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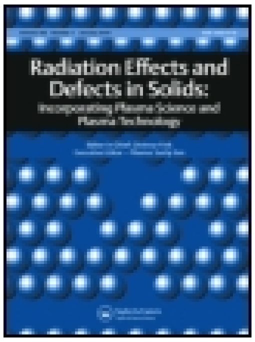

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SCINTILLATION MECHANISM IN $CsGd_2F_7:Ce^{3+}$ AND $CsY_2F_7:Ce^{3+}$ CRYSTALS†

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The scintillation properties of $CsGd_2F_7$ and of isostructural CsY_2F_7 crystals doped with Ce^{3+} together with the energy migration mechanisms to the Ce ions are reported. $Ce^{3+} \rightarrow Gd^{3+}$ as well as $Gd^{3+} \rightarrow Ce^{3+}$ energy transfer, both dependent on temperature and Ce concentration, strongly influence the scintillation properties.

Key words: Scintillation, energy migration, 5d–4f luminescence.

1 INTRODUCTION

Recently we reported on the scintillation properties of $CsGd_2F_7$ crystals doped with Ce^{3+} concentrations between 0.1 and 10 mol% Ce^{3+}.[1,2] The intensity of a fast scintillation component, due to 5d–4f luminescence of the Ce^{3+} ions, appeared to increase with the Ce concentration. On the other hand, a slow component becomes less dominant and its decay time becomes shorter at high Ce concentration. With the expectation to obtain better scintillation properties, crystals with 20 and 30 mol% Ce were studied. To understand the scintillation excitation mechanisms, we also studied the luminescence properties of the isostructural CsY_2F_7 crystals doped with Ce.

For details on the method of crystal growth and the experimental techniques to study scintillation properties, we refer to.[1,3] Two experimental set-ups were used for determining excitation spectra in the vacuum ultra violet (VUV): i) a set-up installed at the SA61 line of the SUPER-ACO synchrotron facility at LURE (laboratoire pour l'utilisation du rayonement) in Orsay, France, and ii) a set-up employing a D_2 lamp, a VUV-monochromator, and MgF_2 optics in Delft, The Netherlands.

2 RESULTS AND DISCUSSION

CsY_2F_7 and $CsGd_2F_7$ crystals have an orthorhombic structure with probably 8 inequivalent sites for the Y and Gd ions.[4] Ce^{3+} is expected to enter the crystal at Y or Gd sites. Optical absorption, luminescence, and excitation spectra indicate the presence of two inequivalent Ce^{3+} centers, hereafter referred to as Ce_I and Ce_{II}. Ce_I centers luminesce near 310 nm and Ce_{II} near 332 nm. Based on optical excitation spectra of these bands and optical absorption spectra, we arrived at the level schemes shown in Figure 1. The main features are: i) the Ce_I luminescence band overlaps the Gd^{3+} $^8S \rightarrow {}^6P$ absorption line causing complete energy transfer from Ce_I to neighboring Gd ions, ii) due to a small overlap of the Ce_{II} emission band at 332 nm with the Gd 312 nm absorption line,

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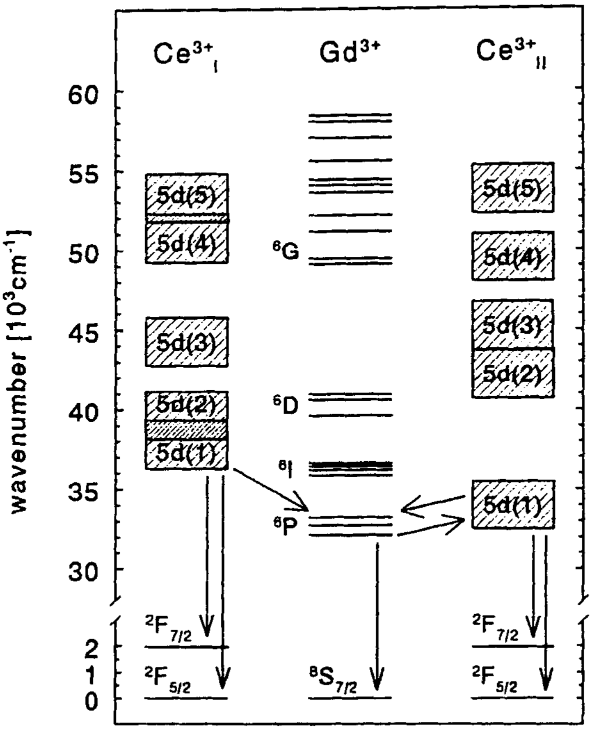

FIGURE 1 Energy level schemes of Gd^{3+}, Ce_I and Ce_{II} centers in $CsGd_2F_7$ and CsY_2F_7 crystals.

$Ce_{II} \rightarrow$ Gd transfer is also possible iii) energy migration is possible over the Gd sublattice, iv) energy transfer is possible from the Ce_I 5d(1) and Gd (^6P) levels to the 295 nm Ce_{II} absorption band.

At room temperature, the X-ray excited emission spectrum of $CsGd_2F_7$:0.1 mol% Ce^{3+} shows a Gd^{3+} emission line at 312 nm and a Ce_{II} type emission band at 340 nm, see Figure 2. The excitation bands at 295 nm and 235 nm are ascribed to the 5d bands of the Ce_{II} centers. The narrow line at 312 nm ($^8S \rightarrow {}^6P$ of Gd^{3+}) in the excitation spectrum indicates that Gd $\rightarrow$ Ce_{II} energy transfer takes place. Excitation at room temperature in the Ce_I 5d(1) band near 265 nm leads to Ce_{II} luminescence due to $Ce_I \rightarrow$ Gd $\rightarrow$ Ce_{II} transfer.

At temperatures of 95 K a narrowing of the Ce_{II} 5d(1) band occurs; the overlap with the 312 nm Gd line disappears, and consequently there is no Gd(^6P) $\rightarrow$ Ce_{II} energy transfer. Both the 312 nm Gd line and the 265 nm Ce_I 5d(1) band then disappear from the excitation spectrum; see spectrum b in Figure 2. Excitation at 160 nm produces in both CsY_2F_7 and $CsGd_2F_7$ a broad emission band near 450 nm which is attributed to self trapped exciton luminescence. The band which was also observed under X-ray excitation is quenched at room temperature.

Based on excitation spectra as a function of Ce concentration, temperature, and wavelength we arrive at the following model for the scintillation mechanism. Details on this model and a justification for it will be presented elsewhere.[5] In CsY_2F_7:Ce the energy transfer from the host crystal to Ce is quite inefficient resulting in a light yield of only

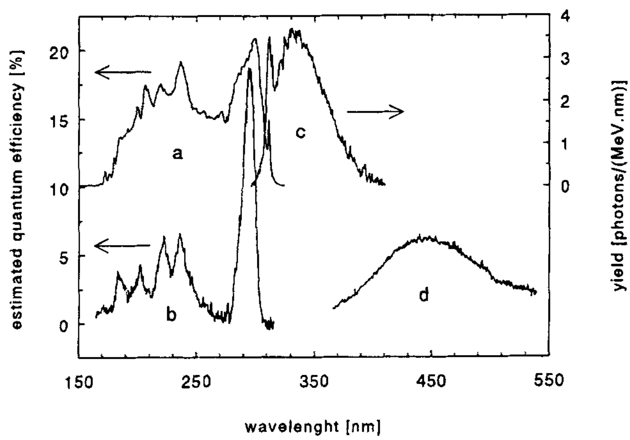

FIGURE 2 a), b) excitation and c), d) emission spectra of $CsGd_2F_7$: 0.1% Ce^{3+}. a) $\lambda_{em} = 340$ nm and T = 295 K. b) $\lambda_{em} = 340$ nm and T = 95 K. c) X-ray excited luminescence (photons/(MeV·nm)) at 295 K. d) $\lambda_{ex} = 160$ nm and T = 95 K in arbitrary units. For illustration purposes, spectrum a) has been shifted upwards by 10

1400 photons/MeV at 5 mol% Ce. Due to fast $Ce_I \rightarrow Ce_{II}$ transfer the scintillation emission spectrum of this crystal shows mainly Ce_{II} luminescence with a decay time of 32 ns. The Gd sub-lattice in $CsGd_2F_7$ crystals causes a more efficient energy transfer from the host lattice to the Ce ions resulting in a light yield of 7300 ± 700 photons/MeV for crystals doped with 20% Ce. The fast nonexponential scintillation component of $CsGd_2F_7(\tau \approx 25$ ns) is ascribed to luminescence of directly excited Ce_{II} ions. The dominating slow component (τ of the order of μs) is attributed to Ce_{II} ions excited via the Gd sublattice.

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REFERENCES

1. P. Dorenbos, R. Visser, C. W. E. van Eijk, N. M. Khaidukov, M. V. Korzhik, *IEEE Trans. on Nucl. Sci.* **40(4)** (1993) p. 338.
2. P. Dorenbos, R. Visser, C. W. E. van Eijk, N. M. Khaidukov, *Proceedings of the 'Crystal2000' international workshop on Heavy Scintillators*, edited by F. de Notaristefani, P. Lecoq, M. Schneegans (Editions Frontieres, Gif-sur-Yvette Cedex, France, 1993), p. 335.
3. P. Dorenbos, J. T. M. de Haas, R. Visser, C. W. E. van Eijk, R. W. Hollander, *IEEE Trans. on Nucl. Sci.* **40(4)** (1993) p. 424.
4. A. Ellens, S. J. Kroes, J. Sytsma, G. Blasse and N. M. Khaidukov, *Mater. Chem. Phys.* **30** (1991) p. 127.
5. D. R. Schaart, P. Dorenbos, C. W. E. van Eijk, C. Pedrini, B. Moine, N. M. Khaidukov, *J. of Phys. Cond. Mat.* 7 (1995) p.1.