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SHORT COMMUNICATIONS

X-Ray Sensitivity of $Cd_{0.9}Zn_{0.1}Te$ Detectors

V. F. Dvoryankin[a], G. G. Dvoryankina[a], A. A. Kudryashov[a], A. G. Petrov[a], V. D. Golyshev[b], and S. V. Bykova[b]

[a] *Kotel'nikov Institute of Radio Engineering and Electronics (Fryazino Division), Russian Academy of Sciences, pl. Vvedenskogo 1, Fryazino, Moscow oblast, 141190 Russia*
e-mail: vfd217@ire216.msk.su
[b] *OOO Granit-A, Lokomotivnaya ul. 1a, Aleksandrov, Vladimir oblast, 601655 Russia*

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Abstract—The X-ray sensitivity of $Cd_{0.9}Zn_{0.1}Te$ detectors as a function of the effective X-ray energy and bias voltage is studied. It is shown that the sensitivity grows with effective X-ray energy and much more significantly with bias voltage. The sensitivity depends on the angle the X-ray beam makes with an electric field in the detector. In the energy range 28–72 keV, the sensitivity is the highest when the X-ray beam is normal to the electric field in the detector.

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$Cd_{0.9}Zn_{0.1}Te$ crystals are today widely used in fabricating X-ray and gamma-radiation detectors. These detectors serve as a basis for designing new devices intended for room-temperature spectroscopy, medical equipment, nondestructive testing, etc. Therefore, it is of interest to study their X-ray sensitivity as a function of the bias voltage, effective X-ray energy, and angle the X-ray beam makes with an electric field in the detector.

In this work, $Cd_{0.9}Zn_{0.1}Te$ single crystals were grown by the method providing an axial heat flux near the crystallization front [1]. The crystals grew under an inert gas pressure of 100 atm by self-seeding in a graphite crucible 50 mm in diameter. Detectors made from these crystals were 3 × 3 × 3-mm cubes. Gold contacts to which a voltage was applied were deposited on the sample surface from a 5% aqueous solution of chloroauric acid ($HAuCl_4$).

Figure 1 shows a typical dark *I*–*V* characteristic of the detector in the absence of X-ray radiation. Obviously, the contacts are ohmic.

The X-ray sensitivity *S* of the detectors was calculated by the formula

$$S = \frac{I_{ph}}{DA}, \quad (1)$$

where I_{ph} is the photocurrent, *D* is the dose of incident X-ray radiation, and *A* is the surface area of the detector. The sensitivity versus the X-ray energy and bias voltage was studied with the X-ray beam oriented parallel and normal to the electric field in the detector.

Figure 2 plots the sensitivity of the detector versus the effective X-ray energy in the range 28–72 keV for three bias voltages. Filled squares and empty circles correspond to the cases when the electric field is aligned with the X-ray beam and is normal to the X-ray beam, respectively. One can see from Fig. 2 that the sensitivity rises with the effective photon energy, this rise being much steeper at higher bias voltages. At any effective energy from the range of 28–72 keV, the sensitivity is higher when the X-ray beam is normal to the electric field in the detector. On the other hand, the difference between the sensitivities is slightly dependent on the effective photon energy at a con-

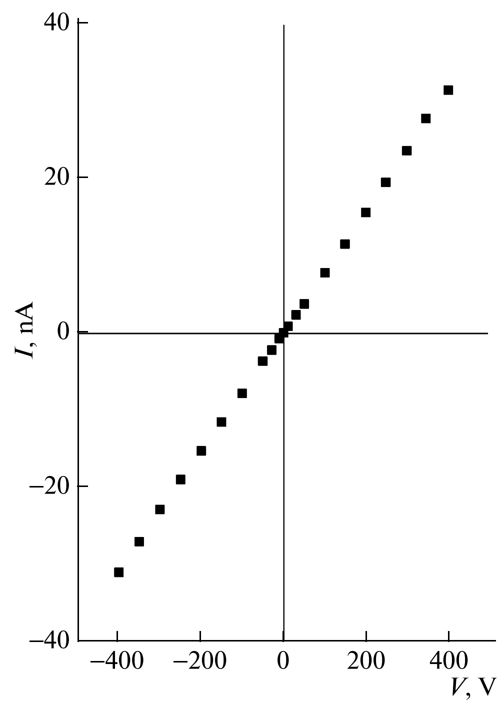

Fig. 1. Typical *I*–*V* characteristic of the $Cd_{0.9}Zn_{0.1}Te$ detector.

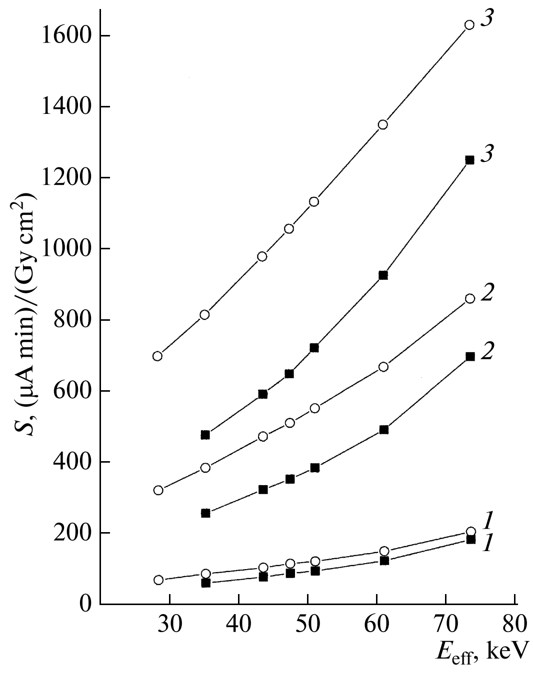

Fig. 2. Sensitivity of the $Cd_{0.9}Zn_{0.1}Te$ detector as a function of the X-ray effective energy for a bias voltage of (*1*) 100, (*2*) 250, and (3) 400 V.

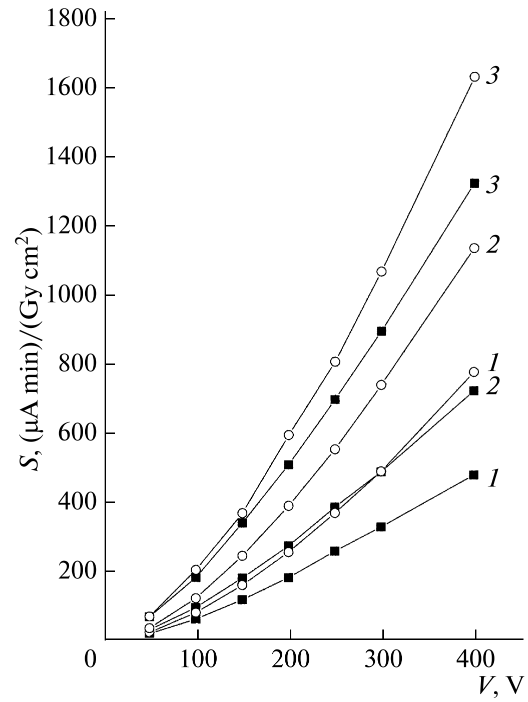

Fig. 3. Sensitivity of the $Cd_{0.9}Zn_{0.1}Te$ detector as a function of the bias voltage for an effective X-ray energy of (*1*) 35, (*2*) 61, and (*3*) 72 keV.

stant bias voltage: the curves marked by empty circles and filled squares run nearly parallel to each other.

In Fig, 3, the sensitivity is plotted against the bias voltage in the range 50–400 V for three values of the effective X-ray energy. It is seen to increase rapidly with the bias voltage. This increase is steeper when the X-ray beam is directed normally to the electric field in the detector.

Figure 4 shows that, at high bias voltages (above 1000 V) and an effective X-ray energy of 61 keV, the sensitivity in the case of normal (beam-to-field) configuration is 1.5–2.0 times higher than in the case of the parallel configuration.

The above dependences of the X-ray sensitivity of the $Cd_{0.9}Zn_{0.1}Te$ detectors can be explained by considering the quantum efficiency of the internal photoelectric effect. This efficiency is defined as the number of electron–hole pairs generated per one X-ray photon absorbed in the detector. The number of electron–hole pairs depends both on the absorbed photon energy and on the detector material. In the given case, the efficiency of X-ray absorption is determined by the large atomic numbers of Cd ($Z = 48$) and Te ($Z = 52$). The average energy needed to generate an electron–hole pair in the $Cd_{0.9}Zn_{0.1}Te$ crystal with a bandgap of 1.6 eV is equal to 5.14 eV [2]. It was found [3] that the absorption of X-rays with energy of up to 250 keV causes the photoelectric effect. In this case, part of the X-ray energy is transferred to those bound electrons leaving atoms, while the rest of the energy is converted to the kinetic energy E_k of these electrons,

$$E_k = h\nu - (E_b)_i. \quad (2)$$

Here, $h\nu$ is the X-ray photon energy and $(E_b)_i$ is the binding energy of an electron on an *i*th atomic shell,

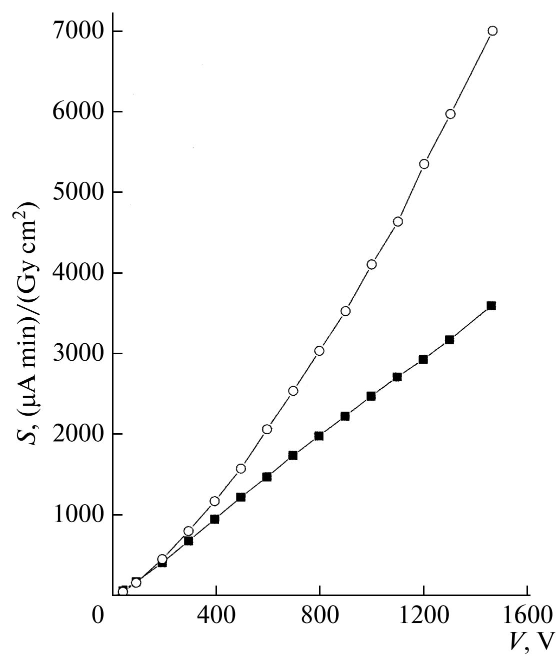

Fig. 4. Sensitivity of the detector as a function of the bias voltage for an effective X-ray energy of 61 keV.

Binding energy (in eV) of electrons on the *K*, *L*, and *M* shells in free Cd, Zn, and Te atoms

Z	Element	Subshell								
		K	L_1	L_2	L_3	M_1	M_2	M_3	M_4	M_5
30	Zn	9663	1198	1047	1024	141	94	91	12	11.2
48	Cd	26715	4022	3732	3542	775	655	621	415	408
52	Te	31820	4945	4618	4347	1012	876	825	589	578

which is equal to the energy needed to remove the electron from the *i*th shell. The binding energies $(E_b)_i$ of electrons on the *K, L*, and *M* shells in free Zn, Cd, and Te atoms are listed in the table [4]. It is evident from relationship (2) that the higher X-ray energy, the higher the kinetic energy of electrons escaping the atoms. When moving in the detector, these photoelectrons generate secondary electrons, which, in turn, produce electron–hole pairs. The bias-induced electric field in the detector adds to the kinetic energy of the photoelectrons, thereby improving the sensitivity of the detector. In accordance with [5], photoelectrons leave atoms normally to the direction of the X-ray radiation. Therefore, the photocurrent, as well as the sensitivity, is expected to be higher when the X-ray beam is directed normally to the bias-induced electric field vector. This is observed in Figs. 2–4.

Thus, it is shown that the sensitivity of $Cd_{0.9}Zn_{0.1}Te$ detectors to X-ray radiation increases with the effective photon energy and bias voltage. It is found that the sensitivity depends on the angle the X-ray beam makes with the electric field in the detector. For effective photon energies ranging from 27 to 72 keV, the sensitivity is higher when the X-ray beam is directed normally to the bias-induced electric field. The difference between the sensitivities for the two directions of the X-ray beam depends on the bias voltage more strongly than on the effective energy of X-rays.

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