observed with increasing concentrations of Ce^{3+} ions. The surface morphology of the prepared phosphors is determined by FESEM, which shows a sphere-like structure and good connectivity of the grains. The authenticity of the formation of nanocrystalline phosphors is examined by HRTEM analysis. Elemental compositional information for the prepared phosphors is gathered by EDX analysis. Photoluminescence studies reveal that the emission spectra of the prepared phosphor shows broad band emission centered at 458 and 550 nm due to the transition of electrons from the 5d → 4f energy levels. The afterglow decay characteristics of different as-synthesized SrS:Ce^{3+} nanophosphors are conceptually described. Copyright © 2016 John Wiley & Sons, Ltd.

Keywords: white light emission; reflectance spectra; FESEM; HRTEM

Introduction

Recently, the level of interest in nanoparticles has increased as their synthesis has become more efficient and their properties have been widely studied (1,2). Nanoparticles can be fashioned using a wide range of metals and semiconductor core materials that impart useful properties such as fluorescence and magnetic behavior (3). Nanoparticles have been a frequent material for the development of modern applications in optics, transmission, communications, energy and data storage, environmental protection, cosmetics, sensing, biology and medicine due to their important optical, electrical and magnetic properties (4).

There has been much interest in white light-emitting diodes (WLEDs) with emission wavelengths in the ultraviolet (UV) to infrared (IR) range. Major developments in wide band gap III–V nitride compound semiconductors have led to the commercial production of high-efficiency WLEDs. The alkali earth sulfide phosphor SrS:Ce^{3+} is a good candidate for WLED applications because it has strong absorption in the blue region.

Most UV-converted phosphors, for example, Y_2O_2S:Eu^{3+}, YAG:Ce or $CaAlSiN_3$:Eu^{3+}, reported to date for application in WLEDs suffer from intrinsic problems, such as thermal instability, color aging or reabsorption by commixed phosphors in the coating of the devices. It has therefore become important to search for a single-phased phosphor, which can efficiently convert UV light to white light. Herein, we report a promising candidate, namely a white light-emitting SrS phosphor doped with Ce^{3+} that can be excited by UV light and resolve the problems given above. Recently, WLEDs based on the absorption and re-emission of light have been produced by precoating the surface of an LED with phosphor layers (5). The most widely used and commercially available WLEDs are based on generating blue light from a InGaN chip and yellow light from yttrium aluminum garnet ($Y_3Al_5O_{12}$). The phosphor can emit yellow light by excitation of the blue InGaN chip, and mixing of the unabsorbed blue light and emitted yellow light can produce white light (6). However, there are still problems associated with this phosphor such as a high color temperature and low color-rendering index due to a lack of red emission of long wavelength (7,8). The most important property of the phosphor is a high excitation efficiency at ~430–480 nm. This is expected due to the dipole-allowed electron transition of the activated ions (9–12). Ce^{3+} ions are commonly used as activators in phosphor, and the spectral location of their absorption and emission lines can be shifted by a crystal field.

In this study, we prepared SrS:Ce powders of different concentrations by the solid-state diffusion method. Only a limited number of studies have examined the luminescence properties of SrS phosphors in regard to LED applications with blue excitation (13–15). This article reports the structural characterization on the basis of X-ray diffraction (XRD), field emission scanning electron microscopy (FESEM), high-resolution transmission electron microscopy (HRTEM) and energy-dispersive X-ray (EDX) analysis, and studies of optical properties were also carried out on the basis

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