Enhancement of single crystal scintillators for scintillation detectors in S(T)EM

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Scintillator is a problematic part of any scintillation detector for S(T)EM. The reason lies in its decay time and especially in its afterglow, which deteriorate the ability to transfer image contrast. In other words, a slow scintillator causes a bad modulation transfer function (MTF) of the whole detector. If a series of alternating white and black points is transferred using such a scintillator, the image is somewhat degraded at the typical S(T)EM spatial frequency. To enhance the MTF of the detector, the kinetics of the cathodoluminescence (CL) of many single crystal scintillators has been studied at our laboratory. Some results concerning single crystals of cerium-activated yttrium aluminum garnet (YAG:Ce) and cerium-activated yttrium aluminum perovskite (YAP:Ce) are presented in this paper.

The pulse mode utilizing a blanking system and 10 keV electrons for the excitation, and a sampling oscilloscope for the CL detection, was used for the measurement of decay characteristics [1]. The measurement was controlled using the IEEE-488 interface and processed by software developed in our laboratory. The decay time and the afterglow as well as the intensity of characteristic and defect emissions of the YAG:Ce and YAP:Ce single crystals, measured under various conditions, are shown in Tab. 1. For comparison, the properties of single crystals of cerium-activated Yttrium Silicate (YS:Ce, i.e. $Y_2SiO_5:Ce^{3+}$) and europium-activated calcium fluoride (CF:Ce, i.e. $CaF_2:Eu^{2+}$) are also shown in Tab. 1.

Deduced from photoluminescence, the ideal decay times of YAG:Ce and YAP:Ce are about 60 ns and 20 ns, respectively [2,3]. The ideal afterglow (measured 1 μs after the excitation stop) is no more than 1 % for the both crystals. It is evident from Tab. 1, that defect centres are responsible for a deterioration of CL decay characteristics of YAG:Ce and YAP:Ce. The possibilities of kinetics enhancement of these scintillators consist in reduction of the influence of the scintillator defect centres. As is seen from Tab. 1, both the thermalization of and the nonradiative recombination from defect centres improve the kinetics of YAG:Ce. Of course, the best way of enhancing the YAG:Ce kinetics would be to increase the Ce concentration because concentration quenching starts at about 1-2 mol% of Ce. Unfortunately, it is

Table I. Cathodoluminescence (CL) decay of single crystal scintillators for S(T)EM. [1] Intensity of the CL emission (in arbitrary units) has been corrected for the S20 photocathode used.

conditions					cathodoluminescence			
single crystal	activator conc. (mol%)	boiled	fired	meas. temp. (K)	intensity [1] (AU) charact. emis.	intensity [1] (AU) defect emis.	decay time (ns)	afterglow (% at 1 : s)
YAG:Ce	3.2×10^{-1}	aqua-regia	H_2	293	137	0.068	100	8
					91	0.044	175	17
			O_2		64	0.02	75	5
		ethylalcohol	H_2		139	0.085	131	10
					100	0.061	125	9
			as grown	380	111	0.015	139	14
				460	125	0.012	120	6
				500	129	0.011	91	3
	2.9×10^{-2}			293	43	0.146	405	24
	1.3×10^{-3}				7.3	0.15	2000	51
YAP:Ce	4×10^{-1}	ethylalcohol	as grown	293	194	0.084	38	6.4
				310	187	0.083	30	3
				320	185	0.082	23	2.3
				340	178	0.079	14	1.9
				360	174	0.072	12	1.1
				380	171	0.063	11	< 0.5
				400	174	0.052	10	< 0.5
Single crystal scintillators for comparison								
YS:Ce		n/a		293	173	n/a	34	< 0.5
CF:Eu					179		1200	42

not possible to grow a YAG:Ce crystal with the Ce concentration higher than 0.32 mol% because of a sharp decrease of the distribution coefficient.

References:
[1] Autrata R. and Schauer P., 1996, Scanning Microsc., Suppl. **9**, 1-12
[2] Weber M.J., 1973, Sol. State Commun., **12**, 741-744.
[3] Weber M.J., 1973, J. Appl. Phys., **44**, 3205-3208.

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