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NEW DETECTORS FOR LOW-ENERGY BSE

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Backscattered electrons (BSE) are mostly used to study the specimen's topography. Nowadays, low energy (units of keV) electron beam imaging is often necessary for example for the research of nanomaterials, biomaterials or semiconductors. Because BSE detectors are mostly non-accelerating or low-accelerating, electrons with approximately the same energy as primary beam (PB) have to be detected. Therefore, BSE detectors need to become optimized for such low-energy electrons. For the scintillation detectors, the biggest problem probably lies in the scintillator. Semiconductor detectors aren't studied in this work. Cerium activated bulk single crystals of yttrium aluminium garnet (YAG:Ce) $Ce_x:Y_{3-x}Al_5O_{12}$ are widely used as scintillators for the detection of high-energy backscattered electrons (BSE). However, commonly used YAG:Ce single crystal strongly loses its light yield (LY) with the decrease of the PB energy [1]. As possible available alternatives for this application, bulk single crystals of yttrium aluminium perovskite (YAP:Ce) $Ce_xY_{1-x}AlO_3$ and CRY018 can be predicted. However, similar LY drop can be expected also with these scintillators.

There are two main reasons, why this occurs. Firstly, slower electrons don't have enough energy to pass through the relatively thick standard conductive layer on the scintillator surface. Therefore, thinner conductive layer has to be used. Secondly, commonly available scintillators suffer from structural defects that are created mostly due to surface damage (as a result of its grinding, polishing, purification or contamination) or already during the own bulk Czochralski growth. The influence of all of these defects on cathodoluminescence (CL) properties can be eliminated by the scintillators in form of thin single crystalline films because, as shown previously [2], the concentration of these defects decreases with the decreasing temperature of the crystal growth. Therefore, single crystalline epitaxial films have attracted a lot of attention recently because the growth temperature of these films is about a half (1000 °C) of the bulk ones (2000 °C). Moreover, appropriate doping of the garnet structure can suppress the influence of the defects on the CL properties.

For the purpose of this work, bulk Czochralski grown single crystals of YAG:Ce, YAP:Ce and CRY018 were studied. Results were compared with those of promising cerium activated single crystalline films of gadolinium aluminium gallium garnet (GAGG:Ce) $Ce_x:Gd_{3-x}Ga_yAl_{5-y}O_{12}$. These films were grown by the isothermal dipping liquid phase epitaxy onto YGG substrates from lead-free $BaO-B_2O_3-BaF_2$ flux [3]. These specimens were coated with conductive layers of different composition and different thicknesses. Properties of these layers are in the table shown in Table 1.

The specimens were excited by an electron beam with energy in range from 0.8 to 10 keV using a specialized CL apparatus [4]. In this energy range, CL LY of YAG:Ce were measured for coating layers of different composition and different thicknesses (Fig. 1). Moreover, CL spectra have been measured for all presented specimens (Fig. 2).

It was shown, that the coating layer with thickness of only units of nm has to be used to allow low-energy BSE penetrating the layer without significant losses. Moreover, it was shown, that the GAGG:Ce film with balanced Ga content shows excellent scintillation properties where the effect of unwanted structural defects was suppressed, the spectrally corrected CL LY value exceeded 160 % of the commercially available bulk YAG:Ce single crystal, and CL decay was dominated by a fast component with 50 ns decay time which is close to that of Ce^{3+} (5d-4f) photoluminescence decay. Thanks to these excellent CL properties at PB energy of 10 keV, GAGG:Ce single crystalline films are new prospective scintillators suitable for low-energy BSE detectors. This research is in progress, therefore other results at different PB energies will be presented at the seminar.

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Film	Atomic number	Atomic weight	Density (g/cm^3)	Thickness (nm)	Trans. of el. of 700 eV (%)
Aluminium (Al)	13	26.98	2.7	3.8	63.2
				5.0	48.0
				10.0	15.1
				15.0	1.3
Scandium (Sc)	21	44.95	2.99	3.0	69.0
				5.0	45.1
Nickel (Ni)	28	58.69	8.91	1.0	74.8
				2.0	50.2
Indium Tin Oxide (ITO)	24.21*	55.11*	7.16	4.0	6.24
				7.0	0.0

**weighted values*

Table 1: Properties of commonly used elements for coating layers for scintillators. Data in the last column were simulated by the Monte Carlo method that used the elastic single scattering model with the Mott cross-sections and the Bethe slowing-down approximation.

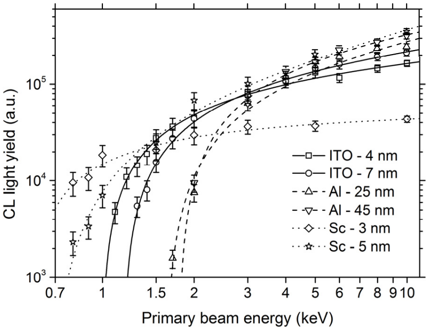

Figure 1 The cathodoluminescence (CL) light yield of the YAG:Ce single crystal scintillator coated with layers of different composition and different thicknesses as a function of the primary beam energy.

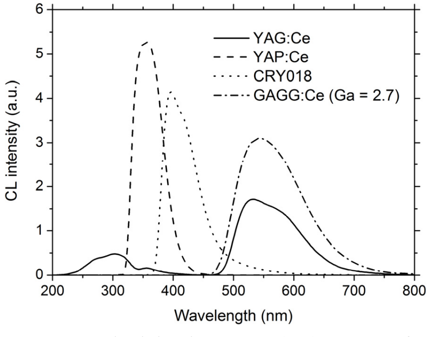

Figure 2 Cathodoluminescence (CL) spectra of $Ce_{0.02}$:$Gd_3Ga_{2.7}Al_{2.3}O_{12}$ (GAGG:Ce) compared with commercially available YAG:Ce, YAP:Ce and CRY018. Spectra were corrected for the apparatus transmissivity and detector spectral sensitivity. Primary beam energy was 10 keV.