Type of presentation: Oral

IT-4-O-1674 Innovation possibilities of scintillation electron detector for SEM

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To evaluate performance of a scintillation detection system for SEM, it is necessary to consider many scintillator parameters. Various attributes of the scintillator for the SEM electron detector are listed in Fig. 1. The very important parameters are those affecting the detective quantum efficiency (DQE) which is primarily a measure of image noise. Not a less important indicator of image quality is the modulation transfer function (MTF) which describes the ability to show fine image details. Therefore, using a scanning imaging system, the detector bandwidth, which is given especially by the scintillator decay time, is the key to the good MTF. Currently, the YAG:Ce single crystal scintillator (introduced already in 1978 [1]) having somewhat limiting decay characteristic is the most frequently used scintillator in the SEM. The aim of this paper is to outline possibilities of scintillator innovation to get the improved MTF and DQE.

A database containing scintillation properties of various materials excited by hard x-rays and/or g-rays, taken from the literature, was established and is maintained at our laboratory. Among collected scintillators is only very limited selection of those that meet requirements for the SEM scintillation detector. For example, all hygroscopic materials must be excluded. Excluded must be also materials that have a low light yield and/or high luminescence decay. Thus the only suitable scintillators are those based on Ce-activated oxides characterized by a very fast 4f-5d emission as selected in Fig. 2.

Current research carried out in our laboratory tries to get faster scintillators by applying substitution of Y and/or Al in the garnet structure on the one hand and by increasing Ce-activator concentration on the other hand. Unfortunately, the Ce concentration increase is not an easy task for the Czochralski grown single crystals because of a sharp decrease of the distribution coefficient at crystal growth. But the development of optical ceramics is promising technology to get a more activated scintillator [2]. Our recent research includes the cathodoluminescence (CL) study of the commercial single crystal scintillators such as CRYTUR CRY18 and CRY19 as well as promising multicomponent garnet films grown by liquid phase epitaxy, for example GdGaLuYAG:Ce (formula $(Gd,Lu,Y)_3(Al,Ga)_5O_{12}:Ce^{3+}$). The new studied scintillators are quite fast as shown in Fig. 3. Their CL emission spectra show acceptable PMT matching as seen in Fig. 4.

References

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[2] Miyata T., Iwata T., Nakayama S. and Araki T., Meas. Sci. Technol. 23 (2012), Article No: 035501, DOI: 10.1088/0957-0233/23/3/035501.

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Property	Principal significance	Significant for DQE	Commercially significant	Aggravating requirement
Efficiency	✓	✓	✓	
Intrinsic noise	✓	✓	✓	
Bandwidth / Decay time	✓	✓	✓	
PMT matching		✓	✓	✓
Dynamic range / Linearity		✓	✓	
Self absorption		✓	✓	✓
Radiation resistance / Lifetime	✓	✓	✓	✓
Construction simplicity			✓	
Use simplicity			✓	
High vacuum applicability	✓		✓	✓
Reliability			✓	
Price			✓	✓

Fig. 1: Influence of various scintillator attributes on the choice of the best scintillator for the SEM electron detector.

Scintillator	Chemical formula	Light yield (photons/keV)	1/e Decay time (ns)	Wavelength of max. emission λ_m (nm)
YAG:Ce	$Y_3Al_5O_{12}$:Ce	11	70	550
LAG:Ce	$Lu_3Al_5O_{12}$:Ce	14	100	520
YAP:Ce	YAlO3:Ce	16,2	30	347
YLAP:Ce	$(Y_{0.3}\text{-}Lu_{0.7})AlO_3$:Ce	13	18/80/450	375
LAP:Ce	$LuAlO_3$:Ce	11,4	16/80/520	375
YSO:Ce	Y_2SiO_5:Ce	18,4	42	420
GSO:Ce	Gd_2SiO_5:Ce	12,5	60, 600	430
LSO:Ce*	Lu_2SiO_5:Ce	27	40	420
LSO:Ce*	$Lu_2Si_2O_7$:Ce	30	30	380
LBO:Ce*	$LuBO_3$:Ce	26	39	410
GAGG:Ce	$Gd_3Al_2Ga_3O_{12}$:Ce	60	88	528 (565)
*ambiguous abbreviation				

Fig. 2: Compilation of x-ray and/or g-ray excited rare-earth activated oxides having the light yield ≥ 10 photons/keV and the decay time ($\tau_{1/e}$) ≤ 100 ns.

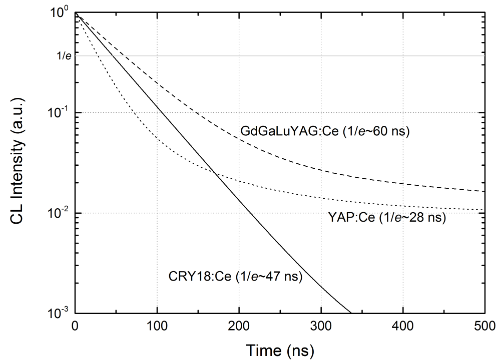

Fig. 3: CL intensity decay characteristics of the new scintillators: CRY18 single crystal and GdGaLuYAG:Ce garnet film. For comparison the decay of the improved YAP:Ce single crystal scintillator is also shown.

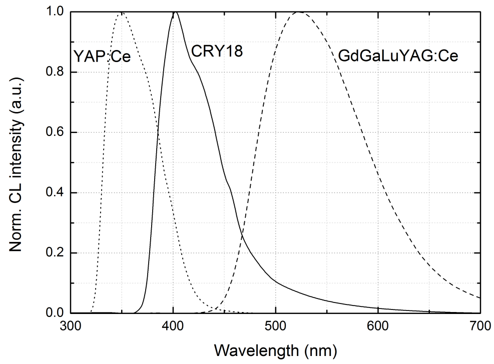

Fig. 4: Normalized CL intensity spectra of the new scintillators: CRY18 single crystal and GdGaLuYAG:Ce garnet film. For comparison the spectrum of the improved YAP:Ce single crystal scintillator is also shown.