VUV studies of radiative recombination in rare-earth activated wide bandgap materials; $LuAlO_3$:Ce

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Wide bandgap materials activated with rare earth (RE) ions have many potential applications, including such diverse areas as lighting, displays, solid state lasers, light emitting diodes, and radiation detectors. It is this last area, motivated by the need for new, fast and efficient scintillator materials for high energy physics and nuclear medicine, that has yielded much of the recent advances in the understanding of UV and VUV solid state luminescent materials. HASYLAB, with the superior VUV and timing characteristics of the SUPERLUMI station has been a major participant, and has conducted a continued effort aimed at scintillator materials. We report here some of our recent results in this area.

In a recent paper Wojtowicz et al. [1] report studies of the role traps play in the scintillation process in $LuAlO_3$:Ce (LuAP), a new, fast and efficient material whose exceptionally high density makes it one of the prime candidates for future generation PET machines [2]. These authors find that one of the traps that are responsible for large variations of scintillation light yield with temperature is also responsible for a 600 ps rise time in scintillation time profiles at ambient temperatures [3]. In this note we report results of spectroscopic and kinetic studies under pulsed VUV synchrotron excitation at various temperatures, specifically designed to verify this assumption and to provide more information on the role of traps in LuAP.

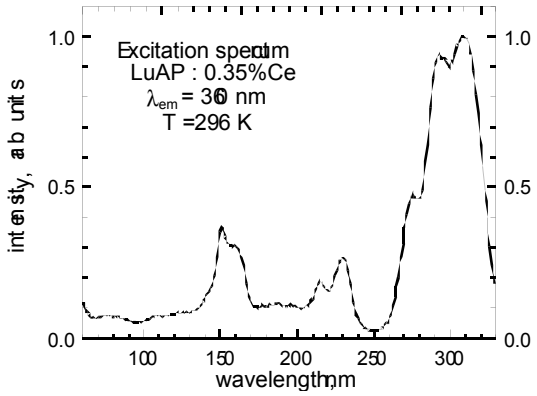

Figure 1: Excitation spectrum of Ce-emission in LuAP.

In Fig. 1 we show an excitation spectrum of the 360 nm Ce-emission in LuAP. In addition to the well known Ce^{3+} 4f-5d and 4f-6s bands, the spectrum reveals a shorter wavelength band at 150 nm superimposed on a long almost featureless tail extending far into VUV. The peaks in the vicinity of the bandgap energy and above have previously been associated with the occurrence of an energy transfer mechanism that enabled the material to scintillate efficiently. Fig. 2 presents the time profiles of the Ce-emission excited by pulsed synchrotron irradiation at a number of different wavelengths at 298 K. For shorter wavelength excitations with enough energy to allow an electron and hole to separate, trapping of any carrier is likely to introduce a rise time or a component of a longer decay time that are related to the trap lifetime by the well known formula:

$$\tau = (s \cdot \exp(-E/kT))^{-1}.$$

In this formula E is the trap depth, s the frequency factor, and k the Boltzman constant. We observe that direct excitation into any of the Ce^{3+} ion 4f-5d or 4f-6s absorption bands (230 and 190 nm shown) produce nearly single-exponential decays of about 17 ns and of only very short rise times, most likely reflecting the instrumental response function. In contrast, all profiles obtained from excitation at shorter wavelengths contain components that are significantly slower, as well as some finite rise times.

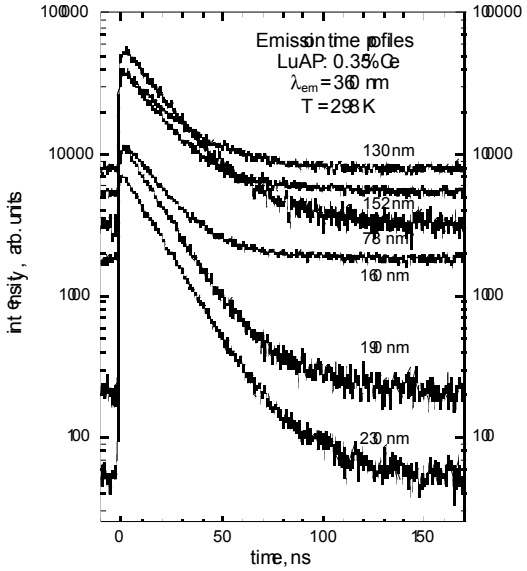

Figure 2: Time profiles of Ce-emission under VUV excitations of various wavelengths.

The time profiles of Ce-emission under short wavelength excitations have been measured at a number of temperatures between 10 and 350 K. In Fig. 3 we show an Arrhenius-type diagram that displays the natural log of rise times found from fits to time profiles obtained under the 78 nm excitation against inverse temperature.

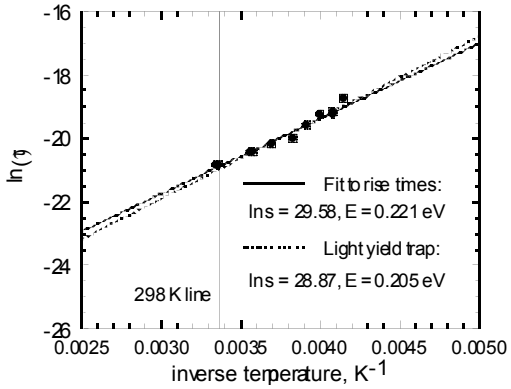

Figure 3: Rise times of Ce-emission under pulsed 78 nm excitation against temperature.

A fit to experimental points in Fig. 3 (solid line) yields trap parameters that are close to those deduced previously by Wojtowicz et al. [1] (dashed line) from independent and unrelated experiments in which the light yield was measured as a function of temperature. The room temperature lifetime value of nearly 0.8 ns obtained from the fit agrees reasonably well with the experimental value of 0.6 ns measured by Derenzo [3]. We conclude that the shallow trap at 0.2 eV in LuAP is responsible not only for large variations of scintillation light yield with temperature but also for the observed finite rise times in scintillation time profiles of that material. A detailed account of this work will be published elsewhere.

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References

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