

Photostimulated passivation of spectrometric CdZnTe detectors

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A method is proposed for side surface passivation of spectrometric detectors based on $\text{Cd}_{1-x}\text{Zn}_x\text{Te}$ solid solution. The influence of photostimulated passivation treatment on electrical and spectrometric properties of the detectors has been established. Considered are the processes occurring on the crystal surface at the treatment and causing changes in the surface phase composition.

Предложен способ пассивации боковой поверхности спектрометрических детекторов на основе твердого раствора $\text{Cd}_{1-x}\text{Zn}_x\text{Te}$. Установлено влияние фотостимулированной пассивирующей обработки на электрические и спектрометрические свойства детекторов. Исследованы процессы, происходящие на поверхности кристаллов при их обработке и приводящие к изменению фазового состава поверхности.

The performance characteristics of radiation spectrometric detectors based on CdZnTe are influenced essentially by the state of the semiconductor crystal surface [1]. The main factors which define this state include the change of the surface composition under machining and contamination of this layer with various impurities reducing the surface electrical resistance.

CdZnTe samples of $5 \times 5 \times 4 \text{ mm}^3$ size were made from the crystals grown by the Bridgman method under high inert gas pressure [2]. The thickness of the layer damaged at mechanical treatment of the sample surface was estimated by microhardness measurements [3]. To that end, the dependence of microhardness values obtained at different loads on the indenter penetration depth into the samples was plotted. The measurements were realized according to the standard procedure on PMT-3 microhardness tester with Vickers diamond pyramid used as the indenter; the indentation load being 0.0098 to 1.96 N. The indenter penetration depth (h) was calculated from the relation $h = d/7$,

where d is the indentation diagonal [4]. The damaged layer thickness was assumed to be equal to the indenter penetration depth at which the values of microhardness at the machined surface were similar to those for the surface free of damaged layer. The experimental results have shown that mechanical treatment caused an insignificant strengthening of the surface; the depth of the damaged surface layer for different samples did not exceed 8 to 10 μm .

The damaged layer can be removed by chemical etching; however, such a procedure results in formation of the chemically unbonded tellurium phase on the sample surface [5, 6]. Crystalline Te is characterized by low electrical resistivity. This causes formation of current leakage channels within the near-surface layer of the semiconductor crystal; as a result, the detector becomes disabled. The existing methods of Te removal include the formation of tellurium compounds such as TeO_2 or tellurium sulfides [7, 8]. Ion-beam and plasma treatment of the crystals in oxygen are la-

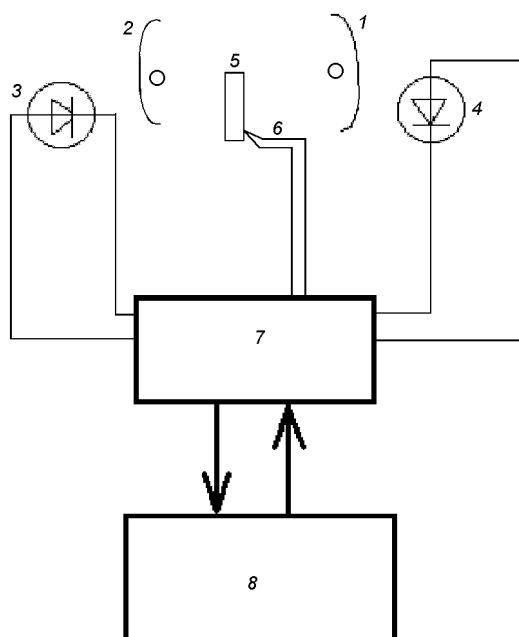


Fig. 1. Block diagram of the unit for photo-stimulated passivation of the surface of CdZnTe crystals: 1, 2, DRT-1000 mercury lamps; 3, 4, photo-receivers for lamp radiation control; 5, the sample; 6, thermocouple; 7, sample-computer interface; 8, computer.

borious and require special equipment [9]. Chemical polishing usually implies the contact of the sample with water, which may cause contamination of the crystal surface and reduction of the surface electrical resistance. Therefore, the development of surface passivation methods is a topical problem for CdZnTe detectors.

Before, we have developed the photothermal oxidation (PhTO) method for crystalline $A^{II}B^{VI}$ samples in oxygen-containing atmosphere [10]. This method was used to obtain 0.1 to 10 μm thick oxide films on the crystal surface at temperatures of about 400°C [11, 12]. In this work, the PhTO has been used to passivate the side surface of CdZnTe detectors at lower temperatures. The temperature restriction is explained by the fact that at heating up to temperatures exceeding 115°C, the detector quality deteriorates sharply [13]. The block diagram of the unit employed for surface passivation is shown in Fig. 1. For photo-stimulated passivation (PhSP) of the sample surface in oxygen-containing medium, the UV radiation of DRT-1000 mercury lamps was used. The radiation power density was varied from 10 kW/m^2 to 20 kW/m^2 , and this provided: (i) high concentration of ozone in the gase-

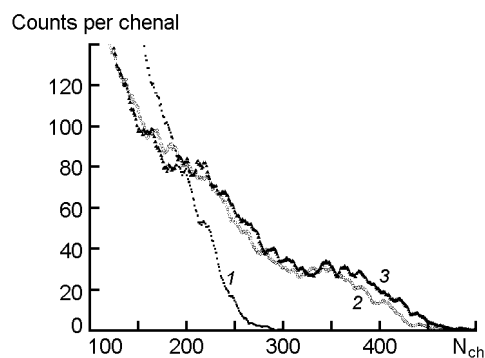


Fig. 2. Spectrometric characteristics of CdZnTe radiation detector: 1, the initial spectrum; 2, the spectrum measured immediately after PhSP treatment; 3, the spectrum of the same sample measured 1 month later.

ous medium, (ii) photo-stimulating (non-thermal) effect of UV radiation [14], and (iii) heating of the samples by absorbed UV radiation of the lamps up to temperatures not exceeding 115°C. It is not expedient to use lower optical radiation intensities, since in this case passivation is insufficient; the upper limit is defined by radiation overheating of the samples.

The results of the dark electrical resistance measurements for CdZnTe detectors performed before and after PhSP are presented in Table. As is seen, The proposed treatment method is seen to result in the increase of the surface electrical resistance of the detectors at $t \leq 115^\circ\text{C}$; this causes a drop of leakage currents over the detector side surfaces. Fig. 2 shows the spectrometric characteristics of CdZnTe detectors measured before and after the treatment. These characteristics were determined using a special setup where the detector was irradiated using a standard 661.65 keV gamma-radiation source Cs^{137} .

Table. Influence of PhSP treatment temperature on the dark electrical resistance of CdZnTe detectors (R_1 and R_2 are the resistances before and after PhSP, respectively).

T, °C	R_1, Ω	R_2, Ω
90	$1.4 \cdot 10^{10}$	10^{11}
115	10^{10}	$1.5 \cdot 10^{11}$
115	$4 \cdot 10^{10}$	$1.4 \cdot 10^{11}$
130	$8 \cdot 10^9$	$5.2 \cdot 10^9$
140	$2 \cdot 10^{10}$	$2 \cdot 10^8$

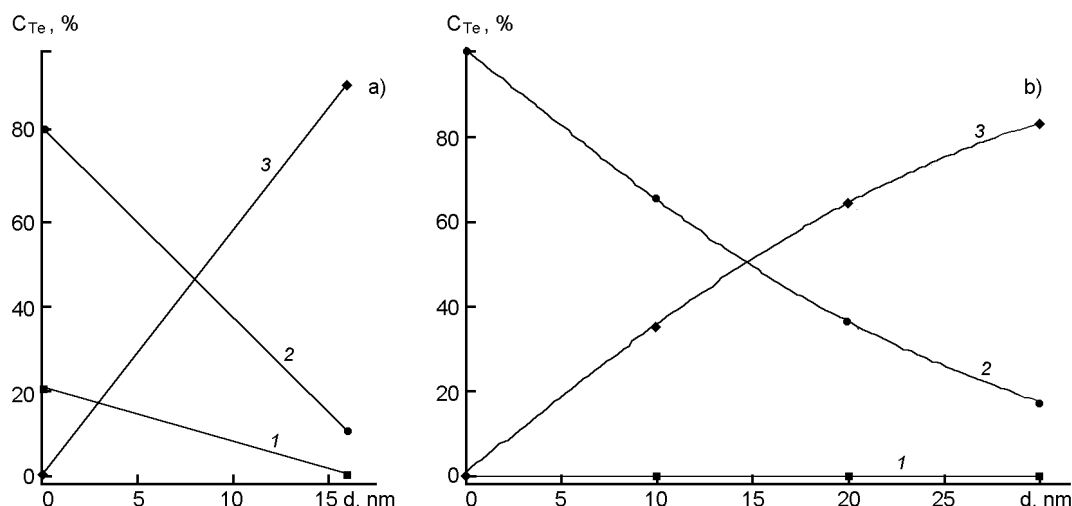


Fig. 3. Distribution of tellurium and its compounds in the near-surface layer of a CdZnTe crystal before (a) and after (b) PhSP treatment (1 — Te, 2 — TeO_2 , 3 — CdZnTe).

It should be noted that PhSP treatment made it possible to raise essentially the maximal working voltage applied to CdZnTe detectors (e.g. from 350 V up to 650 V for the detector characterized by the spectrum shown in Fig. 2). For a number of samples, the maximal working voltage was increased more than by 4 times (from 400 V up to 1650 V), and this permitted to use such detectors not only as counters but also as spectrometers.

The changes in the surface composition of CdZnTe crystals caused by PhSP treatment were established by X-ray phase analysis and X-ray photoelectron spectroscopy (XPS). Fig. 3 presents the distribution profiles of tellurium and its compounds in the near-surface layer of CdZnTe crystals measured by XPS prior to and after PhSP treatment. The layer-by-layer analysis of the surface composition of CdZnTe samples has shown that the thickness of tellurium and cadmium oxides layers increased approximately by an order of magnitude. According to the obtained data, PhSP treatment of CdZnTe crystals resulted in the formation of surface TeO_2 film with a thickness up to 50 nm.

Thus, the developed method of photostimulated passivation of the CdZnTe crystal surface in oxygen-containing atmosphere is shown to increase essentially the surface electrical resistance of the samples and to reduce the leakage currents of CdZnTe detectors. This provides the possibility to use the crystals not only as counters but also as spectrometers. The said changes in the electrical properties are caused by oxidation of

the near-surface layer of CdZnTe crystals with subsequent formation of high-resistance passivating oxide layers with a thickness of ~50 nm on the detector surface.

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Фотостимульована пасивація спектрометричних CdZnTe детекторів

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Запропоновано спосіб пасивації бокової поверхні спектрометричних детекторів на основі твердого розчину Cd_{1-x}Zn_xTe. Встановлено вплив фотостимульованої пасивувальної обробки на електричні та спектрометричні властивості детекторів. Досліджено процеси, які відбуваються на поверхні кристалів при їх обробці і призводять до зміни фазового складу поверхні.