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## Application Note: Kinetics of Persistent Luminescence Phosphors

Persistent luminescence, or commonly called afterglow, is characterized by long-lasting visible emission over several hours after ultraviolet excitation. This finds wide application in glow-in-the-dark signage and in-vivo imaging for disease diagnosis and treatment. Biological tissue, however, allows transmission of near-infrared (NIR) light shorter than 1400 nm due to absorption by water and lipids. The majority of bio-imaging applications utilizes the 700 nm-950 nm window.


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**APPLICATION NOTE**  
**KINETICS OF PERSISTENT LUMINESCENCE PHOSPHORS**  
AN/P28 v.2, Jan. 11, George Anagnostis



**INTRODUCTION**

Persistent luminescence, or commonly called afterglow, is characterized by long-lasting visible emission over several hours after ultraviolet excitation. This finds wide application in glow-in-the-dark signage and in-vivo imaging for disease diagnosis and treatment. Biological tissue, however, allows transmission of near-infrared (NIR) light shorter than 1400 nm due to absorption by water and lipids. The majority of bio-imaging applications utilizes the 700 nm-950 nm window.



**FLS1000 Spectrometer**

Microscopy with persistent luminescence, auto-fluorescence of the tissue is circumvented under continuous illumination. Lanthanides and transition metals such as Eu/Dy/Mn, Eu/Th/Dy, Mn/Cu/Pb have been used as the active centers in silicate, diopside, garnet and germanate hosts. However, silicate and aluminate hosts have seen wider application with Eu<sup>3+</sup> and non-Eu ions. In this note, the persistent luminescence kinetics of SrAl<sub>2</sub>O<sub>4</sub>:Eu<sup>2+</sup>, Dy<sup>3+</sup> are characterized by optical spectroscopy.

**METHODS & MATERIALS**

Excitation and emission spectra, as well as decays were measured in a FLS1000 Fluorescence Spectrometer equipped with a 400 W Xe source and double monochromators. A 250 nm blazed grating was used at the excitation and a 400 nm blazed grating at the emission arm. Luminescence was detected with a photomultiplier tube detector (Hamamatsu, R928P), while higher diffraction orders were filtered by integrated long wave-pass filters in the FLS1000.

SrAl<sub>2</sub>O<sub>4</sub>:Eu<sup>2+</sup>, Dy<sup>3+</sup> micro-crystalline powder phosphor (GlinTech International) was used for all measurements as received. To obtain the persistent luminescence decay of the phosphor, the sample was illuminated for 5 min by a Xe source with the monochromator set between 300 nm - 350 nm. Consequently, illumination was blocked via software-controlled shutters and the luminescence decay was monitored for 1 h with 1 s resolution.

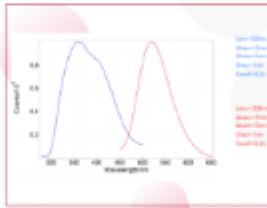
This resolution was adequate to monitor the persistent luminescence kinetics of this phosphor, however, for more complex kinetics and decays as long as 277 h, a resolution of 100 s can be used.

The decay results (not shown) were also acquired in an FLS Spectrofluorimeter equipped with a 150 W Xe source and resulting in similar kinetics.

**RESULTS - DISCUSSION**

SrAl<sub>2</sub>O<sub>4</sub>:Eu<sup>2+</sup>, Dy<sup>3+</sup> is one of the first and most widely studied persistent luminescence phosphors. It's been widely applied mainly due to its long duration, despite some degradation that has been reported after two years in water.<sup>1,2</sup>

The excitation and emission spectra of SrAl<sub>2</sub>O<sub>4</sub>:Eu<sup>2+</sup>, Dy<sup>3+</sup> are shown in Figure 1. The emission peak around 520 nm is a 4F<sub>5/2</sub> to 4F<sub>7/2</sub> transition<sup>3</sup> leading to the phosphor's persistent luminescence. It can be excited in the ultraviolet between 300 nm - 500 nm, however, vacuum ultraviolet studies of doped and pure SrAl<sub>2</sub>O<sub>4</sub> have shown that the excitation onset starts at 200 nm reaching the peak of the afterglow excitation spectrum.<sup>4</sup>



**Figure 1. Excitation and emission spectra of SrAl<sub>2</sub>O<sub>4</sub>:Eu<sup>2+</sup>, Dy<sup>3+</sup>**

The kinetics of the afterglow have been further monitored for 1 h after 5 min excitation. Figure 2 shows characteristic evidence of competition between photoluminescence and energy storage in trap states. Several trap states placed as low as 0.19 eV<sup>5</sup> and up to 1.47 eV<sup>6</sup> were reported, while the optimum energy value has been found around 0.65 eV.<sup>7</sup>

It can be seen that the initial changing phase is excitation dependent. However, this is reduced after correcting for the excitation intensity as shown in a logarithmic scale in the inset and agreeing with normalized excitation and afterglow studies.<sup>8</sup> A similar behaviour is observed for the decay phase, which has been reported previously<sup>9</sup> and correlated with the behaviour of thermo-luminescence. In fact a good agreement of the integrated intensity was reported between the persistent luminescence and the thermo-luminescence curves, exposing the application of the phosphor to radiation dosimetry.

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