Superfast scintillators for SEM electron detectors

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Scanning electron microscopes (SEM) require a high-quality electron detector. Such an electron detector must primarily be very fast to process a large number of imaging data in real time. For example, for the acquisition of a high-quality image in a scanning electron microscope (SEM) in real time, it is usually required to process each pixel in less than 100 ns without a loss of contrast (1). If the mentioned electron detectors are to be formed by scintillation detection systems, they must be equipped with very fast scintillators having a short decay time (decay to 1/*e* value, where *e* is the base of natural logarithms) and low afterglow even at a microsecond time range after an excitation cut-off. The scintillator with the long decay time causes an image blur and the scintillator with the high afterglow reduces image contrast in the SEM. In the scintillation electron detectors, Czochralski grown single-crystal scintillators such as YAG:Ce and YAP:Ce, whose cathodoluminescence (CL) properties have been thoroughly studied, are commonly used. A disadvantage of most of these single-crystal scintillators is their excessive scintillation decay time (even longer than 100 ns for the YAG:Ce) and especially their relatively high afterglow (even about 1 % at 1 μs after the excitation). Thus, new materials and new growth technology resulting in faster decay and substantially reduced afterglow were sought. To obtain new superfast scintillators the liquid phase epitaxy (LPE) technique has been used for the growth of various multicomponent garnets. Two of these multicomponent single crystalline epitaxial garnet films were selected and their CL properties are presented in this paper. (1) LuGAGG:Ce, i.e. $(LuGd)_3(GaAl)_5O_{12}$:Ce film and (2) LuGAGG:Ce,Mg, i.e. Mg^{2+} co-activated $(LuGd)_3(GaAl)_5O_{12}$:Ce film were prepared, measured and studied. The YAG:Ce and YAP:Ce single crystals were used as reference specimens. CL decay characteristics of all mentioned scintillators, measured using the CL apparatus (2), are shown in Figure 1. CL emission spectra including CL intensities of the mentioned scintillators, together with PMT sensitivities, are shown in Figure 2. An important result is that the new multicomponent garnet films have the afterglow 1 to 2 orders lower than the standard single-crystal scintillators. The decay time as low as 28 ns and the afterglow of only 0.02 % at 1 μs after the excitation predetermines the LuGAGG:Ce,Mg film scintillators for extremely fast electron detectors in SEMs where a somewhat reduced intensity can be expendable. If the scintillator efficiency is to be preferred, the LuGAGG:Ce film with the same efficiency as YAG:Ce and still the excellent decay time of 61 ns and the afterglow of only 0.10 % at 1 μs after the excitation is a better choice. Regarding the scintillator-PMT matching, for the both film scintillators a photocathode S20 with a cheap glass window can be used, which is a great advantage compared to the YAP:Ce single crystals.

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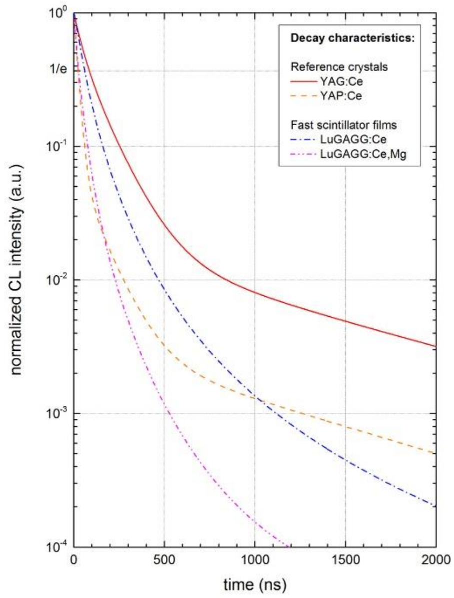

Figure 1. Cathodoluminescence decay characteristics of the LuGAGG:Ce and LuGAGG:Ce,Mg epitaxial film scintillators as well as of the YAG:Ce and YAP:Ce reference single crystal scintillators

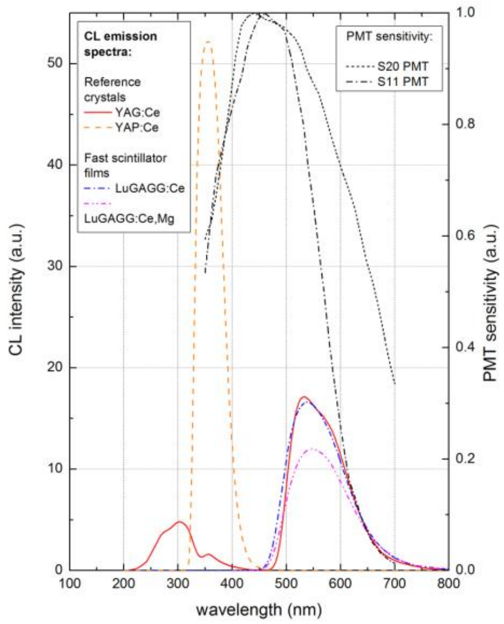

Figure 2. Cathodoluminescence emission spectra including the intensities of the LuGAGG:Ce and LuGAGG:Ce,Mg epitaxial film scintillators as well as of the YAG:Ce and YAP:Ce reference single crystal scintillators. PMT sensitivities are also plotted..