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Original research article

Orange emission of Sm^{3+} in a double phosphate $KMgLa(PO_4)_2$ under near-ultraviolet excitation

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ABSTRACT

A series of $KMgLa(PO_4)_2:Sm^{3+}$ phosphors were synthesized by a conventional high-temperature solid state method, and their luminescence properties including excitation/emission spectra, decay curve and CIE chromaticity coordinates were investigated. Upon excitation with near-ultraviolet (402 nm), $KMgLa(PO_4)_2:Sm^{3+}$ phosphor exhibited four groups of emission peaks corresponding to the $^4G_{5/2} \rightarrow {}^6H_J$ (J = 5/2, 7/2, 9/2, and 11/2) transitions of Sm^{3+}, in which the $^4G_{5/2} \rightarrow {}^6H_{7/2}$ transition at 597 nm is predominant leading to the orange emission. The emission intensity increases with the increasing concentration of Sm^{3+} up to x = 0.05, then decreases due to the concentration quenching effect induced by the dipole–dipole interaction. The current investigation indicated that $KMgLa(PO_4)_2:Sm^{3+}$ phosphor could be a potential orange component for application in w-LEDs.

1. Introduction

Compared with traditional incandescent and fluorescent lamps, white light emitting diodes (w-LEDs) have overriding advantages such as high efficiency, low energy consumption, environmental friendliness, and long lifetime. So, w-LEDs are considered as the new generation solid-state lighting sources [1–3]. Currently, besides the most commercially w-LEDs by combining yellow-emitting YAG:Ce^{3+} phosphors with blue-emitting InGaN chips, another available w-LEDs can be realized by means of the combination of near-ultraviolet (*n*-UV) (350–420 nm) LED chips and red/green/blue phosphors [4–6]. So, the exploration of novel red, green and blue phosphors that can be excited efficiently by near-ultraviolet (*n*-UV) (350–420 nm) has attracted substantial attentions in the past few years.

Sm^{3+}-doped phosphors show efficient orange or red emission and excitation characteristic in *n*-UV region of Sm^{3+} [7–9]. Hence, in nearly a year, some novel Sm^{3+}-doped phosphors have also been developed for w-LEDs application [10–13], e.g. $Ba_3Lu(PO_4)_3:Sm^{3+}$, $Ca_{0.5}La(MoO_4)_2:Sm^{3+}$, $Sr_3B_2SiO_8:Sm^{3+}$, $BaNb_2O_6:Sm^{3+}$, and etc. $KMgLa(PO_4)_2$, a representative double phosphate compound, is isotypic with $LaPO_4$ [14,15]. As we known, Ce^{3+} and Tb^{3+} co-doped $LaPO_4$ is a famous green emitting phosphor, which has been applied in lamp industry for many years. So, the efficient emission of activators in $KMgLa(PO_4)_2$ host can be expected. Based on the above consideration, the luminescence properties and potential industrial application of some activators [14–17] such as Eu^{3+}, Mn^{2+}, Tb^{3+}, Dy^{3+} in $KMgLa(PO_4)_2$ host have been researched in depth. To the best of our knowledge, little attention has been paid to the luminescence properties of Sm^{3+} in $KMgLa(PO_4)_2$ host. In the present work, a series of $KMgLa(PO_4)_2:Sm^{3+}$ orange emitting phosphors were prepared by a traditional high-temperature solid-state reaction, and their luminescence properties were investigated in detail.

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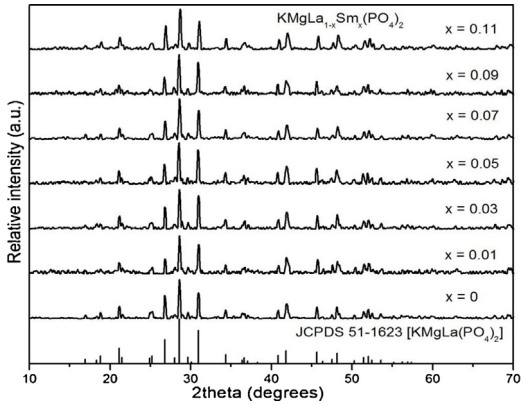

Fig. 1. Experimental XRD patterns of $KMgLa_{1-x}Sm_x(PO_4)_2$ (x = 0, 0.01, 0.03, 0.05, 0.07, 0.09, and 0.11) samples as well as the standard pattern of $KMgLa(PO_4)_2$ (JCPDS 51–1623).

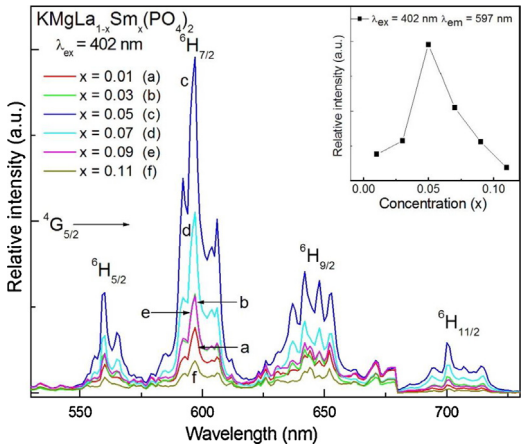

Fig. 2. Emission spectra of $KMgLa(PO_4)_2$:Sm^{3+} phosphors with different Sm^{3+} contents upon excitation with 402 nm.

2. Experimental

In order to obtain a series of $KMgLa_{1-x}Sm_x(PO_4)_2$ (x = 0, 0.01, 0.03, 0.05, 0.07, 0.09, and 0.11) phosphors, the conventional solid-state method was adopted in this work. The stoichiometric amounts of raw materials, K_2CO_3 (A.R.), MgO (A.R.), $NH_4H_2PO_4$ (A.R.), La_2O_3 (99.99%) and Sm_2O_3 (99.99%) were thoroughly mixed in an agate mortar by being ground at least 20 min. Then, the mixtures were transferred into corundum crucibles and fired at 1100 °C in a muffle furnace for 8 h in air. Finally, the obtained products were naturally cooled to room temperature and ground thoroughly into white powder for further measurement.

The X-ray diffraction (XRD) patterns of the as-prepared samples were collected on an Advance X-Ray Diffractometer (Bruker D8) with Cu Kα (λ = 1.5405 Å) radiation. The morphology of the sintered particles was measured with a scanning electron microscope (SEM, JSM-6490LV). The excitation and emission spectra as well as decay curve were measured with a Combined Fluorescence Lifetime&Steady State Fluorescence Spectrometer (EDINBURGH FLS980) with a 450 W xenon lamp and a 60 W μF2 microsecond flash lamp as the excitation source, respectively. All the above measurements were performed at room temperature.

3. Results and discussion

Fig. 1 shows the experimental XRD patterns of $KMgLa_{1-x}Sm_x(PO_4)_2$ (x = 0, 0.01, 0.03, 0.05, 0.07, 0.09, and 0.11) samples as well as the standard pattern of $KMgLa(PO_4)_2$ (JCPDS 51–1623). Obviously, no impurity phases or raw materials can be detected, indicating that single-phase phosphors $KMgLa(PO_4)_2$:Sm^{3+} are obtained successfully and the doped Sm^{3+} ions do not change the crystal lattice of host. Hence, it is reasonable that $KMgLa(PO_4)_2$:Sm^{3+} phosphor has a monoclinic monazite structure with space group $P2_1/n$ [14–16], and Sm^{3+} will substitute for La^{3+} in the host in view of their same valence and ionic radius.