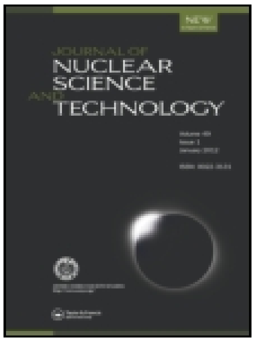

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Comparative Study of a CsI and a ZnSe(Te/O) Scintillation Detector's Properties for a Gamma-ray Measurement

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A ZnSe crystal based on a Ⅱ-Ⅵ compound semiconductor has various physical properties: electroluminescent, photoelectric, luminescent and scintillation. Activated ZnSe crystals are highly-efficient scintillators, and they are already being applied to the detecting units of a X-ray introscopy and a dosimetric system. ZnSe-based scintillators have a high absolute light output, and their radiation spectra matches well with the Si-photodiode spectral sensitivity.

The present study was performed by using a polished ZnSe and CsI(Tl). ZnSe is a low-density crystal(5.42 g/cm^3). The emission wavelength of ZnSe(Te) is 610 nm and ZnSe(O) is 592 nm. We have fabricated 10x10x1 mm and 10x10x2 mm ZnSe crystals in which the activators were doped with tellurium and oxygen. ZnSe and CsI crystals were mounted on a S3590-08 HAMAMATSU PIN photodiode and an R3479 HAMAMATSU PMT. Teflon tape as a reflector for the PIN photodiode and PMT. Gamma-ray spectrum measurements were performed by using ^{241}Am, ^{57}Co, ^{133}Ba and ^{137}Cs radio isotopes. We have compared the measured spectra of ZnSe and CsI under the same conditions.

KEYWORDS: ZnSe, scintillator, PMT, photodiode, pulse height spectrum

I. Introduction

An ideal behavior of a scintillator would be characterized by a proportionality between the energy deposited in the crystal and the number of scintillation photons. The measurement of the absolute light output of a scintillator is very complex and difficult. Photons created by nuclear radiation in the scintillator are affected by many processes that reduce their number before they are converted into photoelectrons in photomultipliers(PMT) or electron-hole pairs in Si photodiodes.[1)]

One of the recent important steps is development of a new type scintillator based on zinc selenide. Development of the scintillator ZnSe has effectively filled the gap in the "scintillator-photodiode" detector series for modern radiation detector.[2)] For example, scintillators based on ZnSe crystals have conversion efficiency of semiconductor scintillator ZnSe(Te) is 1.1-1.3 times higher, and radiation stability 3-4 orders higher as compared with crystals CsI(Tl).[2-4)] Now, the ZnSe scintillators based on the II-VI compound semiconductor doped with various activators were investigated.[5)]

In our study, we measured pulse height spectrum of ZnSe doped tellurium and oxygen in PMT, large area avalanche photodiode (LAAPD) and Si-PIN-Photodiode, and compared with spectra of ZnSe and CsI crystals.

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II. Experiments

All the measurements were done with CsI(Tl), ZnSe(Te) and ZnSe(O) crystal. The ZnSe crystals were delivered from the national academy of sciences of Ukraine in two samples ZnSe(Te) and ZnSe(O) : They were doped tellurium and oxygen activator in ZnSe crystal. An over-view of all the crystals used is given in **Table 1**. The light collection efficiency is a function of the crystal size and its shape.

Table 1. Tested scintillators

Crystal	Activator concentration (mass %)	Size[mm^3]	Surface finish
CsI(Tl)	-	11x12x1.77	Polished
ZnSe(Te)	0.2	10 x 10 x 1	Polished
ZnSe(Te)	0.2	10 x 10 x 2	Polished
ZnSe(Te)	0.2	10 x 10 x 3	Polished
ZnSe(O)	0.02	10 x 10 x 1	Polished
ZnSe(O)	0.02	10 x 10 x 2	Polished
ZnSe(O)	0.02	10 x 10 x 3	Polished

The all samples were polished on both large surfaces, and the crystals were glued onto the PMT and LAAPD with RX 688 silicon grease of REXON Components, Inc.. The crystals were wrapped with several layers of white Teflon tape. We have also used a 630-70-73-510 window-less silicon LAAPD of the Advanced Photonix, Inc., 19 mm diameter R3479 photomultiplier tube of Hamamatsu and S3590-08 Si-PIN-photodiode of the Hamamatsu. The R3479 PMT has range from 185 nm to 650 nm, and wave-length of maximum response is 420 nm.

The preamplifier was used for CR-150-AC-BNC board and CR-110 charge sensitive preamplifier chip of the Cremate, Inc.. CR-110 preamplifier chip is low noise charge sensitive preamplifier for use with various types of radiation detectors including semiconductor detector, PIN-photo-diodes, avalanche photodiodes(APDs) and gas-based detectors.[6] Amplifiers were used ORTEC 572A amplifier with PMT and ORTEC 673 Spectroscopy amplifier with photo-diode. Multi channel analyzer was ORTEC 919E. To prevent radiation incidence on Si-PIN-photodiode, we manufactured and used lead collimator of 5 mm thick and with hole of 2 mm diameter. Light guide of 10 x 10 x 10 mm^3 size was manufactured with lucite, and lucite was polished on all surfaces.

III. Results

The main part of the measurements was carried out for ^{57}Co radiation source. To get the best possible pulse height spectrum, the gain and the shaping time constant on the amplifier were optimized for each scintillator. ZnSe(O) and CsI(Tl) were measured at 6 μsec, and ZnSe(Te) was measured at 10 μsec shaping time constant. Detailed technical characteristics of ZnSe can be found in Table 2.[7]

Table 2. Luminescence spectrum maximum λ_{max}, absorp-tion index α, decay time τ and absolute light output S of the ZnSe-based scintillators.

Scintillator	λ_{max}, nm	α, cm^{-1}	τ, μsec	S, Photon/MeV
ZnSe(Te)	640	0.08-0.15	30-80	Up to $7\cdot10^4$
ZnSe(O)	600	0.05	2-8	Up to $5\cdot10^4$
ZnSe(Cd)	620	0.1-0.15	5-20	Up to $4\cdot10^4$
ZnSe(Cd,Te)	635	0.1-0.15	40-100	Up to $6\cdot10^4$
ZnSe(O,Al)	605	0.1-0.15	3-15	Up to $5\cdot10^4$

1. PMT Experiments

To measure energy spectra of CsI(Tl) and ZnSe crystals, we used for the R3479 PMT of Hamamatsu. Spectra of ^{57}Co source were measured by CsI(Tl), ZnSe(Te) and ZnSe(O) crystals, and we compared with the each spectra. These measurements were carried out at gain of 200 and negative 1500 V. Scintillators have different decay times therefore we separately measured each scintillators. The spectra of ZnSe(O) and CsI(Tl) were measured at shaping time constant of 6 μsec, and ZnSe(Te) was measured at shaping time constant of 10 μsec, respectively.

In general quantum efficiency of bialkali photocathodes in PMT is about 25 % at 400 nm, and this is lower numerical value than quantum efficiency of PIN-photodiode.[8,9] The results of PMT measurement are shown in **Fig. 1**. We found energy peaks of ^{57}Co in spectra of ZnSe(O) and CsI(Tl) crystals, but the energy peaks in ZnSe(Te) were not found except 3 mm thick. The best responses were observed from ZnSe(O) of 2 mm and 3 mm thick.

These results indicate that ZnSe(O) has better response than ZnSe(Te) or CsI(Tl) at PMT, and 122.06 and 136.47 keV energy peaks from ^{57}Co source were not separated from the spectra of ZnSe crystals.

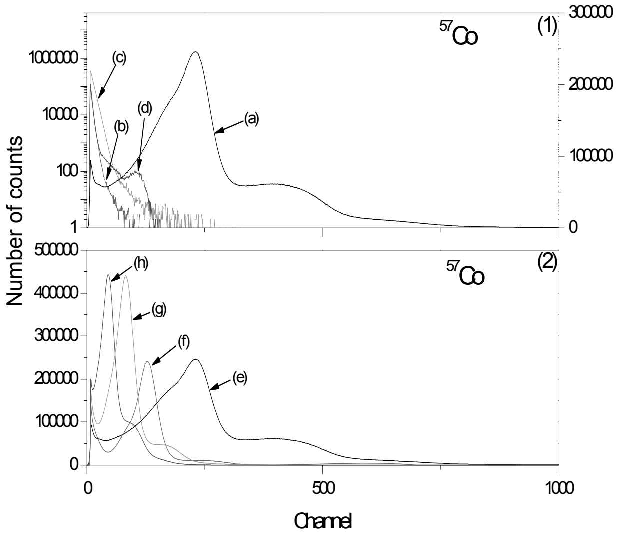

Fig. 1 Energy spectra of γ-rays from a ^{57}Co source measured with samples coupled to the R3479 PMT in the 572A amplifier. Activators of ZnSe(Te) and ZnSe(O) are 0.2 mass% and 0.02 mass%, respectively. (1) is log scale of spectra of ZnSe(Te) at 10 μsec and linear scale of spectrum of CsI(Tl) at 6μsec. (2) is linear scale of spectra of CsI(Tl) and ZnSe(O) at 6 μsec shaping time constant: (a) CsI(Tl), (b) ZnSe(Te) of 1 mm thick, (c) ZnSe(Te) of 2 mm thick, (d) ZnSe(Te) of 3 mm thick, (e) CsI(Tl), (f) ZnSe(O) of 1 mm thick, (g) ZnSe(O) of 2 mm thick and (h) ZnSe(O) of 3 mm thick.

2. LAAPD Experiments

The measurement of LAAPD carried out with the windowless 630-70-73-510 LAAPD of the Advanced Photonics, Inc.. 630-70-73-510 LAAPD has quantum efficiency of 69-77 % at 400nm, dark current of 110-269.4 nA and rise time of 11-16.2 ns.[10] The LAAPD was calibrated with 5.9 keV X-ray of ^{55}Fe source which was directly irradiated on active area of LAAPD. We used Teflon film of two layers as reflector. There experiments were carried out at positive 1800 V, gain of 100 and shaping time constant of 10 μsec. The sample crystals were coupled to a LAAPD with optical silicon grease of the Saint-Gobain.

Fig. 2 shows the energy spectra of ^{57}Co source measured with the ZnSe(Te) of 2 mm thick and ZnSe(O) of 1 mm and 2 mm thick crystals. In LAAPD experiment, we not measured ZnSe(Te) of 1 mm thick because energy peaks of ZnSe(Te) of 2 mm thick were not observed with LAAPD.

These results were indicated that ZnSe(O) has better response than ZnSe(Te), and ZnSe(O) of 2 mm thick has better light output than ZnSe(O) of 1 mm thick. With LAAPD, We measured decay time of ZnSe(Te) and had observed decay time of not less than 100 μsec. Therefore energy peaks of ^{57}Co source in ZnSe(Te) are not measured.

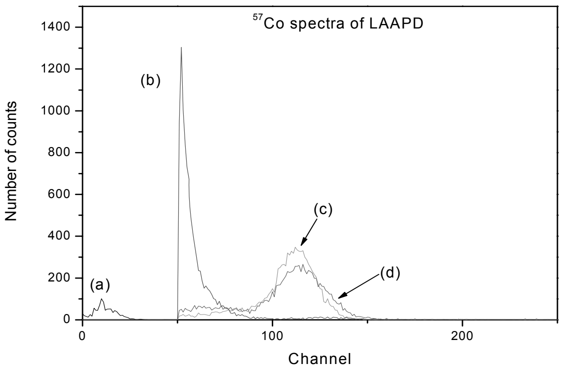

Fig. 2 Energy spectra of ^{57}Co by using a LAAPD. Activators of ZnSe(Te) and ZnSe(O) are 0.2 mass% and 0.02mass%, respectively. (a) noise of LAAPD, (b) ZnSe(Te) of 2 mm thick, (c) ZnSe(O) of 2 mm thick and (d) ZnSe(O) of 1 mm thick.

3. PIN-photodiodes Experiments

Quantum efficiency of 3590-08 PIN-photodiode is about 85 % at 540 nm.[9] With photodiode, we measured spectrum of ^{57}Co source with CsI, ZnSe(Te) and ZnSe(O), respectively. The spectrum was measured at 50 V and for live time of [illegible] VHF [illegible] HP DQXIDFWXUHG OHDG FROOLPDWRU RI [illegible] mm^3 [illegible] VL]H ZLWK KROH RI [illegible] PP [illegible] GLD DQG OXFLWH RI [illegible] mm^3 size as light guide. Lead collimator and lucite light guide were prevent radiation from irradiating on PIN-photodiode. Refractive index of lucite is 1.5.

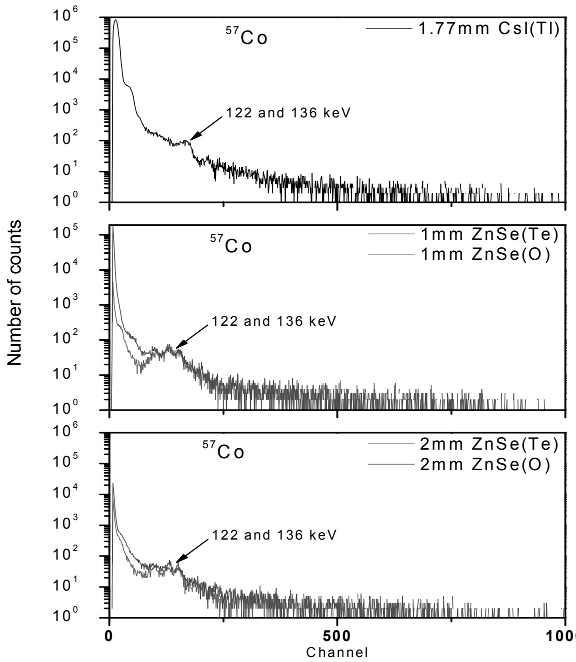

Fig. 3 Pulse height spectrum of γ-ray form a ^{57}Co source measured with CsI(Tl), ZnSe(Te) and ZnSe(O) crystal coupled to S3590-08 PIN-photodiode.

These results were shown in **Fig. 3**. The spectrum of CsI(Tl) was not separated for energy peaks of 122 and 136 keV of ^{57}Co source. This result was shown that CsI(Tl) has good light output, but the resolution of CsI(Tl) is not good. Spectra of ZnSe(Te) and ZnSe(O) were shown that the ZnSe-based scintillators have better resolution than CsI(Tl). However, light yield of used ZnSe(Te) and ZnSe(O) is not more than CsI(Tl). Thus energy peaks of ^{57}Co source were not clearly separated.

IV. Conclusions

Results form this study show that ZnSe(O) have substantial advantages for radiation detection in the 20-200 keV range as compared with CsI(Tl).

ZnSe-based scintillators have excellent properties of high conversion efficiency, low afterglow and good light yield. According to the earlier studies ZnSe(Te) exhibits a very high light output of the maximum 80,000 photons/MeV. However, measured light output of ZnSe(Te) is much lower about 40,000 photons/MeV than the 80,000 photons/MeV.[11,12]

The light collection efficiency is a function of the crystal size and its shape. It is affected by the self-absorption of the light in the crystal and by the reflector material used.[1] For increasing of thickness of ZnSe(O), light collection efficiency of ZnSe(O) was increased.

The obtained results for the ZnSe(O) scintillator have demonstrated the possibility for radiation detection coupled with PMT and PIN-photodiode.

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References

1) M. Moszynski, M. Kapusta, M. Mayhugh, D. Wolski and S.O. Flyck, "AbsoluteLight Output of Scintillators", IEEE, Trans. Nucl. Sci. **44[3]**, 1052 (1997).
2) A.A. Focsha, P.A. Gashin, V.D. Ryzhikov, N.G. Starzhinskiy, L.P. Gal'chinetskii and V.I. Silin, "Properties of semiconductor scintillators and combined detectors of ionizing radiation based on ZnSe(Te,O)/pZnTe-nCdSe structures", Optical materials, **19**, 213 (2002).
3) V. Ryzhikov, N. Starzhinskiy, L. Gal'chinetskii, P. Gâshin, D. Kozin and E. Danshin, "New Semiconductor Scintillators ZnSe(Te,O) and Integrated Radiation Detectors Based Thereon", IEEE, Trans. Nucl. Sci. **48[3]**, 356 (2001).
4) V. Ryzhikov,, G. Tamulaitis, N. Starzhinskiy, L. Gal'chinetskii, A. Novickovas and K. Kazlauskas, "Luminescence dynamics in ZnSeTe scintillators", J. of Luminescence, **101**, 45 (2003).
5) V. Ryzhikov, V. Chernikov, L. Gal'chinetskii, S. Galkin, E. Lisetskaya, A. Opolonin and V. Volkov, "The use of semiconductor scintillation crystals $A^{II}V^{VI}$ in radiation instruments", J. of Crystal Growth, **197**, 655 (1999).
6) Cremat catalog and http://www.cremat.com/CR-110.pdf.
7) W. G. Lee, Y. K. Kim, J. K. Kim, H. J. Seo, V. Ryzhikov, N. Starzhinskiy, O. Vyagin, K. Katrunov and O. Zelenskaya, "Particularities of ZnSe-Based Scintillatios for a Spectrometry of Charged Particles and Gamma Quanta", J. korean Phys. Soc. **48,** 47 (2006).

8) G. F. Knoll, *Radiation Detection and Measurement*, 3rd edition, Wiley, New York, 1999.
9) Hamamatsu catalog and http://jp.hamamatsu.com/resources/ products /ssd/pdf/s3590_series_kpin1052e05.pdf.
10) M. Moszynski, M. Kapusta, D. Wolski, M. Szawlowski and W. Klamra, "Energy Resolution of Scintillation Detectors Readout with Large Area Avalanche Photodiodes and Photomultipliers", IEEE, Trans. Nucl. Sci. **45[3]**, 472 (1998)..
11) M. Balcerzyk, W. Klamra, M. Moszynski, M. Kapusta and M. Szawlowski, "Energy resolution and light yield non-proportionality of ZnSe:Te scintillator studied by large area avalanche photodiodes and photomultipliers", Nucl. Instr. And Meth., A **482**, 720 (2002).
12) V. Ryzhikov, L. Gal'chinetskii, K. Katrunov, E. Lisetskaya, V. Gavrilik, O. Zelenskaya, N. Starzhynskiy and V. Chernikov, "composite detector for mixed radiations based on CsI(Tl) and dispersions of small ZnSe(Te) crystals", Nucl. Instr. And Meth., A **540**, 395 (2005).