

Time Response of Single Crystal Scintillation Detectors for SEM/STEM

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1. INTRODUCTION

The quality of the resulting SEM/STEM image is characterized, to a certain extent, by the type of electron detector used. This is the main reason why in SEM/STEM the semiconductor detectors are not used on a wider scale. The decay of the scintillation detector is determined by the time response of the scintillator, photomultiplier (PMT) and electronic amplifiers. PMT and electronic amplifiers can have a time response shorter than 10 ns. Therefore, it is the scintillator that is the limiting element of the rate of the scintillation detector. If the detector is to suit the TV rates, it must have the decay time of the cathodoluminescent (CL) emission shorter than 100 ns.

2. SCINTILLATORS AND EXPERIMENTAL ARRANGEMENT

At our laboratory, the decay characteristics of some tens of different single crystal scintillators were measured. Of these, single crystals of cerium activated yttrium aluminum garnet (YAG:Ce - $Y_3Al_5O_{12}:Ce^{3+}$) and cerium activated yttrium aluminum perovskite (YAP:Ce - $YAIO_3:Ce^{3+}$) were chosen as the most interesting for SEM/STEM applications. The single crystals were pulled in cooperation with the firm Preciosa Turnov (Czech Republic) by the Czochralski method (Aufrata et al 1983). To measure the decay characteristics, a computer assisted CL apparatus, allowing electrostatic deflecting at the blanking diaphragm and containing a sampling oscilloscope at its output, was assembled.

3. DECAY CHARACTERISTICS

Typical CL decay characteristics for YAG:Ce and YAP:Ce single crystals together with those for the powder phosphor P47 (yttrium silicate - $Y_2SiO_5:Ce^{3+}$) are shown in Fig. 1. The typical excitation pulse duration was 10 ns. Both single crystals have multiexponential decay characteristics. The decay time of YAG:Ce is 110 ns and the afterglow (measured 5 ns after the end of excitation) amounts to 2 %. For YAP:Ce the decay time is only 40 ns and the afterglow amounts to 1 %. It can be seen from Fig. 2 that the short-term component of the CL decay of both single crystals depends only negligibly on the duration of excitation. On the contrary, the long-term component of the decay of excitation depends strongly on the duration of excitation, so that for a very short excitation the afterglow of YAG:Ce and YAP:Ce can be one order and at least two orders lower, respectively. This is advantageous for applications in SEM/STEM, because the images with a rich topographic content can be of higher quality.

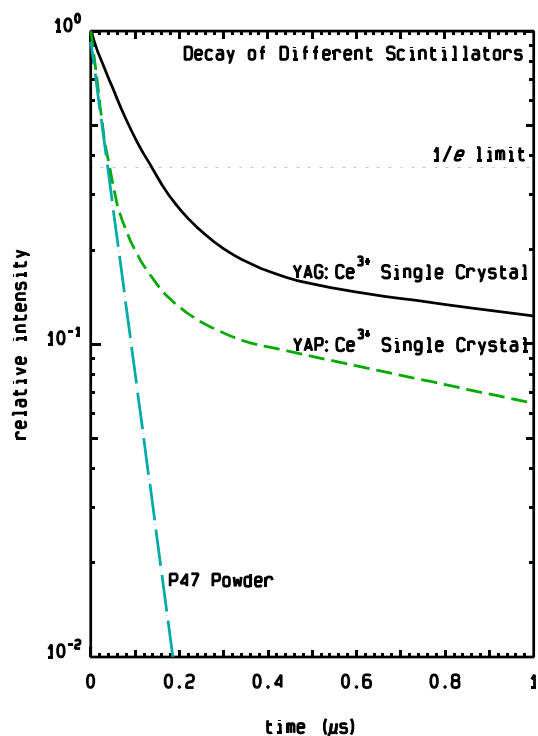


Figure 1: CL Decay of different scintillators at 10 : s excitation.

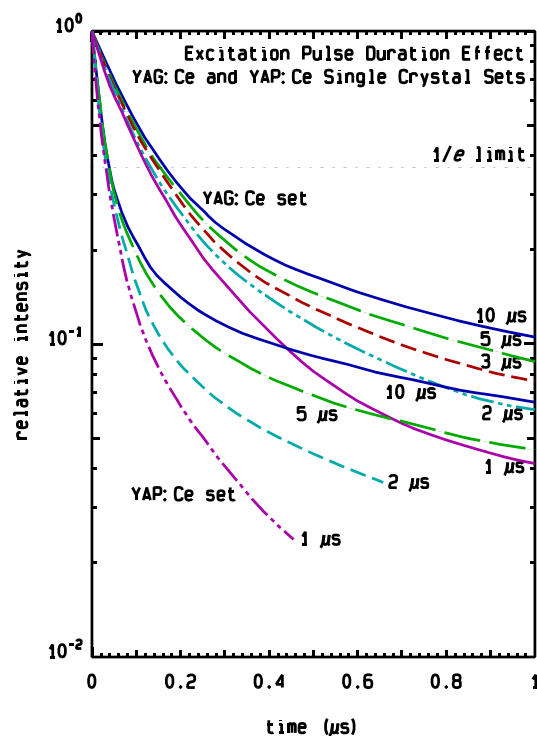


Figure 2: Excitation pulse duration influence on decay characteristics.

Although the decay time of the YAG:Ce single crystal is nearly three times longer than that of the YAP:Ce, the former crystal suggests the widest applicability in EM. The reason is that it is technologically more easily attainable (and thus cheaper). It is therefore necessary to search for a way to shorten the decay time of these scintillators. It is obvious from Fig. 3 that the YAG:Ce single crystals containing the highest amount of cerium are the most fastest. At our laboratory no concentration quenching of CL was recorded for YAG:Ce single crystals. If one succeeded in growing single crystals with a higher concentration of Ce, then there might be a higher probability of direct excitation of the activator, and the CL decay might approach the fast decay measured for UV excitation (Mareš et al 1987). However, there still exists a more simple possibility of reducing the CL response of YAG:Ce. It is obvious from Fig. 4 that single crystals whose surface is cleaned in ethyl alcohol and fired in an oxidizing atmosphere have the shortest decay time. Unfortunately, this favourable effect is accompanied by a decrease in CL efficiency.

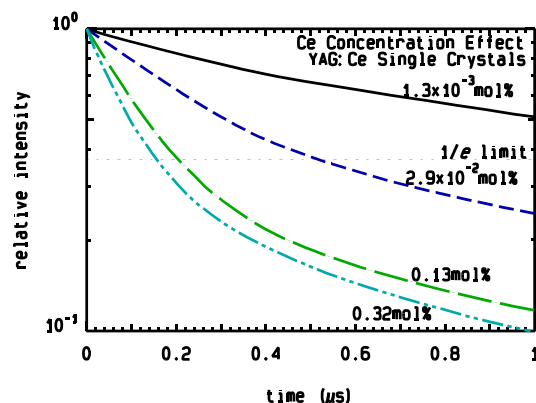


Figure 3: Ce concentration effect.

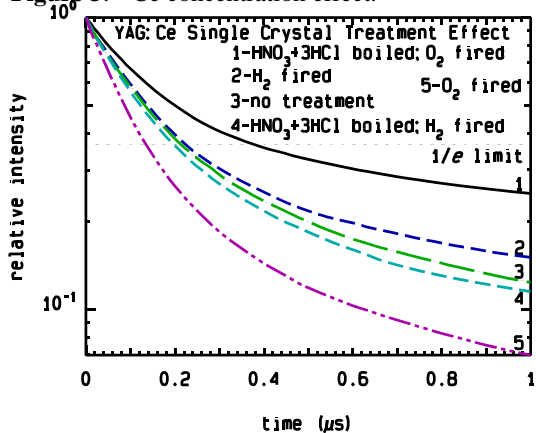


Figure 4: YAG:Ce single crystal treatment effect.