DECAY KINETICS OF SCINTILLATION CRYSTALS FOR SEM ELECTRON DETECTORS

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1. Introduction

The principal quantities of image quality in SEM are contrast, spatial resolution, and noise. However, to quantify the overall performance of an imaging system, the detective quantum efficiency (DQE) is a better tool as it includes both the modulation transfer function and the noise power spectrum. This means that for a detector to have high DQE, it should possess not only high efficiency and low noise, but also good kinetic properties. A study of the decay kinetics of some single crystal scintillators for SEM is presented in this paper.

2. Cathodoluminescence decay measurement

The pulse mode utilizing a blanking system and 10 keV electrons for the excitation and a sampling oscilloscope for the cathodoluminescence (CL) detection were used for the measurement of decay characteristics [1]. The measurement was controlled using the IEEE-488 interface and processed by software written in Microsoft Visual Basic. Single crystals of cerium-activated yttrium aluminum garnet (YAG:Ce), cerium-activated yttrium aluminum perovskite (YAP:Ce), cerium-activated yttrium silicate ($Y_2SiO_5:Ce^{3+}$), and europium-activated calcium fluoride ($CaF_2:Eu^{2+}$) were the scintillators studied as the most interesting ones for SEM.

Some typical CL decay characteristics of single crystals for SEM measured in our laboratory are shown in Fig. 1. The best decay characteristic belongs to the P47 single crystal, whose decay time is 34 ns. YAP:Ce single crystal, having the decay time of 38 ns, is also a very good solution. It has, however, a multi-exponential decay characteristic, so it shows the afterglow of 1 % (measured 5 μs after the end of excitation). If a scintillation detection system in SEM is to be able to operate at TV rates, its decay time should be smaller than 100 ns. Hence, the decay characteristic of YAG:Ce is a little problematic. Having the decay time of 110 ns, it shows the afterglow as high as 2 %. Eu-activated calcium fluoride has the decay time of approximately 1.2 μs, and it is applicable only in slow scan rates.

It can be seen in Fig. 2 that the short-term decay component (decay time) of both YAG:Ce and YAP:Ce single crystals depends only negligibly on the duration of excitation. On the contrary, the long-term component of the decay characteristic depends strongly on the duration of excitation. Therefore, at a very short excitation, the afterglows of YAG:Ce and YAP:Ce are one and two orders smaller, respectively, comparing with a long excitation.

3. Kinetic model

It is evident, after a deconvolution of the decay characteristics from Fig. 2, that not only emission from the Ce activator is present in the CL recombination processes in YAG:Ce and YAP:Ce single crystals. Using the correction for the decay constant of the measuring device, the fastest decay constants at whichever duration of excitation are about 60 ns and 20 ns for the YAG:Ce and YAP:Ce, respectively. This corresponds to the single-exponential decay at the photoluminescence measurement [2]. Therefore, the fastest decay constant of the multi-exponential decay characteristic can be ascribed to the emission from the activator. The other decay constants can be ascribed to both radiative and nonradiative transitions originating from unwanted defect and impurity centers. Utilizing the presented results and other CL measurements (first of all dependences of intensities and decays of spectral peaks on the activator concentration), a schematic kinetic model of radiative and nonradiative transitions in the YAG:Ce single crystal has been created in Fig. 3.

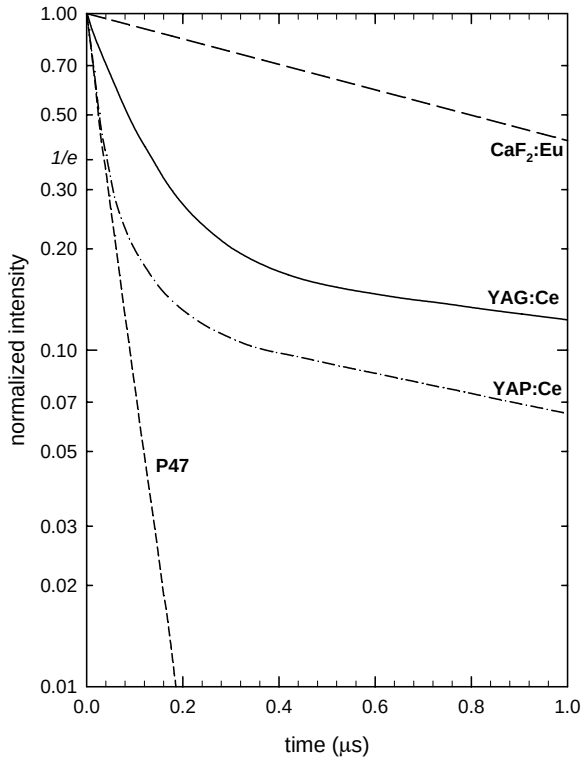

Fig. 1. Cathodoluminescence decay characteristics of single crystal scintillators for SEM. The excitation pulse width was 10 ns.

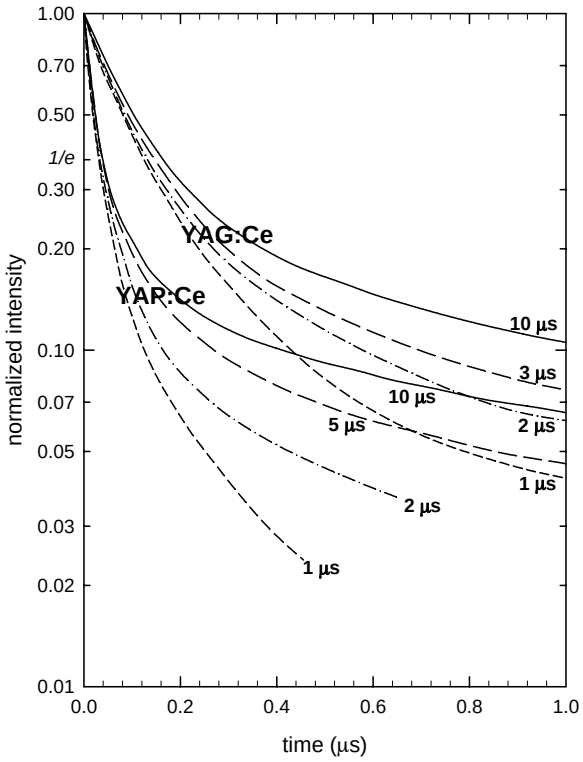

Fig. 2. Influence of the excitation pulse width on the cathodoluminescence decay of YAG:Ce and YAP:Ce single crystal scintillators.

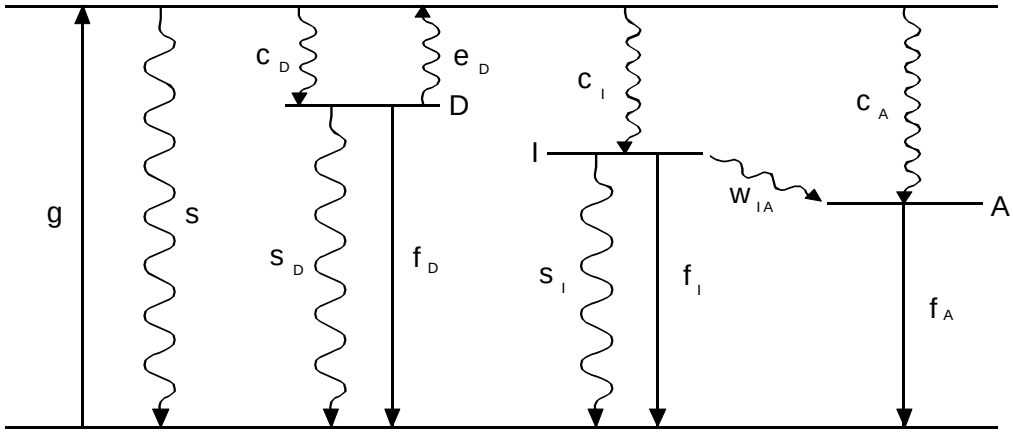

Fig. 3. The kinetic model of the cathodoluminescence of the YAG:Ce. g represents the exciton generation rate; e_D is the thermalization rate from the defect centers; c_D, c_I, and c_A are the capture rates to the defect, impurity and activator centers, respectively; s, s_D, and s_I are the nonradiative rates from the lattice states, defects and impurities, respectively; w_{IA} is the transfer rate from the impurity to the activator centers, and f_D, f_I, and f_A are the radiative (emission) rates from the defect, impurity and activator centers, respectively.

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References

[1] Autrata, R. and Schauer, P.: Scanning Microsc. Suppl. **9** (1996), 1.
[2] Barzowska, J.; Kubicki, A.; Grinberg, M.; et al.: Acta Phys. Polonica A, **95** (1999), 395.