Improved Performance of Strontium Aluminate Luminous Coating on the Ceramic Surface

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Abstract. Phosphor of strontium aluminate co-activated by Eu\textsuperscript{2+} and Dy\textsuperscript{3+} is one kind of important afterglow luminescent materials. In this paper, the phosphors were used with transparent glaze for an inorganic luminous coating on the ceramic surface, which was stable even at high temperature. The chemical structure and microstructure of the luminous coating were identified with X-ray diffraction (XRD) and observed with scanning electron microscopy (SEM), respectively. The photoluminescence of the coating was measured by a HITACHI F-4500 fluorescence spectrophotometer. The afterglow property was recorded by a ST-86LA-3 brightness meter. The samples behaved good performances such as high lighting brightness and long after-glowing time.

1. Introduction
Photoluminescent material with long afterglow is a kind of energy storage material, which can absorb both ultraviolet (UV) and visible lights from the sunlight and gradually release the energy in the darkness at a certain wavelength. This kind of long afterglow materials had been widely studied by many researchers [1,2].

In recent years, Sr\textsubscript{4}Al\textsubscript{14}O\textsubscript{25}: Eu\textsuperscript{2+}, Dy\textsuperscript{3+}, as one of the persistent luminescent materials, has been extensively focused because it provides typical emission bands in blue and green regions [3]. Compared with sulfide phosphorescent phosphors, Sr\textsubscript{4}Al\textsubscript{14}O\textsubscript{25}: Eu\textsuperscript{2+}, Dy\textsuperscript{3+} phosphor possesses safe, chemically stable, very bright and long-lasting photoluminescence in addition to no radiation [4,5], which results in wide field of applications, such as luminous paints in highway, airport, building and ceramics, as well as in textile, dial plate of glowing watch, warning signs and escaping routeway [6].

In this paper, luminous phosphor of Sr\textsubscript{4}Al\textsubscript{14}O\textsubscript{25}: Eu\textsuperscript{2+}, Dy\textsuperscript{3+} was mixed with transparent glaze, coated onto ceramic surface and then heat-treated in different conditions. Microstructure, photoluminescence and afterglow properties were characterized in details.

2. Experimental
The powders were uni-axially pressed at 5 MPa into green body disks of 13 mm in diameter and 3.5 mm in thickness. The luminous glazes were prepared by mixed strontium aluminate phosphors with transparent glazes in anhydrous ethanol, which were transferred to a ultrasonic cleaning bath to sonicate for 10 min, then were vigorously grinded for 10 min in a mortar. The contents of strontium
aluminate phosphors in the luminous glazes were 10%~30% in weight. The luminous glazes were then coated onto the surface of ceramics.

Moreover, the samples were removed into a crucible with a lid, which were then introduced into a muffle furnace and heated at a rate of 5~10 °C/min and maintained at 920 °C for 10~60 min in air or an active carbon atmosphere, and at last the sample was cooled to ambient temperature in the furnace.

The crystal structures were identified by an X-ray powder diffractometer with CuKα radiation generated at 40 kV/30mA. The morphologies of the coating of the samples were observed with scanning electron microscopy. The excitation and emission spectra of photoluminescence were measured using a fluorescence spectrophotometer (HITACHI, F-4500). The decay curves of the luminous coatings were recorded by a brightness meter (Peking Normal University optical instrument plant, China, ST-86LA-3), after the samples were exposed to irradiation from a 8 W conventional tricolor fluorescent lamp (about 1000 lux) for 30 min.

3. Results and discussion

XRD patterns of the samples were shown in Figure. 1, which were heat-treated at a rate of 5 °C/min and soaked at 920 °C for 15 min in an active carbon atmosphere. The diffraction peaks became stronger with the increasing weight ratios of strontium aluminate powders with the luminous glazes.

The SEM image of the coating of sample was also displayed in Figure. 2. It could be seen that the strontium aluminate powders were randomly distributed into the transparent glazes.

![Figure 1. XRD patterns of the samples with different weight ratios of phosphors.](image_url)

![Figure 2. SEM image of the surface coated with 20% in weight of phosphors.](image_url)

The excitation and emission spectra of the samples were present in Figure. 3 in different weight ratios of strontium aluminate phosphors. The results indicated that main excitation peak was at 360 nm and main emission peak at 489 nm. The Sr4Al14O25: Eu2+, Dy3+ luminous phosphor yielded high brightness of blue green luminescence with only one band at ambient temperature. The samples, heat-treated at 920 °C for 15 min, generated a emission at 489 nm, which corresponded to the emission of Eu2+ in Sr4Al14O25 lattice [7]. The intensity of the coatings was increased with the increasing weight of the strontium aluminate phosphors, as shown in Figure. 3. When the samples were heat-treated in an active carbon atmosphere, the intensity of the samples were higher than that in air, as displayed in Figure. 4. Compared with the samples at heating rate of 5 °C/min and 8 °C /min, those at a heating rate of 10 °C/min and soaked at 920 °C for 15 min possessed the stronger intensity, as shown in Figure. 5. Meanwhile when the sample was heat-treated at 920 °C for 10 min, the intensity of the coating was stronger than that for the other holding time, as present in Figure. 6.
Afterglow curve of the coating was displayed in Figure 7, which was heat-treated at a rate of 10 °C/min and soaked at 920 °C for 10 min in an active carbon atmosphere. It could be seen that the coating showed long afterglow property when the coating was efficiently excited by a conventional tricolor fluorescent lamp (8 W, about 1000 lux). When the source lamp was switched off, the intensity
of the afterglow firstly decreased rapidly and finally formed a stable long persistent emission. It was clear that the changing of the intensity of the sample with time was in good accordance with the double-curve equation, \( I = ct^{-n} \) [8], which revealed that the afterglow decay of the phosphor was a complex process. After the excited source was cut off, the afterglow of luminous ceramics allowed to be visually recognized (≥0.32 mcd/m²) and lasted for over 20 h.

The luminous glazes were coated onto the ceramics in size of 50*50 mm, the digital photo of the luminous ceramics in dark room was shown in Figure 8. The luminous glazes were coated onto on a ceramic disk with 13 mm in diameter and 3.5 mm in thickness, which were also imaged in dark (Figure. 9). All of the samples were heat-treated at a rate of 10 °C/min and soaked at 920 °C for 10 min in an active carbon atmosphere.

4. Conclusions
In this paper, Sr₄Al₁₄O₂₅: Eu²⁺, Dy³⁺ luminous ceramic coatings were prepared, which showed excellent performance of long afterglow. The main excitation peak of the samples was at 360 nm and the main emission peak at 490 nm, respectively. The coating heat-treated at a rate of 10 °C/min and soaked at 920 °C for 10 min in an active carbon atmosphere possessed the best performance of luminescence and long afterglow. The afterglow time allowed to be visually recognized for over 20 h at darkness after removal of the excited light source.

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