GROWTH OF $Cd_{0.9}Zn_{0.1}Te_{1-y}Se_y$ CRYSTALS FOR RADIATION DETECTION APPLICATIONS

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Crystals of solid solutions Cd0.9$Zn_{0.1}Te_{1}$-ySe_y with selenium concentration y = 0.02 - 0.07 were grown by the vertical Bridgman method under high pressure of argon gas (up to 26 atm) in graphite crucibles. The obtained crystals are characterized by the crystal structure similar to Cd0.9Zn0.1Te crystals. The distributions of the elemental composition in grown crystals were studied for different ways of raw materials loading. To obtain high-resistivity (detector) crystals an additional doping with Indium was carried out.

Keywords: $A^{II}B^{VI}$ compounds, doping, semiconductor detectors, Bridgman method

In the modern world, the development and production of new materials play a crucial role in the development of various scientific and technical fields. One from such materials attracting the strong attention of researchers is a family of $Cd_{1-x}Zn_xTe_{1-y}Se_y$ solid solution crystals. These new crystals may be used for semiconductor detectors of X-ray and gamma radiation operating at room temperature. $Cd_{1-x}Zn_xTe_{1-y}Se_y$ crystals are similar to the more known $Cd_{1-x}Zn_xTe$ (CZT) crystals and also exhibit high efficiency in gamma radiation detection. But introduction of selenium compound to them leads to the hardening of the crystal structure and reduction the quantity of many extended defects (tellurium inclusions, dislocation networks, etc.) [1, 2].

Crystals of $Cd_{0.9}Zn_{0.1}Te_{1-y}Se_y$ with permissible selenium concentration y = 0.02…0.07 were grown by the vertical Bridgman method under excess pressure of inert argon gas (up to 26 atm) in graphite crucibles. Two methods of initial components loading were selected. In the first method, fragments of finished indium-doped $Cd_{0.9}Zn_{0.1}$Te:In, crystals and charge of binary compound CdSe were used as the raw materials. In the second method, high-purity binary compounds CdTe, ZnTe and CdSe were used. The crystallization zone temperature was maintained at 1160°C, with a temperature gradient of 30°C/cm and a growth rate of 0.6 mm/hour. As a result, crystals up to 60 mm in length and 25 mm in diameter were successfully grown.

Figure 1 shows typical photos of a $Cd_{0.9}Zn_{0.1}Te_{1-y}Se_y$ crystal and a cut plate with a thickness of 5 mm. The obtained crystals have a large-block structure.

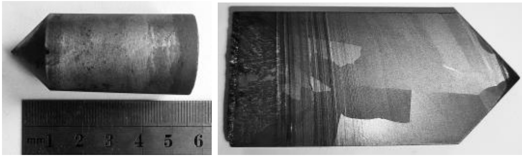

Fig. 1. Photo of a $Cd_{0.9}Zn_{0.1}Te_{1-y}Se_y$ (y = 0.02) crystal and a longitudinally cut plate with a thickness of 5 mm.

Based on the data of performed X-ray diffraction analysis, we found that the obtained crystals are characterized by a crystal structure similar to $Cd_{0.9}Zn_{0.1}Te$ crystals (Fig. 2). The presence of third-party phases was not observed. Introduction of selenium into $Cd_{0.9}Zn_{0.1}Te_{1-y}Se_y$ leads to a shift of the reflection peaks on the X-ray diffraction pattern compared to the reference $Cd_{0.9}Zn_{0.1}Te$ crystal.

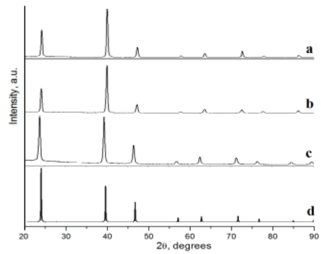

Fig. 2. $Cd_{0.9}Zn_{0.1}Te_{1-y}Se_y$ crystals XRD patterns, where y = 0.01, a = 6.472 Å (lattice period) (a); y=0.08, a = 6.372 Å (b); y=0.15, a = 6.368 Å (c), reference $Cd_{0.9}Zn_{0.1}Te$ (d).

The local chemical composition of the samples was analyzed using an AZtecEnergy X-maxN 50 energy dispersive spectrometer installed on a JEOL JSM-6390 LV scanning electron microscope. Figure 3 illustrates the elemental composition distributions of the grown crystals with the different methods of raw materials loading. In the middle part of crystal ingots, the distribution of solid solution composition is the most homogeneous.

To obtain high-resistivity (detector) crystals it was necessary to dope the material with indium impurity which compensates for the excess hole conductivity of undoped crystals. The table presents values of resistivity along the length of the ingot $Cd_{0.9}Zn_{0.1}Te_{1-y}Se_y$:In with selenium variable concentration y = 0.02…0.07. The crystal was obtained from the initial components of $Cd_{0.9}Zn_{0.1}Te$:In and binary compound CdSe. The indium impurity concentration ranged from 10 to 30 ppm.

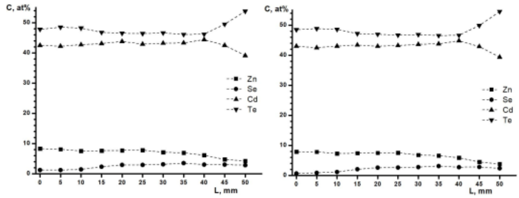

Fig. 3. Distributions of the main atomic components along the length of the obtained ingots with the nominal composition $Cd_{0.9}Zn_{0.1}Te_{0.98}Se_{0.02}$ corresponding to the stoichiometry of the initial components.
On the left – for a crystal obtained from a mixture of $Cd_{0.9}Zn_{0.1}Te$ and CdSe, on the right – for a crystal from a mixture of binary compounds.

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Table 1. Resistivity R measured along the $Cd_{0.9}Zn_{0.1}Te_{1-y}Se_y$: In ingot on the length L.

L, mm	R, Ohm·cm
5	$9.9 \cdot 10^{10}$
10	$2.3 \cdot 10^{11}$
15	$2 \cdot 10^{11}$
20	$1.4 \cdot 10^{11}$
25	$1 \cdot 10^{11}$
30	$1.5 \cdot 10^{11}$
35	$9.5 \cdot 10^{10}$
40	$4.8 \cdot 10^{10}$
45	$<10^{8}$

Thus, crystals of $Cd_{0.9}Zn_{0.1}Te_{1-y}Se_y$ (y = 0.02 - 0.07) with the Ø20x50 mm size were grown by the vertical Bridgman method under high pressure. The crystals have a large-block structure, a low concentration of low-angle boundaries (dislocation networks) and a satisfactorily homogeneous composition distribution along the length of the ingots. The investigated crystals have sphalerite crystal structure similar to $Cd_{0.9}Zn_{0.1}Te$ crystals, with characteristic changes in X-ray reflections, which correspond to the entry of selenium into the anionic sublattice.

1. *Roy U.N., Camarda G.S., James Y. and Cui R.B.* Optimization of selenium in CdZnTeSe quaternary compound for radiation detector applications // Appl. Phys. Lett. – 2021. – 118. – No. 152101.
2. *Park B., Kim Y., Seo J., Byun J., Dedic V., Franc J., Bolotnikov A.E., James R.B. and Kim K.* Bandgap engineering of $Cd_{1-x}Zn_xTe_{1-y}Se_y$ (0<x<0.27, 0<y<0.026) // Nucl. Instrum. and Methods in Physics Research Section A. – 2022. – 1036. – No. 166836.