Photoionization transition in YAlO$_3$:Ce

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Low temperature thermoluminescence (ltTL) of YAP:Ce (YAlO$_3$:Ce) crystals measured between 15-380 K following irradiation at 4 K with the ultraviolet light for each of the following selected wavelengths: 300, 250, 237, 220, and 180 nm were measured by Wojtowicz *et al.* [1]. They found that while in the case of two longest wavelengths the ltTL signal is very low, hardly above the background, the irradiation at the shorter wavelengths led to progressively stronger ltTL signal with the largest at 180 nm. Because the glow curves measured when the sample was irradiated with X-rays rather than UV light are identical to those mentioned above [2] we presume that the mechanism of thermoluminescence production in both these cases should be very similar and, as it was explained in [3] should involve radiative recombination of previously separated and trapped charge carriers, consecutively captured at cerium ions. Following this assumption we have measured time resolved excitation and emission spectra as well as luminescence time profiles of YAP:Ce (0.1 at%) at the Superlumi station, beam I of the DORIS storage ring to get a better knowledge of physical processes leading to the light generation in this material under UV (in particular 180 nm) excitation. The sample used in experiments was grown at the Institute of Electronic Materials Technology (Warsaw).
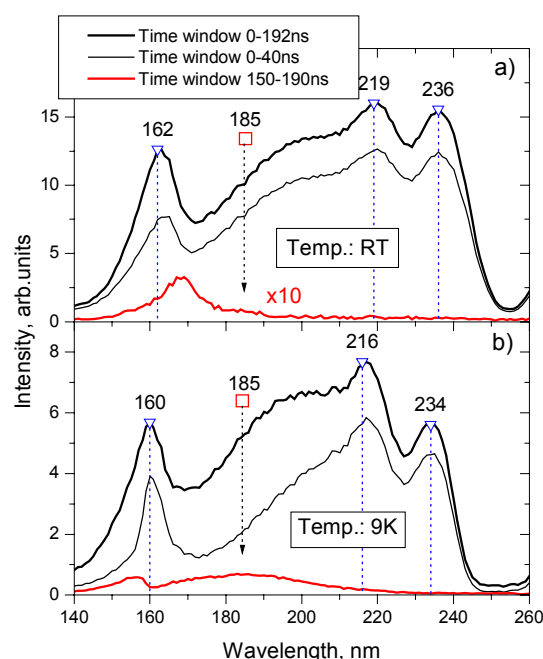

Fig.1. Time resolved excitation spectra of Ce^{3+} emission (resolution 4.32 nm) at RT a) and 9 K b) temperature. The thick black line represents "integrated" spectrum, the thin black and red lines represent "time gated" spectra (see text).

In Fig.1 we present three kinds of excitation spectra of the cerium 365 nm emission of YAP:Ce (0.1 at%) measured at RT and 9 K temperature. The "integrated" spectra were obtained with the signal accumulated between the consecutive synchrotron pulses (every 192 ns). The first "time gated" (thin black lines) spectra were measured within the first 40 ns since the synchrotron pulse, and the second ones (the red lines) were measured within 40 ns time window but delayed by 150 ns from the synchrotron pulse. The spectra measured during the first 40 ns show only the fast components of the entire signal, whereas the spectra registered with time delayed window show mainly the contribution from the slow components. The spectra presented in Fig.1 measured within the first 40 ns and whole (192 ns) window show the two well known absorption bands at about 220 nm and 236 nm, which are the transitions between the ground state $4f(^2F_{5/2})$ to the upper levels of the excited configuration $5d(e_g)$ of Ce^{3+}. The Ce^{3+} emission under excitation into these bands is fast (~17 ns) thus these bands are completely missing in spectrum measured within the delayed time window (red lines). The bands located in the wavelength range 150-170 nm are the result of the band-to-band transitions. But the most interesting in our present discussion is the broad band between 170 nm and 200 nm. This range of wavelengths corresponds to the energies lower than the band-gap of the material (~8 eV) and higher than the energies of f-d Ce^{3+} transitions (~5.6 eV). This band is clearly visible in the spectrum measured at RT temperature within the first 40 ns window but it is hardly detectable when the window is delayed (150-190 ns). However in the temperature 9 K this band appears also within the delayed window. These results show that the cerium emission excited in the spectral range 170-200 nm contains fast or slow components depending on temperature.
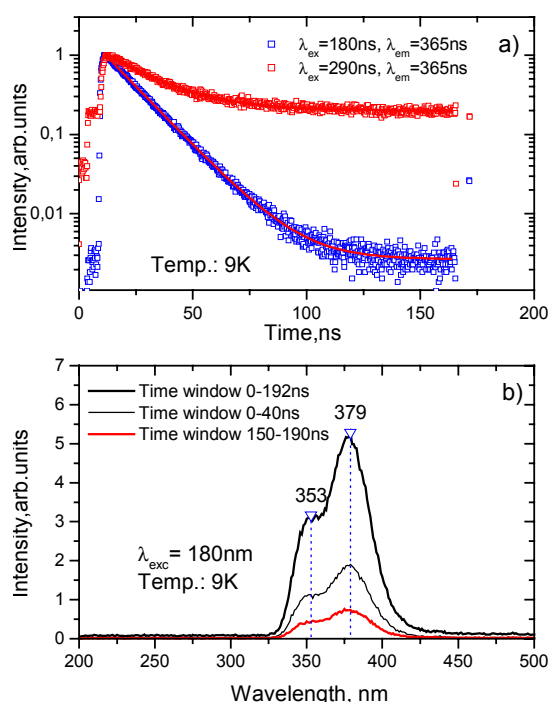
Fig.2 a) Cerium emission time profiles under 180 nm and 290 nm excitation at 9 K.   b) Emission spectra under 180 nm excitation at 9 K.

In Fig. 2a are shown cerium emission time profiles under 180 nm and 290 nm (*f-d* band) excitations at 9 K. It is easy to see that in the case of 180 nm excitation the background level is much higher than in the case of 290 nm excitation. Moreover, the time resolved emission spectra presented in Fig.2b and obtained under 180 nm excitation comprise exclusively Ce^{3+} *d-f* emission with no contribution of any additional host emissions.

The above effects could be easily explained if the light production process initiated by the excitation in the spectral range of 170-200 nm involved traps. Excitation in this spectral range has enough energy to rise the electron into the *s* levels of the Ce^{3+} ion from where the process of autoionization could take place. This process is likely if the localized *s*-level overlaps the continuum of conduction band states. A similar situation has been already observed in BaF_2:Eu [4] or Lu_2O_3:Ce [5] materials. In both cases the lowest excited state of the *5d* configuration of the activator (Eu^{2+} and Ce^{3+}) is situated in the conduction band thus the excitation within the range of *f-d* absorption bands causes the autoinisation of activator. In the case of YAP:Ce any electrons that reach the conduction band as a result of autoionistation can migrate through the lattice and become trapped at lattice defects or return to Ce^{4+}. The lifetime of these trapped electrons depends on temperature in accordance to the following well known formula: $\tau = (s \exp(-E/kT))^{-1}$ (where s - is the frequency factor, E - the trap activation energy, and k - is Boltzmann constant). Thus we can expect that traps will introduce into luminescence time profiles additional components of time constant dependent on temperature. This effect we observe in measured time profiles. At low temperature 9 K we observe slow components (in the form of higher background), but when the temperature is elevated to RT the time constants of these components shorten. In the view of presented results and similarity of glow curves measured for X-ray and UV light irradiated samples we can indeed assume that the mechanism of the thermoluminescence in the case of 180 nm irradiation is due to process of autoinisation and is identical to that observed for X-ray irradiated samples.

References

[1] A.J. Wojtowicz, J.Glodo, A. Lempicki, and C. Brecher, J. Phys.: Condens. Matter 10, 8401 (1998)

[2] J.Glodo, and A.J. Wojtowicz; J. Alloys and Comp. 300-301 289 (2000)

[3] A.J. Wojtowicz, W. Drozdowski, D. Wisniewski, K. Wisniewski, K.R. Przegietka, H.L Oczkowski and T.M. Piters, Radiat. Meas. 29, 323 (1998)

[4] C. Dujardin, C. Pedrini, J.C. Gacon, A.G. Petrosyan, A.N. Belsky and A.N.Vasil'ev, J. Phys.: Condens. Matter **9** 5229 (1997)

[5] W.M. Yen, M. Raukas, S.A. Basun, W. Schaik, U. Happek, J. Lumin. 69 287 (1996)