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Letters to the Editor

Thermoluminescence of mixed yttrium-lutethium scandade crystals doped with neodymium

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Crystals of the rare earth scandades are expected to be very useful for the applications in quantum electronics [1–3]. Scandades of different rare earth metals for solid solutions of optional stoichiometric composition [4–5] enable the introduction of large amounts of the active RE^{3+} ions. In the previous work [6] the thermoluminescence of the yttrium and lutethium scandades as well as their solid solutions doped with RE^{3+} ions has been investigated after X-ray irradiation at the room temperature. The present work deals with the effect of lutethium, yttrium and neodymium on the thermoluminescence (TL) of the neodymium-doped mixed yttrium-lutethium scandades after X-ray excitation at the liquid nitrogen temperature (LNT). Single crystals were grown at the Moscow Institute of Energetics by using the method of optical zones in the air atmosphere. The stoichiometric composition of the crystals investigated can be represented by the formula

$$Lu_xY_{1-x-c}Nd_cScO_3$$

where:

$x = 0,\ 0.5,\ 0.2,\ 0.4,\ 0.6,\ 0.8,\ 0.985,\ 1;$

$c = 0,\ 0.005,\ 0.01,\ 0.015,\ 0.05.$

The composition given above relates to the raw material.

Prior to measurements all the sample were first tempered at the temperature of 900 K in atmospheric air, then mounted on the plate of the vacuum furnace and cooled to the temperature of liquid nitrogen. After cooling the samples were subject to 15 min. X-ray irradiation (Cu, $U = 50$ KV, $I = 12$ mA). Thermoluminescence of the investigated crystals has been measured at the temperature ranging from 100 to 320 K, with the aid of the arrangement described in details in [7]. The samples were heated at a constant rate of $\beta = 0.3$ K/s. An EMI 9648B photomultiplier has been used as the luminescence detector.

The effect of Nd^{3+} ions on the TL spectra of $YScO_3$ and $LuScO_3$ is presented in the Figs. 1 and 2, respectively. As it is seen, the location of the TL peak for yttrium scandades changes from 160 K (for pure $YScO_3$) to 225 K (for $Y_{0,95}Nd_{0,05}ScO_3$). TL curve for lutethium scandade shows two distinct maxima at temperatures of 135 K and 170 K (Fig. 2). A partial substitution of the Nd^{3+}-ions for Lu^{3+}-ions results in vanishing of the low temperature TL peak and the appearance of a new TL maximum at temperature of 200 K. Thermoluminescence curves for mixed yttrium-lutethium scandades with different amounts of neodymium are pre-

sented in the Fig. 3. The stoichiometric composition of the investigated samples was the following: $Lu_{0.4}Y_{0.55}Nd_{0.05}ScO_3$, $Lu_{0.4}Y_{0.59}Nd_{0.01}ScO_3$ and $Lu_{0.4}Y_{0.595}Nd_{0.595}ScO_3$.

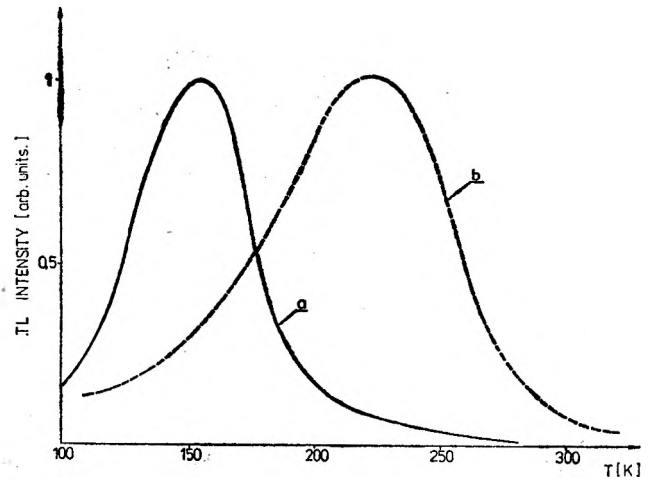

Fig. 1. TL curves for the $YScO_3$ (a) and $Y_{0.95}Nd_{0.05}ScO_3$ (b) crystals after X-ray irradiation at LNT

The sample containing the greatest amount of neodymium shows only one maximum at temperature of 210 K, characteristic of all the samples containing Nd^{+3}-ions. Due to the overlapping with the other maxima, the position of the maximum ascribed to the presence of Nd^{+3}-ions can be slightly changed for samples with different chemical composition. The TL curves for remaining samples display also the maxima characteristic of pure $LuScO_3$ and $YScO_3$. The temperatures of the TL peaks for $Lu_xY_{1-x-0.05}Nd_{0.05}ScO_3$ crystals, ($x = 0$; 0.05; 0.2; 0.4; 0.6; 0.8; 0.95) are given in Table.

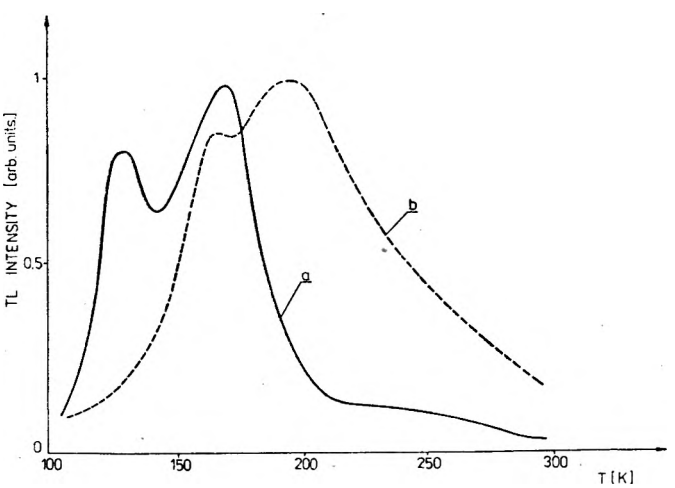

Fig. 2. TL curves for the $LuScO_3$ (a) and $Lu_{0.95}Nd_{0.05}ScO_3$ (b) crystals after X-ray irradiation at LNT

An inspection of the presented in Table shows that increasing amount of Lu^{3+}-ions leads to the appearence of the TL maximum in the vicinity of 170 K, i.e., at the temperature at which there occurs the strongest maximum of TL for pure $LuScO_3$ crystals. With the increasing content of neodymium, the location of the high-temperature TL peak ascribed to the presence of Nd changes from 230 K to 210 K.

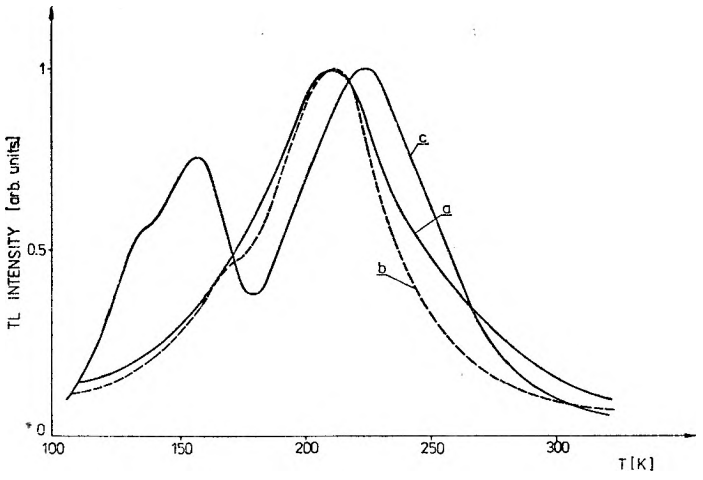

Fig. 3. TL curves for the $Lu_{0.4}Y_{0.55}Nd_{0.05}ScO_3$ (a), $Lu_{0.4}Y_{0.59}Nd_{0.01}ScO_3$ (b) and $Lu_{0.4}Y_{0.595}Nd_{0.005}ScO_3$ (c) crystals after X-ray irradiation at LNT

No.	Sample	Peak position and trap depths		
1	$Y_{0.95}Nd_{0.05}ScO_3$	T_{max} [K]		225
		E [eV]		0.48
2	$Lu_{0.05}Y_{0.9}Nd_{0.05}ScO_3$	T_{max} [K]		230
		E [eV]		0.49
3	$Lu_{0.2}Y_{0.75}Nd_{0.05}ScO_3$	T_{max} [K]		210
		E [eV]		0.45
4	$Lu_{0.4}Y_{0.55}Nd_{0.05}ScO_3$	T_{max} [K]		210
		E [eV]		0.45
5	$Lu_{0.6}Y_{0.35}Nd_{0.05}ScO_3$	T_{max} [K]	170	210
		E [eV]	0.36	0.45
6	$Lu_{0.8}Y_{0.15}Nd_{0.05}ScO_3$	T_{max} [K]	170	205
		E [eV]	0.36	0.44
7	$Lu_{0.95}Nd_{0.05}ScO_3$	T_{max} [K]	170	200
		E [eV]	0.36	0.43

The trap depths were calculated from $E = 2kT_m$

It is commonly accepted that X-ray irradiation of the oxide crystals causes release of the electrons and holes (e. g., from O_2^-). The released electrons and holes can be subsequently trapped at the lattice defects. With the increasing temperature there occurs a thermal liberation and recombination of the trapped charge carriers, being manifested in the form of the glow curves. In the oxide crystals containing the rare earth metal ions, aparat from the recombination luminescence the lines characteristic of the activator may be also observed, being due to the radiationless energy transfer between the lattice defects and the RE^{3+} ions [8]. The preliminary measurements of the X-ray luminescence (RL) of the investigated crystals have shown the presence of a broad emission band with the maximum at 22×10^3 cm^{-1} (Fig. 4), which is ascribed to the transitions from the excited states of the lattice defects.

In the crystals containing neodymium there are the groups of lines characteristic of the $^4F_{3/2} \rightarrow {}^4I_{9/2}$ and $^4F_{3/2} \rightarrow {}^4I_{11/2}$ transitions of the neodymium ions in scandade (Fig. 5) and analogous to those observed in $CdScO_3 : Nd$ [1].

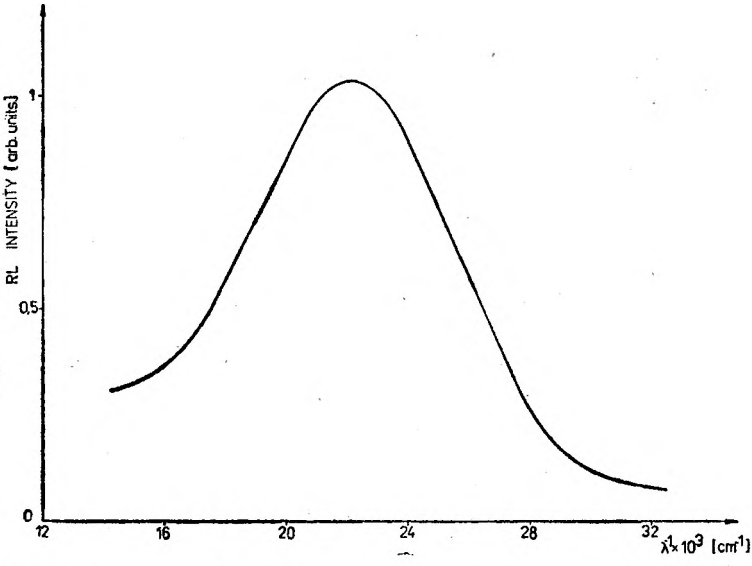

Fig. 4. RL spectra of $Lu_{0.4}Y_{0.595}Nd_{0.005}ScO_3$ at 290 K in the UV region

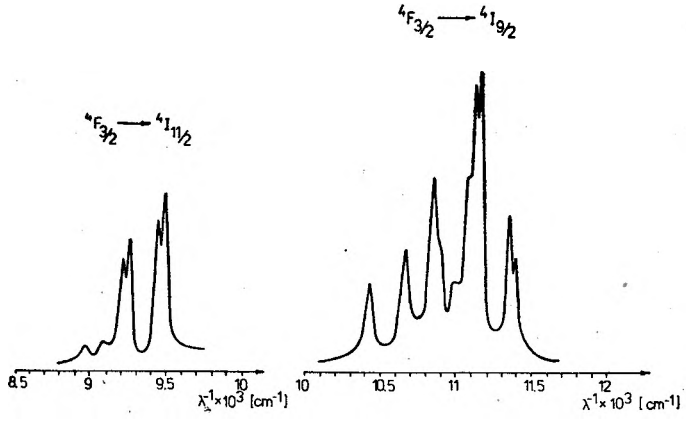

Fig. 5. RL spectra of $Lu_{0.895}Nd_{0.015}ScO_3$ at 290 K, caused by the transitions: $^4F_{3/2} \rightarrow {}^4I_{9/2}$ and $^4F_{3/2} \rightarrow {}^4I_{11/2}$

It seems that the observed thermoluminescence is connected with the same processes as those responsible for RL of the investigated crystals. More detailed studies of the spectral distributions of the TL and RL should permit us to precise the proposed mechanism of luminescence.

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Apodization by a set of slits in one- and two-dimensional optical systems *

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In the paper [1] the influence of selected amplitude apodizers on the resolving power of a two-point image was analysed. The critical values of two-point resolution distance were determined when using the Rayleigh criterion. In this paper the internity distributions of slits image obtained by using apodizers in an incoherent optical system are analysed as a supplement to the previous considerations.

A stationary and linear optical systems with incoherent illuminator may be described as a convolution of intensity distribution $I(x)$ in the object with an intensity point-spread function $S(x)$ of the optical system

$$I(x') = \int_{-\infty}^{\infty} I(x)\ S(x'-x)\,dx. \tag{1}$$

The relation between the point spread function $S(x, y)$ and the pupil function $T(\xi, \eta)$ is given by the squared modulus of the two-dimensional Fourier transform. This relation may be simplified to the squared of the one dimensional Fourier transform in the case of a one-dimensional system

$$S(x') = \left| \int_{-\infty}^{\infty} T(\xi) \exp\left(\frac{ikx'\xi}{f}\right) d\xi \right|^2 \tag{2}$$

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