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EXISTENCE OF A PREDOMINANT DIRECTION OF LIGHT EMISSION FROM OXIDE CRYSTALLINE SCINTILLATORS

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Scintillation single crystals of complex oxides – gadolium silicate Gd_2SiO_5 (GSO), cadmium tungstenate $CdWO_4$ (CWO), lead tungstenate $PbWO_4$ (PWO) – are, on account of their properties (high stopping power, good energy resolution, nonhygroscopicity, and others), in most applications the most promising materials for ionizing-radiation detectors. However, their application is being held back by the fact that their light yield of radioluminescence is lower than for alkali-halide crystals [1-3]. To increase the light yield of these materials it is primarily necessary to improve the technology for preparing high-quality crystals. Another important method for improving the scintillation characteristics is to use the anisotropic properties of the crystal matrix. For this reason it is of interest to study the light yield as well as the spectral characteristics of the luminescence and transmission of single crystals with different crystallographic orientation.

In the present work we investigated the anisotropy of the scintillation properties of GSO and CWO single crystals, belonging to the monoclinic system and possessing the space symmetry group $P2_{1/c}$ and $P2_{2/c}$, respectively, as well as PWO single crystals, belonging to the tetragonal system with space symmetry group $14_{1/a}$.

The single crystals were grown by Czochralski's method. Samples in the form of small cubes with dimensions of 10 × 10 × 10 and 20 × 20 × 20 mm with polished faces oriented relative to the different crystallographic directions, were prepared from them.

The luminescence of the spectra of the samples of GSO, CWO, and PWO single crystals were investigated on a KSVU-23 apparatus. The radiation source consisted of a REIS x-ray tube with a silver tube and anticathode voltage 35 kV, which corresponded to an irradiation energy of ~30 keV.

The radiation of the CWO and GSO crystals was registered with a ^{207}Bi source of ionizing radiation with energy 569 and 1063 keV. The scintillations were registered with the aid of a KHR2412 photomultiplier, the light signals from which were fed into a BUS2-97 spectrometric amplifier and then through an analog-to-digital converter into a multichannel pulse analyzer. The data from the analyzer were fed into a system for processing spectrometric information [4]. In addition, for the CWO and PWO based detectors the relative light yield obtained by irradiating with ^{137}Cs γ-rays with respect to NaI(Tl) and BGO crystals, respectively, was measured. The results of the measurements are presented in Tables 1–3.

TABLE 1. GSO Light Yield.

Series No.	Light collection conditions	Extraction plane	Position of the peaks, channel		
			569 keV	1063 keV	CsI(Tl)
1	With reflector in optical contact with the multiplier	⟨010⟩	162,68 + 2,59	303,07 + 4,58	407,24 + 0,50
		⟨100⟩	160,27 + 2,11	299,16 + 3,92	
		⟨001⟩	163,14 + 4,18	304,62 + 7,77	
2	With reflector with no optical contact	⟨010⟩	82,82 + 0,97	153,18 + 1,12	411,47 + 0,87
		⟨100⟩	83,61 + 0,97	154,61 + 1,13	
		⟨001⟩	82,81 + 2,47	153,06 + 4,49	

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TABLE 2. CWO Light Yield

Series No.	Light collection conditions	Extraction plane	Position of peaks, channel		
			569 keV	1063 keV	CsI(Tl)
1	With reflector in optical contact with the photomultiplier	⟨010⟩	177,37 + 3,45	326,11 + 6,03	427,35 + 1,19
		⟨100⟩	169,61 + 2,18	311,90 + 3,44	
		⟨001⟩	164,08 + 5,27	301,08 + 9,62	
2	With reflector with no optical contact	⟨010⟩	93,61 + 1,69	171,73 + 1,83	432,61 + 1,57
		⟨100⟩	90,94 + 1,94	166,69 + 2,10	
		⟨001⟩	86,39 + 1,92	158,22 + 2,25	
3	With absorber in optical contact with the photomultiplier	⟨010⟩	146,71 + 3,95	269,72 + 7,58	390,35 + 0,67
		⟨100⟩	138,45 + 1,64	254,30 + 2,44	
		⟨001⟩	133,11 + 1,78	243,54 + 1,54	
4	With absorber with no optical contact	⟨010⟩	134,67 + 1,14	248,61 + 1,73	385,03 + 0,70
		⟨100⟩	129,63 + 2,26	238,10 + 3,74	
		⟨001⟩	121,78 + 0,84	223,27 + 1,09	

TABLE 3. Light Yield Obtained by Irradiation with a ^{137}Cs γ-Ray Source, %

Detector No.	Sample dimensions, mm	(001)	(010)	(100)
CWO-1	10×10×10	39,4	39,9	37
CWO-2	-"-	43,4	44,7	43,8
PWO-1	-"-	5,7	5,4	5,5
PWO-2	-"-	6,0	5,8	5,8
PWO-3	-"-	5,7	5,4	5,4
PWO-4	-"-	5,6	5,3	5,4
PWO-5	20×20×20	5,1	4,7	4,7
PWO-6	-"-	5,3	4,9	4,8
PWO-7	-"-	4,9	4,6	4,7
PWO-8	-"-	4,9	4,2	4,2
PWO-9	-"-	5,2	4,9	5,0

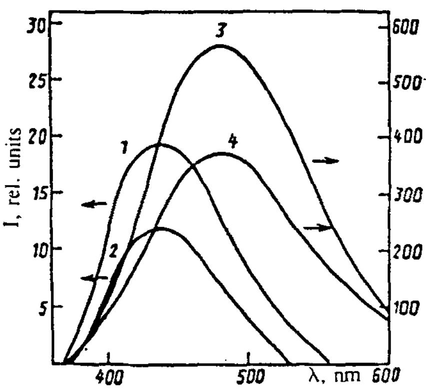

Fig. 1

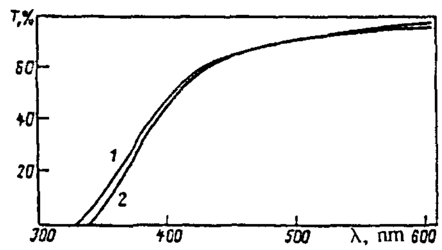

Fig. 2

Fig. 1. X-Ray luminescence spectrum of $PbWO_4$ (1, 2) and $CdWO_4$ (3, 4) crystals for the (001) (1), (100) (2), (010) (3), and (100) (4) directions.

Fig. 2. Transmission spectrum of $PbWO_4$ crystals for the (100) (1) and (001) (2) directions.

The x-ray luminescence spectra (Fig. 1), measured with x-ray excitation energy of ~ 30 keV, showed their form is identical for all investigated crystallographic directions A significantly higher (by $\sim 40\%$) radiation intensity is observed for the PWO crystal irradiated perpendicular to the crystallographic (001) plane, which coincides with the optical axis, than for the other direction studied. A similar situation is also observed for the CWO crystal, whose emission intensity is maximum in the [010] direction. In the transmission spectra (Fig. 2) the edge of the absorption band for the predominant directions of the crystallographic planes for both PWO and CWO is shifted into the longer wavelength region of the spectrum as compared with the edge of the absorption band for the other investigated directions.

Discussion and Conclusions. The investigations of the dependence of the light yield on different crystallographic directions showed that a predominant direction is present in the crystals $CdWO_4$ and $PbWO_4$. The fraction of the light extracted through the (010) plane for $CdWO_4$ and through the (001) plane for $PbWO_4$ is 5-7% higher than for other planes under irradiation with high-energy radiation (0.5-1 MeV). For low energy x-rays (~ 30 keV) this effect is much stronger ($\sim 40\%$).

The predominant-direction effect in $PbWO_4$ and $CdWO_4$ crystals can apparently be explained by the fact that the density of radiation centers is maximum in these directions (the reticular density is highest). This is also confirmed by the fact that the effect is most pronounced with low-energy excitation. Indeed, for excitation energy ~ 30 keV only a $\sim 100\mu m$ thick surface layer is irradiated, in contrast to irradiation with energy $\sim 0.5-1.9$ MeV when almost the entire volume of the sample is irradiated. In the case of low-energy excitation the difference in the number of radiation centers in different planes has a stronger effect on the light yield than in the case of high-energy radiation, i.e., the effect should weaken as the energy of the incident radiation increases.

For Gd_2SiO_5 no dependence of light yield on crystallographic direction was observed.

REFERENCES

1. K. Takagi and T. Fukazawa, "Cerium-activated Gd_2SiO_5 single crystal scintillator," Appl. Phys. Lett. **42**, No. 1, 42-45 (1983).
2. I. Ya. Kushnarenko et al., "Effect of impurities on the characteristic luminescence of cadmium tungstenate," Ukr. Fiz. Zh., **37**, No. 7, 976-983 (1992).
3. Y. A. Kachanov et al., "Properties and beam tests of $PbWO_4$ crystals," LAPP-EXP-93.08, October (1993).
4. G. N. Garkusha, Yu. G. Zdesenko, V. N. Kuts et al., "System for acquisition and processing of spectrometric information in low-background experiments," Preprint No. 86-4, Institute of Nuclear Research, Academy of Sciences of the Ukrainian SSR, (1986).