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Two-state model for cathodoluminescence kinetics of YAG:Ce single-crystal scintillators

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In a scanning electron microscope (SEM), a scintillator is used to detect free electrons reflected from an observed specimen. It is demanding to detect individual electrons with energies below, for example, 20 keV, therefore the current of many electrons is usually detected. In order to understand behavior of scintillators in the SEM, cathodoluminescence (CL) of the scintillator excited by an e-beam pulse is studied. Our study was focused on the cerium activated $Y_3Al_5O_{12}$ (YAG:Ce) single-crystal scintillator, which is frequently used in the SEM. In the past, the CL decay kinetics of YAG:Ce was described using a model of trapped states with different activation energies.[1] According to this model, the released trapped states should be identified in the CL decay characteristic as a component of the multi-exponential function of time. We report that the decay time increases with the increasing width of the excitation pulse (Fig. 1). Moreover, two or three exponential components can be found in the CL decay characteristic excited by the short pulse (below 200 ns), however, more than five components occur in the long pulse excitation. This could be explained by the presence of high number of the trapped states with the different activation energies near *kT*. However, we suggest another explanation of this phenomenon using a physically clearer model presented by Huber.[2] This model is based on only two states, one trap and one luminescence center (cerium ion in our case). The state released from the trap reaches the lum. center directly. In this model, it is assumed that the activation energy of the trapped states varies slightly due to presence of the local environment. This variation is characterized by the time-dependent distribution $\rho(\tau)$ of the mean lifetimes τ (Fig. 2). We supplied the Huber's model with the direct radiative transfer from a YAG oxygen vacancy to the cerium ion. Using this modification, the model corresponds well with the experimental data.

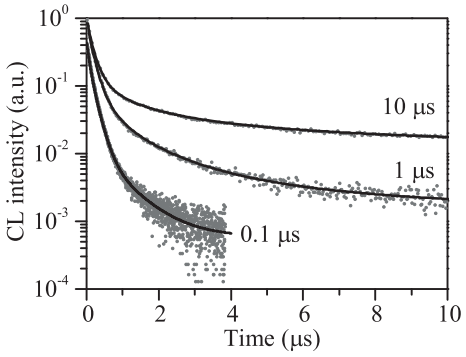

Figure 1: Fitted CL decay characteristics for different widths of the excitation pulse.

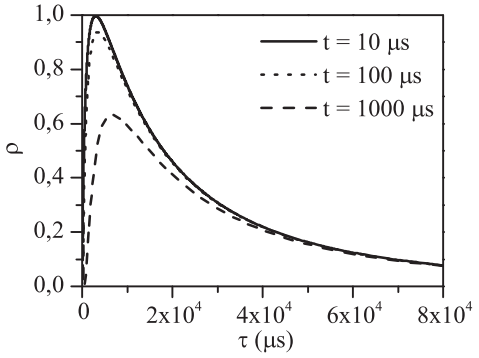

Figure 2: Distribution of remaining lifetimes at different times after the end of 1 μs excitation pulse.

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