Scintillator-photocathode matching in scintillation detector for S(T)EM

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Introduction

Besides the decay time, the efficiency is the most important parameter of a scintillation detector for a scanning electron microscope and/or a scanning transmission electron microscope - S(T)EM. Much attention has been paid to the examination of the energy conversion efficiency in scintillators (Autrata and Schauer 1996). The study of the efficiency of the light transport from scintillator luminescence centres through a light guide to a photomultiplier tube (PMT) has been accomplished too (Schauer and Autrata 1992). But nearly no effort has been devoted to the analysis of the scintillator-photocathode spectral matching. Such an analysis is the topic of this paper.

Experimental arrangement

Cathodoluminescent (CL) emission spectra of the scintillators investigated were measured using a computer assisted CL apparatus (Autrata and Schauer 1996). The CL signal was spectrally decomposed by a mirror monochromator, picked up by a PMT at the output slit of this monochromator, and measured using a lock-in nanovoltmeter. The individual instruments were connected to the general purpose interface bus (GPIB, IEEE-488), and the measuring apparatus was controlled by a personal computer. The measuring and processing software which contained correction algorithms was written in programming languages Turbo Pascal and Basic.

Measured and calculated results

At our laboratory, the single crystals of cerium activated yttrium aluminum garnet (YAG:Ce), cerium activated yttrium aluminum perovskite (YAP:Ce), cerium activated yttrium silicate (chemically corresponds to the powder phosphor P47), and europium activated calcium fluoride (CaF_2:Eu^{2+}) were investigated as the most interesting for S(T)EM applications. Their CL emission spectra corrected for the spectral sensitivity of the detector used and normalized to maxima are shown in Fig. 1. For each single crystal, the position of the peak wavelength (λ_{max}) and the full width of the half maximum (FWHM) are given in Tab. I. For the examination of a scintillator-photocathode spectral matching the S20 and S11 photocathodes were measured. Their spectral properties are drawn and tabulated in Fig. 2 and Tab. II, respectively. In Fig. 2, the curves of photocathode spectral sensitivities are normalized to the maxima, analogously to Fig. 1. Added are also properties of the negative-electron-affinity GaAs:Cs photocathode, taken from Burle C31034 series catalog sheet (Burle Electron Tubes 1992). For the purpose of an assignment of an ideal matching and efficiency, an ideal photocathode having a constant sensitivity of 100 mA/W over all the spectral range was considered. It follows from the results summarized in Tab. I that the CaF_2:Eu and YAP:Ce single crystals show the best and the worse spectral

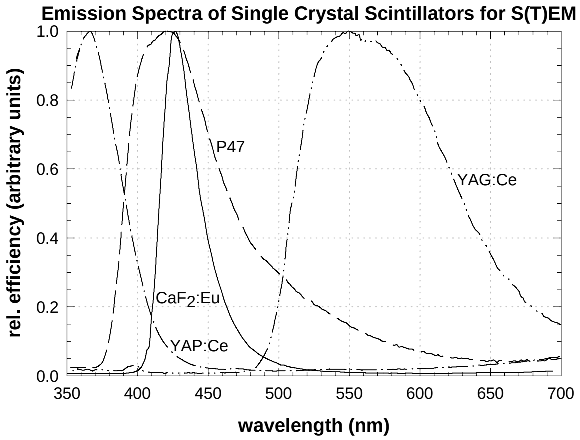

Fig. 1 Normalized cathodoluminescent spectra of single crystal scintillators for S(T)EM.

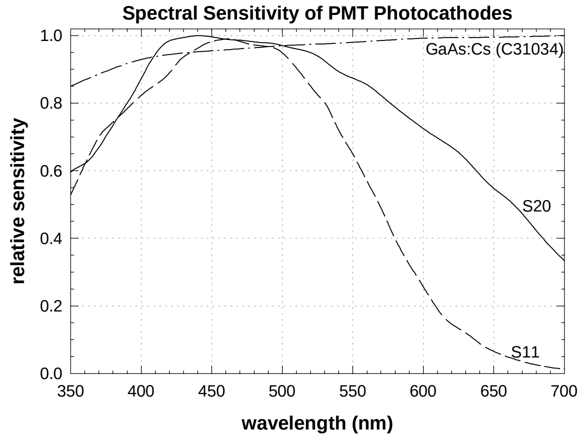

Fig. 2 Normalized spectral response of the sensitivity of the photocathodes used. See also Tab. II.

scintillator	emission spectra[1] (nm)		scintillator-photocathode matching[2] (%)				scintillator-photocathode rel. efficiency[3] (%)			
	λ_{max}	FWHM	ideal	S20	S11	GaAs:Cs	ideal	S20	S11	GaAs:Cs
YAP:Ce	366	52	100	71	66	90	100	31	23	51
YAG:Ce	560	122	100	78	46	98	70	24	11	40
P47	420	77	100	92	84	95	89	36	26	48
CaF_2:Eu	426	30	100	97	91	95	92	39	29	50

Tab. I Spectral properties of single crystal scintillators for S(T)EM, and spectral matching and/or relative efficiency of the scintillator-photocathode system. [1]Peak position (λ_{max}) and full width of the half maximum (FWHM) of the main emission band. [2]Spectral matching of the scintillator-photomultiplier system related to that with an ideal photocathode. [3]Efficiency of the scintillator-photomultiplier system related to that with the best scintillator investigated and an ideal photocathode.

matching, respectively, to the commonly used S20 and/or S11 photocathode. The matching of both YAP:Ce and YAG:Ce. can be upgraded to a great extent by using a photocathode with the negative-electron-affinity. Moreover, the spectral matching of YAP:Ce could be markedly increased by using the PMT with the quartz entrance window. It is not the photocathode itself but the glass entrance window that causes the low spectral sensitivity of PMT in the short wave spectrum region. Omitting the systems with an ideal photocathode and that with very slow CaF_2:Eu, the best choice from the point of view of the scintillator-photocathode matching is the YAP:Ce-GaAs:Cs and P47-GaAs:Cs systems.

photocathode	λ_{max}[1] (nm)	FWHM[2] (nm)	Sensitivity[3] (mA/W)
S20	440	334	62
S11	462	221	50
GaAs:Cs	750	635	81
ideal	- - -	>700	100

Tab. II Photocathode properties of the THORN EMI 9558B (**S20**), TESLA 65PK415 (**S11**), and BURLE C31034 (**GaAs:Cs**) photomultipliers. [1]Peak wavelength of the spectral response. [2]Full width of the half maximum (FWHM) of the sensitivity range. [3]Radiant cathode sensitivity at the peak wavelength.

References

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