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Dielectric inhomogeneities in CdZnTe crystals

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It has been shown that the character of CdZnTe crystal dielectric constant dependence on coordinate (that can be revealed by considering the $d\varepsilon'/dx = f(x)$ function) may be defined not only by the distribution of structure inhomogeneities but also by directions of field gradients generated by the inhomogeneities. To characterize the defect formation processes in the samples prepared from radial and axial ingot sections, the $d\varepsilon'/dx = f(\varepsilon')$ diagrams have been proposed.

Показано, что характер зависимости диэлектрической проницаемости кристаллов CdZnTe от координаты, выявляемый посредством анализа зависимости $d\varepsilon'/dx = f(x)$, может быть связан не только с распределением структурных неоднородностей, но и с направлением создаваемых ими градиентов полей. Для характеристики процессов дефектообразования в образцах, изготовленных из радиальных и осевых срезов були, предложены диаграммы $d\varepsilon'/dx = f(\varepsilon')$.

In the crystals of CdZnTe solid solutions used widely in manufacturing of γ radiation detectors, the structure inhomogeneities may cause changes in the band gap width [1] and result, e.g., in a dependence of the dielectric constant ε on coordinate. This may cause a distortion in the detector signal shape and amplitude. At the other hand, the distribution character of the dielectric inhomogeneities in the radial and axial ingot sections is a source of information on the direction and sequence of defect formation processes in the course of the ingot manufacturing [2]. It is just a search for methods to represent and analyze that information that is the main purpose of this work.

Studied were the $Cd_{1-x}Zn_xTe$ ($x = 0.1$ to 0.2) crystals having the resistivity ρ of 10^{10} to 10^{11} $\Omega\cdot$cm grown by the vertical crystallization technique from the melt [4]. Gold or indium-gallium contacts were applied onto opposite sides of the samples of $5\times5\times2$ mm^3 and $11\times11\times2$ mm^3 size. Samples cut out from radial and axial sections of various parts of the ingots were examined. The structure inhomogeneities were visualized by etching, IR microscopy and shadow method. The real ε' and imaginary ε'' parts of the complex dielectric constant ε^* were measured in the 200 Hz to 10 kHz frequency range at the electric field strength $E = 10$ V/cm using a measuring and calculating setup [5]. The surface was scanned by a monochromatic 50 μm wide light probe at the wavelength corresponding to the photosensitivity maximum of the crystal. The sample was displaced automatically at speeds of 0.2 to 10 mm/min, the signal discretization frequency being 10^4 to 10^6 Hz.

It follows from the consideration of modified Poisson equation that for a spatially inhomogeneous semiconductor $\varepsilon\nabla^2\varphi + \nabla\varepsilon \cdot \nabla\varphi = -\rho$, the direction of dielectric constant gradients generated by separate en-

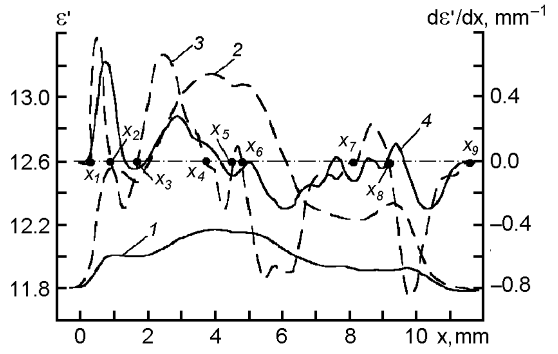

Fig. 1. $\varepsilon' = f(x)$ (*1*, *2*) and $d\varepsilon'/dx = f(x)$ (*3*, *4*) dependences for a $Cd_{0.9}Zn_{0.1}Te$ sample from inhomogeneous ingot part. $F = 1000$ Hz, $T = 293$ K, $\lambda = 0.88$ μm. Solid line corresponds to the photoexcitation level **I**; dashed line, to **3I**.

sembles of structure defects is defined mainly by the character of defect formation process [3]. Therefore, we have studied the coordinate dependences of dielectric constant $\varepsilon'(x)$ where x is the coordinate characterizing the monochromatic probe position. The $\varepsilon'(x)$ dependences obtained by optical scanning of samples from the radial and axial sections of the ingot are unique for both each studied sample and for each individual facet thereof. A typical dependence is shown in Fig. 1 (curve *1*). As the monochromatic emission intensity rises, some curves are transformed. Some extremes increase and other decrease (Fig. 1, curve *2*). Sometimes, inversions are observed, that can be connected with the density redistribution of the free and bound charges.

The influence intensity of the inhomogeneity fields on the crystal electro-physical properties depends on whether the directions of dielectric constant gradients and potential ones are coincident or opposite. As a result, some inhomogeneities in the crystals are responsible for sections where ε' changes fast depending on the coordinate while other inhomogeneities, for slow variations. To prove that supposition in experiment, the $d\varepsilon'/dx = f(x)$ dependences have been examined by averaging the $\varepsilon'(x)$ slopes in two neighboring points. These dependences (Fig. 1, curves *3*, *4*) include numerous extremes and represent, on the whole, the distribution character of opposite charges. The comparison of those curves shows that the increase of the photoexcitation intensity by a factor of 3 results also in a significant transformation of the $d\varepsilon'/dx = f(x)$ dependences, thus evidencing the intensification of the internal fields in some areas and weakening in other ones. The $d\varepsilon'/dx = f(x)$ dependences (Fig. 1, curves *3*, *4*) supplement considerably the $\varepsilon'(x)$ ones (curves *1* and *2*) by making it possible to reveal hardly noticeable inhomogeneities in the samples. It is obvious that the total charge is in proportion the difference of areas encompassed by the bow-shaped sections where $d\varepsilon'/dx$ is larger or smaller than zero. The area difference (determined by graphical integration of the corresponding sections of curves *3* and *4* in Fig. 1) has increased as the photoexcitation intensity has raised. It is logically to associate this fact with the charge accumulation.

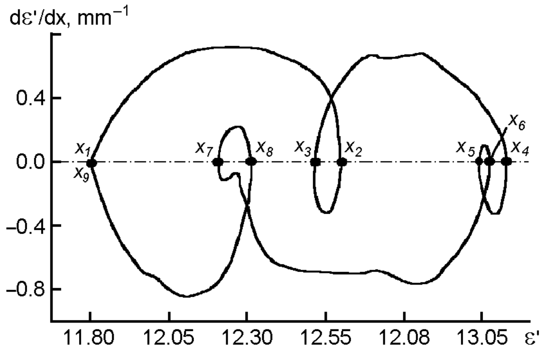

Fig. 2. $d\varepsilon'/dx = f(\varepsilon')$ diagram for a $Cd_{0.9}Zn_{0.1}Te$ sample cut out from an axial ingot section.

Proceeding from an analogy with the phase plane, it can be assumed that the ε' and $d\varepsilon'/dx$ values at the photoexcitation of the sample with the probe as well as the point in the $d\varepsilon'/dx = f(\varepsilon')$ diagram corresponding there to represent a phase of the process that has formed the specific local area of the sample. Such diagrams are sequences of bow-shaped sections (Fig. 2) that form a peculiar graphic image of the crystal.

The number of bow-shaped sections x_ix_j (i, $j = 1, 2, 3...$, $i \neq j$) in the $d\varepsilon'/dx = f(\varepsilon')$ diagram can be assumed to define the number and sequence of the processes occurring during formation of a certain ingot part. Then the loop-like sections formed due to overlapping of neighboring bow-shaped diagram sections (e.g., the x_2x_3 section) evidence the redistribution of internal fields and changes in the process direction. To prove this assumption, we have studied the $\varepsilon'' = f(\varepsilon')$ diagrams obtained basing on the spectral dependences of the real $\varepsilon'(\lambda)$ and imaginary $\varepsilon''(\lambda)$ parts of the complex dielectric constant at the probe photoexcitation of the neighboring crystal areas.

Those diagrams have been considered according to the procedure [6] using the coefficient $K_{ij} = \Delta S/(S_i + S_j)$ where ΔS is the overlap area of $\varepsilon'' = f(\varepsilon')$ diagrams and $(S_i + S_j)$, the total area thereof. The coefficient K_{ij} is numerically equal to the fraction of common states in the neighboring crystal areas and represents at the macroscopic level the coupling extent of two sequential processes forming the specified distribution of structure inhomogeneities. For the crystal areas corresponding to the loop-like sections, $K_{ij} \leq 0.4$ while being 0.7 to 0.8 for any other neighboring areas. This allows us to believe that the former ingot parts to be the most suitable for machining. To obtain reliable data on the direction of internal fields generated by the dielectric inhomogeneities in the samples cut out from the ingot radial and axial sections, the disctretization frequencies at $\varepsilon'(x)$ measurements are to be sufficiently high. In our opinion, the use of $d\varepsilon'/dx = f(x)$ dependences and $d\varepsilon'/dx = f(\varepsilon')$ diagrams can provide an effective means for monitoring of the variations in the crystal characteristics caused by the operation under hard conditions or by technological processing.

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Діелектричні неоднорідності кристалів CdZnTe

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Показано, що характер залежності діелектричної проникності кристалів CdZnTe від координати, що виявляється за допомогою аналізу залежності $d\varepsilon'/dx = f(x)$, може бути пов'язаний не тільки з розподілом структурних неоднорідностей, але і з напрямком створюваних ними градієнтів полів. Для характеристики процесів дефектоутворення в зразках, виготовлених з радіальних і осьових зрізів булі, запропоновано діаграми $d\varepsilon'/dx = f(\varepsilon')$.