SYNTHESIS AND PHOTOLUMINESCENCE PROPERTIES OF ELLIPSOIDAL La$_2$O$_2$SO$_4$:Eu$^{3+}$ PHOSPHORS

Xing Li$^{1*}$, Lutong Gao$^2$, Jingbao Lian$^2$

$^1$Department of Science, Shenyang Jianzhu University, Shenyang, China
$^2$School of Mechanical Engineering, LiaoNing Petrochemical University, Fushun, China

Abstract: This research was focused on the homogeneous precipitation synthesis of a series of Eu$^{3+}$ ion-activated ellipsoidal La$_2$O$_2$SO$_4$ phosphors based on the La$_2$(SO$_4$)$_3$·CO(NH$_2$)$_2$ reaction system. The structural identification, thermal analysis, morphology and luminescence properties of the as-prepared products were characterized with Fourier transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), thermogravimetry and differential scanning calorimetry (TG/DSC), field emission scanning electron microscopy (FESEM) and photoluminescence (PL) spectra. Pure La$_2$O$_2$SO$_4$ ellipsoidal particles with a long radius of about 2 μm and a short radius of about 1 μm were successfully prepared by calcining a rhombus-like precursor at 800 °C for 1 h. The formation mechanism of the precursor and its corresponding calcination product were also proposed. Photoluminescence results revealed that the strongest red emission peak was centered at 619 nm upon 249-nm ultraviolet (UV) light excitation in La$_2$O$_2$SO$_4$:Eu$^{3+}$ ($x = 3, 6, 9, 12$ and $15$) phosphors. The exchange interaction was responsible for the concentration quenching mechanism of the $5D_0\rightarrow 7F_2$ transition of Eu$^{3+}$ ions in the La$_2$O$_2$SO$_4$ host lattice. The optimal $x$ value was 15 and the corresponding decay process showed a single exponential decay behavior whose lifetime $\tau$ and color correlation temperature (CCT) were calculated to be 2.112 ms and 2752 K, respectively.

Keywords: lanthanum oxysulfate, ellipsoidal morphology, homogeneous precipitation reaction, photoluminescence

1 INTRODUCTION

In the past decades, rare-earth (RE) ion-doped phosphors received considerable attention due to their special luminescent properties based on the unique intra $4f$ transitions of trivalent RE ions. Because of this, rare-earth phosphor materials became a research highlight and some phosphors have recently been successfully applied in various fields, such as fluorescent lamps, white light-emitting diodes (WLEDs), X-ray intensifying screen, X-ray computed tomography (X-CT), biological labels, and so forth. As is known to us, the RE phosphor family involves numerous stable host matrices, such as oxides, sulfides, oxysulfides, oxysulfates, fluorides, phosphates, molybdates, etc. Among these compounds, lanthanide oxysulfates (La$_2$(SO$_4$)$_3$) activated by various trivalent RE ions (Eu$^{3+}$, Tb$^{3+}$, Pr$^{3+}$, Ce$^{3+}$, Yb$^{3+}$, Er$^{3+}$ and so on) have attracted considerable attention because of their unique luminescence behavior, sharp emission peaks, high quantum yields, low phonon energy and low toxicity; they have been widely applied in bioimaging, optical temperature sensors, medical surgery and so on. Lanthanum oxysulfate (La$_2$O$_2$SO$_4$) is one of the most important lanthanide oxysulfate matrix materials, and it has attracted increasing attention in recent years due to its high oxygen-storage capacities, good thermal stability, as well as enhanced catalyst activity; it can provide potential applications in the fields including large-volume oxygen-storage materials, auxiliary sensing electrodes, solid electrolytes and catalysts for the water-gas shift reaction.
So far, various synthetic routes have been explored to prepare lanthanide oxysulfate \((\text{Ln}_2\text{O}_2\text{SO}_4)\) materials, including the solid-state reaction method\(^{10}\) thermal decomposition method,\(^{11-12}\) sulfide oxidation method,\(^{8}\) co-precipitation method,\(^{13}\) hydrothermal synthesis,\(^{13}\) template method,\(^{14}\) molten salt synthesis\(^{15}\) and so on. However, the main three methods are high temperature, time-consuming preparation process and the release of sulfur oxide gas \((\text{SO}_2\) or \(\text{SO}_3)\), which is harmful to the environment. The obtained \(\text{La}_2\text{O}_2\text{SO}_4\) compounds are bulk materials with an irregular morphology. Moreover, the morphology of the obtained powder needs to be improved with the co-precipitation method. In recent years, some researchers have prepared a series of high-yield and uniform \(\text{RE}_2\text{O}_2\text{SO}_4\) hollow spheres with the hydrothermal method using L-cysteine as the biomolecular template and polyvinylpyrrolidone \((\text{PVP})\) as the surfactant.\(^{16}\) The study by Mei Yang showed that the three-dimensional \((3D)\) nanofibrous structures of \(\text{La}_2\text{O}_2\text{SO}_4:\text{Eu}^{3+}\) would provide multifunctional applications, such as optical displays, biological labels and bio-imaging.\(^{17}\) However, the procedures involved in these routes are complicated, and it is generally difficult to carry out mass production.

To the best of our knowledge, so far less work has been done on the preparation of ellipsoidal \(\text{La}_2\text{O}_2\text{SO}_4:\text{Eu}^{3+}\) phosphors. So, it is still challenging and imperative to exploit an efficient but simple way for the synthesis of ellipsoidal \(\text{La}_2\text{O}_2\text{SO}_4:\text{Eu}^{3+}\) phosphors. Herein, we thus put forward a homogeneous precipitation reaction to synthesize \(\text{La}_2\text{O}_2\text{SO}_4:\text{Eu}^{3+}\) phosphor using commercial lanthanum sulfate octahydrate \((\text{La}_2\text{SO}_4\cdot8\text{H}_2\text{O})\), europium nitrate hexahydrate \((\text{Eu(NO}_3)_3\cdot6\text{H}_2\text{O})\) and urea \((\text{CO(NH}_2)_2, \text{AR})\) as the starting materials where a structural analysis (FTIR and XRD), thermal analysis, morphology and photoluminescence of the obtained products are characterized and discussed in detail. This homogeneous precipitation method has the characteristics of a simple inexpensive process, easy to use in mass production and environment-friendly. The simplicity of this synthetic approach makes it promising also for the preparation of other \(\text{RE}\)-activated phosphors.

2 EXPERIMENTAL PART

In this study, \(\text{La}_2(\text{SO}_4)_3\cdot8\text{H}_2\text{O}\) (a purity of 99.99 %), \(\text{Eu(NO}_3)_3\cdot6\text{H}_2\text{O}\) (a purity of 99.99 %) and urea \((\text{CO(NH}_2)_2, \text{AR})\) were used as the starting materials without any further purification. Among them, \(\text{La}_2(\text{SO}_4)_3\cdot8\text{H}_2\text{O}\) and \(\text{Eu(NO}_3)_3\cdot6\text{H}_2\text{O}\) were received from Jining Tianyi New Material Co. Ltd, China. Urea was purchased from Sinopharm Chemical Reagent Co. Ltd, China. First of all, a stoichiometric amount of \(\text{La}_2(\text{SO}_4)_3\cdot8\text{H}_2\text{O}\) was dissolved in ultrapure water with a resistivity of 18 M\(\Omega\)-cm and a 0.05-M \(\text{La}_2(\text{SO}_4)_3\) solution was obtained. Secondly, the \(\text{La}_2(\text{SO}_4)_3\) solution with a volume of 250 mL was transferred to a 500-mL beaker. During continuous stirring, urea was added into the precipitant \((\text{La}_2\text{SO}_4\cdot8\text{H}_2\text{O})\) to form the target product \((\text{La}_2\text{O}_2\text{SO}_4)\) through dehydroxylation and decomposition of carbonate at a high temperature. So, the above \(\text{La}^{3+}\) ions and functional groups are easily formed.

3 RESULTS AND DISCUSSION

3.1 Feasibility analysis of preparing a target product

In this study, the selection of \(\text{La}_2(\text{SO}_4)_3\) as the raw material has a dual function of providing rare-earth cations and anion groups. Here, the hydrolyzation process of \(\text{La}_2(\text{SO}_4)_3\) can provide \(\text{La}^{3+}\) ions and liberate \(\text{SO}_4^{2-}\) groups. Moreover, urea is a weak Brönsted base and its aqueous solution can release \(\text{CO}_3^{2-}\) and \(\text{OH}^-\) groups at a temperature of 90 °C for 2 h. In the \(\text{La}_2(\text{SO}_4)_3\)-urea system, \(\text{SO}_4^{2-}\), \(\text{CO}_3^{2-}\) and \(\text{OH}^-\) groups are hard bases and the hardness has the following order: \(\text{SO}_4^{2-} > \text{CO}_3^{2-} > \text{OH}^-\), \(\text{La}^{3+}\) ions are hard acids. According to hard-soft acid-base \((\text{HSAB})\) principle, hard acids prefer to bind to hard bases and soft acids prefer to bind to soft bases.\(^{18}\) So, the above \(\text{La}^{3+}\) ions and functional groups are easily combined with each other to form a precursor containing lanthanum hydroxyl, carbonate and sulfate, which can form the target product \((\text{La}_2\text{O}_2\text{SO}_4)\) through dehydroxylation and decomposition of carbonate at a high temperature.
tion splitting peaks of physically absorbed water, crystal water, hydroxyl groups (near 3453 cm\(^{-1}\) and 1630 cm\(^{-1}\)), the CO\(_3^{2-}\) groups (near 1463 cm\(^{-1}\), 1375 cm\(^{-1}\), 850 cm\(^{-1}\) and 750 cm\(^{-1}\)) and the SO\(_4^{2-}\) groups (near 1142 cm\(^{-1}\), 1067 cm\(^{-1}\), 656 cm\(^{-1}\) and 588 cm\(^{-1}\)), indicating that the precursor is composed of lanthanum hydroxyl, carbonate and sulfate groups with some crystal water. After the precursor is calcined at 800 °C (Figure 1b), the broad absorption peak centered near 3453 cm\(^{-1}\) becomes negligible, which is associated with the dehydroxylation of hydroxyl groups in the precursor. Moreover, a narrow absorption peak centered at about 3609 cm\(^{-1}\) appears, the CO\(_3^{2-}\) absorption peaks (near 1463 cm\(^{-1}\) and 1375 cm\(^{-1}\)) become negligible, suggesting the decomposition of the CO\(_3^{2-}\) groups in the precursor. However, the weak vibration peak near 1480 cm\(^{-1}\) shows that the product absorbed water and carbon dioxide (CO\(_2\)) from the air and then formed CO\(_3^{2-}\) groups. The SO\(_4^{2-}\) absorption peaks (near 1142 cm\(^{-1}\), 1067 cm\(^{-1}\), 656 cm\(^{-1}\) and 588 cm\(^{-1}\)) split into some narrow peaks (near 1173 cm\(^{-1}\), 1100 cm\(^{-1}\), 1058 cm\(^{-1}\), 990 cm\(^{-1}\), 654 cm\(^{-1}\), 616 cm\(^{-1}\) and 592 cm\(^{-1}\)). The FTIR result shows that the SO\(_4^{2-}\) groups still exist in the calcined product and becomes a component of the target product.

The phase structure was investigated with XRD focusing on the precursor and its calcined product, as shown in Figure 2. It is obvious from Figure 2a that the precursor has a good crystalline structure with obvious diffraction peaks. However, the diffraction pattern of the precursor is inconsistent with the data reported in the JCPDS card database and the crystal structure is still unidentified, which may be attributed to the formation of a new phase containing La\(^{3+}\), OH\(^-\), CO\(_3^{2-}\) and SO\(_4^{2-}\) groups and some crystal water. This result is confirmed by the above FTIR spectroscopy. When the precursor is calcined at 800 °C, the precursor undergoes the following thermal decomposition reaction:

\[
\text{La}_2(\text{OH})_2\text{CO}_3\text{SO}_4 \cdot m\text{H}_2\text{O} = \text{La}_2\text{O}_2\text{SO}_4 + \text{CO}_2 \uparrow + (m+1)\text{H}_2\text{O} \uparrow
\]  

Diffraction peaks of the pure La\(_2\)O\(_2\)SO\(_4\) phase begin to appear in the XRD pattern (Figure 2b) and the obtained diffraction pattern is well consistent with the data reported in the JCPDS card No. 00-016-0501 (Figure 2c), further confirming the rationality of the above feasibility analysis and the formation of the target product (La\(_2\)O\(_2\)SO\(_4\)).

### 3.3 DSC-TG-DTG analysis of the precursor

To understand the decomposition behavior and determine the optimal calcination temperature for the precursor, DSC-TG-DTG of the precursor was conducted from room temperature to 1000 °C and the results are shown in Figure 3. The TG curve shows a continuous weight loss between room temperature and 1000 °C with an overall weight loss of approximately 37.19 w%. The total weight loss mainly consists of the following steps over the whole temperature range, seen from the DTG
curve. The weight loss in the temperature range from room temperature to \( \approx 170 \, ^\circ \text{C} \) is about 8.96 \( \% \), which seems to be related mostly to the removal of physically adsorbed water from the precursor. This weight loss corresponds to a weak endothermic peak at around 129 \( ^\circ \text{C} \) in the DSC curve, and DTG maxima at about 123 \( ^\circ \text{C} \) in the DTG curve. The weight loss between \( \approx 170 \, ^\circ \text{C} \) and \( \approx 473 \, ^\circ \text{C} \) is about 8.53 \( \% \); there are no obvious endothermic peak in the DSC curve and no extreme value in the DTG curve, which is related to the removal of crystal water. The weight loss in the temperature range from \( \approx 473 \, ^\circ \text{C} \) to \( \approx 639 \, ^\circ \text{C} \) is about 13.49 \( \% \); this is associated with the complete dehydroxylation of the precursor with a weak endothermic peak at \( \approx 591 \, ^\circ \text{C} \) in the DSC curve. The maximum value on DTG curve also appears near 591 \( ^\circ \text{C} \). The last weight loss of about 6.21 \( \% \) starting at \( \approx 639 \, ^\circ \text{C} \) is associated with the complete decomposition of the \( \text{CO}_3^{2-} \) groups of the precursor. At the same time, this weight loss is accompanied with a weak endothermic peak at around 763 \( ^\circ \text{C} \) in the DSC curve and a broad peak centered at about 763 \( ^\circ \text{C} \) in the DTG curve. Moreover, as shown in Figure 3, little weight changes can be observed at temperatures greater than 800 \( ^\circ \text{C} \) on the TG curve, indicating that at temperatures higher than 800 \( ^\circ \text{C} \) the thermal decomposition is basically finished in the present study. These results are consistent with those obtained with the XRD analysis and FTIR spectra.

### 3.4 FESEM morphological analysis

The morphologies of the precursor and its corresponding calcination product (800 \( ^\circ \text{C} \), 2 h) were investigated with FESEM. Figure 4a shows a FESEM image of the precursor, indicating that the precursor is rhombus-shaped with the edge lengths ranging from 0.5–1 \( \mu \text{m} \) and a thickness about 100 nm. In addition, the obtained particles showed a smooth surface and a good crystal habit. This formation mechanism may be related to the supersaturation degree of crystallographic ions. In the \( \text{La}_2(\text{SO}_4)_3–\text{CO(NH}_2)_2 \) homogeneous reaction system, the molar ratios of \( \text{La}_2(\text{SO}_4)_3 \) and \( \text{CO(NH}_2)_2 \) are relatively small (\( m = 25 \)), making the concentration of crystallographic ions lower and leading to a lower supersaturation. According to the Gibbs-Thomson formula of the classical nucleation theory Equation (2) is formed as follows:19

\[
J = A \exp[B(\ln S)^{-2}]
\]

where \( J \) and \( S \) are the nucleation rate and supersaturation, and \( A, B \) are the constants. Therefore, nucleation rate \( J \) of the current reaction system is low. Accordingly, the nucleus growth is dominated by attachment kinetics, and a free growth of crystal faces takes place, resulting in...
in the formation of rhombus-like crystals related to their inherent crystal structure. Figure 4b shows a FESEM image of La$_2$O$_2$SO$_4$. Compared with Figure 4a, it can be seen from Figure 4b that the La$_2$O$_2$SO$_4$ particle morphology changed significantly. These particles are seriously agglomerated and no longer have smooth surfaces or a regular shape. In order to clearly observe the internal structure of the particles, Figure 4c shows a higher-magnification FESEM image of La$_2$O$_2$SO$_4$. The obtained La$_2$O$_2$SO$_4$ particles possess an ellipsoidal shape with a long radius of about 2 μm and a short radius of about 1 μm. Moreover, the ellipsoidal surface is mainly composed of quasi-spherical small particles with a size of less than 100 nm. The above investigation might be explained as follows. During the calcination of the precursor, rhombus-like crystals were destroyed due to a high temperature and ellipsoidal particles were found. At the same time, the water vapor and carbon dioxide were generated during the calcination of the precursor. These gases generated a great pressure inside the precursor, promoting the decomposition of rhombic crystals into nanoparticles.

### 3.5 Photoluminescence analysis

Figure 5 shows the PL excitation and emission spectra of La$_2$O$_2$SO$_4$:x%Eu$^{3+}$ ($x = 3, 6, 9, 12$ and 15) phosphors. From Figure 5, we can see that the contour lines of all the PL excitation and emission spectra of La$_2$O$_2$SO$_4$:x%Eu$^{3+}$ ($x = 3, 6, 9, 12$ and 15) phosphors are similar and the PL intensity of the excitation and emission spectra is maximum when the doping concentration of Eu$^{3+}$ is 15 x%. As a representative, La$_2$O$_2$SO$_4$:15%Eu$^{3+}$ phosphor was selected for the excitation and emission spectra analysis. The excitation spectrum was recorded by monitoring the emission wavelength of 619 nm. As can be seen in Figure 5a, two broad absorption peaks located at approximately 249 nm and 305 nm are observed; they can be attributed to the change-transfer transitions of O$_2^{-}$-Eu$^{3+}$ and SO$_4^{2-}$-Eu$^{3+}$, respectively. The other characteristic absorption peaks can be ascribed to the f-f transitions of Eu$^{3+}$ ions at (363, 380, 395, 414, 464 and 465) nm in the longer wavelength region. These characteristic absorption peaks for the electron transition of Eu$^{3+}$ ions in the excitation spectrum can be similar to those of the Eu$^{3+}$ doped La$_2$O$_2$SO$_4$ materials achieved with other synthetic routes. As shown in Figure 5b, upon excitation at 249 nm, the emission spectrum of La$_2$O$_2$SO$_4$:15%Eu$^{3+}$ phosphor consists of five emission peaks corresponding to the $^3D_0\rightarrow^7F_1$ ($J = 0, 1, 2, 3, 4$) transitions of Eu$^{3+}$ ions. It can be seen that the strongest red emission peak is centered at 619 nm, arising from the $^3D_0\rightarrow^7F_2$ transition of Eu$^{3+}$ ions. Other characteristic emission peaks in Figure 5b can be assigned to the $^3D_0\rightarrow^7F_1$ (581 nm), $^3D_0\rightarrow^7F_3$ (596 nm), $^3D_0\rightarrow^7F_4$ (651 nm) and $^3D_0\rightarrow^7F_5$ (701 nm) transitions of Eu$^{3+}$ ions, respectively.

For the maximum doping concentration of La$_2$O$_2$SO$_4$:x%Eu$^{3+}$ phosphors, we prepared a series of Eu$^{3+}$ doped La$_2$O$_2$SO$_4$:x%Eu$^{3+}$ phosphors. Figure 6 shows the curve of the influence of the concentration of Eu$^{3+}$ ions on the luminescent intensity of La$_2$O$_2$SO$_4$:x%Eu$^{3+}$ phosphors and its corresponding log(I/C) and log(C) fitting curve. As shown in Figure 6a, the luminescent intensity is enhanced with the increasing Eu$^{3+}$ ion concentration when the concentration of Eu$^{3+}$ is less than or equal to 12 x%; then it reaches its maximum value when 15 x%. Therefore, it is reasonable to believe that the optimal concentration of Eu$^{3+}$ can be determined to be 15 x% in the present study. In order to explore the concentration quenching mechanism, the relationship plot of the log(C) versus log(I/C) for the luminescent intensity of La$_2$O$_2$SO$_4$:x%Eu$^{3+}$ (x = 3, 6, 9, 12 and 15) phosphors at the 249 nm excitation and 619 nm emission wavelengths is shown in Figure 6b. According to Dexter’s theory, the luminescence intensity is related to the doping concentration of the activator. The concentration can be expressed with Equation (3):
\[
\log \left( \frac{I}{C} \right) = \left( \frac{-s}{d} \right) \log C + \log f
\]  
(3)

where \( d = 3 \), \( C \) is the doping concentration and \( f \) is a constant independent of the doping concentration. When \( s = (3, 6, 8 \) and \( 10) \), the mechanism of concentration quenching is exchange interaction, electric dipole-electric dipole, electric dipole-electric quadrupole and electric quadrupole-electric quadrupole interaction, respectively.

By fitting the high concentration point in Figure 6b, the fitting curve with the R-square value of 0.99857 is:

\[
\log (I/C) = 4.62334 - 0.77844 \log (C)
\]  
(4)

The slope parameter \(-s/d\) was determined to be \(-0.77844\) (close to \(-1\)), yielding the corresponding value of 3 for \( s \), and indicating that the mechanism of exchange interaction can be responsible for the concentration quenching effect of \( \text{Eu}^{3+} \) ions.

To figure out the emission color composition with different doping concentrations of \( \text{Eu}^{3+} \) ions, we employed the CIE chromaticity diagram to calculate the red emission and the results are shown in Table 1 and Figure 7. When \( x \% \) increases from 3 \% to 15 \%, in Table 1, the CIE chromaticity coordinates are calculated to be (0.6239, 0.3415), (0.6313, 0.3539), (0.6372, 0.3476), (0.6399, 0.3441) and (0.6420, 0.3391), respectively, where the CIE coordinates of the five samples are observed in a very narrow red area. This result demonstrates that \( \text{Eu}^{3+} \) ion-doped La2O2SO4 phosphors exhibited good red light emission with excellent color saturation. Moreover, the color correlation temperature (CCT) was also calculated to characterize the color emission. The CCT data are summarized in Table 1. The CCT is determined with McCamy’s empirical Equation (5):

\[
\text{CCT} = -437n^4 + 3601n^2 - 6861n + 5514.31
\]  
(5)

where \( n = (x - x_e)/(y - y_e) \) and the chromaticity epicenter coordinates \((x_e, y_e)\) are (0.3320, 0.1858). Their CCT values for La2O2SO4:xEu3+ \( (x = 3, 6, 9, 12 \) and \( 15) \) phosphors are 2787 K, 2 247 K, 2 452 K, 2 577 K and 2 752 K, respectively, belonging to the penetrating low CCT light luminescence, which can be useful in a white light emitting diode (WLED) device and other fields.

Table 1: CIE coordinates and CCT values for La2O2SO4:x%Eu3+ \( (x = 3, 6, 9, 12 \) and \( 15) \) phosphors

<table>
<thead>
<tr>
<th>No.</th>
<th>Samples</th>
<th>CIE ((x, y))</th>
<th>CCT (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>La2O2SO4:3%Eu3+</td>
<td>(0.6239, 0.3415)</td>
<td>2 429</td>
</tr>
<tr>
<td>2</td>
<td>La2O2SO4:6%Eu3+</td>
<td>(0.6313, 0.3539)</td>
<td>2 247</td>
</tr>
<tr>
<td>3</td>
<td>La2O2SO4:9%Eu3+</td>
<td>(0.6372, 0.3476)</td>
<td>2 452</td>
</tr>
<tr>
<td>4</td>
<td>La2O2SO4:12%Eu3+</td>
<td>(0.6399, 0.3441)</td>
<td>2 577</td>
</tr>
<tr>
<td>5</td>
<td>La2O2SO4:15%Eu3+</td>
<td>(0.6420, 0.3391)</td>
<td>2 752</td>
</tr>
</tbody>
</table>

The luminescent decay process of the as-prepared La2O2SO4:15%Eu3+ phosphor excited at 249 nm and
monitored at 619 nm was measured and plotted in Figure 8. The decay curve can be fitted into a single exponential function as shown in Equation (6): 

$$I = I_0 + A \exp(-t/\tau)$$

(6)

where $I$ and $I_0$ are the luminescence intensities when the time is determined as $t$ and 0, respectively, $A$ is the constant, $\tau$ is the time and $\tau$ is the lifetime value. The single exponential fitting specific equation with a R-Square value of 0.98295 is shown in the inset of Figure 8. The corresponding value of $\tau$ for La$_2$O$_2$SO$_4$:15%Eu$^{3+}$ phosphor is 2.112 ms.

4 CONCLUSIONS

Ellipsoidal La$_2$O$_2$SO$_4$:Eu$^{3+}$ phosphors have been successfully obtained with a homogeneous precipitation reaction combined with a calcination based on the La$_2$(SO$_4$)$_3$– Eu(NO$_3$)$_3$–CO(NH$_2$)$_2$ system, using La$_2$(SO$_4$)$_3$, Eu(NO$_3$)$_3$, and CO(NH$_2$)$_2$ as the starting materials. The as-prepared precursor is composed of rhombus-like particles and can be converted into ellipsoidal La$_2$O$_2$SO$_4$ particles at 800 °C in air. Photoluminescence properties reveal that the 15%Eu$^{3+}$ doped La$_2$O$_2$SO$_4$ phosphor possesses the highest red peak (619 nm) under 249-nm UV light excitation whose corresponding life-time and color correlation temperature (CCT) are calculated to be 2.112 ms and 2.752 K. These results imply that Eu$^{3+}$ doped La$_2$O$_2$SO$_4$ phosphors have potential applications in white light emitting diode (WLED) devices and other research fields, such as oxygen storage or red display devices. The homogeneous precipitation synthesis is also a convenient and feasible method for synthesizing other rare-earth oxysulfate materials.

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