CURRENT STATE AND PROSPECTS OF SCINTILLATION MATERIALS FOR DETECTORS IN SEM

P. Schauer and J. Bok

Institute of Scientific Instruments of the AS CR, v.v.i., Královopolská 147, Brno, CZ-61264, Czech Republic
*e-mail: petr@isibrno.cz

The two principal quantities are important for assessing the quality of each imaging system. Firstly, it is the detective quantum efficiency (DQE), which is primarily a measure of image noise. As the DQE is determined by signal to noise ratio (SNR), the efficient and noise-free components are the key to the high DQE. Second, not less important indicator of image quality is also the modulation transfer function (MTF). MTF describes the ability of adjacent pixels to change from black to white in response to patterns of varying spatial frequency, and hence it determines the actual capability to show fine detail, whether with full or reduced contrast. Using a scanning imaging system the fast components are the key to the good MTF. In a scintillation electron detector of scanning electron microscope (SEM) the scintillator is the most crucial component, because it significantly influences both the DQE and MTF. The aim of this study is to assess the scintillation materials suitable for SEM detectors characterized by the both high efficiency and fast decay characteristic.

Looking for scintillators suitable for detectors in SEM, it is necessary to exclude all standard hygroscopic materials such as CsF, NaI:Tl, CsI:Tl or BaF_2. They are not suitable for electron detectors as they require a housing to be protected from moisture. Unfortunately, for the same reason some newly developed products including $LaCl_3$:Ce and $LaBr_3$:Ce do not come into consideration. It is a pity, because they are characterized by excellent light yield, stability and linearity as well as by a very fast response. Excluded must be also so call cross-luminescent materials, as they have a relatively low light yield. Thus the only scintillators suitable for detectors in SEM are those based on oxides. However the self-activated oxides have a poor combination of light yield and time response, so that only activated oxides can be considered. From these the scintillators characterized by a very fast 4f-5d emission are the best choice.

Earlier CL studies of scintillators carried out in our laboratory [1] and shown in Table 1 resulted in conclusions that defect centres are responsible for a deterioration of CL decay characteristics of YAG:Ce and YAP:Ce, and the possibilities of kinetics enhancement consist in a reduction of the influence of these defect centres. The CL properties of the Crytur scintillators recently studied in our laboratory are listed in Table 2. The durations of excitation pulses at the earlier as well as at the present measurements have been 10 μs. It can be seen that the current single crystal scintillators from the Crytur Company are generally faster. First of all they possess much lower afterglow. It succeeded, although the CL efficiency was retained or even increased. This is due to elimination of the defect centrum influences. Of course, scintillators having lower activator concentration are slower width lower efficiency.

In the future, probably the major way to reduce the afterglow of scintillators and at the same time to increase the efficiency will be efforts of increasing the activator concentration.

Unfortunately, this is not an easy task for a single crystal grown because of a sharp decrease of the distribution coefficient at the crystal growth. Feasible, but at the expense of some efficiency decrease can be crystal co-doping to reduce the afterglow through nonradiative recombination. As for the material structure, very promising is the development of optical ceramics for the scintillator applications [2].

Table 1. Cathodoluminescence properties of earlier [1] YAG:Ce single crystal scintillators for SEM. [1]Intensities of the CL emission (in arbitrary units) have been corrected for the photocathode used.

	— conditions —		— cathodoluminescence —		
single crystal	**activator conc. (mol%)**	**fired**	**intensity[1] of char. emis.(AU)**	**decay time (ns)**	**afterglow (% at 1 μs)**
YAG:Ce	0.32	O_2	64	75	5
		H_2	139	131	10
		as grown	100	125	9
YAP:Ce	0.4	as grown	194	38	6.4

Table 2. Cathodoluminescence properties of new generation of Crytur single crystal scintillators for SEM. [2]Intensities of the CL emission have been corrected for the photocathode used and have been related to the intensities of the scintillators in Table 1.

	— conditions —		— cathodoluminescence —		
single crystal	**activator conc. (mol%)**	**fired**	**intensity[2] of char. emis.(AU)**	**decay time (ns)**	**afterglow (% at 1 μs)**
YAG:Ce	0.4	as grown	109	125	5.9
YAP:Ce	0.1		171	67	5.6
YS:Ce	0.2	n/a	95	47	0.6
CRY18	n/a		188	56	0.3
CRY19			173	41	0.8
LXSR			160	46	0.3

The authors thank the company Crytur Turnov for the supply of single crystal scintillators. This work was supported by Grant No. P102/10/1410 of the Czech Science Foundation and by Grant No. CZ.1.07/2.3.00/20.0103 of the Ministry of Education, Youth and Sports of the Czech Republic.

References:

[1] Autrata R. and Schauer P., Scanning Microscopy (Supplement), **9** (1996), p. 1-12.

[2] Miyata T., Iwata T., Nakayama S. and Araki T., Meas. Sci. Technol. **23** (2012), AN: 035501, DOI: 10.1088/0957-0233/23/3/035501