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FEATURES OF KINETIC EFFECTS IN SEMICONDUCTOR SINGLE CRYTALS WITH HETEROGENEOUS DISTRIBUTION OF IMPURITIES

The influence of inhomogeneities in the distribution of tellurium alloying impurity on kinetic effects in single crystals of cadmium antimonide was investigated. It was noted that the presence of layered periodic inhomogeneities along the growth axis of the crystal leads to the formation of internal electric fields between the growth layers. It was found that upon illumination in samples cut parallel to the axis of crystal growth, the values of mobility and average transport length of the free path of charge carriers significantly increase.

Keywords: *layered periodic inhomogeneities, cadmium antimonide, illumination, mobility, switching effect, Hall effect.*

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ОСОБЛИВОСТІ КІНЕТИЧНИХ ЕФЕКТІВ В НАПІВПРОВІДНИКОВИХ МОНОКРИСТАЛАХ З НЕОДНОРІДНИМ РОЗПОДІЛОМ ДОМІШОК

Досліджено вплив неоднорідностей в розподілі легуючої домішки телуру на кінетичні ефекти в монокристалах антимоніду кадмію. Відмічено, що наявність шаруватих періодичних неоднорідностей вздовж осі росту кристалу зумовлює утворення внутрішніх електричних полів між шарами росту. Виявлено, що при освітленні в зразках, вирізаних паралельно осі росту кристалу, значно зростають значення рухливості та середньої транспортної довжини вільного пробігу носіїв заряду.

Ключові слова: *шаруваті періодичні неоднорідності, антимонід кадмію, освітлення, рухливість, ефект перемикання, ефект Холла.*

Problem formulation. It became clear lately, that now subsequent increase of reliability and economy of devices of semiconductor electronics can not be carried out only by the improvements of technology, and is limited by heterogeneities of physical and chemical properties of semiconductor materials [1, 2]. That is why the problem of heterogeneities research both in general and in particular at different influences was and remains actual.

Presentation of the main material. The purpose of our work was to explore influence of illumination, electric and magnetic fields and also heterogeneities in the division of alloying admixtures on kinetic effects in antimonide cadmium monocrystals. Measurings of conductivity, division of specific resistance along length of exemplars, Hall effect and switching effect from high-resistance in the low-resistance state at different physical and active influences were conducted for achievement of the put purpose.

During the researches of division of specific resistance on length of the exemplars cut out parallel and athwart to growth to the crystal, the presence of the stratified periodic heterogeneities is discovered in direction of growth of monocrystals of *CdSb*, that results in appearance in this direction of gradients of specific resistance [3], and accordingly, predetermines formation of the internal electric fields. It is confirmed by researches of switching effect from high-resistance in the low-resistance state of monocrystals of antimonide of cadmium of alloyed by tellurium, which volt-ampere characteristic of the exemplars cut out parallel (I group) and perpendicular (II group) to growth to the crystal were taken off during, at the different levels of illumination. From experimental data the value is expected $j=f(E)$ for the exemplars of both groups (figure 1, 2).

The substantial difference of thresholds values of tension of the electric field is marked for the exemplars of different groups subject to the condition identical (thresholds values of tension of the electric field in exemplars first groups take on far greater values), both for unlit and at the different levels of illumination, that contacts with existence of the compensating electric fields between the layers of growth. For the exemplars cut out athwart to growth, but in different crystallographic directions, value $j=f(E)$ practically repeat, that well conformed to data of work [4].

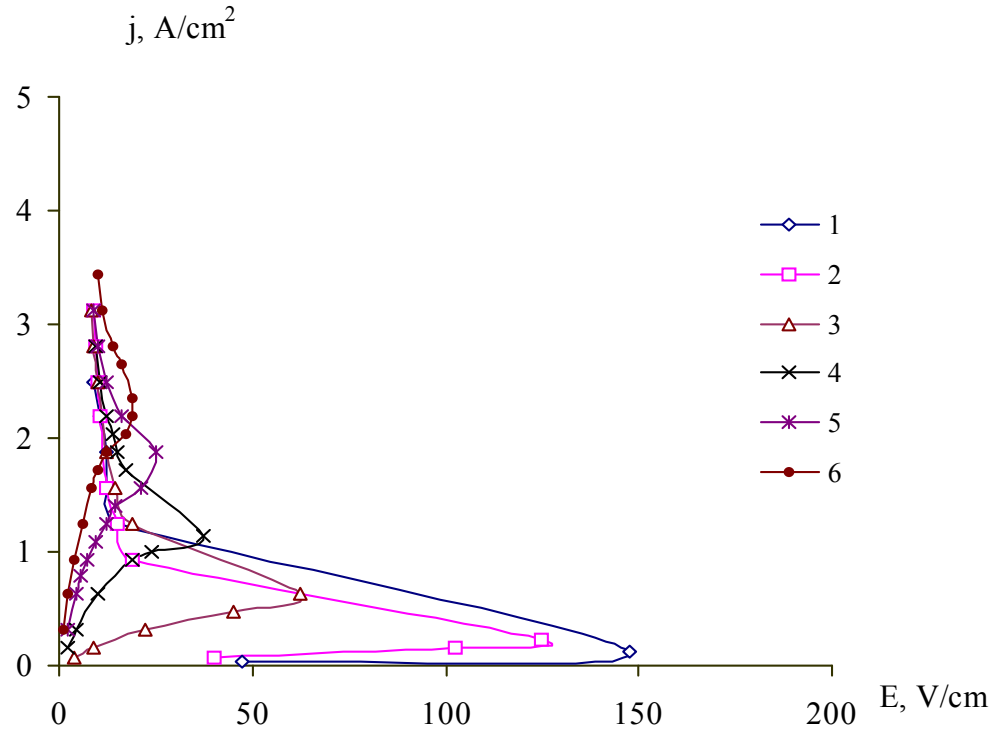

Fig.1. **Dependences $j = f(E)$ for the parallel to growth axis cut out exemplars *CdSb(Te)*, by the different lighting levels: curve 1 – without lighting, curves 2 -6 with the growing lighting level**

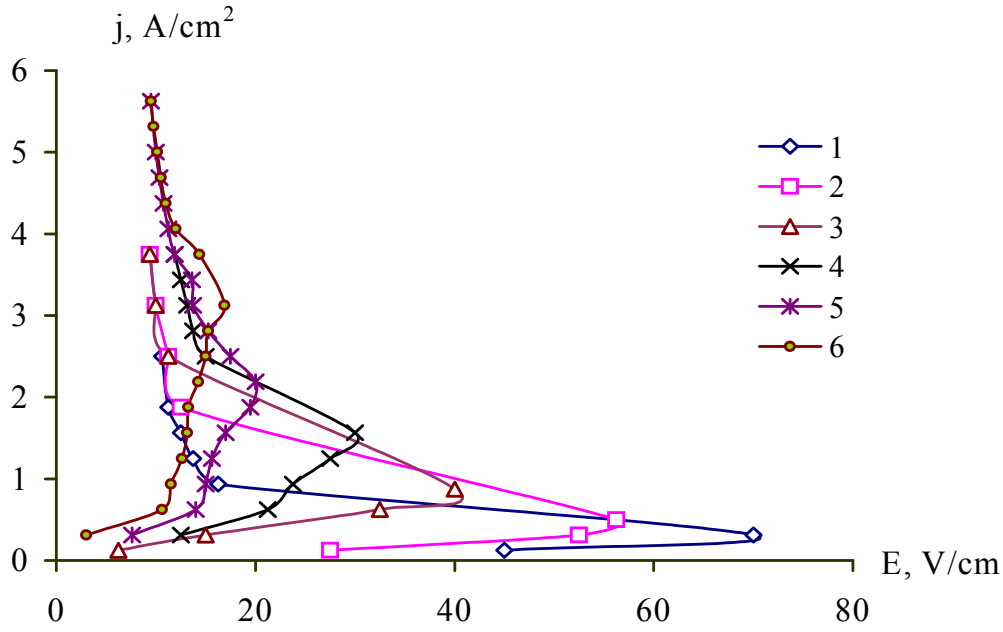

Fig. 2. **Dependences $j = f(E)$ for the exemplars *CdSb(Te)*, which are cut out perpendicularly to the growth axis, by the different lighting levels: curve 1 – without lighting, curves 2 -6 with the growing lighting level**

For the unlit exemplars of both groups of growth of tension of the electric field takes place to the values, at what Joule warmth, that is selected on the proper exemplars, is become sufficient for ionization of the tellurium donor level (E_c - 0,12 *eV*). Thus there is transition of electrons in the area of conductivity [4] that results in the jump of density of current. At the increase of intensity of illumination diminishing of thresholds sizes of tension of the electric field is marked, both for the exemplars of cut out parallel and athwart growth to the crystal. At what, there is the gradual approaching of thresholds values of tension of

the electric field for the exemplars of the first group to the values for the exemplars of the second group (figure 3). This fact is explained by gradual tellurium photoionization in the electrical active layers of growth.

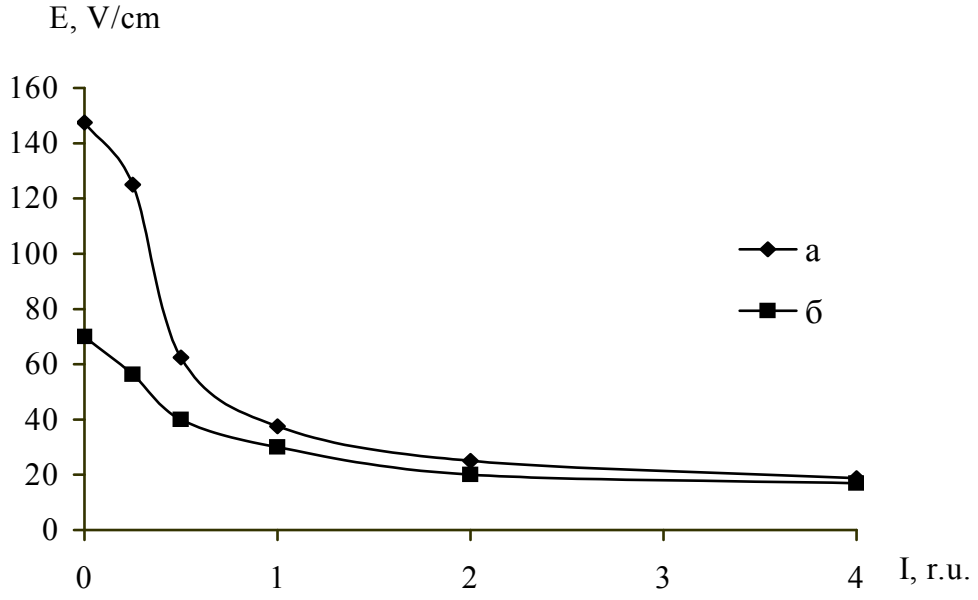

Fig. 3. **Dependences of the threshold values of the electrical field tension on the lighting level for the exemplars *CdSb(Te)*, which are cut out: a – parallel, b - perpendicularly to the crystal growth axis.**

Research of Hall effect is conducted, the experimental results of which for the exemplars of both groups at different intensities of illumination (ρ_d/ρ_i, where ρ_d and ρ_i it is value of specific resistance in darkness and at illumination) are resulted in a table 1.

Table 1.

The results of research on the Hall effect for the exemplars *CdSb(Te)*, which are cut out: parallel (I group) and perpendicularly (II group) to the crystal growth axis

Exemplars of the I group			
ρ_d/ρ_i	ρ, Om·cm	μ, $cm^2/V·s$	n, cm^{-3}
1	145,7	2087	$1,10·10^{13}$
11	13,25	2195	$2,74·10^{14}$
85	1,71	2750	$1,26·10^{15}$
165	0,88	7230	$9,70·10^{14}$
180	0,81	10120	$7,50·10^{14}$
230	0,63	19100	$6,10·10^{14}$
Exemplars of the II group			
ρ_d/ρ_i	ρ, Om·cm	μ, $cm^2/V·s$	n, cm^{-3}
1	348	2323	$7,12·10^{12}$
3	116	2463	$2,06·10^{13}$
12	29	2598	$8,62·10^{13}$
36	9,67	2845	$2,12·10^{14}$
70	4,97	2800	$4,03·10^{14}$
140	2,49	2762	$7,80·10^{14}$
230	1,51	2780	$1,56·10^{15}$

Sharp growth of mobility of transmitters of charge is marked at the increase of intensity of illumination in the exemplars, cut out parallel to growth that is explained by the change of potential relief amplitude.

It is shown in work [5], that potential relief amplitude is determined as:

$$\delta = \frac{e^2 \cdot N_{\partial}^{\frac{2}{3}}}{\chi \cdot n_{екр}^{\frac{1}{3}}}, \quad (1)$$

where χ is dielectric permeability, $n_{екр}$ and N_{∂} - concentration of screening transmitters of current and charged defects. Accordingly, in our case at the increase of intensity of illumination *of* δ will diminish from the increase $n_{екр}$ level of tellurium predefined by photoionization.

From experimental data of research of effect of Hall dependence of transporting length of free run of transmitters of charge (λ_c) is expected on the level of illumination (figure 4).

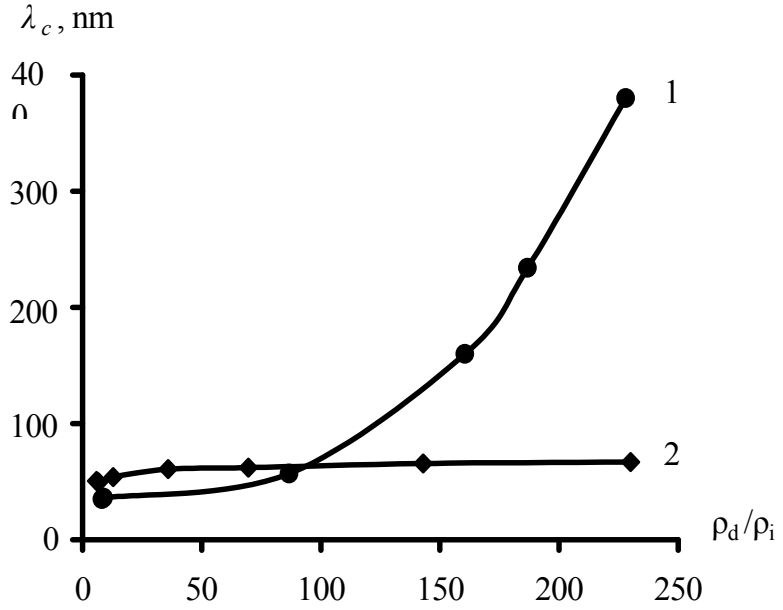

Fig. 4. **Dependence of middle transporting length of free run of electrons on illumination for the exemplars cut out parallel (curve 1) and perpendicular (curve 2) to the crystal growth axis.**

Taking into consideration the nonsingularity of electronic gas in the examined crystals, according to [6] the expression for the medium transport length of free run of current carriers was used in such a way:

$$\lambda_c = \frac{m_c^* \upsilon_c}{e^2} \cdot \frac{1}{\rho n_0}, \quad (2)$$

where $\upsilon_c = \left(\frac{8kT}{\pi m_c^*}\right)^{\frac{1}{2}}$.

There is growth on the got dependences λ_c in the exemplars of the first group at the increase of intensity of illumination that confirms a presence in direction of growth to the crystal of thin structure of electrostatic charge pattern.

Conclusions. On the basis of the conducted researches it is possible to draw conclusion that the presence of heterogeneities in the crystals of *CdSb* results in anisotropy of properties. The study of these features creates pre-conditions for the account of the effects marked higher at constructing of different sort of semiconductors sensors, and also will provide the real ways of minimization of displays of these effects wherein they can appear undesirable enough.

Bibliography

1. Семенюк А.К. Радіаційні ефекти в багатодолинних напівпровідниках. – Луцьк: Ред. - вид. відділ ЛДТУ, 2001. – 324 с.

2. Баранський П.І. Федосов А.В., Гайдар Г.П. Неоднорідності напівпровідників і актуальні задачі міждефектної взаємодії в радіаційній фізиці і нанотехнології. Київ–Луцьк : РВВ Луцьк. нац. техн. ун-ту, 2006. 316 с.

3. Yu.V. Koval, D.A. Zakharchuk, L.V. Yashchynskyy, L.I. Panasyuk, S.A. Fedosov. Features of Structural Inhomogeneities in Doped Cadmium Antimonide Crystals // Physics and Chemistry of Solidstate. – 2017. – V. 18, № 3 (2017). – P. 321–323.

4. Доскоч В.П., Панкевич З.В., Раренко И.М., Семенюк А.К., Федосов А.В. Температурно-электрическая неустойчивость в монокристалах антимонида кадмия // Известия вузов. – 1989. – №4. – С. 108–109.

5. Шкловский Б.И., Эфрос А.Л. Примесная зона и проводимость компенсированных полупроводников // ЖЭТФ. – 1971. – Т. 60. – С. 867–878.

6. Blakemore J.S. Solid State Physics // W.B., Saunders Company Philadelphia. – 1970. – 487p

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